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Assessment of Geosites within a Natural Protected Area: A Case Study of Cajas National Park

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Abstract: Cajas National Park (CNP), located in southern Ecuador, comprises an area of high natural, scientific and cultural value with wide recognition worldwide. This national park has a large number of elements that, as a whole, constitute a relevant geological heritage. However, this geological heritage requires an enhancement that complements the important contribution made by the Natural Park in terms of conservation and protection of the natural heritage. This study aims to evaluate sites of geological relevance present in CNP through international geosite assessment methodologies and thus provide knowledge favouring these resources' sustainable use and geoconservation. The study phases comprise four stages: (i) a base information analysis of the study area; (ii) identification and selection of sites of geological interest; (iii) a geosite and geomorphosite assessment using the Inventario Español de Lugares de Interés Geological (IELIG) method and Brilha method; (iv) a qualitative assessment using a strengths, weaknesses, opportunities and threats (SWOT) analysis for the contribution and influence of geomorphosites in the development of the study area. This work made it possible to determine that all the analysed geosites and geomorphological sites (14) have a high and very high interest. The Llaviucu valley site stands out for its relevant scientific, academic and tourist value. The IELIG method revealed that 50% of the evaluated sites have a high protection priority, while the rest are in the "medium" category. In addition, the investigation through the SWOT analysis revealed that the geomorphosites could provide significant added value to the development of geotourism and of the NP itself, complementing the already known natural attractions; moreover, the study presented strategies for the use of these in the sustainable development of the area.

Keywords: geodiversity; geoheritage; geoconservation; geosite; glacial geomorphology; Cajas National Park

1. Introduction

"Geodiversity" is a key term used to understand the role of geological elements within the natural diversity of the territory [1]. More specifically, geoheritage refers to the occurrence of in situ or ex situ elements with a strong geoscientific content of said natural diversity (e.g., rocks, minerals, fossils, landforms and geological collections in museums) [2–4]. However, this term also includes the cultural, social, economic and environmental values presented by the various geological elements of a territory [5], which are important for understanding the geological history of the sector [6].

The conservation of the geological heritage of a place that includes its management, protection, promotion and periodic monitoring of its preservation to ensure that these sites remain accessible as reference sites for the future, is known as "geoconservation" [4,7]. It is important to note that many official programs (e.g., Global Geoparks from UNESCO, the Geoheritage Specialist Group of the International Union for Conservation of Nature and geoheritage–federal programs from the USA) aim to preserve the sites that are most valuable in terms of their geodiversity, especially if they are classified as geoheritage. Additionally, the geodiversity's preservation and conservation can also be under other protection figures such as natural or national parks [8–10]. However, some natural parks have very relevant geological features that have led to their recognition as geoparks (e.g., Fforest Fawr Geopark [11] and Cilento Vallo di Diano Geopark [12]).

Geoparks are born as a model for promoting natural heritage (both biotic and abiotic) and cultural heritage (tangible and intangible) in an environment of sustainable development with benefits for local communities [13,14].

When a certain area is recognised by the predominance of geological elements of high scientific interest, portions of that territory can recreate the earth's geological evolution [15]. This singularity also includes an example of geodiversity; these geological or geomorphological objects are called "geosites" [16].

Depending on the geological elements' representation level, geosites can be of various types (e.g., stratigraphical, geomorphological, paleontological and mineralogical) [17]. More specifically, Panizza [18] suggests the term "geomorphosite" to define those sites with high geomorphological content, which present scenic, socio-economic, cultural and scientific values, which can be useful to society.

Unlike other sites (e.g., paleontological sites), geomorphosites become unique geoheritage sites because they have aesthetic dimension, dynamics dimension and imbrication scales [19]. In addition, they constitute an essential tool to promote geocultural diffusion [20] and geological education [21].

Protected areas host glacial features with outstanding universal value as geoheritage sites [22]. The sectors with geoheritage elements of glacial origin are not limited to a specific region; several examples of protected areas that present geoheritage elements of glacial origin that exist worldwide are Chirripó National Park (Costa Rica) [22], Mt. Kumgang (DPR Korea) [23] and the Ruiz–Tolima Volcano and Glacier Complex (Colombia) [24]. Within the UNESCO Global Geoparks (UGGp) Network, there are numerous examples of geoparks with glacier representation; among them are Chablais (France) [25], Estrela (Portugal) [26] and the Courel Mountains (Spain) [27].

The protection and promotion of geoheritage has led to the generation of various assessment methodologies with scientific, educational and recreational use and management approaches [28–30]. The assessment dimensions vary by method. In the literature, there are a large number of quantitative and qualitative methodologies for geological heritage inventories and site evaluations; among the most prominent are: Reynard et al. [31], Brilha [32], Pereira et al. [33], de Lima et al. [34], Kubalíková [35], Pralong [36,37], Cendrero and Bruschi [38], Coratza and Giusti [39], García-Cortés and Carcavilla [40], Vujičić et al. [41] and Comanescu and Nedelea [42]. The methodologies' evaluation criteria help quantify the state of the sites of geological interest evaluated in each case study, allowing the determination of strategies for the sustainable use of the geological heritage.

