Ecotourism Potential Assessment for District Lower Chitral-Pakistan Using Integration of GIS and Remote Sensing

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Ecotourism is a sustainable and responsible tourism approach that emphasizes the protection of natural ecosystems while offering visitors immersive experiences. This study evaluates the ecotourism potential of District Lower Chitral, Pakistan, using an integrated approach that combines Geographic Information Systems (GIS) and Remote Sensing technologies. Planning for ecotourism development is a multi-criteria process that often involves spatial analysis. A Multi-Criteria Decision Analysis (MCDA) model was employed to assess ecotourism suitability in District Lower Chitral. Eighteen variables, selected based on local knowledge and expert opinion, were considered, encompassing natural beauty, infrastructure, and physical parameters of the area. The study's results indicate that the majority of the study area has a moderate potential for ecotourism, covering 3,141.026 km² (51.33%) of the total area. Additionally, 103.3733 km² (1.69%) was classified as "Very Highly" suitable for ecotourism, and 1,750 km² (26.61%) was deemed "Highly" suitable. Areas classified as having low suitability measured 1,118.666 km² (18.28%), while the very low suitability category covered the smallest proportion, with 5.645 km² (0.09%).

Keywords: Ecotourism, Multi-Criteria Decision Analysis (MCDA) Model, GIS, Remote Sensing, Chitral.

Introduction:

Ecotourism is defined as "responsible travel that conserves the environment and improves the well-being of local people" [1]. Also referred to as "nature tourism," its primary goal is to minimize tourism's environmental impact [2]. This concept seeks to harmonize conservation, community development, and sustainable practices through travel [3]. Ecotourism includes activities such as nature travel, bird watching, camping, adventure travel, whale watching, fishing, skiing, archaeological digs, and trophy hunting [7]. It is broadly applied to regions like grasslands, wetlands, water-dominated landscapes, forests, and protected areas [10]. Ecotourism typically involves visiting natural areas, fostering respect for diverse cultures and ecosystems, and promoting socio-economic benefits for local communities [8][28]. Sustainable tourism development aims to reduce environmental and cultural impacts while generating income, employment, and conserving local ecosystems [9]. Ecotourism plays a crucial role by providing financial support for conservation, creating job opportunities for local communities, and raising environmental awareness among tourists. It integrates sustainability principles into tourism practices, ensuring that current tourism development meets the needs of both present tourists and host regions while safeguarding future opportunities [11].

The term "ecotourism" was first coined in 1983 to describe the relationship between tourism activities in natural landscapes and environmental conservation along with cultural heritage preservation [40]. As environmentalism grew, so did the focus on sustainability. Ecotourism emerged as a tool for sustainability in tourism, emphasizing the management of human activities based on ecological and cultural factors [29] and contributing to environmental conservation and development [41]. Sustainable tourism highlights the interconnectedness of ecotourism and sustainable development, incorporating environmental, socio-cultural, and economic systems [32]. The rising popularity and conservation potential of ecotourism offer unique opportunities for integrating rural development, tourism resource management, and protected area management worldwide [12]. Ecotourism can attract political and financial support for preserving threatened natural areas [13].

Identifying potential ecotourism sites involves evaluating various criteria and indicators [42]. In recent decades, geospatial technologies like remote sensing, GIS, and GPS have been widely used to identify suitable ecotourism locations [14]. GIS-based land suitability analysis using methods such as the Analytical Hierarchy Process (AHP) and Multi-Criteria Decision Analysis (MCDA) have been applied for modeling and overlay analysis [15]. These methods have also been employed to identify nature-based tourism potential sites based on socio-economic and environmental indicators [16]. Among different MCDA methods, AHP is preferred for its ability to analyze data based on relative importance and hierarchical ordering [17]. Ecotourism is a crucial aspect of sustainable tourism development in both developed and developing countries [18]. Proper planning for ecotourism begins with selecting suitable sites, influenced by various physical, socio-cultural, environmental, and infrastructural factors that vary by location and context [19].

Literature Review:

The tourism sector, particularly ecotourism, is widely recognized for its significant impact on sustainable development [20]. Sustainable development balances social progress, environmental preservation, and economic growth [21]. Ecotourism emphasizes responsible visitation to natural areas, aiming to maximize economic benefits while minimizing environmental and local impacts [22][23]. It supports conservation efforts and often includes activities such as wildlife observation, outdoor recreation, and support for local businesses and communities [24]. By promoting sustainable practices and generating revenue for conservation and local economies, ecotourism aids in the long-term preservation of natural resources and cultural heritage [20]. Recent literature (2018-2023) highlights ecotourism's role in sustainable tourism, balancing environmental, socio-cultural, and economic systems [4]. For instance, [4] identified ecotourism zones in the Batticaloa District using AHP in a GIS environment, integrating thematic layers such as landscape, protected areas, topography, accessibility, and community characteristics. This study identified five potential ecotourism zones, with 12.53% of the land area deemed very suitable to extremely suitable for development. Similarly, [5] used spatial MCDA in Portugal's Beira Baixa region, integrating nine criteria with AHP in GIS, revealing high suitability for ecotourism due to the region's significant natural heritage.

In Jordan, [6] used AHP, GIS, and remote sensing to map nature-based tourism attractions, assessing landscape, accessibility, infrastructure, and facilities. Their assessment prioritized desert attractions and forests for ecotourism development. [7] identified potential ecotourism sites in Gilgit Baltistan using GIS and AHP, considering factors such as elevation, slope, lake proximity, adventure activities, hotel accessibility, historical sites, cultural sites, road connectivity, land cover, precipitation, and climate suitability. Their findings revealed that 11.5% of the study area had very high ecotourism suitability. In the Great Himalayan National Park, [27] utilized GIS, remote sensing, and MCDA techniques to identify potential ecotourism sites, concluding that the southwestern and central parts of the park have high potential.

In Ethiopia, [30] assessed the ecotourism potential of the Munessa Shashemene Concession Forest using GIS-based suitability modeling. They evaluated factors such as land cover, wild animal zones, unique features, topography, and proximity to roads, identifying highly suitable areas for ecotourism development.

Studies in Iran, including those by [33][34] and [35][36], demonstrated the integration of GIS and remote sensing to prioritize ecological attractions for tourism and ecotourism development. These studies emphasized the potential of ecotourism planning to mitigate the overuse of popular sites and enhance conservation efforts through detailed mapping and strategic development. [39] showcased the effectiveness of GIS and remote sensing techniques in identifying and classifying natural areas with high ecotourism potential, facilitating balanced tourist distribution and promoting local conservation efforts through increased participation.

