CARC Research in Social Sciences 3(1) (2024) 113-123

15-CRISS-424-113

Content list available at:
https://journals.carc.com.pk/index.php/CRISS/article/view/113

CARC Research in Social Sciences

Journal homepage : journals.carc.com.pk

Assessment of Potential Ecotourism Sites using Multi-Influencing Factor and Geo-spatial Technique in District Swat, Pakistan

Zahid Ali[1*], Muhammad Jamal Nasir[1] & Shahid Iqbal[2]

[1] Department of Geography and Geomatices, University of Peshawar
[2] Center for Disaster Preparedness and Management, University of Peshawar

ARTICLE INFO

Article history:

Received: February 20, 2024
Revised: March 26, 2024
Accepted: March. 28, 2024
Published: March. 31, 2024

Keywords:

Ecotourism
Environment
MIF
Potential sites
Economic Development

ABSTRACT

The main purpose of the present research is to assess and identify the potential ecotourism sites in district Swat of Pakistan using the Multi- Influencing Factor (MIF) and Geographical Information System (GIS). Landscapes/naturalness, rainfall, temperature, sunny day. Wildlife distribution, land use land cover (LULC), elevation, slope, proximity to cultural and historical sites were taken into consideration. The literature review was used as the basis to determine the parameters. The multi influencing techniques was efficiently utilized in the present study to delineate sub-parameters as suitable, less suitable and unsuitable. In order to figure out the potential sites for ecotourism, the final weighting of the parameters was calculated in the ArcGIS 10.8. based on the analysis, there is a lot of opportunity for ecotourism in the selected site; however, the southern part of the study area has greater potential compared to the rest. The main contributors are the accessibility, rich historical archaeological sites, wildlife distribution, and its infrastructure. Although there are amazing glacial lakes, dense vegetation and scenic scenery in the northern part, but accessibility is a main challenge. The central and western sites having the less potential for an ecotourism f perspective. Results of the study are expected to be useful in the identification of ecotourism potentiality in Swat district and socioeconomic growth in the region.

1. INTRODUCTION

The word tourism is derived from the Hebrew word "Tora" meaning "to study, learn, and research". There is no single accepted definition of ecotourism as there are many aspects of ecotourism defined by several researchers [1]. The term ecotourism was first used in 1987 by Ceballes-Lascuraine and refers to it as "visiting the comparatively untouched and virgin area with the definite objective to appraise not only culture and customs of the area but also appreciate the natural landscape and wildlife [2]. Ecotourism is a voluntary journey to untouched areas to enjoy the natural beauty and to familiarize yourself with the customs and traditions of the local society [3]. Ecotourism is traveling to relatively untouched natural areas with a specific goal to study and enjoy the landscapes, wildlife, and plants. Ecotourism has many advantages including conservation of the natural environment, preservation of wildlife, and projection of cultural objectives and historical perspectives [4].

The central theme of ecotourism is the protection of cultural and natural assets along with financial gain. The United Nations World Tourism Organization states that communities can benefit financially from ecotourism in many ways including job opportunities, service provision to tourists, sale of goods and local handicrafts investment in hospitality services, etc. [5]. In several regions of the World, ecotourism has wiped out poverty and has also helped in

*Corresponding author:

Zahid Ali, Department of Geography and Geomatices, University of Peshawar
e-mail: azahidlec@gmail.com

How to Cite:

Ali, Z., Nasir, M. J., & Iqbal, S. (2024). Assessment of Potential Ecotourism Sites using Multi-Influencing Factor and Geo-spatial Technique in District Swat, Pakistan. *CARC Research in Social Sciences, 3(1)*, 113–123.

DOI: https://doi.org/10.58329/criss.v3i1.113

natural resource conservation [6]. Therefore, ecotourism is more business than philosophy. It is a worldwide income-generating industry; that generates 10% of global GDP [7].

Geographic Information System (GIS) can be effectively utilized in finding suitable locations for ecotourism by taking multiple factors into account and helping in formulating strategy by providing ecotourism potentiate sites map in return [8]. The Multi influencing Factors approach is a technique for assessing the factors that influence the decision-making process [9]. GIS-based multi-influencing factors approach has been efficiently used for the development of the tourism sector by the delineation of potential ecotourism sites, tourism environmental impact assessment, assessing tourist flow, and management of selected sites [10] pointed out the role of GIS technology in developing a database and analyzing data related to tourist accommodations in Malaysia. [11], evaluate the ecotourism potential of Kermanshah, Iran based on landscape, soil, slope, aspect, elevation, vegetation cover, rainfall, and temperature using GIS. (Waswa Wanyonyi et al., 2016), used an integrated approach of GIS and the Analytical Hirarcy Process (AHP) to evaluate the ecotourism perspective in Kwale County, Kenya. The study delineates the ecotourism potential site based on landscape, wildlife, topography, accessibility (distance from the road, heritage sites, etc.), and community attributes. [12] used an integrated approach based on GIS, multi-criteria evaluation (MCE), and analytic network process (ANP) to assess the priorities of sustainable ecotourism development of the Cameron Highlands in Malaysia. [13] evaluated the geo-tourism potential of three districts i.e. Soma, Kula, and Salihli of Manisa province, Turkey. The study utilized qualitative and quantitative evaluation criteria.

The study area, district Swat is blessed with enormously striking landscapes, waterfalls, glacial lakes, and biodiversity-rich valleys and has extraordinary potential for ecotourism, but still, most parts of the district are hidden. Due to the technological advancement, and application of geospatial and MIF technique, the scenic sites of the study area by no means will be as hidden as it was in the past. The systematic MIF approach and integrated GIS will explore the virgin areas and hidden potentials for the ecotourism of Swat and will settle positive impacts both in natural and cultural landscapes. The first step for ecotourism development is the identification and delineation of areas with tourism potentiality, followed by tourism infrastructure development [14]. Therefore, keeping in view the present study is aimed at identifying the ecotourism potential sites using the MIF approach int the ArcGIS environment.

2. METHODS & MATERIALS

Study Area

Khyber Pakhtunkhwa of Pakistan alone holds three-fourths of Pakistan's tourist attractions in the form of scenic beauty, a site of archeological, cultural, historical, and religious implications. Some of the important tourist attractions are the Gilgit-Baltistan, Swat Valley commonly known as Switzerland of Pakistan, Chital Valley, Kaghan Valley, and Galliyat area [15]. The Swat district has the benefit of a high potential site for ecotourism development because of its snow-covered mountains, lush green forests, glacial lakes, wildlife, and diversity in folks and cultures. Swat district is indubitably the best attractive ecotourism destination in the Northern Khyber Pakhtunkhwa (KP) province in Pakistan. Swat is both an administrative district and a valley. The geographical location of Swat is from $34^{0}36'\ 59''$ to $35^{0}\ 44'\ 51''$ N Latitude to $72^{0}\ 29'\ 52''$ to $72^{0}\ 09'\ 52''$ E Longitude. It lies in the north of the lofty mountainous range of the Himalayas where some mountains are almost 5600 meters high. On the south is the mountainous ridge of Malakand Pass, on the east is the Kohistan area which borders the mighty Indus River, and on the west is the region of district dir. The average elevation of swat is 980 m which causes a cooler and wetter climate compared to most of the areas of Pakistan. Figure 1 illustrates the location of the study area.