The inclusion of communities in the disclosure of space with high geoscientific content has allowed the development of a new concept within studies related to these spaces [43]. This new term is "geotourism", which is a concept that has a degree of uncertainty in the scientific literature [44]. One of the first accepted definitions was the one proposed by Hose [45], stating that its meaning includes the provision of facilities to promote geological knowledge beyond an aesthetic appreciation.

Ecuador is a megadiverse country [46] with an international level of natural and cultural diversity [47], having being recognised as one of the countries with the greatest biodiversity worldwide [48]. In contrast, Sánchez-Cortez [49] explains that the Ecuadorian state has not presented specific criteria for developing strategies focused on protecting geoheritage. In recent years, these have been promoted by the academic and private sectors, significantly impacting tourism development in local communities.

In Ecuador, the Cajas National Park (CNP) is part of the national system of protected areas of the Ministry of the Environment of Ecuador, which groups 56 protected areas and national parks in the country [50]. At the same time, CNP presents two UNESCO designations: world biosphere reserve (since 2003) [51] and site protected by the Ramsar Convention (since 2002) [52]. Within its limits, there is also part of the oldest network of roads in the American continent, called Qhapaq Ñan or Camino del Inca, which was also recognised by UNESCO as a World Heritage Site in 2014. In addition, the park has a great number of elements of glacial origin, which constitute a heritage of regional and international reference within glacial geomorphology [53].

As for the UNESCO geopark protection figure, in 2019 this denomination was granted to the Imbabura geopark initiative. This recognition opened a new trend in developing geological heritage in the country. Currently, Ecuador has two aspiring geoparks: Napo-Sumaco and Volcán Tungurahua, as well as another twelve in progress [54].

The Ecuadorian state has recognised CNP as a national park, and to favour and complement its sustainable development, the enhancement of its geological elements is appropriate. Therefore, the main aim of this research is to evaluate CNP geosites and geomorphosites using two international assessment methodologies, to highlight the geological qualities of CNP as a complement to the current figure of protection and sustainable development of the area.

To fulfil this aim, this research has three sections. The first section provides a vision of the geographical, geological and geomorphological environment of CNP, especially reviewing the scientific bases and concepts related to glacier geomorphology. Section 2 presents the methodological approach of the study and details the selection of the 14 representative geosites–geomorphosites and their evaluation by the semi-quantitative methods of García-Cortés [40] and Brilha [32], including technical details of its particularities. In addition, a qualitative analysis was carried out to determine geoconservation strategies. Section 3 shows the results obtained from the study, while Section 4 discusses the findings and comparisons with other glacial geological sites. Finally, Section 5 summarises the conclusions and future implications of the research.

1.1. Study Area

Cajas National Park (CNP) is in the southern part of mainland Ecuador, within the Province of Azuay (UTM WGS 1984, 17 South Zone: 678000–707000 E/9674000–9696000 N) (Figure 1a), with an area of approximately 149 km^2, 140 km from the city of Guayaquil and 21 km from the centre of the city of Cuenca, the second and third largest city in terms of demographic, commercial and cultural importance in the country. The administrative framework is within the Molleturo, Sayausí, Chaucha and San Joaquín parishes (Figure 1b). CNP owes its name to the Quichua word "cassa", which means "door or entrance to the Sierra Nevada" [55], referring to the intra-mountain valleys that facilitated transport and trade between the Coastal and Andean regions since pre-Columbian times.

Within the immediate area of influence of the park, there are nine localities with a markedly low population density, distributed among the four parishes that share space with CNP. In 2011, the Municipality of Cuenca recorded the following figures for the total population of said communities: Miguir (192), Río Blanco (306), Patul (55), Llano Largo (57), Zhin Alto (87), Angas (12), San Antonio de Chaucha (226), Soldiers (177) and Baute (4). This low population density is the product of the population's motivation to take advantage of the area for productive activities such as agriculture or livestock [56,57].