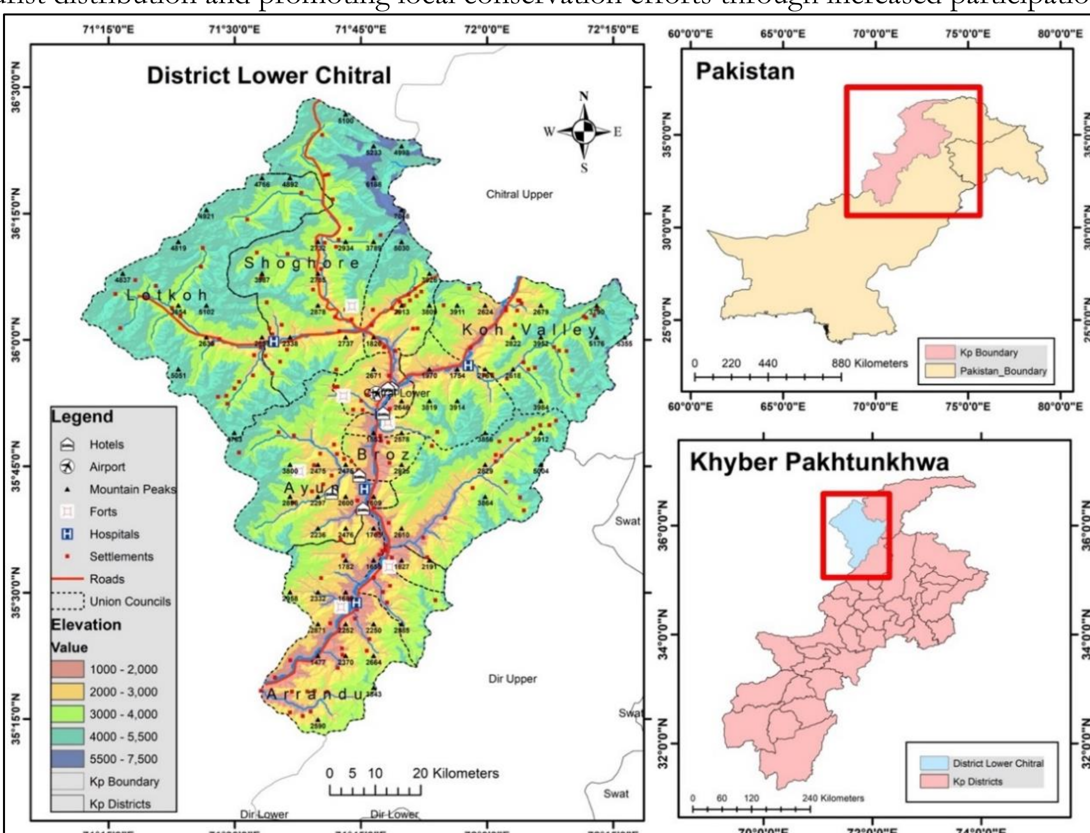

Figure 1: Location Map of the study area

Study Area:

Lower Chitral, a district in Khyber Pakhtunkhwa province, Pakistan, is situated in the northern part of the province. It borders Afghanistan to the southwest and northwest, Upper Chitral to the northeast, and Upper Dir to the southeast. The district extends from 35°13'3"N to 36°28'42"N latitude and from 71°11'48"E to 72°17'56"E longitude (Figure 1). Characterized by its rugged and mountainous terrain, Lower Chitral lies within the Hindu Kush range, surrounded by towering peaks. The district is renowned for its scenic valleys nestled between the mountains. Chitral's climate is predominantly dry Mediterranean (Köppen Csa), with extremely hot summers and minimal rainfall. Spring thunderstorms driven by western frontal systems are the main source of precipitation. Summers in Chitral are warm, with daytime highs ranging from 25–35°C (77–95°F), while winters are cold, often seeing temperatures drop below freezing, especially at higher elevations where snowfall is common. The monsoon season, from July to September, brings moderate to heavy rainfall, rejuvenating the region's lush green landscapes and enhancing its picturesque appeal. Outside the monsoon period, the district experiences drier conditions, making it a popular destination for tourists seeking a blend of natural beauty and cultural experiences.

Data Collection:

By integrating information from both primary and secondary sources, eighteen criteria layers were developed to assess site suitability for ecotourism in Lower Chitral. This process involved interviews with experts in ecotourism, environmentalists, local knowledge holders, and academic members, as well as extensive literature reviews. These sources collectively identified key factors and criteria essential for ecotourism in the region.

Geospatial Database:

Google Earth, an open-source platform, was utilized to gather geospatial data on various elements, including lakes, mountain peaks, hotels, adventure activities, historical and cultural sites, wildlife sightings, settlements, roads, and airports. Boundaries of protected areas were obtained from the Protected Planet database (https://www.protectedplanet.net/). The Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM) with a 30 m spatial resolution was employed to analyze topographic features such as slope and Topographic Roughness Index. Additionally, Sentinel-2 data from the Environmental System Research Institute (ESRI) was used for Land Use and Land Cover (LULC) classification in Lower Chitral.

Sentinel-2 Image Collection:

Land use classification is crucial in remote sensing analysis for identifying and categorizing different land cover types. Sentinel-2 imagery is particularly valuable due to its 10 m spatial resolution and 12-bit spectral resolution, which facilitates detailed land use analysis. This study utilized a pre-processed land use classification dataset derived from Sentinel-2 imagery, providing an efficient solution for researchers and practitioners interested in analyzing land use patterns without extensive data preprocessing or classification.

Table 1: Spatial data analysis and sources used for ecotourism suitability analysis

Data	Description	Source
Elevation	30 m resolution	SRTM (DEM)
Slope	Degree	SRTM (DEM)
River Proximity	-	SRTM (DEM)
Topographic Roughness	Index	SRTM (DEM)
Hotel Accessibility	-	Google Earth
Settlement Proximity	-	Survey of Pakistan
Road Proximity	-	Google Earth
Airport Proximity	-	Google Earth
Historical and Cultural sites	-	Google Earth
Adventure Activities	-	Google Earth

Mountain Peaks	-	SRTM (DEM)
Lakes	-	Google Earth
Wildlife Sighting	-	Google Earth
Precipitation	-	(CRU TS)
Protected Areas	-	Protected Planet
Fort Proximity	-	Google Earth
Hospital proximity	-	Google Earth
Land use landcover Type	10 m resolution	Sentinel-2

Precipitation Data:

Annual mean precipitation data from 2011 to 2022 was obtained from the Climatic Research Unit Time Series (CRU TS) dataset, which includes monthly time series for precipitation as well as daily maximum and minimum temperatures. This dataset, provided by the University of East Anglia's Climatic Research Unit (CRU), is a widely recognized global gridded resource that offers comprehensive information on historical precipitation trends and patterns.

