

Ecotourism Suitability Analysis in the Manglaralto River Watershed using a GIS-based Analytic Hierarchy Process (AHP)

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Abstract

Ecotourism can support sustainable territorial development by integrating environmental conservation with local economic opportunities. This study evaluated ecotourism suitability in the Manglaralto River basin (Santa Elena, Ecuador) using an integrated Geographic Information System–Analytic Hierarchy Process (GIS–AHP) approach. Ten biophysical, environmental, and socioeconomic criteria were considered: slope, altitude, permeability, land cover and land use, vegetation cover, species diversity, conservation areas, tourist attractions, proximity to roads, and proximity to rural areas. The criteria were weighted through pairwise comparison matrices evaluated by five experts and integrated to generate a spatial ecotourism suitability index, classified into very high, high, moderate, low, and very low suitability. Species diversity received the highest individual weight (18.95%), highlighting its relevance within the multicriteria assessment. The results showed that 23.72% of the basin was classified as having high or very high ecotourism suitability, mainly in the western and central-western sectors, including areas associated with the Manglaralto River–Aquifer System UNESCO Ecohydrology Demonstration Site. The GIS–AHP framework provides a spatial decision-support tool for identifying and prioritizing areas for sustainable ecotourism while integrating environmental conservation, territorial planning, and local tourism development.

Keywords

Environmental education, Natural resources, Tourism, Environmental conservation, Ecology

1. Introduction

Ecotourism has been seen in recent decades to grow the global tourism sector, based on responsible travel to natural areas to preserve the environment and boost the well-being of local communities [1]. However, the transition from conceptual ecotourism to the implementation of sustainable tourism needs a rigorous framework that balances economic viability with ecological integrity [2]. Sustainability in ecotourism doesn't happen spontaneously; it needs participatory governance mechanisms, a multidimensional

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assessment of ecosystems' carrying capacity, and restrictive land-use planning to prevent the degradation of fragile habitats [3].

For the implementation of sustainability principles, the scientific community has resorted to Geographic Information Systems (GIS) combined with Multi-Criteria Decision Analysis (MCDA) [4]. This combination enables the organization, normalization, and overlay of spatial information derived from environmental, topographic, socioeconomic, and accessibility variables to identify areas with varying levels of ecotourism suitability. Among MCDA methods, the Analytic Hierarchy Process (AHP) has become one of the most widely used techniques due to its flexibility, transparency, and ability to incorporate expert judgment [5].

The AHP, developed by Saaty in 1980 [6], structures complex decision problems into a hierarchy of goals, criteria, and alternatives. The relative importance of each criterion is determined by using pairwise comparison matrices, whose values enable the calculation of normalised weights and the verification of the consistency of expert judgments. When GIS-AHP is integrated, it makes it easier to represent weights and spatially overlay variables. This approach has been applied in various geographic contexts, including coastal islands, estuaries, protected areas, and basins such as the Do Hezar (Iran) and Lake Tana (Ethiopia) basins, incorporating topographic, hydrological, environmental, and accessibility variables to map ecotourism potential [4]. Most recently, the assessment of the Yellow River Estuary National Park (China) integrated tourism suitability with environmental carrying capacity in a coastal land-sea interaction context [7]. In Latin America, Costa Rica has established itself as an international benchmark for ecotourism by incorporating species conservation and sustainable tourism into its public policy. However, research linking the zoning of ecotourism suitability in coastal watersheds with the explicit protection of aquifer recharge areas remains limited, a critical issue in semi-arid territory where tourism development depends on the availability and sustainability of water resources [8].

Ecuador is a country well positioned for the application of spatial planning tools such as GIS, due to its vast megadiversity and vulnerable ecosystems. An example of this is Napo, where community tourism has connected ecology with indigenous nationalities [9]. In this context, the Manglaralto River basin, located in the province of Santa Elena (Ecuador), is a strategic area for assessing ecotourism potential using geospatial and multi-criteria tools. For this purpose, we asked the following research question: Which areas in the Manglaralto River basin are most suitable for sustainable ecotourism based on GIS-AHP? Accordingly, this study aims to identify and spatially prioritize areas with high ecotourism suitability using a GIS-AHP multicriteria framework that integrates environmental conservation, accessibility, and existing infrastructure, thereby supporting sustainable tourism planning and territorial decision-making.

