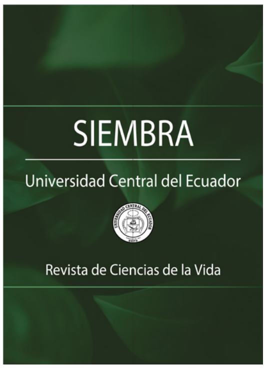
Geotourism Routes as a strategy for the recognition and conservation of geoheritage in the Puyango Petrified Forest Geopark Project



Las Rutas Geoturísticas como estrategia de reconocimiento y conservación del geopatrimonio en el Proyecto Geoparque Bosque Petrificado de Puyango

Vivian Fernanda Lincango Benalcázar[1], Patricia Mercedes Pazmiño Valle[2]

Siembra 12 (1) (2025): e7664

Received: 15/12/2024 / Revised: 16/01/2025 / Accepted: 26/01/2025

[1] Universidad Central del Ecuador. Facultad de Ciencias Agrícolas. Carrera de Turismo. Jerónimo Leiton y Av. la Gasca s/n. Ciudadela Universitaria. Quito. 170521. Ecuador.
✉ vivifer-99@hotmail.com
https://orcid.org/0009-0004-1220-5318
[2] Universidad Central del Ecuador. Facultad de Ciencias Agrícolas. Carrera de Turismo. Jerónimo Leiton y Av. la Gasca s/n. Ciudadela Universitaria. Quito. 170521. Ecuador.
✉ pmpazmino@uce.edu.ec
https://orcid.org/0000-0001-9699-211X

Corresponding author: pmpazmino@uce.edu.ec

Abstract

This study is framed in the field of geotourism as an alternative for the dissemination and conservation of the geopatrimony of the Petrified Forest of Puyango, an aspiring Global Geopark of the United Nations Educational, Scientific and Cultural Organization [UNESCO] Global Geopark. The area shows significant evidence of geosites and geopaleontological remains from the Cretaceous period, which have been insufficiently studied. Geosites are defined as enclaves with distinctive geological features that serve as evidence of the Earth's past and evolution. The proposal of geotourism routes aims not only at the recognition of geological resources, but also at their conservation, through informative, interpretative and educational activities. Two types of routes were identified, for recreational and scientific purposes, following a methodology that establishes a scale of priorities based on expert judgment and prioritizes several alternatives according to a series of criteria. The results indicate that the proposal will effectively contribute to the recognition of the geoheritage, as well as to the conservation and tourism development of the Puyango Petrified Forest Geopark Project.

Key words: geotourism, geosites, geotourism route, geoconservation, geoheritage recognition.

Resumen

Este estudio está enmarcado en el ámbito del geoturismo como una alternativa de difusión y conservación del geopatrimonio del Bosque Petrificado de Puyango, aspirante a geoparque mundial de la Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura [UNESCO]. El territorio muestra una evidencia significativa de geositios y restos geopaleontológicos del periodo Cretácico, que han sido insuficientemente investigados. Los geositios se conciben como enclaves con características geológicas distintivas que actúan como evidencia del pasado y evolución de la Tierra. La propuesta de las rutas geoturísticas no busca únicamente el reconocimiento de los recursos geológicos, sino también su conservación, a través de actividades divulgativas, interpretativas y educativas. Se obtuvieron dos tipos de recorridos orientados a fines recreativos y científicos, elaborados de acuerdo con una metodología que establece una escala de prioridades bajo un juicio de expertos y prioriza varias alternativas de acuerdo a una serie de criterios. Los hallazgos indican que la propuesta contribuiría de manera eficiente al reconocimiento del geopatrimonio, así como a la conservación y el desarrollo turístico del Proyecto Geoparque Bosque Petrificado de Puyango.

Palabras clave: geoturismo, geositios, ruta geoturística, geoconservación, reconocimiento del geopatrimonio.

SIEMBRA
https://revistadigital.uce.edu.ec/index.php/SIEMBRA
ISSN-e: 2477-5788
Frequency: half-yearly
vol. 12, issue 1, 2025
siembra.fag@uce.edu.ec
DOI: https://doi.org/10.29166/siembra.v12i1.7664

1. Introduction

Geotourism has been conceived as a form of tourism distinct from mass tourism, with the purpose of highlighting geological and geomorphological resources within a sustainable cultural and environmental context (Hose, 2011). Coutinho et al. (2019) and Tavera Escobar et al. (2017) state that geotourism emerged as an alternative to disseminate geological knowledge and to promote understanding and interpretation of these resources for conservation purposes. In this way, tourism linked to geological heritage—or geoheritage—has acquired a multidisciplinary and holistic definition that converges around three main elements: geoeducation, geoconservation, and sustainable development (Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura [UNESCO], 2021). Geotourism activities have therefore become drivers of economic and social growth in regions with geological heritage of rarity, beauty, or scientific significance (Brilha et al., 2018; Pilogallo et al., 2019).

Worldwide, studies on the recognition and conservation of geoheritage are scarce. It was not until 1993 that the European Association for the Conservation of Geological Heritage was created, in response to the loss of geosites and geomorphosites in the United Kingdom (Hose, 2012). In 2015, during UNESCO's 38th General Conference, the UNESCO Global Geoparks Network was established to ensure proper management of significant geological sites and landscapes (Palacio Prieto et al., 2016). In Latin America, one of the first key events took place in 2006 in Ceará, Brazil, following the inclusion of the Araripe Geopark in the Global Geoparks Network—the first in the region. Since then, conferences, symposiums, and initiatives focused on geoconservation have taken place. However, Palacio Prieto et al. (2016) state that the environmental legislation in Latin American countries lacks criteria that recognize the role of geodiversity and geoheritage in environmental protection. In other cases, such criteria are incipient and scarce, leading to inefficient and poorly coordinated projects.

Much of the protection and conservation efforts have focused on flora, fauna, and fragile ecosystems. Martínez Fernández (2013), Palacio Prieto et al. (2016), and Tavera Escobar et al. (2017) argue that geoheritage and abiotic elements have been underestimated and may, in fact, be more fragile than biological resources. Geoheritage is equally important, as it includes geological formations and structures, rocks, fossils, soils, and manifestations that reveal the origin and evolution of the Earth and life (Carcavilla Urquí, 2014). For this reason, many of these elements have a high susceptibility to impacts caused by natural events or human activity, which increases the urgency of their protection (Martínez Fernández, 2013).