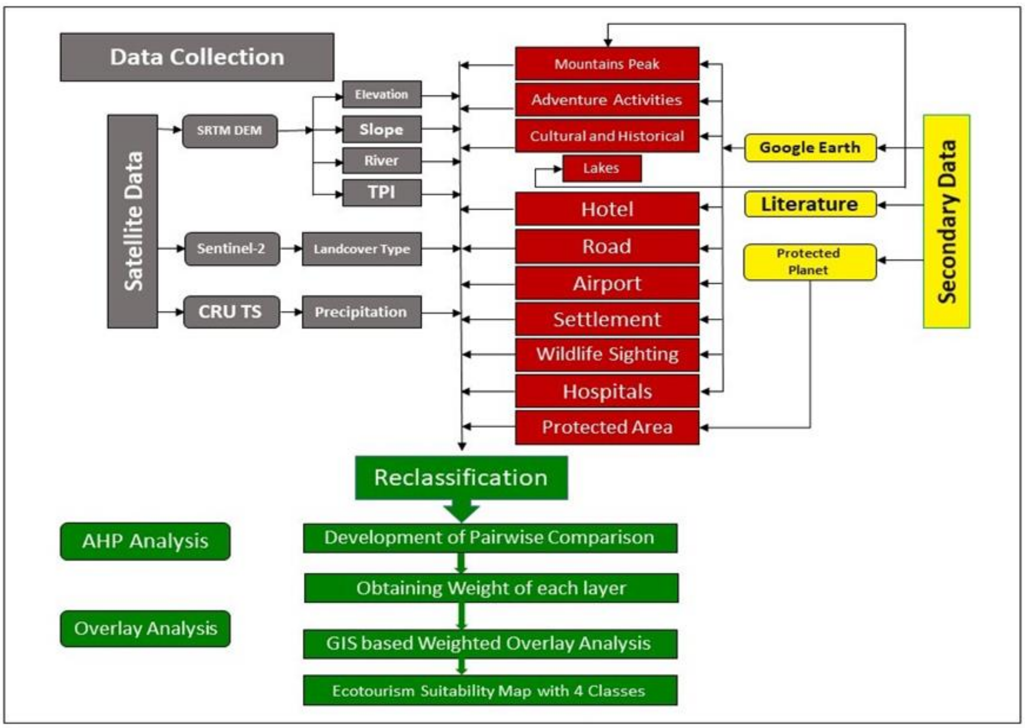

Figure 2: Flow chart showing the methodology of the study

Methodology for AHP Approach and Integration:

The selection of ecotourism potential sites consists of three steps: (1) geospatial database generation, (2) application of the Analytical Hierarchy Process (AHP) for normalization of criteria weights and site preparation, and (3) validation and interpretation of results [25]. The AHP method enables a comparative analysis of each criterion individually, based on their relative significance and ranking to identify potential sites [26].

The Multi-Criteria Decision Analysis (MCDA) using AHP involves establishing a hierarchical structure, assessing the weight of criteria and sub-criteria, assigning preferred weights to each alternative, and determining normalized scores for each criterion [37]. Numerous studies have effectively integrated GIS and AHP to identify suitable ecotourism sites, focusing on planning, management, and sustainability [38].

All parameters and criteria were selected based on their importance, literature review, and local knowledge. For identifying ecotourism potential sites, thematic layers considered included elevation, slope, topographic roughness index, river proximity, precipitation, land cover, lakes, mountain peaks, hotel accessibility, protected areas, adventure activities, historical and cultural sites, settlement proximity, road connectivity, and airport proximity (Figure 2).

Results and Discussion:

The thematic maps provide valuable insights by analyzing data in a visual and spatial context. These maps cover a wide range of topics, including elevation, slope, river proximity, topographic roughness, hotel accessibility, settlement proximity, road connectivity, airport proximity, historical and cultural sites, adventure activities, mountain peaks, lakes, wildlife sightings, precipitation, protected areas, fort proximity, hospital proximity, and land use and cover type. The selection of parameters was guided by their importance, literature review, and local knowledge.

The potential for ecotourism can be expanded by increasing the availability of services, such as introducing new adventure activities, improving the road network, and renovating historical sites. Enhancing these elements is expected to raise the overall potential for ecotourism.

Road Connectivity:

A systematic approach was used to create five buffer zones around existing road proximity layers to identify potential ecotourism sites. Buffer distances were set at intervals of 1,000 meters, ranging from 1,000 to 5,000 meters. Each zone was assigned a potential level: "very high," "high," "moderate," "low," and "very low," based on the correlation between road connectivity and ecotourism potential in the study area. This zoning approach facilitated the identification of ecotourism locations with direct road access, aiding in the prioritization and planning of ecotourism development while considering accessibility and environmental sustainability (Figure 3).

Wildlife Sighting:

Wildlife sighting is crucial for ecotourism, serving as a significant attraction for nature enthusiasts and wildlife lovers. Five suitability classes were developed for wildlife sighting proximity: 0-5 km (very high), 5-10 km (high), 10-15 km (moderate), 15-20 km (low), and beyond 20 km (very low) (Figure 4).

River Proximity:

The importance of river proximity in ecotourism led to the use of drainage analysis with SRTM DEM. Proximity to the drainage network was analyzed to identify desirable locations for ecotourism development. Five suitability zones were established: extremely high suitability (0-2 km), high (2-4 km), moderate (4-6 km), low (6-8 km), and very low suitability (beyond 8 km). Land closer to the river is considered more significant for ecotourism development compared to areas farther away (Figure 5).

Precipitation:

Precipitation can trigger landslides and rainstorms [7], making it crucial for ecotourism sites in mountainous regions to experience limited precipitation to ensure tourist safety. Precipitation data (in mm) was categorized into five suitability classes: "very high" suitability corresponds to lower precipitation levels, while "very low" suitability indicates higher precipitation levels (Figure 6).