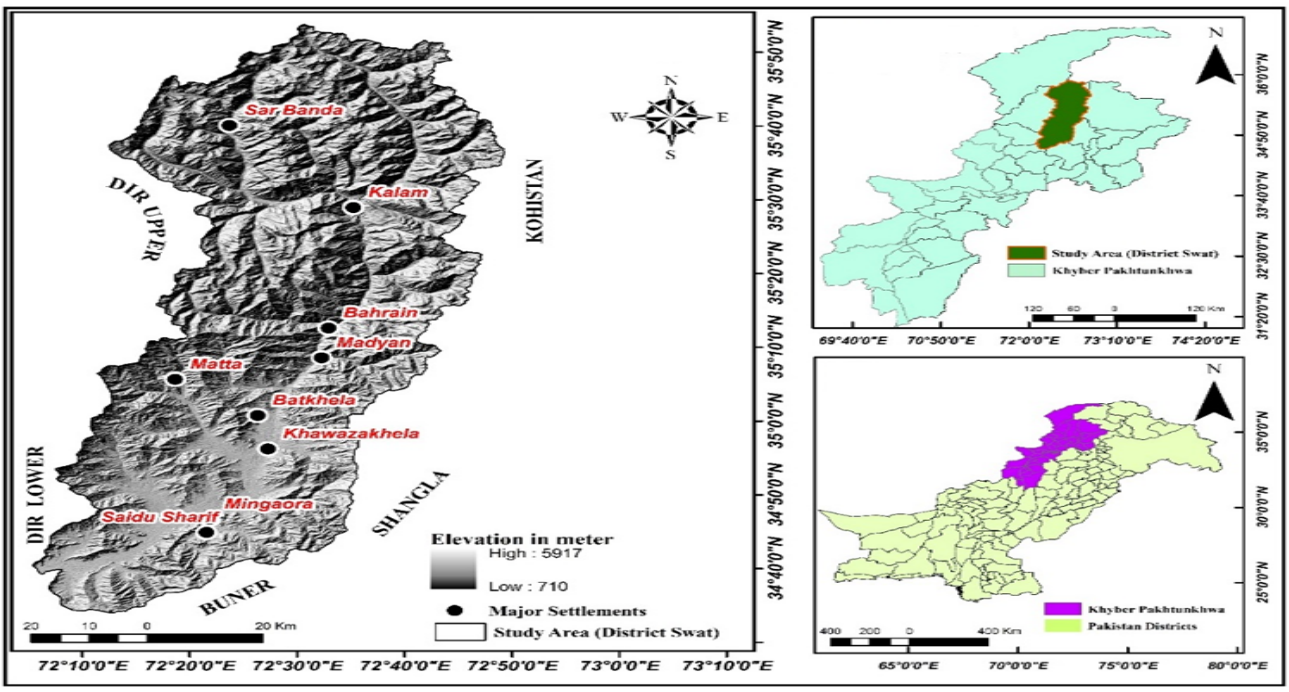

Figure 1. Locational map of the Swat District. Hill shed derived from SR Earth Explorer.

Data Collection

To assess suitability sites for ecotourism, 18 criteria layers has been created utilizing both, the primary and secondary data. Interviews with experts in several sectors, including ecotourism, activists, literature reviews and local experts, were conducted to determine components and criteria for ecotourism in the Swat district.the thematic layer has been chosen from the ecological, topography, climatic, landscape, cultural and historical sectors, based on literature analysis and expert feedback. Furthermore, 11 respondents were asked to rate the importance of each criterion on a scale 0-2. We were able to determinte the weight of each parameter by using such approach.

Remote Sensing Data

After pre-processing the open-source satellite imagery, the following parameters were generated:

Digital elevation Model(DEM)

Advanced Space borne Thermal Emission and Reflection Radiomater (ASTER) and GDEM V3, with a 15m spatial resolution, was utilized to collect landscape (elevation and slope) and river proximity data. The Land Process Distributed Active Archive Centre of NASA has been obtained the upgraded ASTER GDEM V3, which includes extra stereo-pairs, increased coverage, and decreased artifacts.

Sentinel 2 Image Collection

Utilizing the Google Earth Engine cloud-based computing platform, land cover categorization was done on an atmospherically modified Sentinel-2 satellite, level-2 Surface Reflectance (SR) composite. The S2 images were produced as 12 UINT16 spectral band with a spatial resolution of 10m, showing SR and scaled by 10,000. The four different spectral bands included Red 0.665 mm, Green 0.560 mm, Blue 0.490 mm, and near infrared 0.842mm. From May to September 2022, a median image composite with a minimum of 20% cloud cover was created using the median ee.Redul.cer function. It also removed pixels that was overly dark or bright.

Geospatial Secondary Data

Secondary data were used to identify location for lakes, mountainous peaks, historical sites, settlements, roads and river. Protected area were obtained from Protected Planet's database (https://www.protectedplanet.net/), while sites for adventure activity like game sanctuary and hunting, wildlife distribution were recorded from literature (W. Rashid et al., 2020).

Methodology for MIF Approach

The Multi Influencing (MIF) Technique was used to assign scores to sub parameters such as suitable, moderate suitable and unsuitable. The ultimate weight of the parameters was then calculated in ArcGIS 10.5.2 environment to assess the ecotourism potential sites. The methodology is shown in Figure 2 and Figure 3.