Given this issue, geotourism products have emerged as a strategy to bring people closer to geoheritage. According to UNESCO (2021), the themes of geotourism products are highly diverse; they can be tangible or intangible and stem from the culture, traditions, natural heritage, art, and other living treasures of local communities. This creates a connection between the community and geoheritage, fostering a sense of identity through the development of new tourism products. Dóniz Páez et al. (2021) and Morante-Carballo et al. (2020) state that these products serve as tools for communication, recreation, and conservation, helping people understand the natural, political, and socioeconomic processes of geoparks or aspiring geopark territories, and providing them with management opportunities. López et al. (2022), based on the premise of Newsome and Dowling (2018), affirms that geoproducts promote geoscience in a sustainable and ecological manner by highlighting geoheritage through recreational, cultural, and educational activities.

In this regard, the implementation of geoactivities is an effective way to combine leisure and recreation with geological education and scientific outreach (Arrage, 2024; Geoparque Sobrarbe Pirineo, 2024). Geoactivities allow geopark projects to function as spaces for dissemination and awareness through on-site learning, direct observation, and interpretation of geological and paleontological resources (Damas Mollá et al., 2024; Schilling, 2019). The development of conferences, guided excursions, permanent and temporary exhibitions, thematic workshops, field trips, audiovisual rooms, and more constitutes a useful strategy for formal, non-formal, and informal education for both specialized and non-specialized audiences (Damas Mollá et al., 2024; Fernández-Martínez et al., 2014; Schilling, 2019). Scientific and interpretive outreach presents the territory from a geological perspective and builds connections between geoheritage and other forms of heritage (Damas Mollá et al., 2024), while also enabling the understanding of geological hazards, thus serving as a mechanism for geoconservation (Bruschi et al., 2023).

Geotourism routes are conceived as a key strategy and tool for the interpretation and dissemination of geoheritage (Dóniz-Páez & Quintero Alonso, 2016), as they contribute to the diversification of current tourism products (Meléndez-Hevia et al., 2011). These routes aim to connect sites of geological interest [SGI] with other natural and cultural points of interest, creating a robust tourism offering that integrates geology with biodiversity, culture, and ecology (Carrión-Mero et al., 2021; Dóniz Páez et al., 2021; Drinia et al., 2022).

The creation of geotourism routes, geo-trails, geoactivities, and guided visits to SGI contributes positively to the appreciation, conservation, and learning of geoheritage and geodiversity through Earth Sciences (Coutinho et al., 2019; Dóniz-Páez & Quintero Alonso, 2016; Morante-Carballo et al., 2020). According to López et al. (2022), these initiatives have a positive impact on the geoscientific education of society, as tourists experience attractions from a geological perspective. Therefore, they are able to recognize the various processes that shaped and gave rise to the current landscape (Drinia et al., 2022; López et al., 2022).

Developing projects related to geotourism routes is important for the recognition and protection of a largely overlooked form of heritage. It serves as a scientific outreach strategy by creating interpretive spaces accessible to non-specialized audiences. The aim of this study is to propose a geotourism route in the Puyango Petrified Forest, which is part of the aspiring UNESCO Global Geoparks projects, in order to highlight the importance and need for the protection of geoheritage and its contribution to sustainable local development.

2. Materials and Methods

2.1. Area of Study

The Puyango Petrified Forest Geopark Project (PGBPP), covering an area of 2,658 hectares, is located in southern Ecuador (Figure 1), bordered to the east by the Andes Mountain range and to the west by the Amotape-Tahuín mountain range (García et al., 2002). It includes a total of 10 parishes in the southwest of El Oro Province, within the canton of Las Lajas, and the northwest of Loja Province, within the canton of Puyango. The canton of Las Lajas, with a total area of 308.86 km², comprises the parishes of San Isidro, La Libertad, El Paraíso, and La Victoria (Gobierno Autónomo Descentralizado Las Lajas, 2015). Meanwhile, the canton of Puyango, covering a total area of 643 km², includes the parishes of El Arenal, Ciano, Mercadillo, Alamor, Vicentino, and El Limo (Gobierno Autónomo Descentralizado Puyango, 2019).

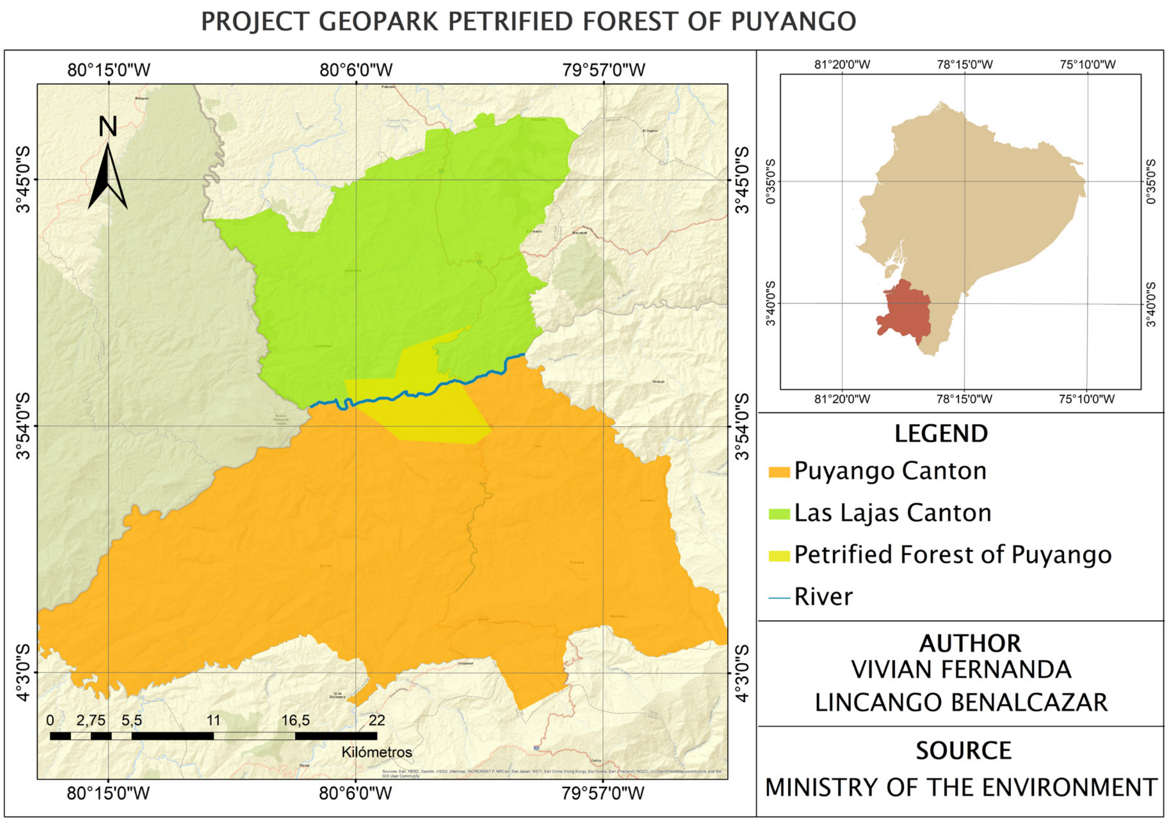


Figure 1. Location of the study site.