Protected Areas:

Ecotourism development within protected areas enhances the protection of biological and environmental resources [31]. These areas provide essential ecological services, including habitats for wildlife. The research area is particularly suitable for ecotourism and adventure activities due to the presence of Chitral Gol (National Park), Agram Basti (Wildlife Sanctuary), Gehrait Gol, and ParitGol/Ghinar Gol (Game Reserve). Cultural resources, if present, are preserved through the establishment of ecotourism destinations within these protected areas. Furthermore, these areas offer facilities for a range of adventurous activities, such as designated camping grounds, hunting areas, and trekking routes. Suitability was classified into five categories based on proximity: 0-2 km (very high), 2-4 km (high), 4-6 km (moderate), 6-8 km (low), and beyond 8 km (very low) (Figure 7).

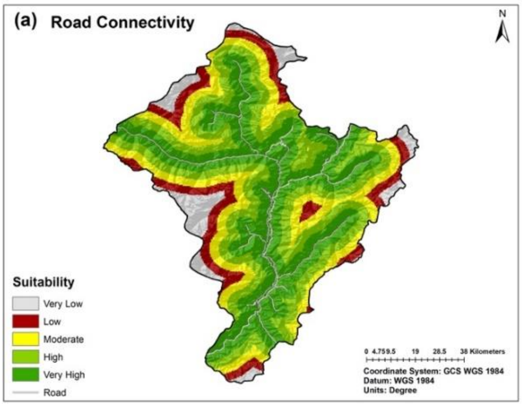

Figure 3: Road Connectivity

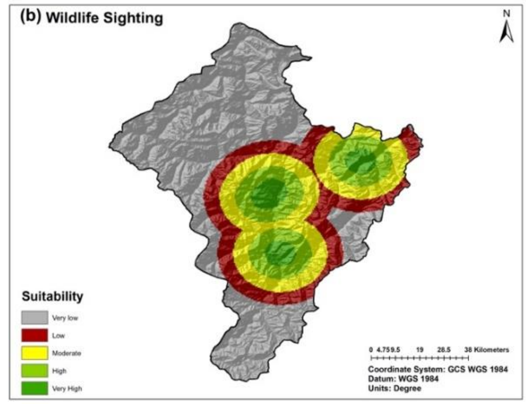

Figure 4: Wildlife Sighting

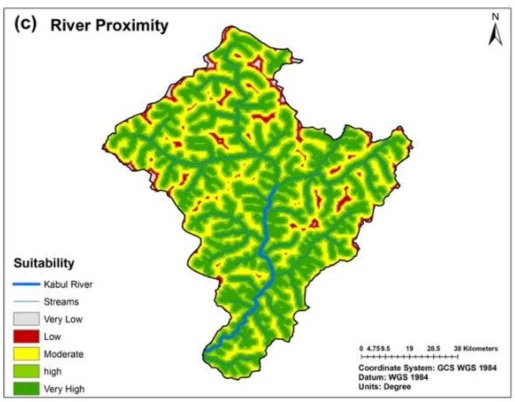

Figure 5: River Proximity

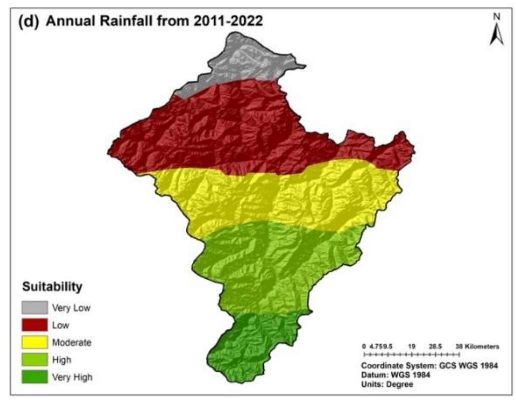

Figure 6: Annual Rainfall 2011-2022

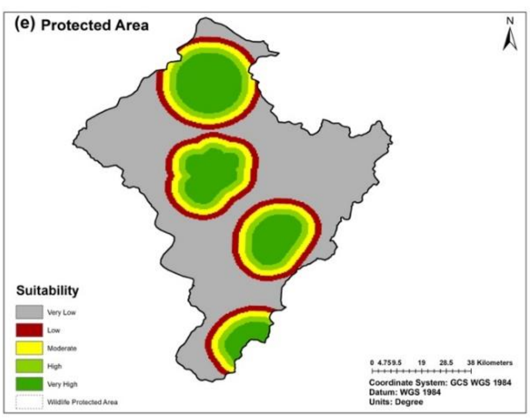