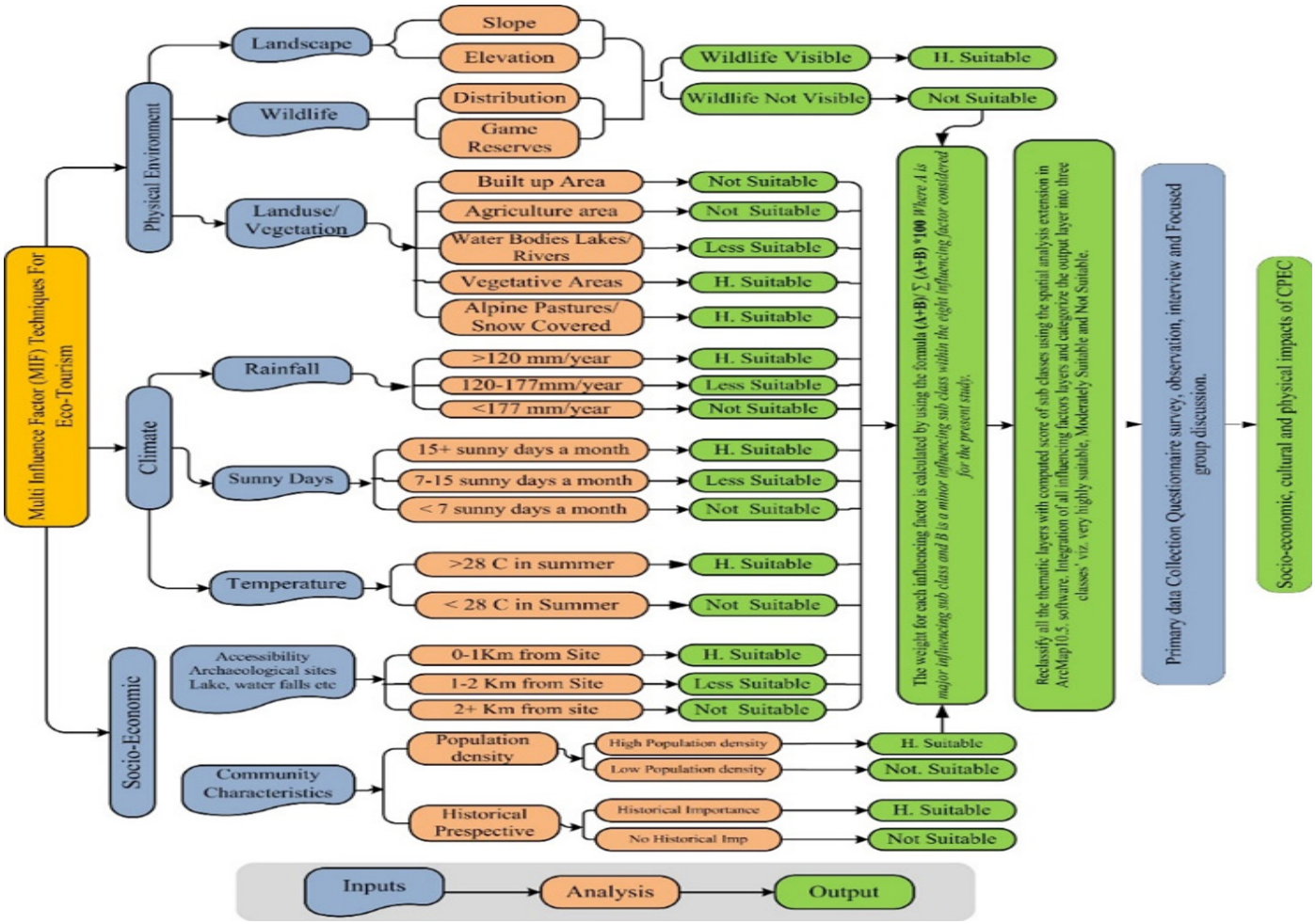

Figure 2: Flow chart of the methodology adopted for assigning suitability score to parameters

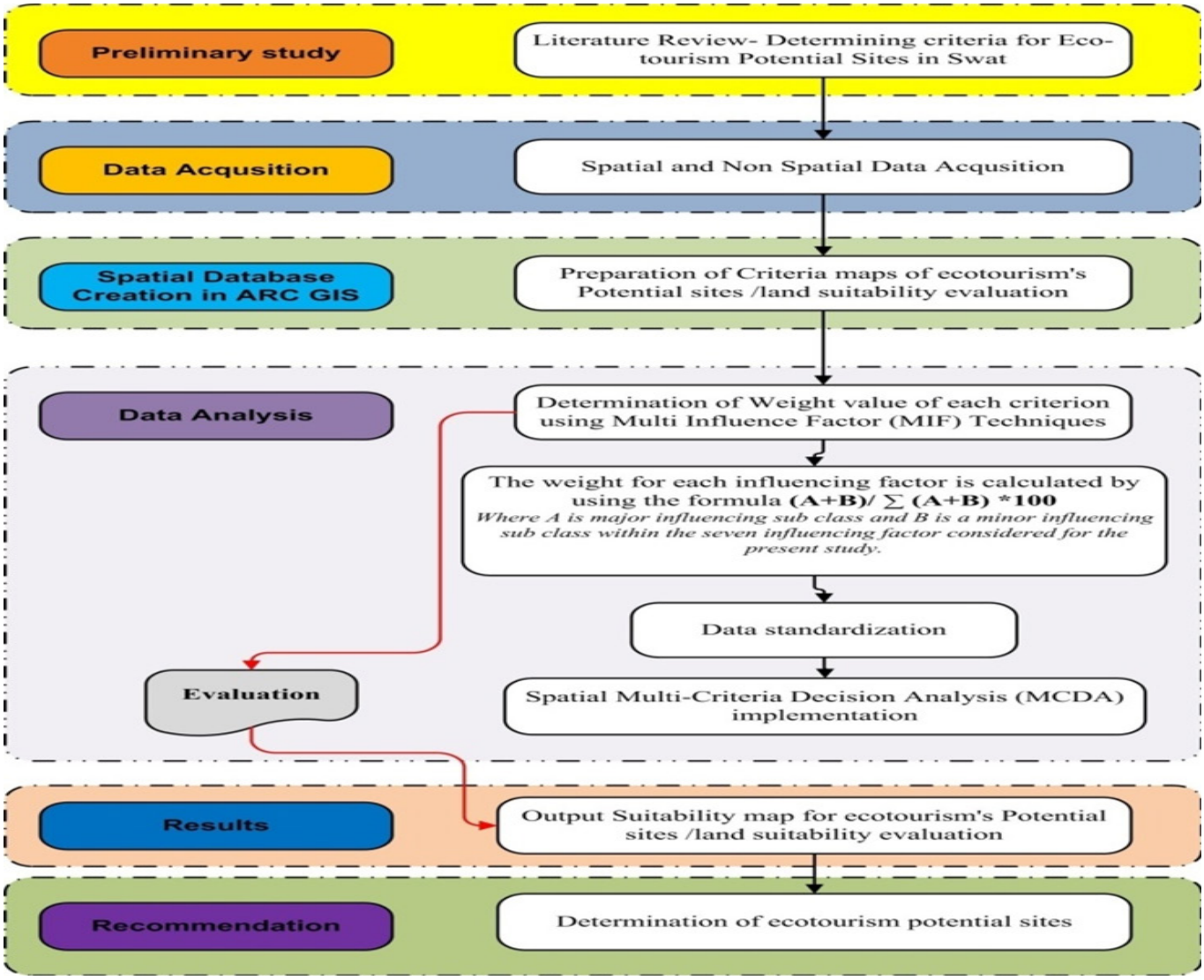

Figure 3: Showing the methodology for identification of Ecotourism Potential Sites (EPS).

Creation of Geo-Spatial Database and Map Creation

The first stage in this study is to select criterion or theme layers [16]. All factors and different criteria has been chosen on the basis of important, literature review and local experts. Thematic layers such as view shed and slope, rainfall, proximity to rovers, LULC, peaks, lakes, adventure activities, cultural and historical sites, roads and prominent settlements were used to identify potential ecotourism sites (Figure 2).