Source: The map was elaborated using data sourced from the MAATE geoportal.

2.2. Methodology

The creation of geotourism routes in the PGBPP was based on a mixed-methods approach, combining qualitative and quantitative data. For the technical diagnosis, ranking, and prioritization of geosites and tourist attractions included in the route, the Analytic Hierarchy Process [AHP] methodology proposed by Saaty in 1980 was used. This methodology allows for multicriteria decision-making by ranking various elements or alternatives based on several criteria within an expert judgment framework (Nantes, 2019). Its application was divided into seven phases.

In Phase 1, the criteria and alternatives for the analysis of geosites and tourist attractions were determined. These criteria included nine scientific valuation criteria (representativeness, type locality, scientific knowledge, conservation, rarity, diversity, spectacularity and beauty, observation conditions, association with other heritage) and three recreational use criteria (content/outreach use, possible activities to be carried out, accessibility) (Cendrero Uceda, 1996). For the ranking of the criteria in Phase 2, the paired comparison matrix was applied; the result was an eigenvector indicating the degree of importance or interest of each criterion. For weighting, fundamental scale of Saaty (1980) shown in Table 1 was used.

Table 1. Fundamental paired comparison scale.

Value	Definition	Comments
1	Equal importance	Criterion A is equally important as criterion B
3	Moderate importance	Experience and judgment slightly favor criterion A over B
5	Strong importance	Experience and judgment strongly favor criterion A over B
7	Very strong importance	Criterion A is much more important than criterion B
9	Extreme importance	The superiority of criterion A over B is beyond any doubt
2,4,6,8	Intermediate values between the above	
Reciprocals of the above	If criterion A is of strong importance compared to criterion B, the notations are as follows: • Criterion A more important than criterion B = 5/1 • Criterion B more important than criterion A = 1/5	

Source: Aznar Bellver and Guijarro Martínez (2020).

For the ranking of the recreational use valuation criteria, only the three criteria identified in methodology of Cendrero Uceda (1996) were considered, as they coincide with those established in the methodology of the Ministry of Tourism (Ministerio de Turismo del Ecuador [MINTUR], 2018), shown in Table 2.

Table 2. Description of the recreational use assessment criteria.

Element	Description	Weighing
Accessibility	Refers to the conditions for accessing the attraction, the nearest town or city, the existence of access roads, transportation services, and signage.	18
Possible activities	Refers to the conditions of the attraction for carrying out leisure and recreational activities related to the natural environment (water, air, land), as well as activities practiced at cultural attractions and their potential for use.	9
Outreach content	Refers to the public's interest in and knowledge of the attraction through its dissemination and presence in publications, national or international specialized journals, websites, social media, press, television, and other media outlets.	7

Source: MINTUR (2018), Cendrero Uceda (1996).

It is important to clarify that the valuation presented in the MINTUR methodology allowed for the weighting of criteria in Phase 2.

Phase 3, the normalization of matrices, made it possible to obtain the eigenvector, that is, the weight [W] involved in the decision-making process. In Phase 4, paired comparison matrices between alternatives were created, considering the order of importance of the criteria from the previous phase and the weighting performed by a group of experts in the geological field for scientific valuation, and by MINTUR for recreational valuation.

By normalizing the paired comparison matrices of the geosites and tourist attractions alternatives (Phase 5), the weight W of each one was obtained. For the consistency validation of each matrix (Phase 6), the formulas for the consistency index [CI] (equation [1]) and consistency ratio [CR] (equation [2]) were applied. If the matrix exceeds the maximum consistency ratio, the weightings need to be reviewed; otherwise, the matrix is accepted as consistent, and the selection process continues.

$$CI = \frac{(Lambda\ max - N^{\circ}\ of\ colums)}{2} \quad [1]$$

Where, the number of columns is related to the number of criteria.

$$CR = \frac{CI}{CA} \quad [2]$$

Where the value of the random consistency [RC] depends on the size of the matrix (Tables 3 and 4).

Table 3. *Random consistency.*

Matrix size (n)	1	2	3	4	5	6	7	8	9	10
Consistency ratio	0.00	0.00	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

Source: Aznar Bellver y Guijarro Martínez (2020).

Table 4*. Maximum percentages of CR.*

Matrix size (n)	**Consistency ratio**
3	5%
4	9%
≥ 5	10%

Source: Aznar Bellver y Guijarro Martínez (2020).

Finally, in Phase 7, the prioritization order or importance of each geosite and attraction was obtained to decide their integration into the geotourism routes.

The route proposal was complemented with the methodology of Chan (2005), which includes four fundamental elements: 1) creativity to innovation, 2) concrete space, 3) geoheritage, and 4) theme. It should be noted that the first element was not considered due to the absence of previous projects related to the topic of this research.

For the design, ArcMap Geographic Information System version 10.8 was used. Meanwhile, for the study of the geotourist profile, an annual population of 13,000 visits to the PGBPP was identified, according to figures from the Gobierno Autónomo Descentralizado Puyango (2019). The sample was calculated using probabilistic sampling, applying the finite population formula with a margin of error of 0.05. The resulting sample consisted of 373 individuals, who were surveyed with a questionnaire containing 21 closed questions and 2 open questions during February 2023 (a vacation period coinciding with the blooming of guayacan trees in Mangahurco), in the PGBPP tourist area. This survey was validated through a pilot test with 10% of the sample, that is, 37 visitors.

3. Results

This section presents the results obtained from the analysis of on-site visits. A total of 14 geosites were identified in the Puyango Petrified Forest (BPP), of which 12 were visited due to lack of accessibility in the Tunima and El Gineo ravines. Of these, only seven geosites are located within the 2,658 hectares protected under the designation "Forest and Protective Vegetation".

Applying methodology of Saaty (1980), six geosites were prioritized based on scientific value criteria, with most of them showing high scores in representativeness, type locality, and association with other heritage. Regarding recreational use criteria, six geosites were prioritized, highlighting the criteria of content/outreach use and possible activities to be carried out. During the tours, five geosites with high intrinsic value were selected, enabling the dissemination of geological scientific knowledge and connected with other attractions of equal value. Table 5 shows the scientific and recreational prioritization:

Table 5. Prioritized geosites.