Figure 7: Protected Area

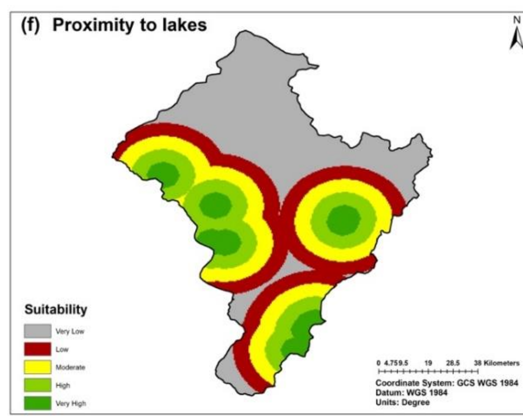

Figure 8: Proximity to lakes

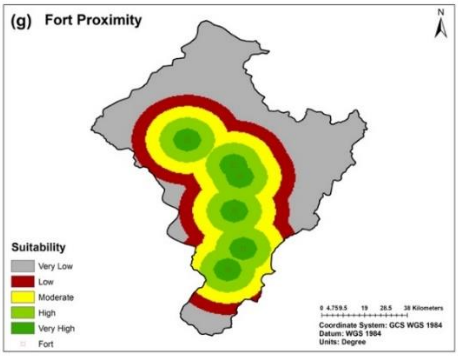

Figure 9: Fort Proximity

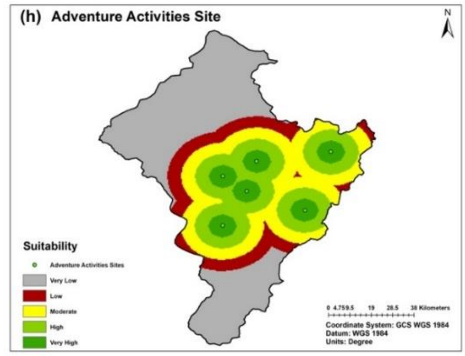

Figure 10: Adventure activity sites

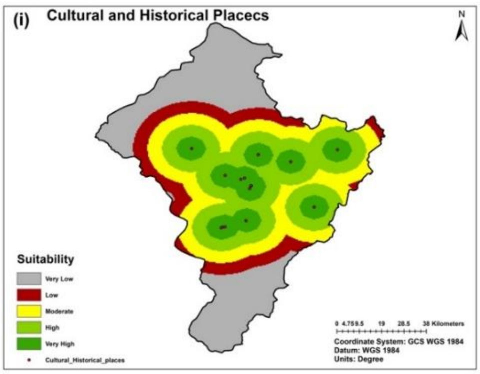

Figure 11: Cultural and historical places

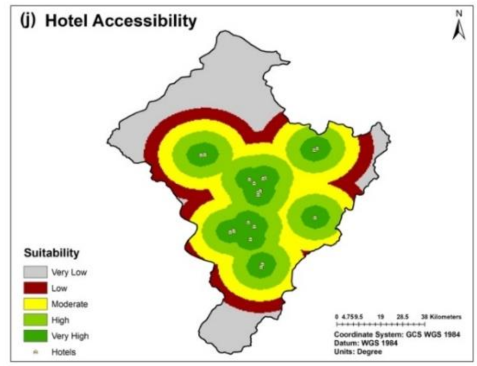

Figure 12: Hotel accessibility

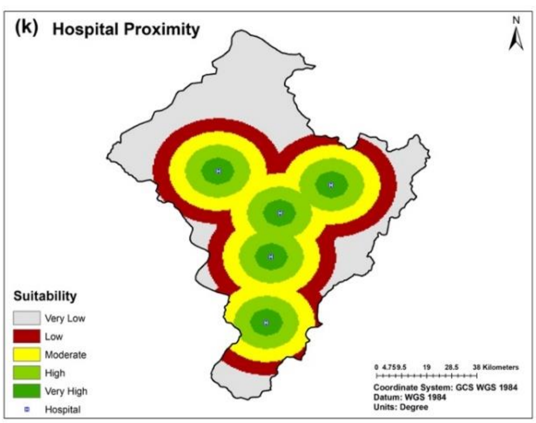

Figure 13: Hospital proximity

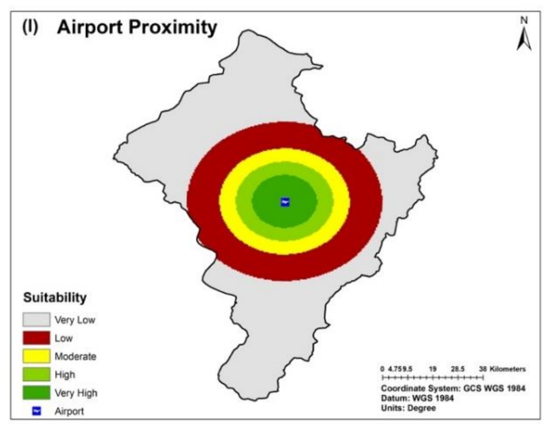

Figure 14: Airport proximity

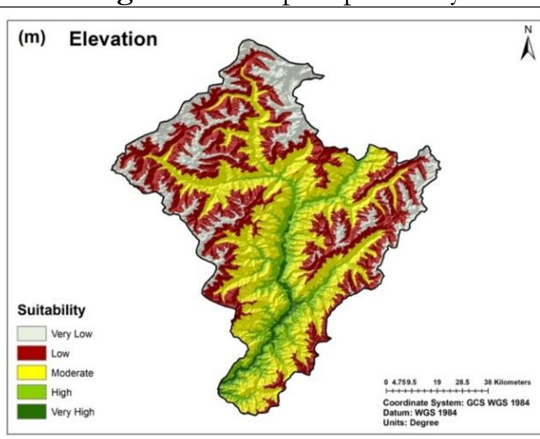

Figure 15: Elevation

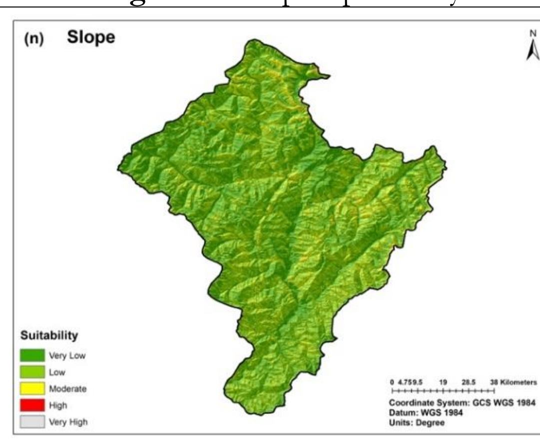

Figure 16: Slope

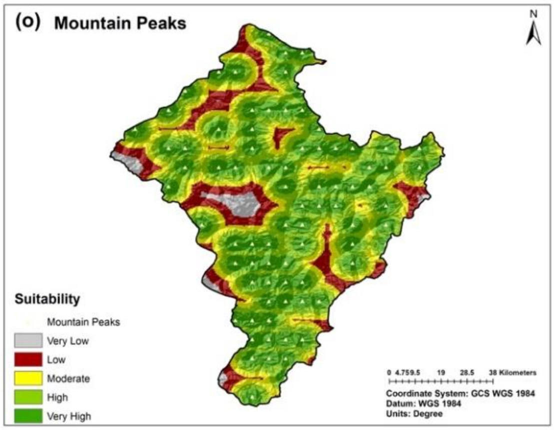

Figure 17: Mountain peaks

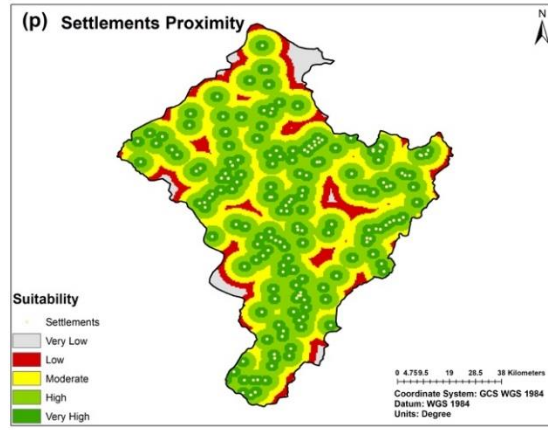

Figure 18: Settlements proximity

Lake's Proximity:

Lakes are essential for ecotourism, providing unique natural attractions and enhancing the overall tourism experience. They offer opportunities for various adventurous activities and should be located close to key ecotourism destinations. Proximity to lakes was categorized into five suitability classes: 0-5 km (very high), 5-10 km (high), 10-15 km (moderate), 15-20 km (low), and beyond 20 km (very low) (Figure 8).