2. Study Area

The Manglaralto River basin is in the parish of the same name in the northern part of Santa Elena province [10] (Figure 1), covering an area of about 131.5 km². It has ecological and landscape diversity, including tropical dry forests, agricultural areas, and recharge zones [11, 12]. In March 2025, one of the sites in the basin (Manglaralto River-aquifer system) was declared an Ecohydrological Demonstration Site (EDS) by UNESCO [13]. Additionally, part of the Spondylus route runs through this area, crossing the entire Manglaralto coastal profile and connecting local towns and communities, where there is growing tourism activity linked to wellness and nature [14]. The area receives between 25% and 30% of all tourists entering Santa Elena province annually [15], spread across the communities of Montañita, Olón, and Libertador Bolívar [16]. The place has an arid climate with two seasons: from May to December, rainfall is between 6.1 and 32.7 mm per year; the second season runs from late December to April, with higher rainfall between 72.0 and 155.4 mm per year [17].

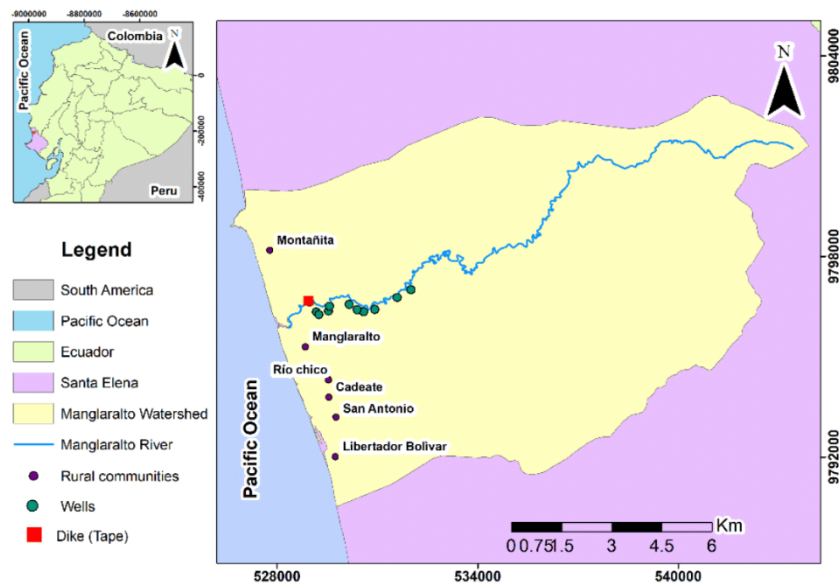


Figure 1: Location map of the Manglaralto basin.

3. Materials and Methods

The study adopts the methodology proposed by Razandi et al. (2015) [18] to identify and define potential ecotourism development areas, integrating GIS and AHP. This analysis is carried out through three phases (Figure 2): i) preprocessing the geospatial database, ii) AHP modelling and consistency analysis, and iii) Map algebra and Weighted Linear Combination (WLC).

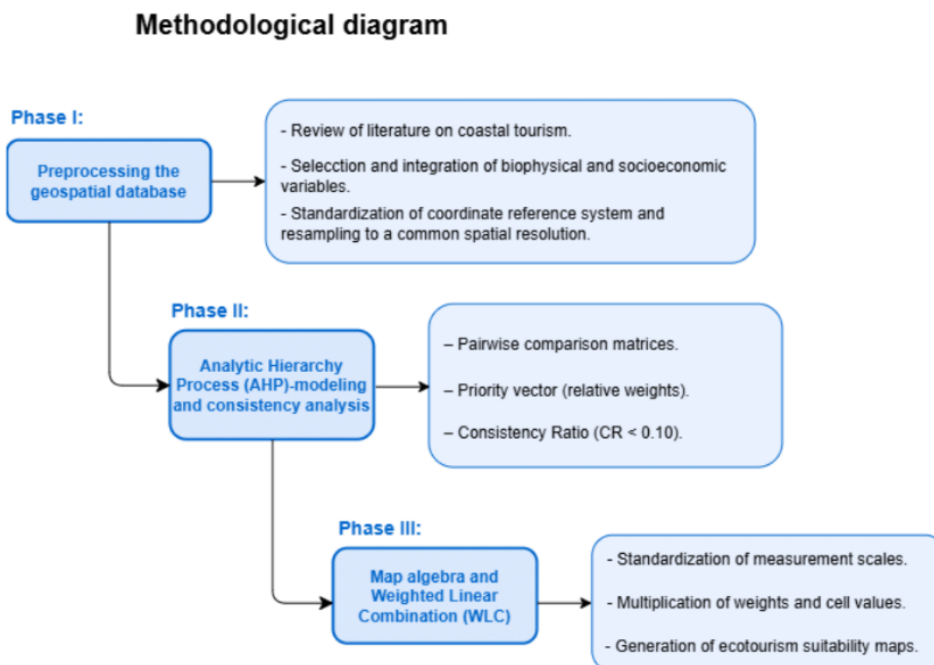


Figure 2: Methodological diagram for ecotourism evaluation in the Manglaralto River basin.