Geosite	Scientific prioritization	Recreational use prioritization	Type of prioritization
El Limo Fold	0.08	0.06	Scientific
El Derrumbo Fold	0.07	0.07	Scientific
La Libertad Fold	0.07	0.10	Scientific – recreational
Puyango Fault	0.07	0.07	Scientific
El Tigre Ravine	0.07	0.06	Scientific
Cochurco Ravine	0.07	0.11	Recreational
El Limón Ravine	0.07	0.07	Scientific
Buddynage El Basal	0.06	0.08	None
Los Zábalos Ravine	0.06	0.06	Recreational
Playa El Gringo	0.06	0.10	Recreational
Chirimoyo Ravine	0.06	0.12	Recreational
Quemazón Ravine	0.06	0.11	Recreational

On the other hand, eight tourist attractions were recorded along the existing trails (Table 6); seven of them are of geological interest. The significant recreational use criteria were accessibility and the possible activities that could be carried out. Of the eight attractions, four of geological interest were prioritized. A substantial difference was noted in the content/outreach use criterion for the giant petrified trunk, even though it was not included in the prioritized attractions. As the most complete and important specimen of petrified wood and due to its high educational value, it was included in the geotourism routes, considering the importance of conserving and valuing geological heritage.

Table 6. Prioritized tourist attractions.

Attraction	Recreational Use Prioritization	Prioritization Type
Giant Petrified Trunk	0.23	None
Giant Petrino	0.39	Recreational
Petrified Trunk Deposits	0.27	None
Fossilized Trunks	0.38	None
Puyango Petrified Forest Museum	0.41	Recreational
Yamanasaurus Dinosaur	0.39	Recreational
Brachiosaurus Dinosaur	0.39	Recreational
Cross to the Unknown Soldier	0.38	None

3.1. Geoturist profile

Once the diagnostic was completed, the visitor profile (Table 7), referred to in this study as the geotourist, was determined. The data obtained from the survey were used to develop the proposed geotourism routes.

Table 7. Geotourist profile.

Sociodemographic Characteristics					
Gender	Female	52%	*Occupation*	Private employee	33%
	Male	48%		Student	25%
Level of Education	Higher Education	55%		Public employee	18%
	Secondary	31%		Other	19%
	Postgraduate	11%	*Average Income*	$0 - $300	36%
	Primary	3%		$301- $600	20%
Place of origin	Ecuador	99%		$601 - $1.000	21%
	Foreigner	1%		Más de $1.000	23%
Tourist Consumption					
Travel Group	Family	61%	*Travel motivation*	Vacation	48%
	Friends	13%		Ecotourism	34%
	Couple	12%		Visit Friends/family	9%
	Solo	7%		Geotourism	7%
	Other	7%		Other	2%
Means of Transport	Private	40%	*Overnight Stay*	1 night	1%
	Own vehicle	34%		2 nights	21%
	Touristic transport	19%		3 or nights	8%
	Public transport	7%		None	21%
Tourism Spending					
Average Spending	$0 - $20	40%	*Information Sources*	Social media	49%
	$21 - $40	28%		Friends/family	42$
	$41 - $60	16%		Websites	6%
	More than $60	16%		Other	3%
Motivations					
Reason for visit	Enjoying the landscape	21%	*Geotourism Motivation*	Petrified wood	30%
				Petrinos trees	24%
	Observation of flora and fuana	17%		Fossils	17%
				Archaeology	9%
	Photography	16%		Others	20%
	Relaxation and entertainment	16%	*Undertaken activities*	Hiking	29%
				Photography	23%
	Sports and adventure	15%		Flora and fauna	23%
				Museum visit	15%
	Other	15%		Others	10%
Interest in Geotourism Route					
Yes		99%	Self-guided		25%
No		1%	Guided		75%

3.2. Proposed Geotourism Routes

Two routes were designed: one recreational and one scientific, integrating geosites prioritized through the AHP methodology, as well as those of high geological relevance and geotourism appeal. These routes promote conservation, appreciation of geoheritage, the advancement of geoscience, and research in this territory of high geological potential.

3.2.1. Recreational Geotourism Route

The route called "A Cretaceous Journey" offers a glimpse of large and small archaeological and paleontological outcrops that are part of the geological history of southern Ecuador. It is located between the parishes of Alamor and La Libertad, in the cantons of Puyango and Las Lajas, in the provinces of Loja and El Oro, respectively.

The route includes 10 stops: four geosites and four tourist attractions prioritized with AHP, along with two accessible sites for observing flora and fauna. It was designed for occasional tourists motivated by recreation and leisure. The linear route spans 12.60 km, from the Cochurco Ravine (UTM 606621 E; 9571757 S) to the Chirimoyo Ravine (UTM 602622 E; 9569062 S). Mobility options include walking, biking, driving, or a combination; transportation is required between stops 1–3 and 9–10. This route aims to balance recreation and accessibility, encouraging enjoyment of the geological and touristic environment. Specifications of the route are shown in Table 8.

Table 8. Recreational route.

Stops	Estimates Time for Visit/Interpretation	Transport	Points of Interest	Coordinates (UTM)
P1 - P3	1 hour	By car	**P1.** Cochurco Ravine (Swimming Area)	UTM 606621 E; 9571757 S
			P2. Historic Puyango Bridge	UTM 601912 E; 9570780 S
			P3. Petrified Forest Museum of Puyango	UTM 600844 E; 9570962 S
P3 - P9	1 hour 30 min	On foot	**P4.** Yamanasaurus	UTM 600841 E; 9570983 S
			P5. Giant Petrino	UTM 600740 E; 9571085 S
			P6. Los Zábalos Ravine	UTM 600714 E; 9571130 S
			P7. Giant Petrified Log	UTM 600512 E; 9571270 S
			P8. Viewpoint – Petrified Forest of Puyango	UTM 600699 E; 9571398 S
P9 - P10	1 hour 30 min	On foot and by car	**P9.** Panoramic Viewpoint – Puyango Fault	UTM 601052 E; 9570972 S
			P10. Chirimoyo Ravine (Swimming Area)	UTM 602622 E; 9569062 S

The proposed route integrates stops and complementary services to enhance the tourist experience, support the local community, and promote natural, geological, and cultural resources. Figure 2 identifies points of interest, geosites, and natural and cultural attractions, along with the georeferencing of food services, lodging, recreation, and connectivity routes, which facilitate and contribute to tourism development.

The route highlights a geodiversity that combines tropical dry forest and Mesozoic and Paleozoic deposits, with the Puyango River as the central axis (Jaramillo et al., 2017). To the north, Paleozoic clastic and volcanic rocks predominate, while to the south, there are shales, calcareous shales, and sedimentary sandstones (García et al., 2002).