Fort Proximity:

Forts significantly contribute to ecotourism by adding historical and cultural depth to destinations. These ancient structures combine architectural beauty and historical significance, creating unique attractions. Forts often feature remarkable craftsmanship and provide a setting where visitors can explore the region's history, local customs, and cultural heritage. Proximity to forts was assessed using five buffer zones: 0-5 km (very high), 5-10 km (high), 10-15 km (moderate), 15-20 km (low), and beyond 20 km (very low) (Figure 9).

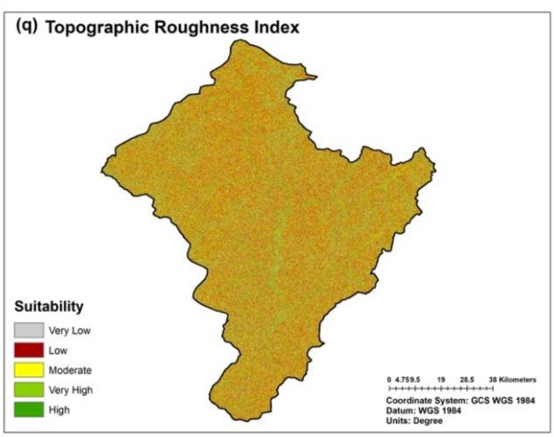

Figure 19: Topographic roughness index

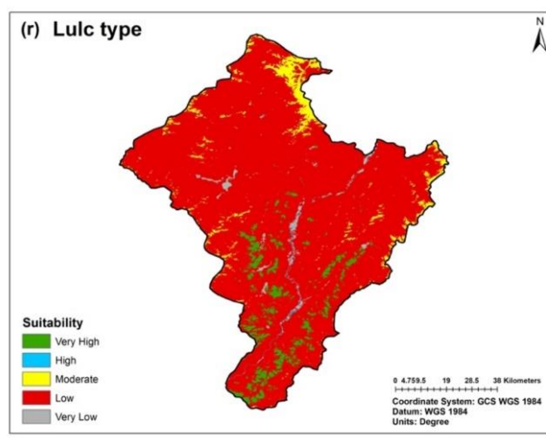

Figure 20: Land use land cover type

Adventure Activities Sites:

Adventure activities such as camping, hiking, fishing, boating, bird watching, paragliding, and hunting attract tourists [11]. Thus, higher weightage was given to areas close to these activities. Proximity to adventure sites was classified into five suitability categories: 0-5 km (very high), 5-10 km (high), 10-15 km (moderate), 15-20 km (low), and beyond 20 km (very low) (Figure 10).

Cultural and Historical Sites:

Historical and cultural locations, identified from Google Maps, are significant for ecotourism as they offer cultural engagement opportunities that support rural tourism growth. The preservation of local culture is a core goal of ecotourism. Proximity to these sites was analyzed and categorized into five suitability zones: 0-5 km (very high), 5-10 km (high), 10-15 km (moderate), 15-20 km (low), and beyond 20 km (very low) (Figure 11).

Hotel Accessibility:

Effective ecotourism relies on accessibility to accommodations, including eco-friendly hotels, lodges, and restaurants. Proximity to hotels was classified into five suitability levels: 0-5 km (very high), 5-10 km (high), 10-15 km (moderate), 15-20 km (low), and beyond 20 km (very low) (Figure 12).

Hospital Proximity:

Hospitals are crucial for ensuring the health and safety of tourists, enhancing the overall ecotourism experience. Although not directly related to primary ecotourism activities, their presence is important. Hospital proximity was categorized into five suitability classes: very high, high, moderate, low, and very low (Figure 13).

Airport Proximity:

Airports are vital for international tourists seeking efficient travel options. Proximity to the only airport in the study area was classified into five suitability levels, with areas closer to the airport being more suitable for ecotourism (Figure 14).

Elevation:

Elevation influences ecotourism site development, with higher elevations typically being less suitable due to reduced oxygen levels and lower human habitation possibilities [31][27]. Elevation was categorized into five suitability classes: 0-2000 m (very high), 2000-3000 m (high), 3000-4000 m (moderate), 4000-5500 m (low), and 5500-7500 m (very low) (Figure 15).

Slope:

Slope is a critical factor for ecotourism site development, with flatter land being more favorable [14]. Slope was assessed using the Shuttle Radar Topographic Mission (SRTM) DEM, categorized into: 0°-30° (very high), 30°-40° (high), 40°-50° (moderate), 50°-60° (low), and 60°-70° (very low) (Figure 16).

Mountain Peaks:

Mountain peaks offer scenic views and opportunities for activities such as hiking and wildlife sighting. Proximity to these peaks was categorized into five suitability levels based on distance, with areas closer to the peaks being more favorable for ecotourism (Figure 17).

Settlement Proximity:

The presence of human settlements enhances cultural diversity, appealing to tourists interested in local traditions. Proximity to settlements was classified into five suitability zones: 0-5 km (very high), 5-10 km (high), 10-15 km (moderate), 15-20 km (low), and beyond 20 km (very low) (Figure 18).

Topographic Roughness Index:

The Topographic Roughness Index (TRI) inversely correlates with ecotourism potential, indicating terrain ruggedness [27]. TRI was calculated based on local elevation and terrain roughness (Figure 19).

Land Cover Type:

Land cover types describe the physical characteristics of the study area's surface. The study area was categorized into eight land cover types: Bare Land, Built-Up Area, Crops, Flooded Vegetation, Rangeland, Snow/Ice, Trees, and Water. Forested and tree-covered areas were considered most suitable for ecotourism (Figure 20).

Land Use and Land Cover:

The Sentinel-2 LULC global map was used to classify the study area into six categories: water bodies, built-up areas, rangeland, snow cover, barren land, and forested regions (Figure 21). The land use and land cover classification highlights areas suitable for various levels of ecotourism activities based on slope, elevation, and vegetation (Figure 22).