The LULC map derived from the classification of satellite image was reclassified according to the suitability of different land use classes i.e. vegetation, snow cover, water body, agriculture, and built-up areas for ecotourism potentiality. The wildlife data was collected from the wildlife, forestry, and environmental departments. The data were plotted in ArcGIS 10.8 as points layer and a wildlife map was generated. This map along with the community reserve and slope map generated through the DEM derived from the USGS Earth Explorer website was utilized to compute a viewshed map. The wished map shows the points on the map from where the wildlife is visible.

Climate is one of the most important factors among various other factors affecting tourism. The climate of the destination is of great significance for tourists while planning a visit [17]. The temperature and the precipitation data were obtained from the meteorological office in Peshawar. The data is collected from the six meteorological stations. Saidu Sharef, Kalam and Malam Jaba were located within the Swat district, while the other three were from the surrounding area Drosh, Timergara (Dir Lower), and Dir Upper. The locations of the met stations were digitized and the temperature and rainfall data were entered in the attribute table. The second step was the creation of rainfall and temperature zones. This was done through kriging interpolation in ArcGIS 10.8 spatial analyst environment. The rainfall and temperature interpolated layer is then classified into various zones depending upon its appropriateness in delineating the eco-tourism potential sites. The logic behind this was the fact that appropriate rainfall is the source of beauty and attraction. The lowest temperature was believed as more appropriate for both the human recreation and ecotourism sites because no one wants rainfall while they are on vacation and visiting a beautiful place with their family.

Ecotourism often takes place in cultural, historical, and traditional places. It also takes place in scenic areas with glaciated lakes. Therefore, access to such sites is an important

factor for ecotourism. Roads provide access to the locations of tourists' choice. The Euclidean distance tool was applied to roads, historical sites, and lakes. Equal distance buffers were created around all the roads, historical sites, and lakes in the study area. The distance layer was then classified depending upon the appropriate corridor into suitable and unsuitable zones and consequently re-classified with the appropriate score.

The accessible heritage and cultural center are a significant tourist attraction. Visitors are often interested in the cultural and archaeological heritage of a particular area. Such sites are highly desirable for tourism development and, therefore are considered an important parameter for determining the eco-tourism potentiality of a particular area. District Swat is culturally and historically a very significant region in the Northern area of Pakistan. It is famous not just for its striking landscape and scenic beauty but also for its antique Buddhist monasteries and archaeological sites. The southern part is rich in history and remains of Buddhist stupas. These sites were mapped with the help of fieldwork (accessible areas were mapped with the help of GPS waypoints) and available literature.

The Euclidean distance tool was applied to historical sites. Equal distance buffers were created around all the historical sites the study area. The distance layer was then categorized into suitable (1km) and unsuitable zones (more than 1km) and consequently re-classified with an appropriate score of 2 and 0 respectively. Figure 4 shows the parameter maps used in the analysis.

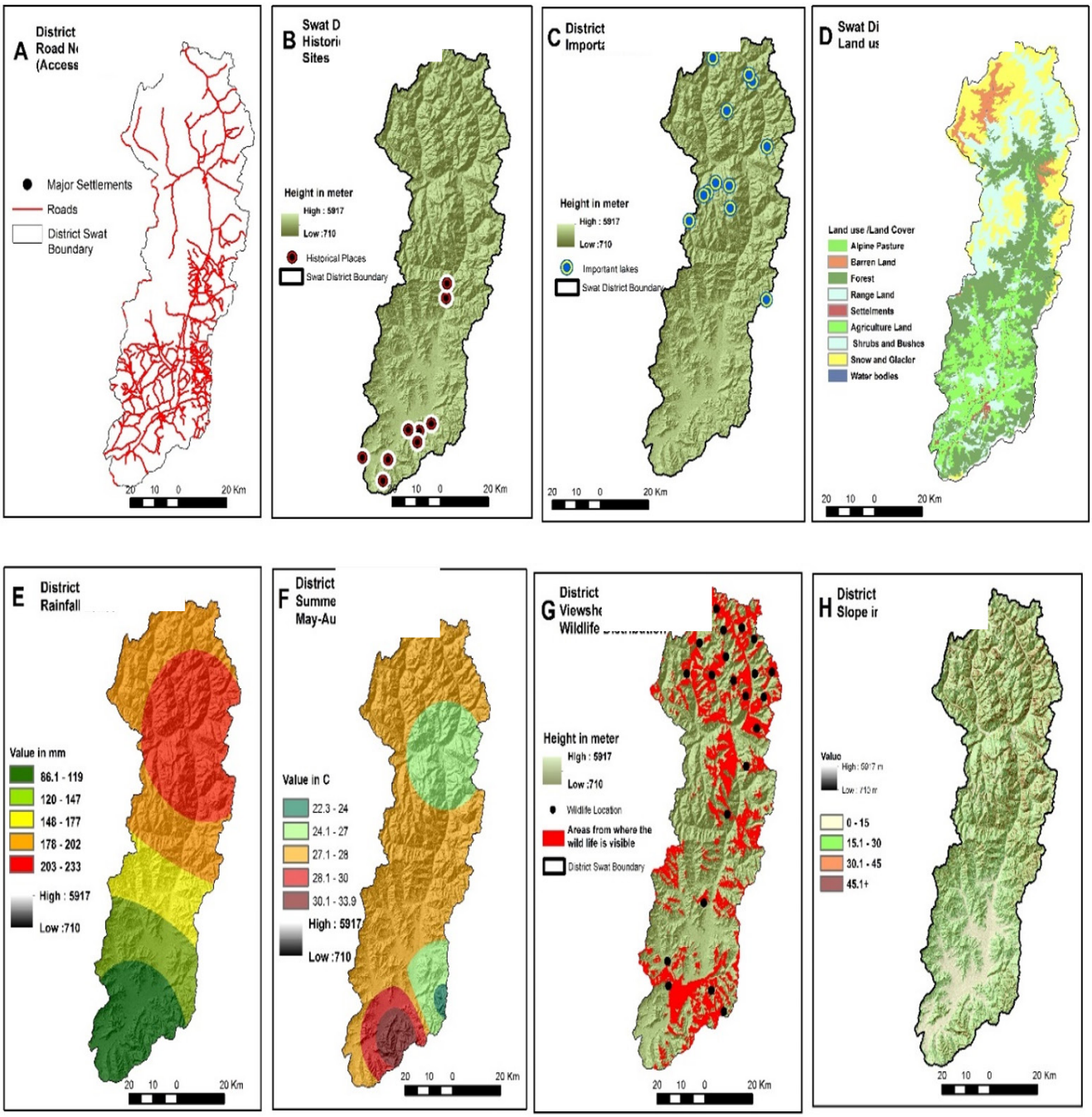

Figure 4. Showing Parameter maps used for analysis A. Roads B. Historical /Archeological Sites C. Important Lakes D. LULC E. Rainfall F. Temperature G. View Shed H. Slope

Determination of weight using MIF

The above parameter were processed, and an appropriate rating was ascribed to sub-class within each of the selected parameters. The sub-parameter classes with high suitability (A) were assigned a score of 2 and and less suitable class (B) was marked a score of 1 . The sub-classes that are not suitable for eco-tourism potentiality have given a score of zero (0). The accumulative score (A+B)of major (A) and Minor (B) effects were were considered for finding the relative effect (Table 1). Apart, the relative effects was then further utilized to compute the influencing parameter weight [18], [19], [20], [21]. Equation 1 has been used to identify the each influencing factors' weight.

$$\frac{A+B}{\sum(A+B)} * 100 \qquad (1)$$

A is for the Suitable while B is for the less suitable class

The influencing parameter was equally divided and then for each sub class was given a rank. Table 2 shows the rank and weight of sub-class of each factor. Figure 5 shows processed parameter maps for the delineation of ETPS.