The fossilized trunks of the Petrified Forest, dated to the Early Cretaceous (Aptian-Albian) (120–96 million years ago), represent the only Cretaceous samples from the west coast of South America (Jaramillo et al., 2017). Mainly belonging to the genera *Agathoxylon, Metapodocarpoxylo*n, and *Araucarioxylon* (García et al., 2002), they form the largest collection of petrified wood worldwide. Additionally, the museum houses fossils of ammonites, shells, and plants, enriching its scientific and heritage value.

The study area is located within the Tropical Andes ecoregion and the Southern Andes and Tumbesina regions, highlighting its geodiversity and biodiversity, including numerous endemic species (Gobierno Autónomo Descentralizado Parroquial Rural de La Libertad, 2021). The route includes the BPP viewpoint to facilitate the observation of flora and fauna, considering the 202 plant species and 169 animal species documented through direct observation and bibliographic sources (Jumbo Eras et al., 2021). Furthermore, the route is ideal for photography and species watching activities.

The "Cretaceous Path" combines recreation and geoheritage, incorporating geosites such as the Cochurco and Chirimoyo ravines, which offer evidence of fossilized rocks and serve as accessible natural bathing spots. This route balances tourist leisure with the recognition and appreciation of geological heritage.

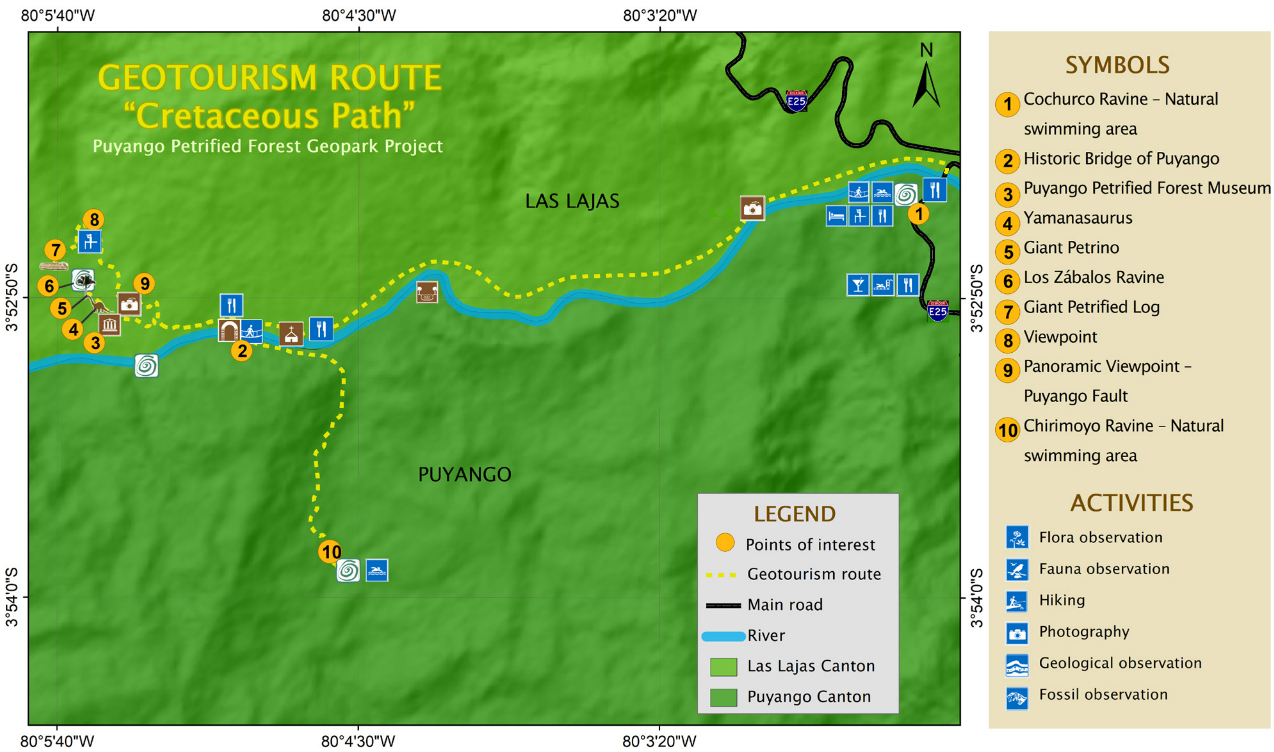


Figure 2. Map of the recreational geotourism route.

3.2.2. Scientific Geotourism Route

The scientific route "Discovering the Cretaceous" spans 9.85 km between Alamor and La Libertad, notable for its valuable geological and paleontological remains. With seven points of interest prioritized through the AHP methodology, it includes geosites, tourist attractions, and a meteorological station for Earth Science studies. Designed for academic purposes, it promotes the analysis of Cretaceous processes and structures, strengthening geological knowledge. The route starts at the Petrified Forest Museum and ends at the "Los Fósiles Trail," allowing pedestrian, vehicular, or biking mobility. The parameters of the complete route are shown in Table 9.

The duration of the route depends on the visitor's research focus and interests. The route prioritizes geosites, geological attractions, and tourist services, excluding recreational areas due to its scientific nature (Figure 3).

The route highlights the La Libertad Fold, a key geosite for studying low-grade metamorphic rocks. Its location reveals landforms typical of alluvial plains and tectonic reliefs, with lithology composed of metamorphic and igneous rocks, sandstones, shales, and schists (Gobierno Autónomo Descentralizado Parroquial Rural de La Libertad, 2021).

The petrified wood specimens from the Cretaceous period are complemented by notable fossils along the "Los Fósiles Trail" in the Chirimoyo Ravine. These include mollusks from the classes Pelecypoda and Cephalopoda, internal and external molds, and petrified shells in sedimentary rocks (García et al., 2002). Additionally, ammonites, bivalves, and echinoderms are observed both on the trail and in the museum, enriching their scientific and educational value (Jumbo Eras et al., 2021).

Table 9. Scientific georoute.