Ecotourism Potential Assessment:

Standardization:

Standardizing the criteria across anthropological, ecological, topographical, and natural dimensions is crucial for comparison. Raster data for each parameter were assigned values based on their significance and suitability for ecotourism. This standardization facilitates the creation of an ecotourism potential map by assigning priority scores and rankings based on the importance and suitability of each sub-criteria.

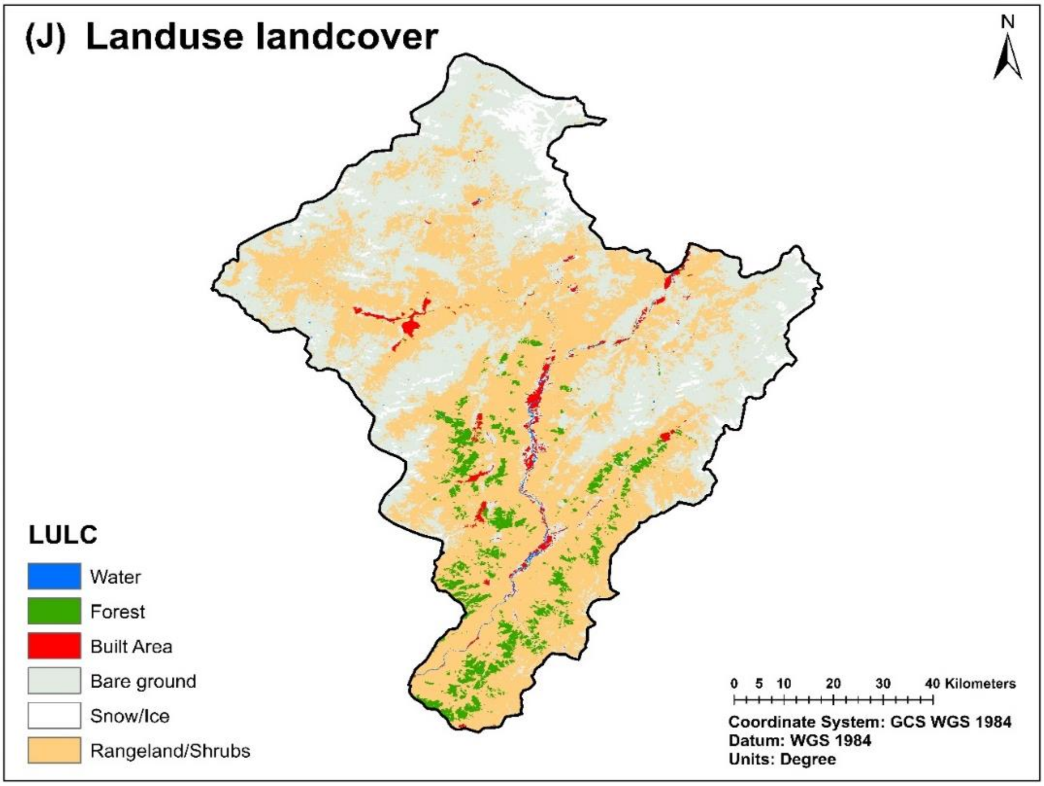

Figure 21: Map showing land use land cover of the study area

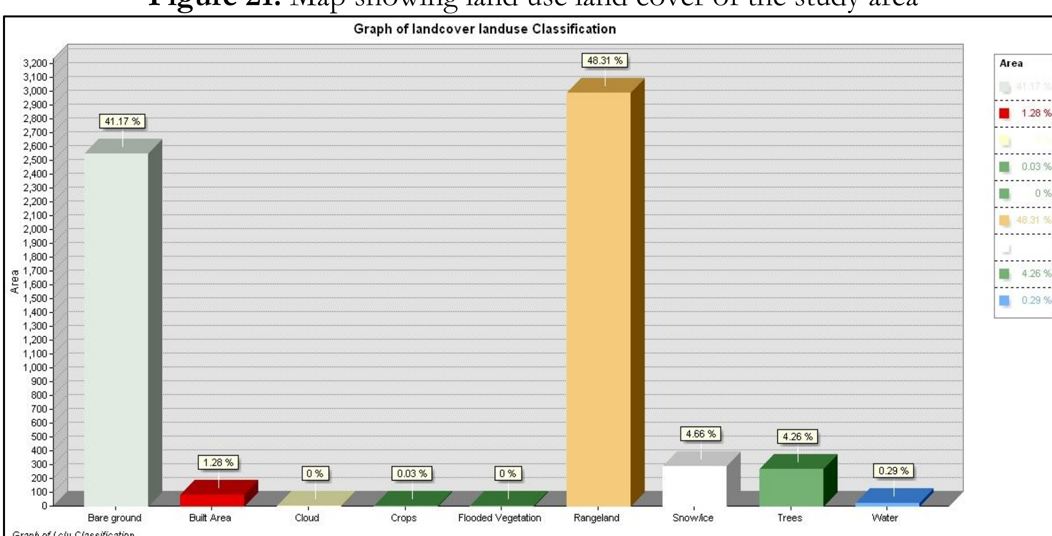

Figure 22: Graph showing land use and land cover classification of the study area

Suitability Assessment:

To identify the most suitable locations based on the combined suitability scores of each factor, a multi-factor analysis is conducted. This analysis uses a linear combination approach to create a final suitability map. The algorithm generates pixel-based classes from the factor maps and integrates these using a weighted overlay method, which incorporates the results from the Analytic Hierarchy Process (AHP).

For the final suitability map, each raster data layer, including its classes and criteria for the eighteen parameters, is multiplied by its corresponding AHP weight. The resulting map of ecotourism potential zones is based on these weighted values (see Figure 23). The ecotourism potential is categorized into five levels: Very High, High, Moderate, Low, and Very Low. The majority of the study area falls into the Moderate category, covering 3141.026 km² (51.33%). This is followed by Low at 1118.666 km² (18.28%), High at 1750 km² (26.61%), Very High at 103.3733 km² (1.69%), and Very Low, which covers the smallest area at 5.645 km² (0.09%) (see Figure 24).