Table 1.
Showing different thematic layers and the Score assigned to them

Theme	Class	Potentiality/suitability	score
Land use/ Land Cover	Alpine Pasture	Highly Suitable	2
	Snow	Highly Suitable	2
	Forest Area	Less Suitable	1
	Water Bodies	Less Suitable	0
	Agriculture	Not Suitable	0
	Built-Up	Not Suitable	0
Rainfall	< 120mm	Highly Suitable	2
	120-177mm	Less Suitable	1
	>177mm	Not Suitable	0
Accessibility	0-1km	Highly Suitable	2
	1.2km	Less Suitable	1
	2+	Not Suitable	0
Temperature	< 28 °C	Highly Suitable	2
	> 28 °C	Less Suitable	1
Historical Area	0-1 km	Highly Suitable	2
	1.2-km	Less Suitable	1
	2+ km	Not Suitable	0
Wildlife Visibility	Wildlife Visible	Highly Suitable	2
	Not Visible	Less Suitable	0
Lakes	0-1km	Highly Suitable	2
	>1Km	Less Suitable	0

Table 2.
Effect of influencing factor, Their Potentiality, and related Score and proposed weightage for each Selected parameter.

Parameters	Highly suitable (A)	Less suitable (B)	Proposed Effect (A+B)	Proposed Weight of each influencing factor
Land use land cover	4	1	5	24
Rainfall	2	1	3	14
Accessibility	2	1	3	14
Temperature	2	1	3	14
Historical Area	2	1	3	14
Wildlife Visibility	2	-	2	10
Lakes	2	-	2	10
			∑ 21	100

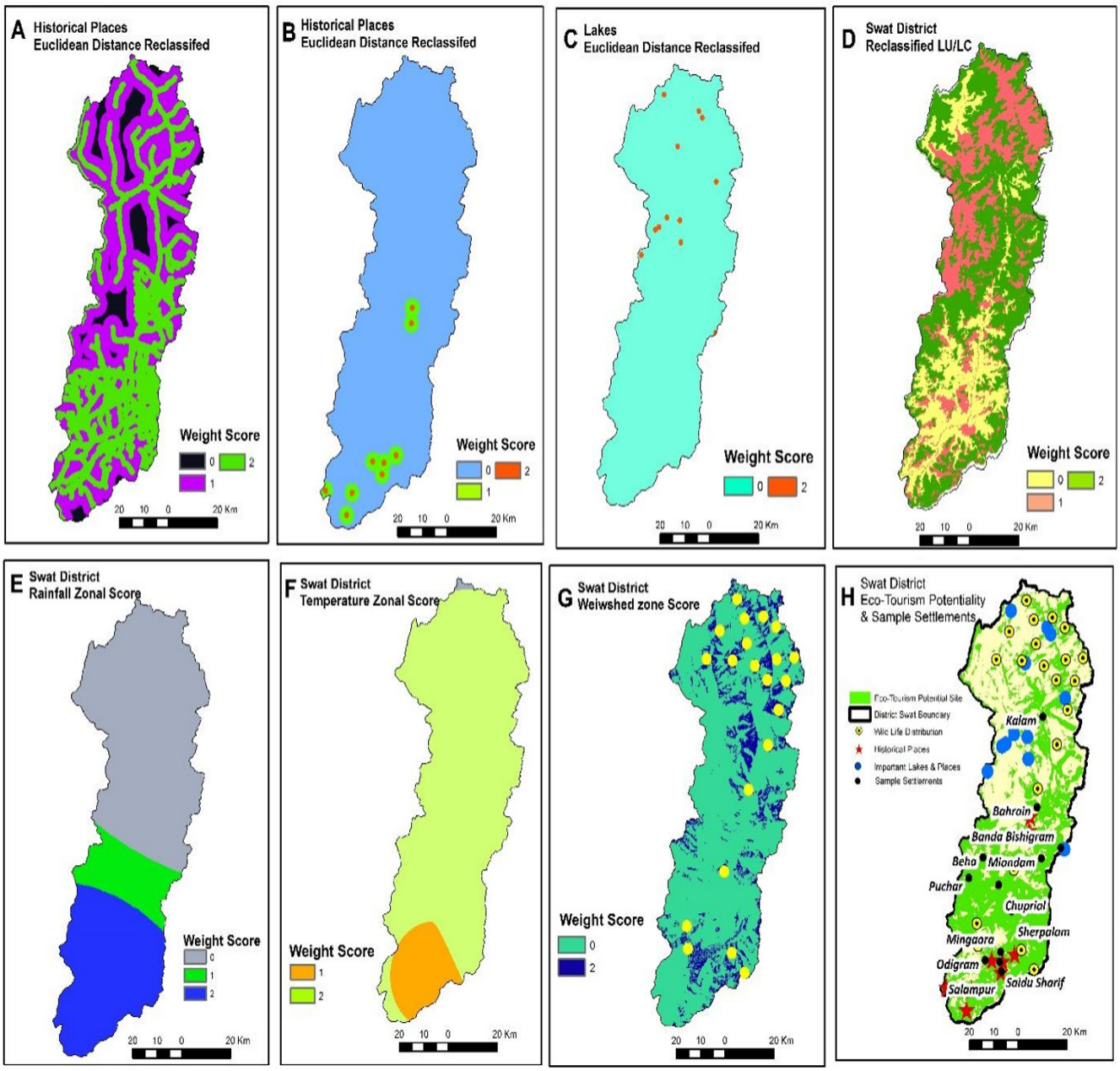

Figure 5. Showing Reclassified Parameter maps used for delineation of ETPS A. Roads B. Historical /Archaeological Sites C. Important Lakes D. LULC E. Rainfall F. Temperature G. View Shed H. Slope

Results

Figure 6 shows the computed ecotourism potential site of district Swat. The analysis reveals that the majority of areas in the south have important possible for ecotourism. The main reasons are accessibility, the archaeological and cultural sites, and the presence of game reserves. Besides, the region is also supported by its development infrastructure for historical sites. One can easily visit the natural and historical sites both in summer and winter. The areas possess six influencing factors out of the total nine. These influencing factors are the road network, historical sites, game reserves, wildlife distribution, wildlife-protected areas, and suitable rainfall conditions. The summer bearable temperature, scenic beauty, and wildlife distribution in the northern regions of district Swat are favorable for ecotourism development but inaccessibility is considered as a leading challenge. The northern area has beautiful glacial lakes that scatter all over the area. These famous lakes are, Kandol Lake (Utror, Kalam) Andrab Lake (Kalam), and Spin Khwar (white stream) are some of them. The central region generally and western area especially, having less potential for the development of ecotourism perspective. Some sites in the central part of district Swat show potential for ecotourism. Bashigram Lake (Madyan) and Daral Lake (Bahrain) are well-known lakes surrounded by mountains and awesome scenery. These lakes are approachable through trekking and hiking for a few hours.