3.1. Phase I: Preprocessing the geospatial database

Phase I consisted of the acquisition, cleaning, selection, and integration of biophysical and socioeconomic variables in raster and vector format. This phase requires cartographic standardisation by reprojecting layers into the WGS 1984/UTM Zone 17S coordinate system and setting a cell spatial resolution of 30m x 30m using the Manglaralto DEM [19].

Based on the morphology, aquifer characteristics, and availability of geospatial information for the Manglaralto basin, 10 structural criteria were selected for ecotourism modelling, enabling the territory to be assessed for ecotourism activities without compromising aquifer recharge areas.

1. Slope: This criterion represents terrain conditions that may influence the suitability of areas for trails and recreational activities. Gentle to moderate slopes generally provide more favourable conditions for tourism development and may reduce erosion-related constraints [20].
2. Altitude: Elevation influences landscape configuration and can help distinguish areas associated with valleys, ridges, and potential scenic viewpoints [21].
3. Permeability: This criterion represents the capacity of geological and soil materials to allow water infiltration and was incorporated to consider hydrogeological sensitivity within the ecotourism suitability assessment [22].
4. Land cover and land use: This criterion represents the spatial distribution of natural and human-modified land-cover classes, which may influence the type and intensity of recreational activities that can be developed [23].
5. Vegetation cover: Measures the aesthetic of the landscape; the presence of native flora or forests makes the place more attractive and contributes to microclimatic regulation [24, 25].
6. Species diversity: It represents the spatial distribution of recorded flora and fauna genera and was included as an indicator of ecological value relevant to nature-based tourism [26].
7. Conservation areas: It identifies areas subject to conservation or environmental management considerations, where tourism activities may require greater compatibility with conservation objectives and existing management regulations [27].
8. Tourism Point: It's the ability to receive visitors; the closer the tourist infrastructure, the better the economic benefit [28].
9. Proximity to road: Measures geographic and transport accessibility; being close ensures visitor flow [29].
10. Proximity to rural area: It measures the spatial distance to rural settlements and represents the potential relationship between ecotourism areas and nearby communities, where local services and community-based tourism activities may be available [30].

The geospatial data and mapping used in the ecotourism suitability criteria were obtained from official institutional sources, global platforms, and Ecuadorian land registries. The processed layers, as well as their source, are listed in Table 1.

3.2. Phase II: Analytic Hierarchy Process (AHP)-modeling and consistency analysis

During this phase, the evaluation of the criteria was carried out using an approach between Delphi and AHP [41, 42], involving a multidisciplinary panel of five specialists in geosciences, hydrology, environment, and tourism. The anonymity of each expert was ensured, and they were formally notified of the research objective and asked to participate voluntarily. Then, the experts provided individual opinions according to the matrix using Saaty's scale (1 to 9) [6]. The individual judgments were consolidated using the geometric mean to form a square, reciprocal, and positive matrix $A = (a_{ij})$ (1010), from which the principal eigenvector was calculated to obtain the weights [43]:

$$A = \begin{pmatrix} a_{1,1} & a_{1,2} & \cdots & a_{1,10} \\ a_{2,1} & a_{2,2} & \cdots & a_{2,10} \\ \vdots & \vdots & \ddots & \vdots \\ a_{10,1} & a_{10,2} & \cdots & a_{10,10} \end{pmatrix} \quad (1)$$

Table 1

Geospatial data used in ecotourism suitability criteria.