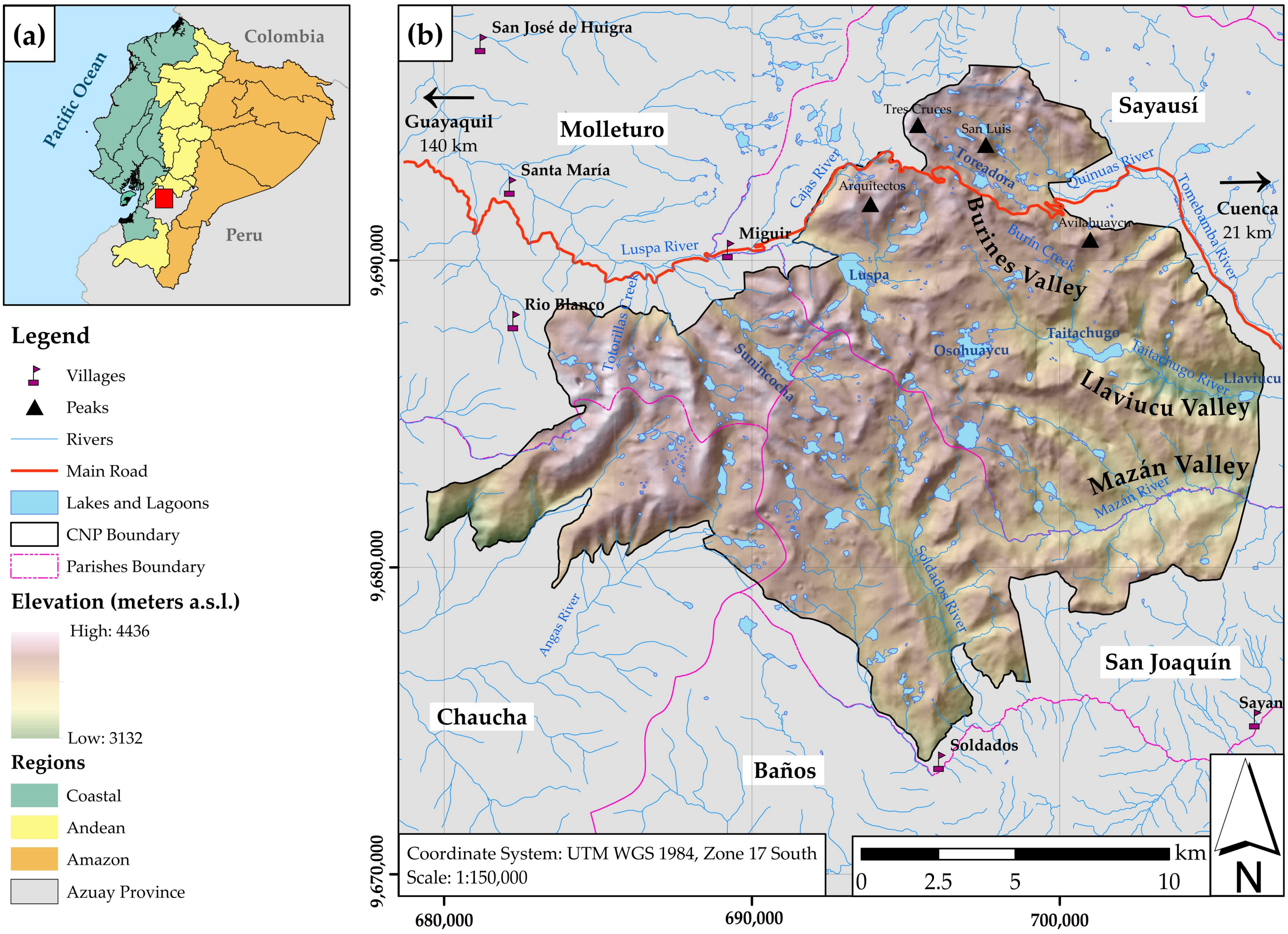

Figure 1. Location of Cajas National Park (CNP): (**a**) mainland Ecuador, with its three natural regions, from left to right: Coastal (blue), Andean (green) and Amazon (red). CNP location is highlighted in the box, inside the Azuay Province (grey); (**b**) local extension of CNP, within the parishes: Baños, Molleturo, San Joaquín and Sayausí.

The biodiversity of CNP has species of both plant and animal origin. Within the flora species, it is contemplated that there are 500 vascular plants, corresponding to half of the genera of this type located in the paramos worldwide, of which 71 are endemic species of Ecuador and 16 are under extinction threats [57,58]. The most dominant vegetation in the area corresponds to the grassland of the páramo. The fauna of the park has the following numbers of species: birds (152), mammals (43), amphibians (15) and reptiles (4) [58].

The climate is characteristic of the high Andean system, strongly influenced by the Andes Mountain range, generating many microclimates depending on the location. The warm waters of the El Niño current cause a marked presence of clouds, unlike other Andean areas in South America [59]. Between 1965–1990, the average precipitation was 1072 mm, with maximum values close to 1400 mm and minimum values of 829 mm [58]. The humidity of the area and other variables, such as the large presence of organic matter and materials of volcanic origin, allow effective water retention in its soils [60]. The temperature fluctuates between −2 °C and 18 °C, presenting moderate to high rainfall without a spatial variability defined by the influence of direction winds and relief [61]. Solar radiation presents a strong daily cycle due to its location in a tropical zone [60].

The altitude varies between 3152 and 4500 m.a.s.l. The lower altitude is found at the easternmost end of CNP, corresponding to the valleys, inter-Andean trenches and many of the towns in the country's south, including Cuenca city. Meanwhile, the highest points have an elevation close to 4500 m.a.s.l. in the westernmost part of the park [57], highlighting "Cerro Arquitectos" with 4300 m (Figure 1b).