Validation of Result

Figure 7 shows the validation of the study results i.e. delineated ecotourism potential sites, the computed potential site was overlaid by historical sites and the glacial lake of the study area. The overlay analysis reveals that almost all the historical and archaeological sites are well within the delineated potential sites. The same results were demonstrated by lakes; all the lakes are well within the potential sites. Figure 6 shows the delineated ecotourism potential sites overlapped by historical archaeological sites and Lakes. The same analysis was carried out with wildlife visible areas and was found satisfactory. A similar analysis was done with accessibility by roads and was found that almost all the delineated sites were accessible by road.

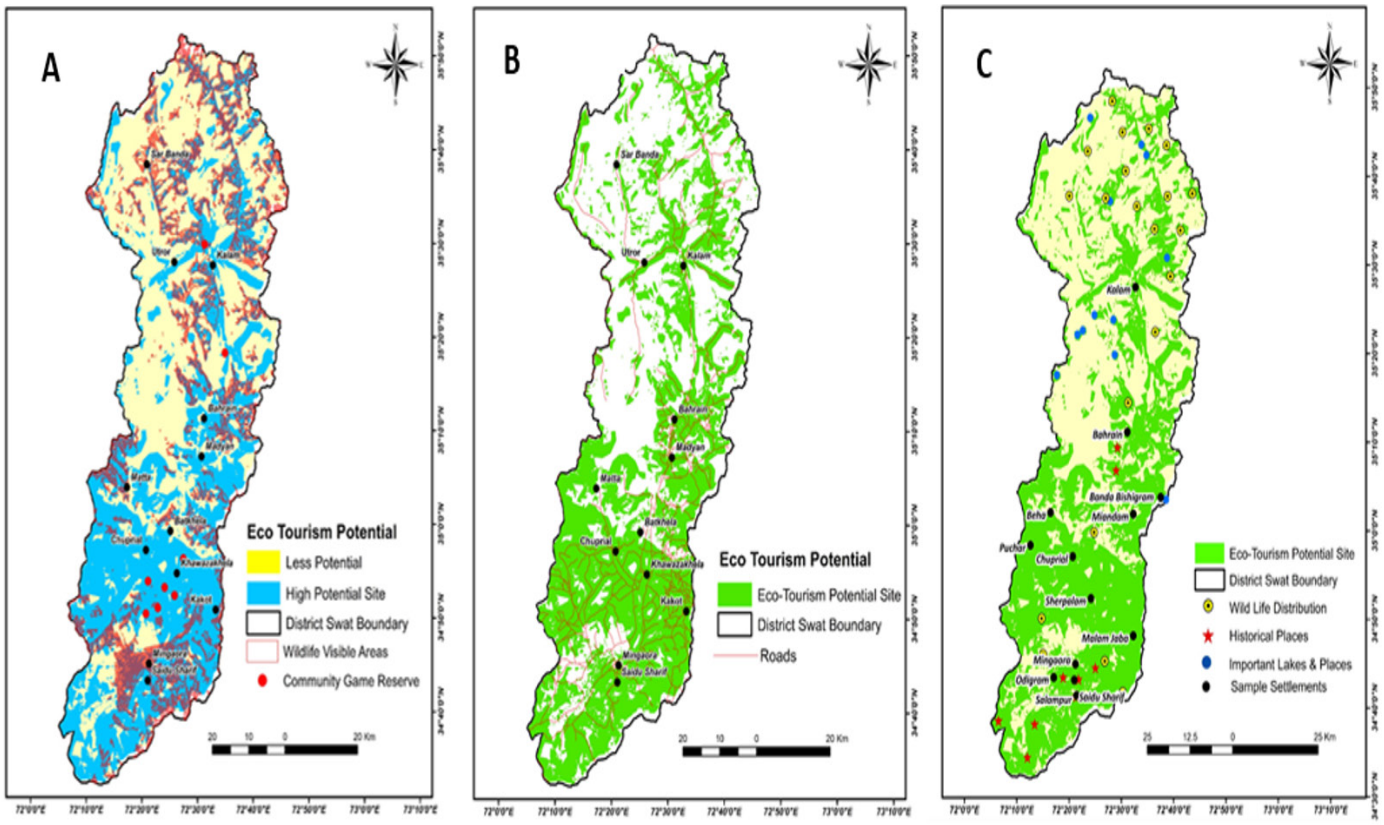

Figure 6: A: Potential sites overlapped by wildlife visible area B: Potential sites overlapped by road network C: Ecotourism Potential sites overlapped by wildlife, historical places and important lakes