Variables	Sources of Variables	Cite	Variables	Sources of Variables	Cite
Slope			Species diversity	Global Biodiversity Information Facility (GBIF)	[31]
Altitude	SIGTIERRAS. (2017). Orto-fotografía del Ecuador: El país desde otra perspectiva. Quito	[32]	Conservation areas	Ministerio del Ambiente y Energía. Sistema Nacional de Áreas Protegidas–SNAP. Infraestructura de Datos Espaciales del MAATE (IDE Ambiente). Ministerio del Ambiente y Energía. Áreas de conservación individual y comunitaria Infraestructura de Datos Espaciales del MAATE (IDE Ambiente).	[33, 34]
Permeability	Mapa Hidrogeológico del Ecuador Instituto Nacional de Meteorología e Hidrología (INAMHI)	[35]	Tourism Point	Ministerio de Turismo de Ecuador. Catastro Turístico Total. Tourism diversification applying cultural routes, in Manglaralto County, in the province of Santa Elena	[36, 37]
Land cover and land use	Ministerio de Agricultura y Ganadería – Geoportal, “Mapa de Cobertura y uso de la tierra del Ecuador continental, escala 1:100.000,”	[32, 38]	Proximity to roads	OpenStreetMap Foundation.	[39]
Vegetal cover	Ministerio del Ambiente y Energía. Patrimonio Forestal del Estado. Infraestructura de Datos Espaciales del MAATE (IDE Ambiente).	[31]	Proximity to rural area	Instituto Geográfico Militar (IGM). (2013). Poblados– Cartografía básica escala 1:50 000 [Shapefile]. Geoportal IGM Ecuador.	[40]

Where: $a_{ij} = 1$ for the elements on the main diagonal, ($i = j$), $a_{ji} = 1/a_{ij}$ for reciprocal evaluations.

From this square pairwise comparison matrix, the normalised relative weight vector (w) was obtained by solving the principal eigenvector equation [44]:

$$AW = \lambda_{max}W \quad (2)$$

Where: A represents the 10×10 pairwise comparison matrix, w : normalized eigenvector that defines the weights of each criterion, λ_{max} : corresponds to the maximum eigenvalue of the matrix.

To ensure mathematical rigour and rule out transitive inconsistencies in the expert panel's judgments, hierarchical consistency was evaluated using the Consistency Index (CI) [45]:

$$CI = \frac{\lambda_{max} - n}{n - 1} = \frac{\lambda_{max} - 10}{9} \quad (3)$$

Next, the Consistency Ratio (CR) was calculated [45, 46]:

$$CR = \frac{CI}{RI} \quad (4)$$

Where: RI = Average Random Index.

For a matrix of order $n = 10$, a value of $RI = 1.49$ was adopted [45]. The weight vector w is valid after checking with the Consistency Ratio, which stays below the 10% tolerance threshold ($CR < 0.10$).

To unify the experts' values, the standard AHP method using the geometric mean was used, following the mathematical formula:

$$a_{ij}^{group} = \sqrt[5]{a_{ij}^1 \cdot a_{ij}^2 \cdot a_{ij}^3 \cdot a_{ij}^4 \cdot a_{ij}^5} \quad (5)$$

3.3. Phase III: Map algebra and Weighted Linear Combination (WLC)

In this phase, the measurement scales for each criterion were standardised. Afterwards, map algebra was performed using the Raster Calculator tool in QGIS (version 4.2.0), in which the AHP-derived weights were spatially multiplied by the cell values of each criterion, generating the continuous suitability map. Table 2 presents the parameterisation and weighting criteria for the analysis of ten physical, ecological, and territorial aptitudes, assigning values from 1 to 5. Where 1 = very low aptitude and 5 = very high aptitude.

Table 2

Valuation ranges of the criteria used in the spatial model.

Criterion	Very Low (1)	Low (2)	Moderate (3)	High (4)	Very High (5)
Slope	25° - 35°	15° - 25°	10° - 15°	5°-10°	0°-5°
Altitude	<10%	10-25%	75-100%	25-50%	50-75%
Permeability	Shallow	Very low	Generally low	Medium	Generally high
Land cover and land use	None	Not applicable	Medium	Light	High
Vegetal cover	Anthropic area	Shrubland	Agricultural lands	Other lands	Forest
Species diversity	0-5	6-21	22-35	36-55	55-104
Conservation area	>1500m	1000-1500m	500-1000m	250-500m	0-250m
Tourism Point	>1500m	1000-1500m	500-1000m	250-500m	0-250m
Proximity to road	>1500m	1000-1500m	500-1000m	250-500m	0-250m
Proximity to rural area	>1500m	1000-1500m	500-1000m	250-500m	0-250m

4. Results

4.1. Weighting and ranking of evaluation criteria

The calculation of the eigenvector of the square pairwise comparison matrix determined the importance of the 10 criteria analysed. The consistency evaluation yielded a value of $\lambda_{max} = 10.0881$, $CI = 0.010$, and $CR = 0.007$, validating the mathematical coherence of the weights assigned by the expert panel ($CR < 0.10$). Figure 3 shows the final values from the experts.