Stops	Estimates Time for Visit/Interpretation	Transport	Points of Interest	Coordinates (UTM)
P1 - P4	1 hour 30 min	On foot	**P1.** Petrified Forest Museum of Puyango	UTM 600844 E; 9570962 S
			P2. Giant Petrino	UTM 600740 E; 9571085 S
			P3. Giant Petrified Log	UTM 600512 E; 9571270 S
P4 - P5	1 hour	On foot	**P4**. Meteorological Station	UTM 600710 E; 9571410 S
			P5. La Libertad Fold	UTM 600036 E; 9572876 S
P5 - P6	1 hour 15 min	On foot	**P6.** Panoramic View of the Puyango Fault	UTM 601052 E; 9570972 S
P6 - P7	1 hour	On foot and by car	**P7**. Chirimoyo Ravine (Los Fósiles Trail)	UTM 602491 E; 9569899 S

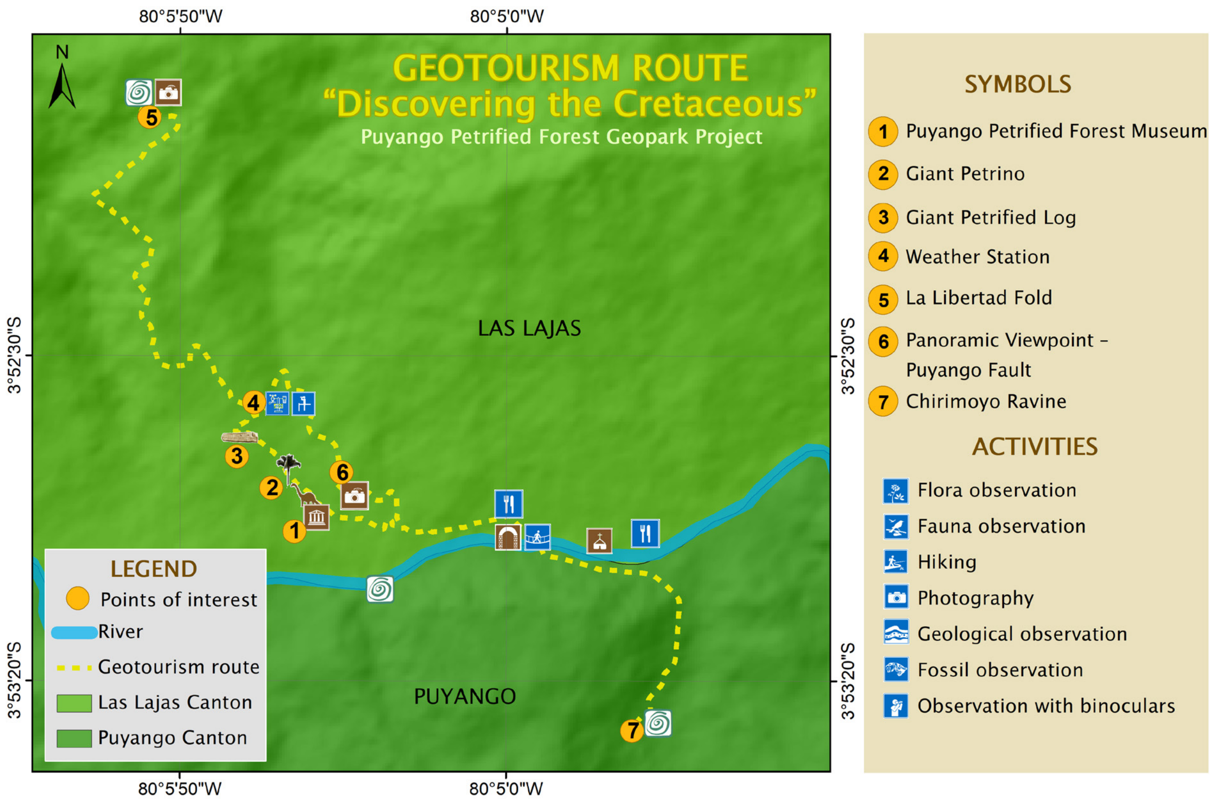


Figure 3. Map of the scientific geotourism route.

The diversity of flora and fauna in the tropical dry forest stands out for its timber trees and bird species. The route to the La Libertad Fold, with elevations ranging from 300 to 600 m a.s.l., is ideal for promoting birdwatching activities for recreational and scientific purposes.

The route emphasizes the richness of specimens and deposits, especially at the La Libertad Fold and Los Fósiles Trail geosites, where scientific activity has been limited despite favorable conditions of low acoustic interference and reduced visitor flow. These sites, along with others, offer valuable material to advance the study of geological features reflecting Earth's evolution over millions of years.

4. Discussion

Research on geoheritage and geotourism activities in Ecuador face challenges in areas without geological recognition, generally being limited to complementing conventional tourism (Carrión-Mero et al., 2021; Palacio Prieto et al., 2016). The PGBPP, which houses the largest collection of petrified wood worldwide, introduces an innovative proposal focused on highlighting its geoheritage through geotourism. This approach promotes both its scientific and touristic appreciation, marking a significant advance in the identification and characterization of geoheritage in the country, where such initiatives have been scarce and mainly linked to traditional tourism.

In this context, the AHP methodology allowed prioritization of geosites based on their potential and accessibility, highlighting some such as Los Zábalos Ravine, Chirimoyo, Cochurco, and the museum, previously emphasized by Morante-Carballo et al. (2020). However, certain sites were discarded due to limited connectivity, an essential characteristic for designing a functional and accessible geotourism route (Pilogallo et al., 2019).

The design of these routes depends not only on the scientific characteristics of the geosites but also on considering the interests and profiles of potential geotourists, as suggested by Meléndez-Hevia et al. (2011). This approach allows adapting points of interest and experiences to the needs of a diverse audience, from occasional to specialized tourists. Additionally, the creation of simplified scientific concepts facilitates the understanding and appreciation of geoheritage, improving the visitor experience and promoting integration between science and tourism (Coutinho et al., 2019). Thus, the route not only fulfills an educational role but also reinforces the recognition and preservation of geoheritage.

Geotourism, therefore, emerges as an opportunity for geoconservation and local development (Hose, 2011, 2012; Pilogallo et al., 2019). Although geotourism products remain limited, they contribute positively to the dissemination and management of geoheritage with a focus on sustainability.

Moreover, geotourism is becoming established as a key strategy for geoconservation and sustainable local development, integrating the promotion and management of geoheritage along with natural and cultural resources (Hose, 2011, 2012; Pilogallo et al., 2019). Its sustainability-oriented approach allows for the protection of heritage while generating a positive impact on local communities (Coutinho et al., 2019; Drinia et al., 2022; UNESCO, 2021). In this context, geotourism routes stand out, as they facilitate the understanding and conservation of geoheritage through accessible and educational interpretation models (López et al., 2022; Tavera Escobar et al., 2017).