1.2. Geologic Framework

CNP is to the west of the western fringe of the Ecuadorian Andes, better known as the Western Cordillera (Figure 2a). Lithologically, it has various formations of volcanic origin ranging from the Eocene to the Quaternary. Among the geological units reported by Dunkley and Gaibor (Figure 2b) [62] are: the Saraguro group (E-Ms)–middle Eocene to early Miocene, formed by predominantly andesitic to dacitic calc-alkaline volcanic rocks; rhyolites are also common. The Chulo unit (E Sc), composed of a sequence of rhyolitic to dacitic tuffs, breccias and lacustrine sediments, despite the unknown age, is dated to the late Eocene. The Tomebamba unit (O Stb)–early Oligocene is distributed mainly in the Tomebamba valley (northern part of CNP), composed of massive andesitic and basic dacitic tuffs with lapilli. The Chanlud formation (O Scd)–early Oligocene presents lithologies of andesitic lavas with breccias and intercalations of volcanic sediments; in some sectors, there are dacitic and basaltic compositions. The Rio Blanco formation (O Srb)–early Oligocene (the western portion of CNP) comprises feldspathic andesitic lavas, tuffs and breccias intercalated with sandstones and dacitic tuffs. The La Soldados formation (O Ss) compounds by crystal-rich dacitic tuffs divided into three ash flow tuff units, abundant feldspar and quartz and chloritic lapilli. The Plancharumi formation (O Sp) has very poor lithification, composed of rhyolitic volcanoclastic and fluvial–lacustrine sediments; in some places, they present pumice-rich white ash tuffs.

Regionally, most of the main faults in mainland Ecuador follow a NE–SW direction [63] (Figure 2a). Due to the proximity of the CNP area to the Chaucha batholith and Quimsacocha caldera [64–66], both located in the surrounding areas of CNP, some faulting was generated inside its official protected area; most of these faulted sectors facilitated the passage of giant masses of ice (glaciers), represented by landforms of ice transport erosion, such as "U-shaped" valleys.

The historical geology of the sector can be summarised by several important events in the area: (i) the formation of the continental island arc due to the subduction of the Nazca (oceanic) Plate with the South American (Continental) Plate; (ii) a tectonic uplift, which started in the Miocene and currently continues; (iii) deposition of volcanic materials towards both sides of the main axis of elevations of the Western Cordillera in the course of high activity during the Miocene being less frequent in the Pliocene [66]; (iv) filling with fluvial–lacustrine sediments from depressions in the eastern part of the study area (Cuenca Basin) [67,68].

1.3. Geomorphological Framework

CNP topography is marked by volcanic arc activity in the northern part of the park [73] and the events of great glaciations of the late Pleistocene, which covered about 450 km^2, distributed in the vicinity of the study area [74]. In addition, these volcaniclastic sediments (mostly tephras) are near the larger CNP lakes [73].

It presents a great abundance of small to medium-size lakes (about 250) [75], which are above 3000 m.a.s.l.; these are permanent, being fed by both the surface and groundwater [76]. Similarly, there are exhibited characteristic landforms, such as a "U" shaped valley and different kinds of moraines, which is a product of said glaciations (see Figure 3) [77]. Navarrete [53] reports several sites that stand out, for example, the glacial evidence of Llaviucu lake (709090 E; 9685471 N), the fluvial–glacial landforms of the Tomebamba River valley in the NE limit of the park, and the lakes that surround the segments of the Inca Trail or Qhapaq Ñan (north-central part of CNP).