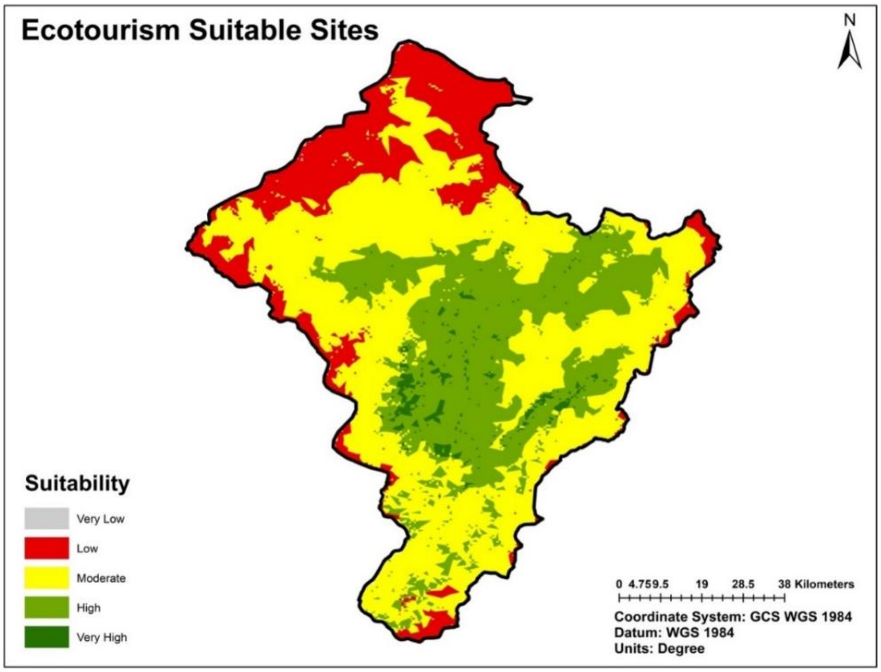

Figure 23: Ecotourism suitability assessment results

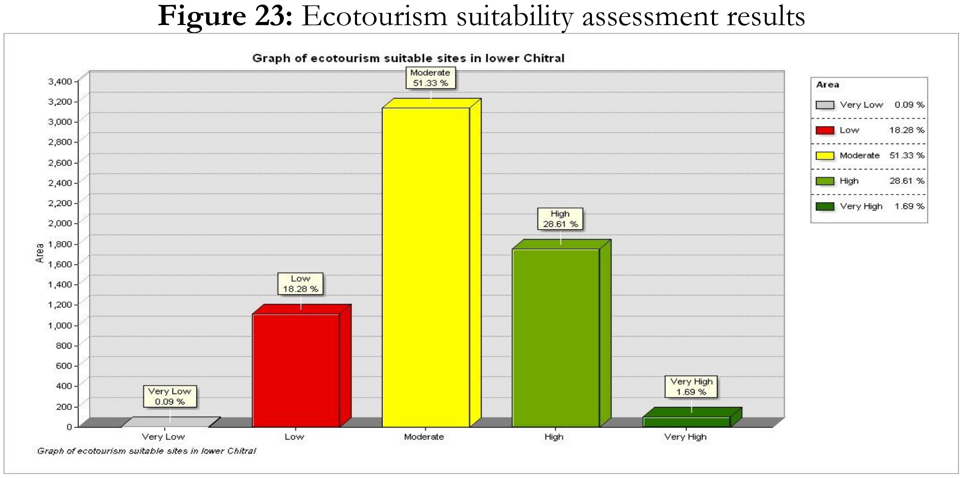

Figure 24: Graph showing ecotourism suitable sites in Lower Chitral

Conclusion:

Evaluating ecotourism potential is crucial for organizations managing ecotourism and environmental conservation. This research, leveraging both primary and secondary data alongside extensive spatial and attribute analysis through GIS tools, aimed to identify suitable ecotourism sites in Lower Chitral. By integrating remote sensing, GIS, and Multi-Criteria Decision Analysis (MCDA) techniques, the study uniquely assessed ecotourism potential by considering a diverse range of physical, cultural, environmental, and infrastructural factors. The study area was classified into five ecotourism suitability zones: Very Low, Low, Moderate, High, and Very High. Results indicated that 0.09% of the area was categorized as Very Low, 18.28% as Low, 51.33% as Moderate, 28.61% as High, and 1.69% as Very High. These findings illustrate the varied potential for ecotourism development across Lower Chitral and offer a detailed framework for sustainable tourism planning.

Based on these findings, it is recommended that areas identified as highly suitable for ecotourism should receive investments in infrastructure such as roads, accommodations, and visitor facilities to improve accessibility and comfort for tourists, thus fostering sustainable tourism growth. Engaging local communities in the planning and development process ensures that economic benefits are distributed locally. Implementing training programs in hospitality, tour guiding, and environmental conservation for community members can enhance local involvement. Environmental education programs for tourists and locals can raise awareness about conservation issues and promote sustainable practices. Targeted marketing campaigns showcasing Lower Chitral's unique ecotourism opportunities can attract both domestic and international tourists by highlighting the area's natural beauty, cultural heritage, and adventure activities. Strict regulations to manage tourist activities and monitor environmental impact, including visitor caps in sensitive areas, waste management protocols, and regular environmental assessments, are essential.

This research has significant policy implications. Formulating policies that promote sustainable tourism practices and support ecotourism development is crucial. These policies should encourage low-impact tourism, protect natural and cultural heritage, and provide incentives for sustainable business practices. Both government and non-governmental organizations should offer financial support and resources for ecotourism projects, including grants and subsidies for infrastructure development and community-based tourism initiatives. Developing a comprehensive ecotourism strategy that integrates environmental conservation, community development, and economic growth can ensure the long-term sustainability of tourism in Lower Chitral. Conducting longitudinal studies to monitor the environmental, economic, and social impacts of ecotourism can provide valuable insights and inform adaptive management strategies. Utilizing advanced technologies such as drone mapping, AI, and machine learning can enhance the precision and efficiency of ecotourism potential assessments. Investigating the impact of climate change on ecotourism potential and developing adaptive strategies will be crucial for future sustainability. Extending similar studies to other regions in Pakistan can broaden the understanding of the country's ecotourism potential and contribute to creating a national ecotourism network. Engaging local communities in participatory research can provide deeper insights into the socio-cultural dimensions of ecotourism, ensuring that development initiatives are culturally appropriate and locally accepted. By implementing these recommendations and pursuing future research, Pakistan can harness the potential of ecotourism to promote sustainable development, environmental conservation, and socio-economic benefits for local communities.

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