Table 3 presents the weights and percentages in the comparison matrix for the ten criteria, highlighting species diversity with the highest weight of 0.1895, conservation areas with 0.1588, and vegetation cover with 0.145, underscoring the importance of environmental criteria over physical or socioeconomic criteria.

			j1	j2	j3	j4	j5	j6	j7	j8	j9	j10
	Criterion	i/j	ALT	SLP	LC	PER	VC	SD	CA	TP	PR	PRA
i1	Altitude	ALT	1	7/8	3/5	1/2	2/5	2/7	1/3	3/5	2/3	2/3
i2	Slope	SLP	1 1/7	1	2/3	4/7	3/7	1/4	2/5	1	1	4/5
i3	Land cover and land use	LC	1 2/3	1 3/7	1	4/9	3/7	2/5	1/2	1	1	5/6
i4	Permeability	PER	2	1 5/7	2 1/5	1	2/3	2/3	3/4	1 1/2	1 3/5	1 2/3
i5	Vegetal Cover	VC	2 1/2	2 2/5	2 1/3	1 5/9	1	3/4	4/5	2	2 1/6	2
i6	Species diversity	SD	3 2/7	3 7/8	2 1/2	1 1/2	1 1/3	1	1 1/7	2 4/5	3 2/9	2 1/2
i7	Conservation area	CA	7/8	2 1/2	2 1/6	1 1/3	1 1/4	7/8	1	2	2 3/7	2 5/8
i8	Tourist point	TP	1/3	1/2	1	2/3	1/2	1/3	1/2	1	1 3/7	1 3/7
i9	Proximity to road	TD	1/3	2/5	2/3	5/8	1/2	1/3	2/5	2/3	1	1 1/2
i10	Proximity to rural area	DBT	2/5	3/8	2/3	2/3	1/2	2/5	3/8	2/3	2/3	1

Figure 3: Criteria comparison matrix.

Table 3

Ranking of criteria according to weights assigned by experts.

Criterion	Weights	Weighting (%)	Criterion	Weights	Weighting (%)
Species diversity	0.1895	18.95	Tourist point	0.07	7.00
Conservation area	0.1588	15.88	Proximity to rural area	0.0684	6.84
Vegetal Cover	0.1455	14.55	Proximity to road	0.0664	6.64
Permeability	0.1134	11.34	Slope	0.0597	5.97
Land cover and land use	0.0778	7.78	Altitude	0.0505	5.05

4.2. Classification of evaluation criteria

Table 4 shows that the highest proportions of high and very high suitability were associated with proximity to roads (62.66%), altitude (61.43%), and slope (54.83%), indicating favourable conditions for ecotourism development in terms of accessibility and terrain characteristics. In contrast, land cover and land use and species diversity showed the largest proportions of very low suitability, accounting for 93.29% and 57.96%, respectively. In the case of species diversity, this pattern should be interpreted cautiously because the species inventory was derived from GBIF occurrence records and may therefore reflect differences in sampling effort and data availability across the basin rather than actual low biodiversity. Overall, these results highlight the need to integrate physical accessibility with environmental and biodiversity-related constraints when identifying areas for sustainable ecotourism development.

4.2.1. Physical criteria

In the process of reclassifying the suitability criteria, it allowed quantifying the territorial distribution, obtaining significant contrasts and concentration zones of the following criteria:

- Slope: the territory has a topography that is highly favourable for ecotourism, with Very High suitability (34.41 km²) and High (39.95 km²), mainly coinciding in the intramontane valleys and the lower part of the basin (Figure 4a).
- Altitude: a total of 80.81 km² have high and very high suitability, corresponding to areas with microclimate conditions that are easy to access (Figure 4b).
- Permeability: in this case, more than 77% of the basin has filtration and lithology features that favour terrain stability and natural drainage (Figure 4c).