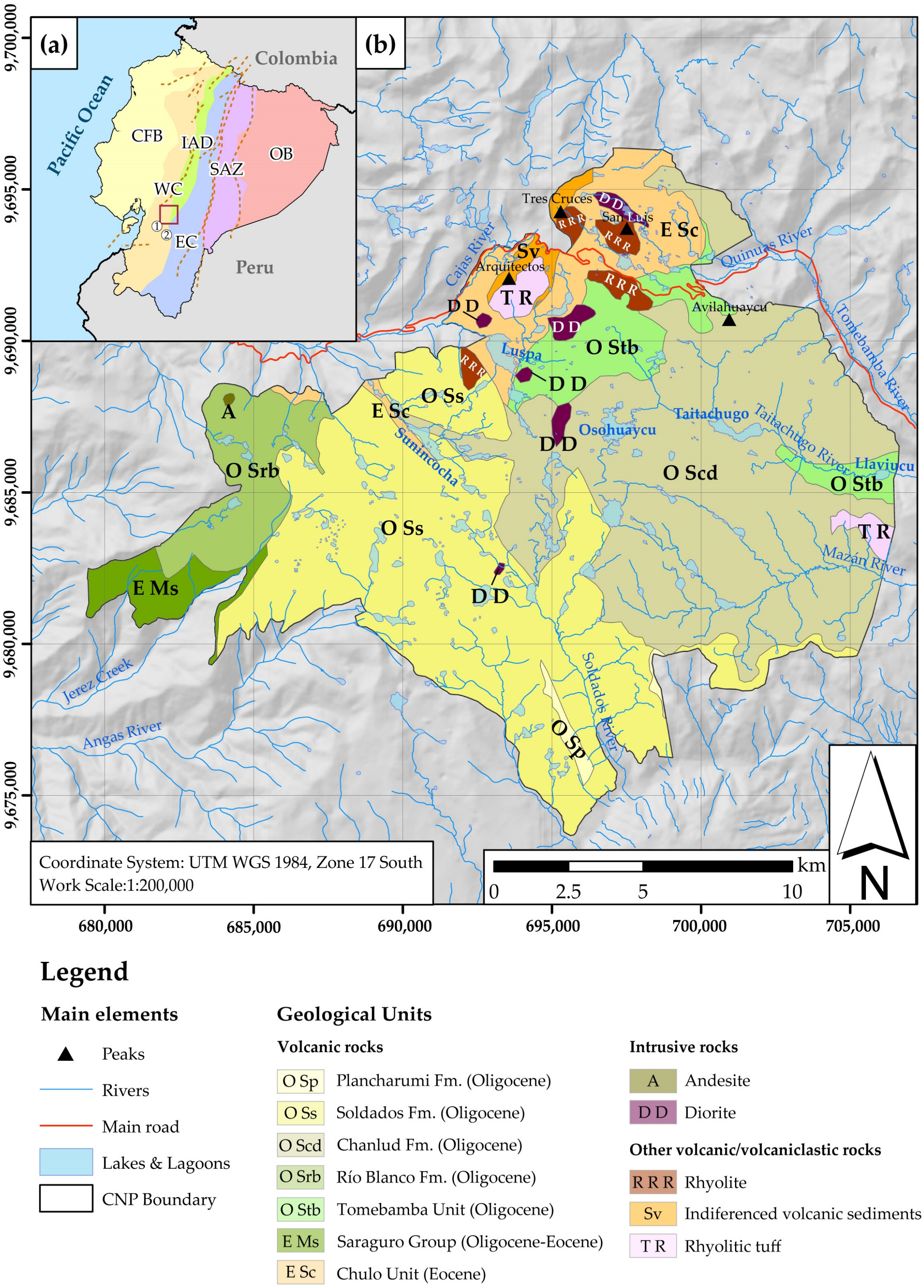

Figure 2. Geologic map of the study area. (**a**) Morphotectonic regions and major faults of mainland Ecuador (dotted lines), study area (red square). Modified from Aspden and Litherland [69], BGS-CODIGEM [70], Cediel et al. [71] and Jackson et al. [72]. Abbreviatures stand for: CFB: Coastal Foreland Basin, WC: Western Cordillera, IAD: Interandean Depression, EC: Eastern Cordillera, SAZ: Subandean zone and OB: Oriente Basin. Other features include: 1. Chaucha batholith, 2. Quimsacocha caldera; (**b**) geological units inside CNP, modified from Dunkley and Gaibor [62].