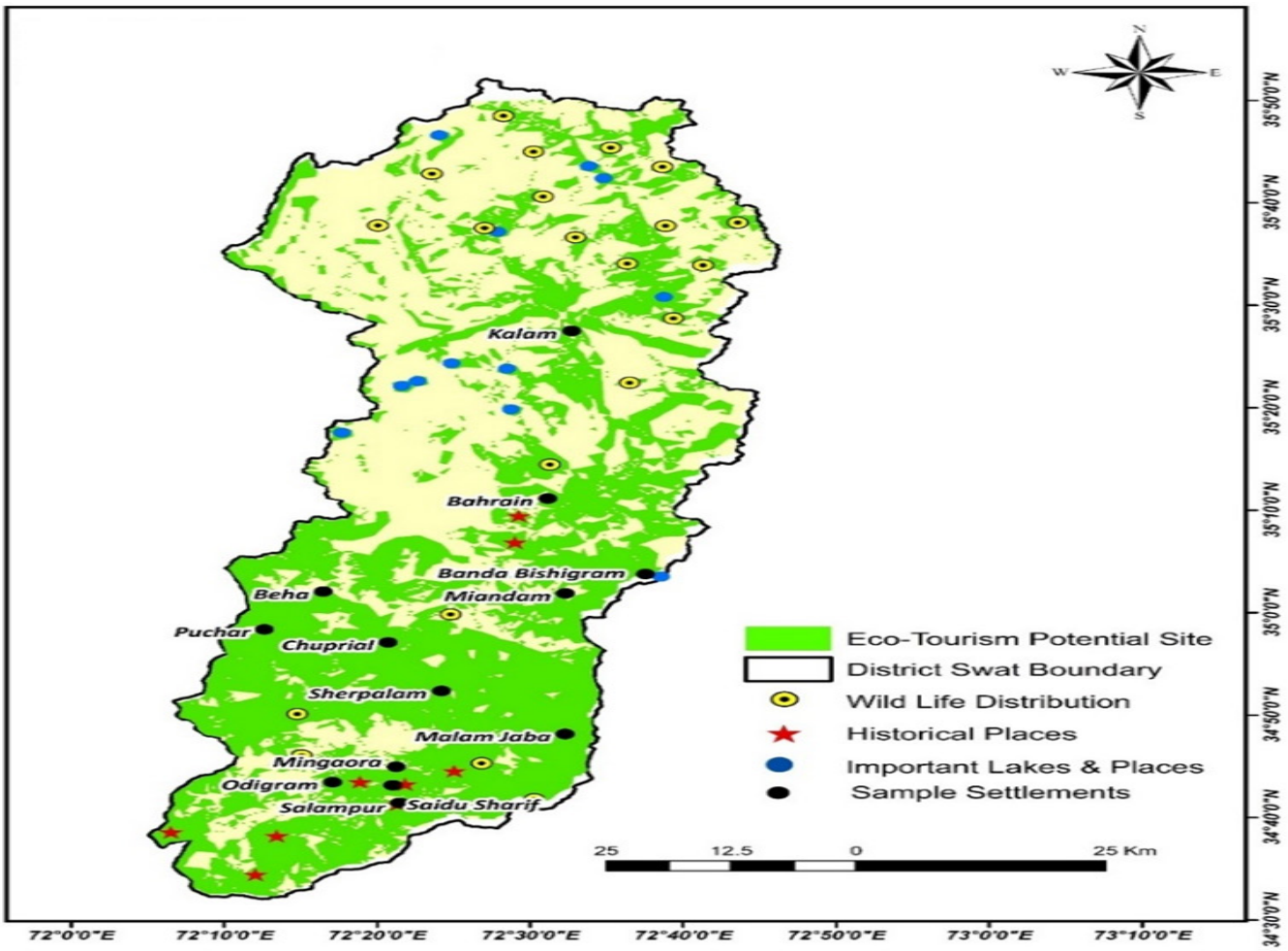

Figure 7. Showing Ecotourism Potential Map of District Swat

Discussion

The study underscores the significant role of tourism in the global socio-economic landscape, highlighting its position as a major economic driver worth trillions of dollars. Its substantial contribution to global GDP and employment, accounting for over 10% and 1 in 10 jobs respectively, reflects its importance. Projections from the United Nations World Tourism Organization forecast a rise in international tourists to 1.8 billion by 2030, indicating the sector's potential for growth [22].

Turning to Pakistan's context, the study examines the evolving tourism landscape, particularly in light of the China-Pakistan Economic Corridor (CPEC). This strategic initiative has led to an influx of foreign tourists, with a notable emphasis on Chinese visitors. Among Pakistan's picturesque destinations, Swat, often referred to as the "mini-Switzerland" of the country, stands out. Its captivating natural beauty and historical significance position it as a haven for ecotourism, offering untapped growth potential [23].

However, despite these favorable prospects, Pakistan's Travel and Tourism Competitiveness Index ranking remains lower compared to neighboring countries. Recognition from sources such as the British Backpacker Society and Lonely Planet's acknowledgment of Pakistan's appeal underscores both the challenges and opportunities within the sector. The study underscores the need to bridge this gap and harness Pakistan's immense tourism potential for socio-economic development [24].

Technological advancements, particularly geospatial techniques like the MIF Technique, have emerged as tools to showcase the beauty of destinations like Swat. This integration of technology presents a platform to attract global attention and create positive impacts on local landscapes and economies. Moreover, the study identifies the potential of tourism to alleviate poverty, providing a socially significant dimension to the narrative [25].

In conclusion, the study presents a comprehensive overview of tourism's significance and potential in Pakistan. It elucidates the dynamics of the sector on both a global and local scale, emphasizing the role of technological advancements in shaping its future. With its rich natural landscapes and historical heritage, Pakistan stands poised to tap into its tourism potential, thereby contributing to economic growth and community well-being.

3. CONCLUSION

This study integrates Geospatial and the MIF techniques to determine suitable ecotourism geographical area using a multi-criteria decision model. The appropriateness analysis of Swat's ecotourism locations makes good use of data from secondary sources and remote sensing. Based on ten influencing factors ranging from low to high appropriateness, the study divides the area into three ecotourism suitability zones. The southern regions have a great deal of promise for ecotourism because accessibility, a large number of historical sites, and the existence of wildlife reserves. Because of the well-established infrastructure for historical sites in these places, tourists can enjoy year-round exploration of both natural and historical treasures. The region's overall ecotourism potential is influenced by six main factors: a well-developed road network, historical sites, game reserves, diverse wildlife populations, protected regions, and adequate rainfall. Conversely, the northern areas of the Swat district have favourable sites for ecotourism. A large portion of the region is still unexplored despite its potential because of inadequate infrastructure, services, and advertising. Contrary to this, the district's western and central areas have less promise for ecotourism, yet Bashigram Lake and Daral Lake, which are reachable by hiking and trekking paths, have encouraging prospects due to their attractive and mountainous surroundings. Much of the region has great potential for the growth of sustainable ecotourism destinations in the near future, which might increase revenue for the local government and the community. This study is a pioneer in the target region and helps build a strong model to identify ecotourism zones in other mountainous areas. One of the recommendations is to regularly analyze the suitability of ecotourism, taking into account newly built tourist services. The main objectives of action plans for the growth of sustainable ecotourism must be to strengthen organizational capability, introduce investment project, create new protected areas, market tourism destinations, and support the development of human resources.

Acknowledgement

The authors extend their appreciation to all.

Conflict interests

The authors has declared that no competing interests exist.

References

A. Rehman *et al.*, "Groundwater potential zone mapping using GIS and Remote Sensing based models for sustainable groundwater management," *Geocarto Int.*, vol. 39, no. 1, p., Jan. 2024,

doi: 10.1080/10106049.2024.2306275.

M. Haseeb *et al.*, "Spatio-temporal assessment of aerosol and cloud properties using MODIS satellite data and a HYSPLIT model: Implications for climate and agricultural systems," *Atmos. Environ. X*, vol. 21, no. December 2023, p. 100242, Jan. 2024,

doi: 10.1016/j.aeaoa.2024.100242.

R. W. Aslam *et al.*, "Monitoring landuse change in Uchhali and Khabeki wetland lakes, Pakistan using remote sensing data," *Gondwana Res.*, vol. 129, no. 2024, pp. 252–267, May 2024,

doi: 10.1016/j.gr.2023.12.015.

A. ur rehman *et al.*, "Assessment of heavy metal accumulation in dust and leaves of Conocarpus erectus in urban areas: Implications for phytoremediation," *Phys. Chem. Earth, Parts A/B/C*, vol. 132, p. 103481, Dec. 2023,

doi: 10.1016/j.pce.2023.103481.

B. G. Mousa, H. Shu, M. Freeshah, and A. Tariq, "A novel scheme for merging active and passive satellite soil moisture retrievals based on maximizing the signal to noise ratio," *Remote Sens.*, vol. 12, no. 22, pp. 1–23, Nov. 2020,
doi: 10.3390/rs12223804.