These routes use Earth Sciences as an educational tool for society, promoting the care and sustainable use of geological heritage (Carcavilla Urquí, 2014; Martínez Fernández, 2013). Examples such as Uluru in Australia or the Iguazú Falls demonstrate how tourism can highlight significant landforms without compromising their integrity (Brilha et al., 2018). In addition, guided visits with proper interpretation strengthen understanding and appreciation for geological heritage that is often overlooked (Dóniz Páez et al., 2021; Drinia et al., 2022). Altogether, geotourism not only promotes geoeducation but also boosts the local and global economy in a sustainable way.

5. Conclusions

This research highlights the geotourism potential of the PGBPP as a consolidated site of geological vestiges and global endemism. This area showcases the transformation of the landscape throughout geological eras, as well as the characteristic flora and fauna of each period. It is a site of high geoscientific value that currently lacks the necessary national and international recognition, as well as adequate dissemination.

The implementation of geotourism routes becomes a tool to diversify tourism through geoheritage. The geotourist profile, combined with routes designed for scientific and recreational purposes, enables interaction and interpretation for both specialized and non-specialized audiences interested in geosciences. Ecuador does not yet have a well-developed geotourism offering, even after receiving the designation of a new UNESCO Global Geopark (Imbabura Geopark). For this reason, the present study focused on prioritizing high interest geosites in the PGBPP and enhancing their value through two routes that provide invaluable information about the country's geological resources.

Studies that merge geology with societal interests are part of an emerging international academic field. While they continuously implement measures for the management and protection of geological resources, they also promote ongoing development in geoscience and geoeducation. Through the identification of 12 geosites and the creation of geotourism routes, this research aims to achieve a holistic understanding of geoheritage and geodiversity, seeking their recognition, management, and conservation for the benefit of local communities and contributing to the sustainable development of geotourism in designated UNESCO Global Geoparks.

Acknowledgments

We acknowledge and thank all the local guides of the Puyango Petrified Forest for their participation and support during the data collection for this study. Special thanks to Eng. Tania García Fonseca, coordinator of the initial candidacy process for the Puyango Geopark Project, for her valuable contributions and guidance in the field of geosciences, as well as to Mr. Santiago Granda, Head of the Culture, Tourism, and Recreation Unit of the Puyango Municipal Government, for his collaboration during the study.

Contributor roles

- Vivian Fernanda Lincango Benalcázar: conceptualization, investigation, data curation, resources, writing – original draft.
- Patricia Mercedes Pazmiño Valle: conceptualization, formal analysis, methodology, supervision, writing – original draft.

Ethical implications

The authors declare that all ethical principles were observed in relation to the implementation of the survey that formed part of the research titled "Geotourism Routes as a Strategy for Recognition and Conservation of Geoheritage in the Puyango Petrified Forest Geopark Project," ensuring transparency in the handling of procedures and results.

Conflict of Interest

The authors declare that they have no affiliation with any organization with a direct or indirect financial interest that could have appeared to influence the work reported.

Referencias

Arrage, J. A. (2024). Geot*ourism for UNESCO Global Geoparks: a toolkit for developing and managing tourism*. UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000391228?posInSet=22&queryId=4199e863-4ec4-4742-953c-970a75d32689

Aznar Bellver, J., & Guijarro Martínez, F. (2020). *Nuevos métodos de valoración. Modelos Multicriterio*. Universitat Politècnica de València. http://hdl.handle.net/10251/19181

Brilha, J., Gray, M., Pereira, D. I., & Pereira, P. (2018). Geodiversity: An integrative review as a contribution to the sustainable management of the whole of nature. *Environmental Science & Policy*, *86*, 19-28. https://doi.org/10.1016/j.envsci.2018.05.001

Bruschi, V., Sánchez Carro, M. A., Gutiérrez, G., & Flor-Blanco, G. (2023). La divulgación del patrimonio geológico como herramienta de sensibilización de la sociedad hacia el riesgo geológico. *Geogaceta*, *74*, 87-90. https://doi.org/10.55407/geogaceta98329

Carcavilla Urquí, L. (2014). Guía práctica para entender el patrimonio geológico. *Enseñanza de las Ciencias de la Tierra*, *22*(1), 5-18. https://raco.cat/index.php/ECT/article/view/284026

Carrión-Mero, P., Borja-Bernal, C., Herrera-Franco, G., Morante-Carballo, F., Jaya-Montalvo, M., Maldonado-Zamora, A., Paz-Salas, N., & Berrezueta, E. (2021). Geosites and Geotourism in the Local Development of Communities of the Andes Mountains. A Case Study. *Sustainability*, *13*(9), 4624. https://doi.org/10.3390/su13094624

Cendrero Uceda, A. (1996). *El patrimonio geológico: bases para su valoración, protección, conservación y utilización*. Ministerio de Obras Públicas, Transportes y Medio Ambiente.

Chan, N. (2005). *Circuitos-turísticos. Programación y cotización* (3rd ed.). Ediciones turísticas de Mario Banchik.

Coutinho, A. C. A., Urano, D. G., Mate, A. J., & Nascimento, M. A. L. do. (2019). Tourism and Geotourism: A conceptual problem. *Revista Rosa Dos Ventos - Turismo e Hospitalidade*, *11*(4), 754-772. https://doi.org/10.18226/21789061.v11i4p754

Damas Mollá, L., Bodego, A., Uriarte, J. A., Zabaleta, A., & Aranburu, A. (2024). Talleres sobre geología y patrimonio cultural en el Geoparque Unesco Las Loras (Burgos/Palencia). *Geogaceta*, *75*, 75-78. https://doi.org/10.55407/geogaceta100688

Dóniz Páez, J., Becerra-Ramírez, R., & Beltrán Yanes, E. (2021). Geomorfositios en el Geoparque Mundial Unesco de El Hierro (Islas Canarias, España) para fomentar el geoturismo en espacios volcánicos. *Revista de Geografía Norte Grande*, *80*, 165-186. https://doi.org/10.4067/S0718-34022021000300165

Dóniz-Páez, J., & Quintero Alonso, C. (2016). Propuesta de rutas de geoturismo urbano en Icod de Los Vinos (Tenerife, Islas Canarias, España). *Cuadernos Geográficos*, *55*(2), 320-343. https://revistaseug.ugr.es/index.php/cuadgeo/article/view/3014

Drinia, H., Voudouris, P., & Antonarakou, A. (2022). Editorial of Special Issue—"Geoheritage and Geotourism Resources: Education, Recreation, Sustainability" *Geosciences*, *12*(6), 251. https://doi.org/10.3390/geosciences12060251

Fernández-Martínez, E., Orus, A. H., Alcalá, L., Monasterio, J. M., Martínez, J. A., & de Santisteban Bové, C. (2014). Actividades de divulgación del patrimonio geológico en geoparques. *Enseñanza de las Ciencias de la Tierra*, *22*(1), 61-68. https://raco.cat/index.php/ECT/article/view/284031