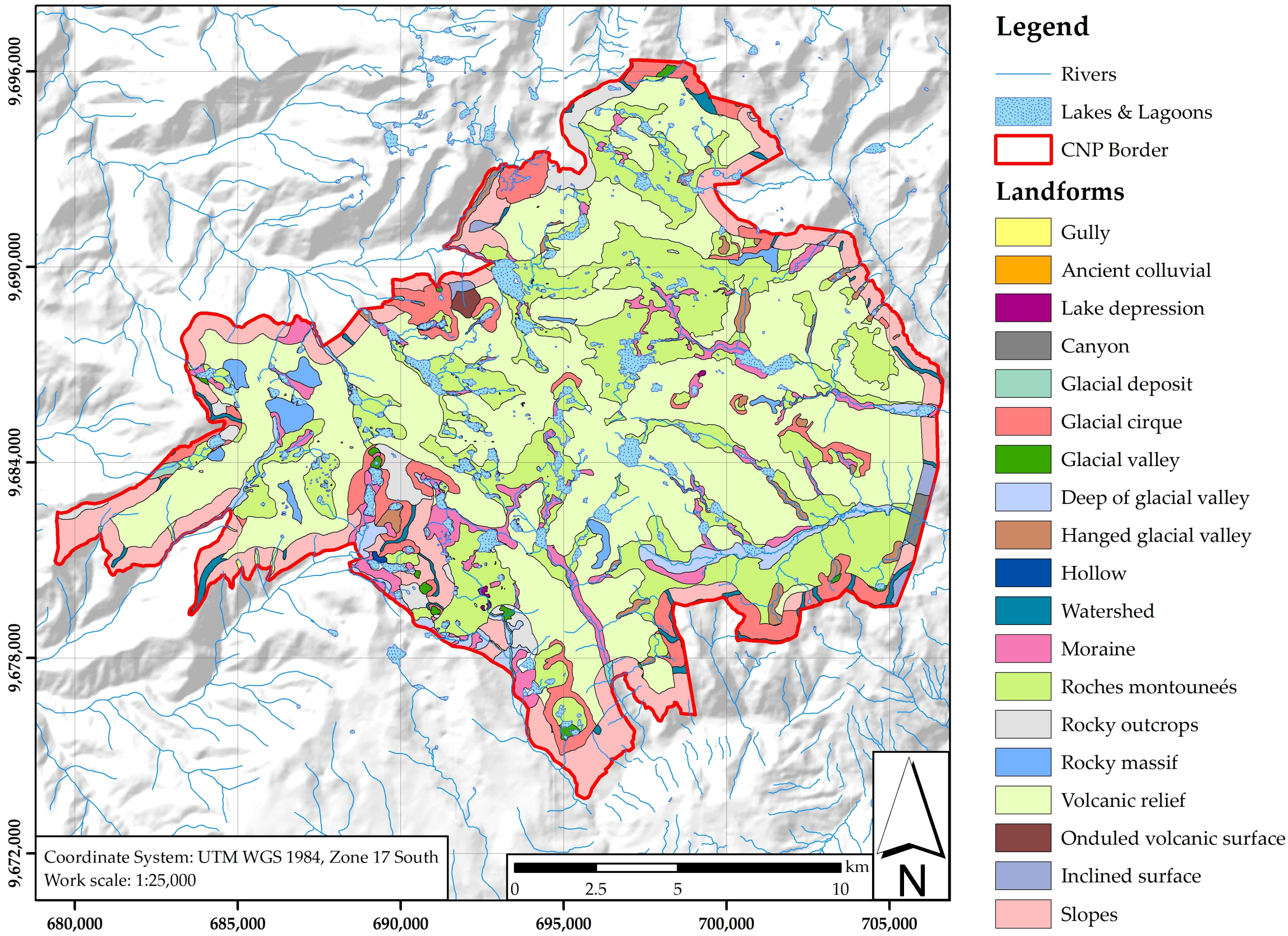

Figure 3. Simplified geomorphological map of Cajas National Park, modified from MAG-SENPLADES-IEE (2007) [78].

2. Materials and Methods

This work was carried out through four phases (Figure 4): (i) base information analysis of the study area, (ii) identification and selection of sites of geological interest, (iii) geosites and geomorphosites assessment, and finally (iv) qualitative assessment, through the development of a strengths, weaknesses, opportunities and threats (SWOT) analysis.

2.1. *Stage I: Base Information Analysis of the Study Area*

The first stage considers the review of the information available on CNP, which includes: international scientific publications, park tourism websites, government documents, basic cartography of the study area and other technical documents from park management (e.g., plan management of CNP). All these data will serve to make a list of possible sites of interest, notified in said literature and the tourist trails at the park. Similarly, within this same phase, a literature review of methodologies used to assess geosites and geomorphosites was carried out to select the most appropriate methods to assess the sites.

2.2. *Stage II: Identification and Selection of Sites of Geological Interest*

The second stage consists of the identification of sites of geological interest (SGI) by processing the cartographic information collected in the previous phase, which includes: topographic maps, geological maps, geomorphological maps (e.g., MAG-IEE-SENPLADES Landforms Inventory on 1:25,000 scale [78]), digital terrain models (DTM) and ArcGIS digitisation of current tourist trails within the CNP boundary. Additionally, this stage included the public database's geolocated points, which refer to the protected area's natural resources, sites available in the CNP tourist inventory files and other geological elements presented in the scientific literature. Finally, potential sites for fieldwork were chosen using the Delphi method [79,80], which were directed to five experts with knowledge of the study area. The tool used was an interview (questionnaire) based on (i) importance of the geological heritage of CNP, (ii) proposal of potential sites, and (iii) expert's self-evaluation. For this study, 14 SGIs were selected based on the representativeness of geological elements, accessibility and other additional values (e.g., cultural aspects) of the 51 SGIs registered and documented in the literature.