U. Saeed, J. Dempewolf, I. Becker-Reshef, A. Khan, A. Ahmad, and S. A. Wajid, "Forecasting wheat yield from weather data and modis ndvi using random forests for punjab province, Pakistan," *Int. J. Remote Sens.*, vol. 38, no. 17, pp. 4831–4854, 2017,
doi: 10.1080/01431161.2017.1323282.

S. H. Fatima, S. Atif, S. B. Rasheed, F. Zaidi, and E. Hussain, "Species Distribution Modelling of Aedes aegypti in two dengue-endemic regions of Pakistan," *Trop. Med. Int. Heal.*, vol. 21, no. 3, pp. 427–436, 2016,
doi: 10.1111/tmi.12664.

M. F. B. and T. K. S. A. Anjum, M. F. Saleem , M. A. Cheema, "An Assessment To Vulnerability, Extent, Characteristics and Severity of Drought Hazard in Pakistan," *Pakistan J. Sci. (Vol.*, vol. 64, no. 2, 2012.

R. Khanum, A. S. Mumtaz, and S. Kumar, "Predicting impacts of climate change on medicinal asclepiads of Pakistan using Maxent modeling," *Acta Oecologica*, vol. 49, pp. 23–31, 2013,
doi: 10.1016/j.actao.2013.02.007.

P. Mahmoudi, S. A. Shirazi, F. Firoozi, S. M. A. Jahanshahi, and N. Mazhar, "Detection of land cover changes in Baluchistan (shared between Iran, Pakistan, and Afghanistan) using the MODIS Land Cover Product," *Arab. J. Geosci.*, vol. 13, no. 23, 2020,
doi: 10.1007/s12517-020-06284-9.

S. A. Ali, R. Khatun, A. Ahmad, and S. N. Ahmad, "Application of GIS-based analytic hierarchy process and frequency ratio model to flood vulnerable mapping and risk area estimation at Sundarban region, India," *Model. Earth Syst. Environ.*, vol. 5, no. 3, pp. 1083–1102, 2019,
doi: 10.1007/s40808-019-00593-z.

K. Khosravi, E. Nohani, E. Maroufinia, and H. R. Pourghasemi, "A GIS-based flood susceptibility assessment and its mapping in Iran: a comparison between frequency ratio and weights-of-evidence bivariate statistical models with multi-criteria decision-making technique," *Nat. Hazards*, vol. 83, no. 2, pp. 947–987, 2016,
doi: 10.1007/s11069-016-2357-2.

S. Hathout, "The use of GIS for monitoring and predicting urban growth in East and West St Paul, Winnipeg, Manitoba, Canada," *J. Environ. Manage.*, vol. 66, no. 3, pp. 229–238, 2002, doi:
https://doi.org/10.1006/jema.2002.0596.

M. Yawar Ali Khan and M. ElKashouty, "Watershed prioritization and hydro-morphometric analysis for the potential development of Tabuk Basin, Saudi Arabia using multivariate statistical analysis and coupled RS-GIS approach," *Ecol. Indic.*, vol. 154, p. 110766, 2023, doi:
https://doi.org/10.1016/j.ecolind.2023.110766.

A. Shalaby and R. Tateishi, "Remote sensing and GIS for mapping and monitoring land cover and land-use changes in the Northwestern coastal zone of Egypt," *Appl. Geogr.*, vol. 27, no. 1, pp. 28–41, 2007,
doi: 10.1016/j.apgeog.2006.09.004.

S. Yerramilli, "A Hybrid Approach of Integrating HEC-RAS and GIS Towards the Identification and Assessment of Flood Risk Vulnerability in the City of Jackson, MS," *Am. J. Geogr. Inf. Syst.*, vol. 1, no. 1, pp. 7–16, 2012,
doi: 10.5923/j.ajgis.20120101.02.

M. Y. A. Khan, M. ElKashouty, A. M. Subyani, F. Tian, and W. Gusti, "GIS and RS intelligence in delineating the groundwater potential zones in Arid Regions: a case study of southern Aseer, southwestern Saudi Arabia," *Appl. Water Sci.*, vol. 12, no. 1, p. 3, 2021,
doi: 10.1007/s13201-021-01535-w.

A. Tariq *et al.*, "Spatio-temporal analysis of forest fire events in the Margalla Hills, Islamabad, Pakistan using socio-economic and environmental variable data with machine learning methods," *J. For. Res.*, vol. 13, p. 12, May 2021,
doi: 10.1007/s11676-021-01354-4.

S. Sutradhar, P. Mondal, and N. Das, "Delineation of groundwater potential zones using MIF and AHP models: A micro-level study on Suri Sadar Sub-Division, Birbhum District, West Bengal, India," *Groundw. Sustain. Dev.*, vol. 12, p. 100547, Feb. 2021,
doi: 10.1016/j.gsd.2021.100547.

A. Ahmed, A. Alrajhi, and A. S. Alquwaizany, "Identification of Groundwater Potential Recharge Zones in Flinders Ranges, South Australia Using Remote Sensing, GIS, and MIF Techniques," *Water 2021, Vol. 13, Page 2571*, vol. 13, no. 18, p. 2571, 2021,
doi: 10.3390/W13182571.

N. S. Magesh, N. Chandrasekar, and J. P. Soundranayagam, "Delineation of groundwater potential zones in Theni district, Tamil Nadu, using remote sensing, GIS and MIF techniques," *Geosci. Front.*, vol. 3, no. 2, pp. 189–196, Mar. 2012,
doi: 10.1016/j.gsf.2011.10.007.

A. Tariq *et al.*, "Integrated use of Sentinel-1 and Sentinel-2 data and open-source machine learning algorithms for burnt and unburnt scars," *Geomatics, Nat. Hazards Risk*, vol. 14, no. 1, p. 28, Dec. 2023,
doi: 10.1080/19475705.2023.2190856.

S. S. Wahla, J. H. Kazmi, A. Sharifi, S. A. Shirazi, A. Tariq, and H. Joyell Smith, "Assessing spatio-temporal mapping and monitoring of climatic variability using SPEI and RF machine learning models," *Geocarto Int.*, vol. 37, no. 27, pp. 14963–14982, Dec. 2022,
doi: 10.1080/10106049.2022.2093411.

A. Tariq, F. Mumtaz, M. Majeed, and X. Zeng, "Spatio-temporal assessment of land use land cover based on trajectories and cellular automata Markov modelling and its impact on land surface temperature of Lahore district Pakistan," *Environ. Monit. Assess.*, vol. 195, no. 1, p. 114, Jan. 2023,

doi: 10.1007/s10661-022-10738-w.

A. Tariq *et al.*, "Assessing Burned Areas in Wildfires and Prescribed Fires with Spectral Indices and SAR Images in the Margalla Hills of Pakistan," *Forests*, vol. 12, no. 10, p. 18, 2021, doi:

https://doi.org/10.3390/f12101371.