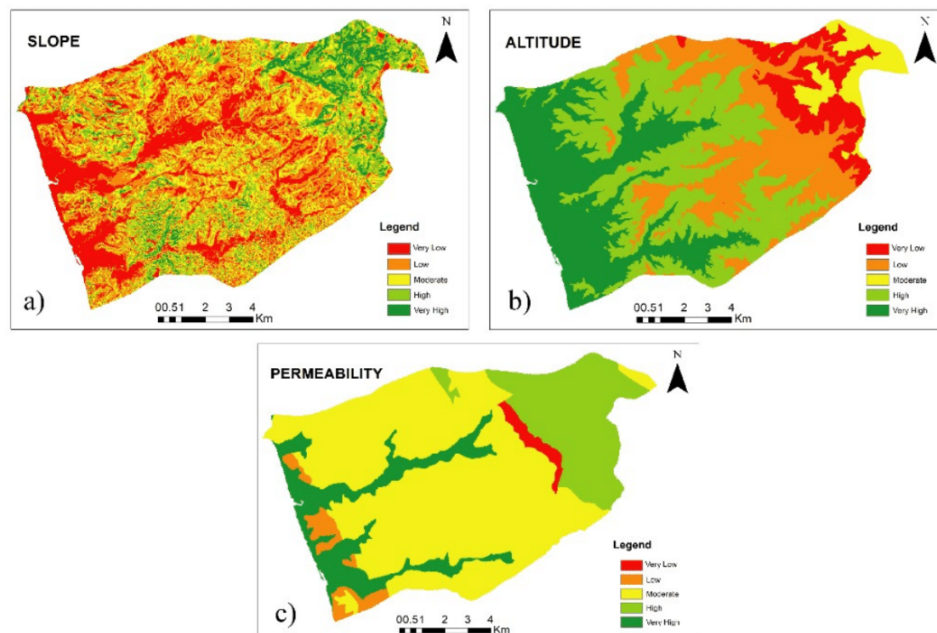
4.2.2. Environmental criteria

These criteria show the level of conservation and biodiversity in the area.

Table 4

Distribution and reclassification of the areas according to the evaluation criteria.

Criterion	Subclasses of variables	Area (km ²)	Area (%)	Criterion	Subclasses of variables	Area (km ²)	Area (%)
Slope	[5] Very high aptitude (S5)	34.41	25.38	Species diversity	[5] Very high aptitude (S5)	5.22	4.01
	[4] High aptitude (S4)	39.95	29.45		[4] High aptitude (S4)	16.28	12.51
	[3] Moderate aptitude (S3)	33.56	24.74		[3] Moderate aptitude (S3)	13.57	10.4
	[2] Low aptitude (S2)	19.63	14.47		[2] Low aptitude (S2)	19.7	15.12
	[1] Very low aptitude (S1)	8.09	5.96		[1] Very low aptitude (S1)	75.51	57.96
Altitude	[5] Very high aptitude (S5)	36.3	27.6	Conservation area	[5] Very high aptitude (S5)	51.13	39.78
	[4] High aptitude (S4)	44.51	33.83		[4] High aptitude (S4)	7.78	6.05
	[3] Moderate aptitude (S3)	7.1	5.4		[3] Moderate aptitude (S3)	13.59	10.57
	[2] Low aptitude (S2)	31.4	23.87		[2] Low aptitude (S2)	22.43	17.46
	[1] Very low aptitude (S1)	12.23	9.3		[1] Very low aptitude (S1)	33.59	26.14
Permeability	[5] Very high aptitude (S5)	16.39	12.58	Tourist point	[5] Very high aptitude (S5)	11.36	8.61
	[4] High aptitude (S4)	24.54	18.84		[4] High aptitude (S4)	31.31	23.74
	[3] Moderate aptitude (S3)	82.89	63.63		[3] Moderate aptitude (S3)	46.67	35.39
	[2] Low aptitude (S2)	4.28	3.29		[2] Low aptitude (S2)	32.1	24.34
	[1] Very low aptitude (S1)	2.19	1.68		[1] Very low aptitude (S1)	10.45	7.92
Land cover and land use	[5] Very high aptitude (S5)	0.16	0.12	Proximity to road	[5] Very high aptitude (S5)	55.76	42.41
	[4] High aptitude (S4)	1.52	1.16		[4] High aptitude (S4)	26.63	20.25
	[3] Moderate aptitude (S3)	0.2	0.15		[3] Moderate aptitude (S3)	28.81	21.91
	[2] Low aptitude (S2)	6.92	5.28		[2] Low aptitude (S2)	13.7	10.42
	[1] Very low aptitude (S1)	122.31	93.29		[1] Very low aptitude (S1)	6.59	5.01
Vegetal cover	[5] Very high aptitude (S5)	53.81	41.05	Proximity to rural area	[5] Very high aptitude (S5)	11.45	10.73
	[4] High aptitude (S4)	2.16	1.65		[4] High aptitude (S4)	14.23	13.33
	[3] Moderate aptitude (S3)	0.05	0.04		[3] Moderate aptitude (S3)	28.6	26.79
	[2] Low aptitude (S2)	70.00	53.4		[2] Low aptitude (S2)	23.46	21.98
	[1] Very low aptitude (S1)	5.06	3.86		[1] Very low aptitude (S1)	29.00	27.17