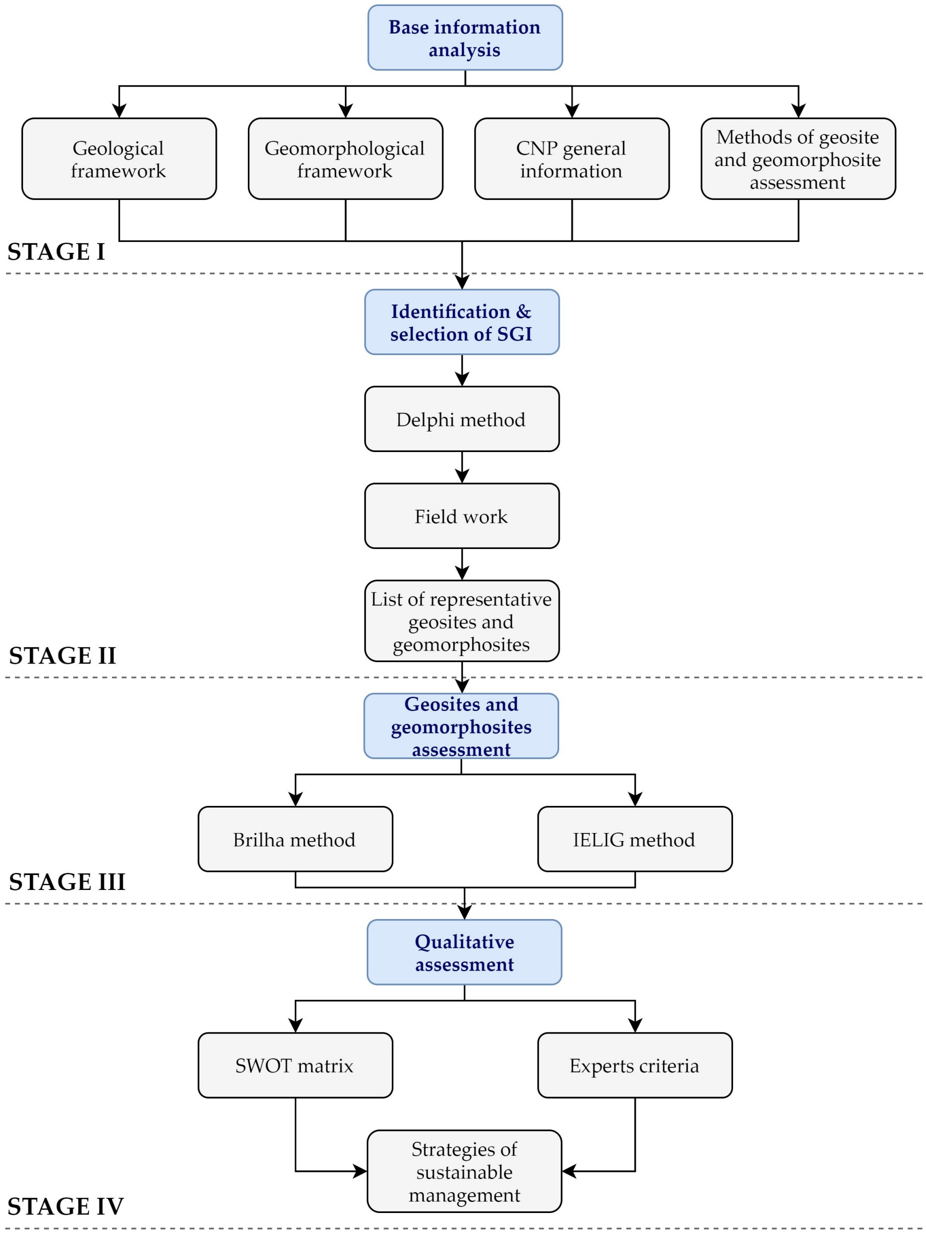

Figure 4. Methodology diagram applied in this study. Abbreviations: SGI, sites of geological interest.

2.3. Stage III: Geosite and Geomorphosite Assessment

The third stage, the evaluation of the 14 geosites and geomorphosites, was developed using two methods, Brilha [32] and the Spanish Inventory of Places of Geological Interest (IELIG), designed by García-Cortés and Carcavilla [40]. These methods present great versatility in evaluating sites of any type, including those of geomorphological interest dominant in the CNP area. Both methods have been used for national inventories of sites of geological importance in Brazil and Spain [81].

2.3.1. Brilha Method

This method includes the evaluation of sites of geological importance based on four dimensions: scientific (S), use educational potential (UEP), potential tourism use (PTU) and degradation risk (DR) (Table 1). When evaluating the S, UEP and PTU indicators, a high value has a positive connotation for the geosite. However, when assessing the DR indicators, high values represent negative connotations (risk) for the geosite. It has been used since 1997 by the Geological Survey of Brazil (known as CPRM in Portuguese) and currently through the GEOSSIT platform, which includes a geological heritage inventory proposal available in an online database with national coverage in Brazil [82]. Furthermore, it has been used for inventory and the assessment of geosites and geomorphosites (e.g., [83–85]).

Table 1. Details of the evaluation criteria for each type of value (S, UEP, PTU and DR) with their respective scores and weight (constant values in %) (Brilha [32]). Interpretation: S, UEP and PTU classification, high (400–301), moderate (300–201), low (200–101) and very low (100).

Criteria	Values							
	Scientific (S)		Educational Potential (UEP)		Potential Tourism Use (PTU)		Degradation Risk (DR)	
	R [1]	W [2]	R [1]	W [2]	R [1]	W [2]	R [1]	W [2]
Representativeness	1–4	30	1–4	0	1–4	0	1–4	0
Key locality		20		0		0		0
Scientific knowledge		5		0		0		0
Integrity		15		0		0		0
Geological diversity		5		10		0		0
Rarity		15		0		0		0
Use limitations		10		5		5		0
Vulnerability		0		10		10		0
Accessibility		0		10		10		15
Safety		0		10		10		0
Logistics		0		5		5		0
Density of population		0		5		5		10
Association with other values		0		5		5		0
Scenery		0		5		15		0
Uniqueness		0		5		10		0
Observation conditions		0		10		5		0
Didactic potential		0		20		0		0
Interpretative potential		0		0		10		0
Economic level		0		0		5		0
The proximity of recreational areas		0		0		5		0
Deterioration of geological elements		0		0		0		35
Proximity to areas/activities with potential to cause degradation		0		0		0		20
Legal protection		0		0		0		20
Total	-	100	-	100	-	100	-	100

[1] R: score range; [2] W: weight.

Based on the total degradation risk (DR) obtained per site, Brilha [32] proposed a classification of DR in three categories (Table 2). These categories allow the configuration of a geosite improvement strategy plan.

Table 2. Degradation risk (DR) classification.