García, M., Jiménez, N., Ordóñez, M., Suarez, J., & Tigreros, J. (2002). Paleontología y Micropaleontología del Bosque Petrificado de Puyango Provincia de Loja. In *Estudio de valoración y diagnóstico de paleontología, botánica, arqueología y etnografía en los cantones de Puyango, Celica y Paltas de la provincia de Loja, 2001-2002* (Vol. 1, pp. 53-66). CEAA-ESPOL. https://downloads.arqueo-ecuatoriana.ec/ayhpwxgv/informes/ProyectoLoja1.pdf

Geoparque Sorarbe Pirineo (2024). *Semana de los Geoparques Europeos*. https://www.geoparquepirineos.com/contenidos.php?niv=1&cla=_2OA1CDG68&cla2=_2OB01IYE9&cla3=&tip=2&idi=1

Gobierno Autónomo Descentralizado Las Lajas. (2015). *Plan de Desarrollo y Ordenamiento Territorial del cantón Las Lajas*. https://www.laslajas.gob.ec/gaceta/2.%20Plan%20desarrollo%20PDyOT%20las%20lajas.pdf

Gobierno Autónomo Descentralizado Parroquial Rural de La Libertad. (2021). *Plan de Desarrollo y Ordenamiento Territorial de la parroquia rural "La Libertad"*. https://lalibertadeloro.gob.ec/images/PDOT_LA_LIBERTAD_JULIO_2018.pdf

Gobierno Autónomo Descentralizado Puyango. (2019). *Plan de Desarrollo y Ordenamiento Territorial cantón Puyango*. https://www.gadmpuyango.gob.ec/index.php/files/27/RC-Enero-2021/354/Literalk.pdf

Hose, T. A. (2011). The english origins of geotourism (as a vehicle for geoconservation) and their relevance to current studies. *Acta Geographica Slovenica*, *51*(2), 343-359. https://doi.org/10.3986/AGS51302

Hose, T. A. (2012). Editorial: Geotourism and Geoconservation. *Geoheritage*, *4*(1–2), 1-5. https://doi.org/10.1007/s12371-012-0059-z

Jaramillo, J. P., GarcíaFonseca, T., & Bolaños, M. (2017). Bosque Petrificado de Puyango y sus alrededores: inventario de lugares de interés geológico. *GeoLatitud*, *1*(1), 18–18. https://geolatitud.geoenergia.gob.ec/ojs/ojs/index.php/GeoLatitud/article/view/7

Jumbo Eras, E., Herrera-Feijoo, R. J., Ávila-Andrade, A., Chicaiza-Ortiz, Á., Morocho-Cuenca, M., & Chicaiza-Ortiz, C. (2021). Evaluación de la biodiversidad, amenazas y estatus de conservación de la flora y fauna del Bosque Petrificado Puyango. *Green World Journal*, *4*(2), 18. https://doi.org/10.53313/gwj42018

López, J. P., Medina, W., Bellos, L. I., & Martínez, F. (2022). Geoturismo en el valle de Tafí: el desarrollo de georutas como contribución al conocimiento geocientífico de la sociedad. *Serie Correlación Geológica*, *38*(2), 29-46. https://doi.org/10.5281/zenodo7738336

Martínez Fernández, M. de la P. (2013). Invitación al geoturismo. Reflexiones sobre geodiversidad y potencial geoturístico en la Patagonia Argentina. Boletín Geográfico, (35), 61-78. https://revele.uncoma.edu.ar/index.php/geografia/article/view/62

Meléndez-Hevia, G., Moreira, J. C., & Carcavilla-Urqui, L. (2011). Geoturismo: el paso de un recurso a un atractivo. *Terr Plural*, *11*(2), 327-337. https://doi.org/10.5212/TerraPlural.v.11i2.0010

Ministerio de Turismo del Ecuador, [MINTUR]. (2018). *Manual de atractivos turísticos*. MINTUR. https://servicios.turismo.gob.ec/gestion-y-desarrollo-turistico/

Morante-Carballo, F., Herrera-Narváez, G., Jiménez-Orellana, N., & Carrión-Mero, P. (2020). Puyango, Ecuador Petrified Forest, a geological heritage of the Cretaceous Albian-Middle, and its relevance for the sustainable development of geotourism. *Sustainability*, *12*(16), 6579. https://doi.org/10.3390/su12166579

Nantes, E. A. (2019). El método Analytic Hierarchy Process para la toma de decisiones. Repaso de la Metodología y Aplicaciones. *Revista de la Escuela de Perfeccionamiento en Investigación Operativa*, *27*(46), 54-73. https://revistas.unc.edu.ar/index.php/epio/article/view/26474

Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura [UNESCO]. (2021). *Memoria de la reunión internacional: Geoparques, Turismo Sostenible y Desarrollo Local*. UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000380262.locale=es

Palacio Prieto, J. L., Sánchez Cortez, J. L., & Schilling, M. E. (2016). *Patrimonio geológico y su conservación en América Latina. Situación y perspectivas nacionales*. Universidad Nacional Autónoma de México. Instituto de Geografía. https://doi.org/10.14350/gsxxi.li.18

Pilogallo, A., Nolè, G., Amato, F., Saganeiti, L., Bentivenga, M., Palladino, G., Scorza, F., Murgante, B., & Casas, G. las. (2019). Geotourism as a Specialization in the Territorial Context of the Basilicata Region (Southern Italy). *Geoheritage*, *11*(4), 1435-1445. https://doi.org/10.1007/s12371-019-00396-9

Saaty, T. L. (1980) *The Analytic Hierarchy Process*. McGraw-Hill.

Schilling, M. (2019). Actividades educativas en los Geoparques : El potencial educativo fuera del aula. In *II Taller Regional para Geoparques Mundiales Aspirantes de la Unesco en América Latina y El Caribe*. Servicio Geológico Colombiano. Manizales. https://www2.sgc.gov.co/patrimonio/Documents/II-Taller-Geoparques-Unesco/23-Octubre/Actividades%20educativas%20en%20los%20Geoparques%20-%20El%20potencial%20educativo%20fuera%20del%20aula%20Dr.%20Manuel%20Schilling.pdf

Tavera Escobar, M. A., Estrada Sierra, N., Errázuriz Henao, C., & Hermelin, M. (2017). Georutas o itinerarios geológicos: un modelo de geoturismo en el Complejo Volcánico Glaciar Ruiz-Tolima, Cordillera Central de Colombia. *Cuadernos de Geografía: Revista Colombiana de Geografía*, *26*(2), 219-240. https://doi.org/10.15446/rcdg.v26n2.59277