**Figure 4:** Physical criteria: a) Slope, b) Altitude and c) Permeability.

- Land cover and land use: the map shows a very low suitability for this criterion, due to soil degradation and its vulnerability to the substrate (Figure 5a).
- Vegetation cover: there is a high forest remnant, making it ideal for hiking and environmental interpretation (Figure 5b).
- Species diversity: The upper part of the basin shows a concentration of 6.35% of the total genera found throughout the basin, while in the central part of the basin you can see a transition area leading to high (12.51%) and very high suitability (4.01%), being the main spot for bird watching, such as *Pelecanus occidentalis*, *Fregata magnificens*, *Leucophaeus atricilla*. Reptiles like *Microlophus occipitalis*. Mammals like *Didelphis marsupialis*, *Transandinomys talamancae*, *Nasua nasua*, *Glossophaga valens*. Crustaceans such as *Ocypode gaudichaudii*. Flora like *Gossypium barbadense*, a common cotton species (Figure 5c).
- Conservation areas: the zone with the highest suitability is due to its direct adjacency to the conservation areas, giving the area high value, while in the lower part of the basin it has low suitability due to the proximity to the towns (Figure 5d).

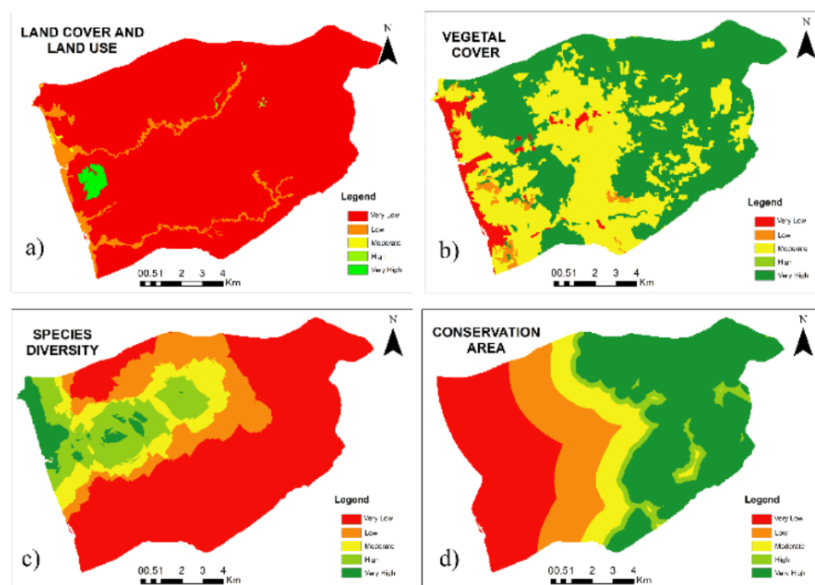


Figure 5: Enviromental criteria. a) Land cover and land use, b) Vegetal cover, c) Species diversity and d) conservation area.

4.2.3. Socioeconomic criteria

The socioeconomic criteria were used to assess the spatial relationship between potentially suitable ecotourism areas and existing tourist attractions, roads, and rural settlements.

- Tourist spots: areas with high and very high suitability are mainly concentrated in the central and southwestern sectors of the basin, where several existing tourist attractions are located. Their spatial distribution may support the planning of ecotourism routes and connections between points of interest (Figure 6a).
- Proximity to road: High and very high suitability classes account for 62.66% of the basin, indicating that a large proportion of the territory is relatively close to the existing road network (Figure 6b). However, this criterion represents spatial proximity and does not account for road condition, travel time, or seasonal accessibility (Figure 6b).

- Proximity to rural areas: in the southwestern part of the basin, there are well-established coastal communities, such as Manglaralto, Olon, Montañita, and Dos Mangas. Proximity to these communities may facilitate connections with locally available services and support the development of community-based tourism activities (Figure 6c).

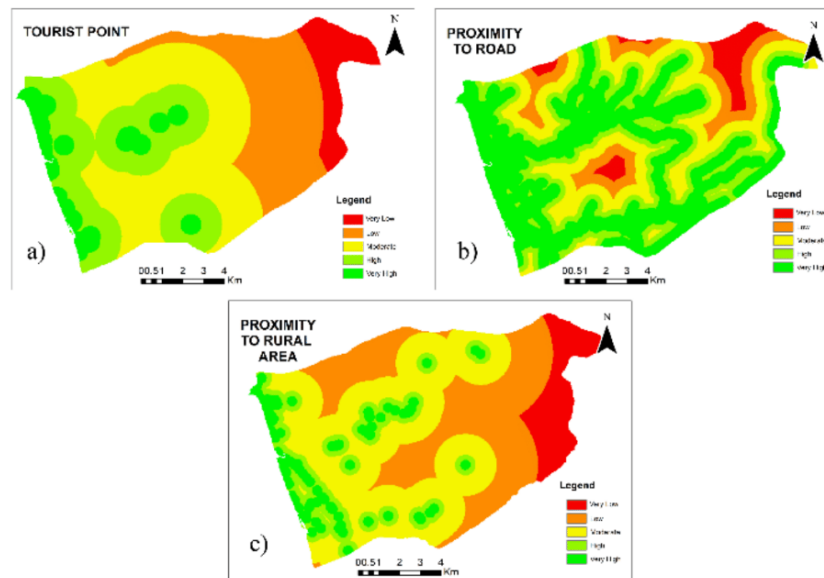


Figure 6: Socioeconomic criteria: a) Tourist point, b) Proximity to road and c) Proximity to rural area.

4.3. Suitability map in the Manglaralto basin

Figure 7 shows the spatial distribution of ecotourism suitability across the Manglaralto River basin. Very high and high suitability areas are mainly concentrated in the western and central-western sectors, covering 12.17 km² (9.54%) and 18.08 km² (14.18%) of the basin, respectively. These areas are characterised by flat to moderately sloping terrain (slopes < 15°), elevations below 150 m a.s.l., and proximity of less than 1.5 km to roads and populated areas. They also contain 70.86% of the flora and fauna genera recorded in the species database, highlighting their ecological relevance. Moreover, this sector includes important ecotourism attractions, such as the Dos Mangas reserve and the UNESCO Ecohydrology Demonstration Site of the Manglaralto River–Aquifer System.

Moderate-suitability areas cover 30.50 km² (23.91%) and may support low-impact recreational activities, such as hiking and cycling, while maintaining active conservation measures [46]. In contrast, low- and very low-suitability areas predominate in the eastern and south-central sectors, accounting for 48.07 km² (37.69%) and 18.72 km² (14.68%), respectively. These areas are generally associated with steeper slopes (>35°), elevations above 350 m a.s.l., and greater distances from roads, populated areas, and tourist attractions. Consequently, these sectors present greater constraints for tourism development and may be more appropriate for environmental conservation and the protection of water-source areas within the basin.

5. Conclusion

The high and very high ecotourism suitability areas cover 23.72% of the Manglaralto River basin and are mainly concentrated in its western and central-western sectors. Environmental criteria, including species diversity, conservation areas, and vegetation cover, account for a combined weight of 49.38%, highlighting the importance of environmental conservation in the suitability assessment compared with physical criteria such as slope (5.97%) and altitude (5.05%). The GIS–AHP approach enabled the spatial

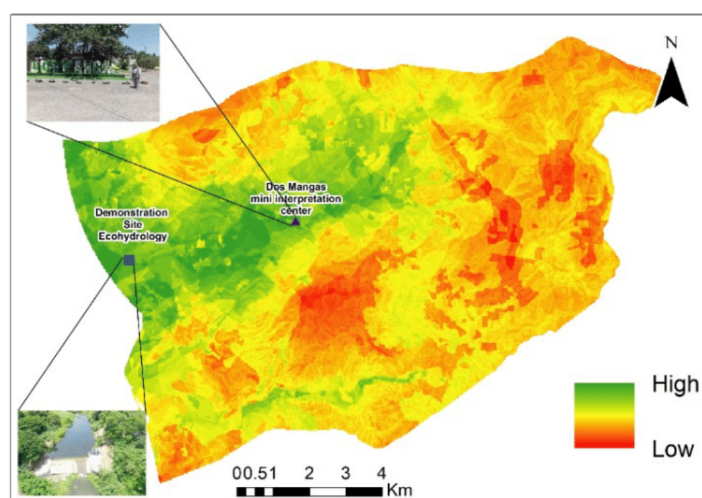


Figure 7: Ecotourism Suitability Map in the Manglaralto River Basin.

identification and prioritization of areas with greater potential for sustainable ecotourism, providing a decision-support tool for integrating tourism development, environmental conservation, and territorial planning. In addition, 84.57% of the basin falls within the moderate to very high suitability classes for proximity to roads, indicating that a large proportion of the territory is relatively close to the existing road network; however, this criterion reflects spatial proximity rather than road condition or effective accessibility. Future studies should therefore incorporate road condition, travel time, seasonal accessibility, and tourism carrying-capacity assessments, particularly in areas with high recorded biodiversity and conservation value, to minimize tourism pressure and support sustainable management of the basin.

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Declaration on Generative AI

The authors have not employed any Generative AI tools.

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