Total (DR)	Degree of Degradation
<200	Low
201–300	Moderate
301–400	High

2.3.2. IELIG Method

IELIG, also known as the Spanish Inventory of Places of Geological Interest, was developed by the Geological and Mining Institute of Spain (IGME), in response to Law 42/2007 of the Government of Spain, on natural heritage and biodiversity to establish a national database. IELIG collaborated with ministries, local and regional governments and educational and scientific institutions in the country. This method considers three values or interests: scientific, academic and tourist. Each assessment parameter has a scale from 0 to 4; the score assigned is multiplied by its corresponding value weight (Equation (1)) (see the weight in Table 3). The structure of the evaluation criteria is detailed in Table 3, while the criteria for the evaluation of degradation susceptibility (DS) are in Table 4.

$$\text{Total (value)} = \sum(\text{Score} \times \text{Weight}), \quad (1)$$

Table 3. Details of the evaluation parameters for each value type with their respective scores and weight (constant values in %) (García-Cortés and Carcavilla [40]). Interpretation: maximum (400), very high (267–400), high (134–266), medium (50–134) and low (<50).

Parameters	Score Range	Value (Weight)		
		Scientific (S)	Academic (A)	Touristic (T)
Representativeness	0 to 4	30	5	-
Standard of reference site		10	5	-
Knowledge of the site		15	-	-
State of conservation		10	5	-
Conditions of observation		10	5	5
Scarcity, rarity		15	5	-
Geological diversity		10	10	-
Educational values		-	20	-
Logistics infrastructure		-	15	5
Population density		-	5	5
Accessibility		-	15	10
Size of site		-	-	15
Association with other natural elements		-	5	5
Beauty		-	5	20
Informative value		-	-	15
Possibility of recreational/leisure activities		-	-	5
Proximity to other places		-	-	5
Socio-economic situation		-	-	10
Total (weight)		100	100	100

Table 4. Parameters for calculating degradation susceptibility (DS). Interpretation of DS: maximum (400), very high (400–200), high (199–68), medium (67–13) and low (<13).

Parameter	Fragility (F)		Vulnerability (V)	
	Score	Weight	Score	Weight
Geosite size	0 to 4	40	0 to 4	-
Vulnerability to looting		30		-
Natural hazards		30		-
Proximity of infrastructure		-		20
Mining exploitation interest		-		15
Protected area designation		-		15
Indirect protection		-		15
Accessibility		-		15
Ownership status		-		10
Population density		-		5
Proximity of recreational areas		-		5
Total (weight)		100		100

The degradation susceptibility was evaluated based on 12 parameters, of which 3 have a fragility focus, while the others focus on vulnerability (Table 4). Both values are used to calculate degradation susceptibility (Equation (2)).

$$DS = \frac{Fr. \times Vul.}{400}, \quad (2)$$

Additionally, this method also includes a series of metrics that relate the three values (S, A and T), for the calculation of the protection priority (Pp), according to said values: scientific priority (S-Pp), priority academic (A-Pp) and recreation/tourism priority (T-Pp). Table 5 presents the detail of these equations.

Table 5. Protection priority equations proposed by García Cortés and Carcavilla [40]. Interpretation of Pp: very high (400–113), high (112–17), medium (16–1) and low (<1).

Protection Priority	Equation
Scientific Priority (S-Pp)	$(IS)^2 \times DS \times (1/400^2)$
Academic Priority (A-Pp)	$(IA)^2 \times DS \times (1/400^2)$
Tourist/recreational priority (T-Pp)	$(IT)^2 \times DS \times (1/400^2)$,
Protection Priority (Pp)	$\left(\frac{IS + IA + IT}{3}\right)^2 \times DS \times (1/400^2)$

2.4. Stage IV: Qualitative Assessment

Stage IV includes the qualitative analysis through a SWOT matrix [86], which explores four variables: strengths, weaknesses, opportunities and threats on the total list of evaluated geosite–geomorphosites. For the SWOT analysis, an evaluation was carried out under the criteria of five experts in general geology, mines, geomorphology, geological heritage and tourism, who are members of the academy and who know the area. The SWOT matrix allowed for a comprehensive evaluation considering positive and negative aspects of the sites and their environment to generate strategies that combine the development of geotourism and geoconservation with the current conservation plan of CNP.

3. Results

3.1. Geosites and Geomorphosites of CNP

This section presents a list of 14 geosites and geomorphosites and their main features, resulting from the inventory and evaluation process using the qualitative and semi-quantitative methodologies proposed in this study, in addition to the field trips carried out at CNP (Table 6). The geosites are classified into four areas of interest: (i) geomorphological, (ii) glacial, (iii) lithological and (iv) periglacial. In addition, Figure 5 shows some examples of the most representative geosites of CNP and Figure 6 shows the location of the 14 CNP geosites.

Figure 5 shows some of the 14 geosites that highlight the scenic value of glacial environments and volcanic origin elements present within CNP limits.

3.2. Geosite and Geomorphosite Assessment

The assessment of geosites and geomorphosites, through both methods, is detailed below.

3.2.1. Assessment by the Brilha Method

Table 7 shows the assessment through the Brilha method on the 14 geosites selected; the first 3 columns contain the study values of the method (S–scientific, UEP–educational and PTU–touristic). In all three values, the "moderate" category obtained the highest number of geosites (Figure 7a). Within the scientific category (S), the highest value was obtained by volcanic flows (G4), while the lowest value corresponds to the camp of erratic boulders/Llaviucu river (G9). In terms of educational potential, two geosites obtained the highest value (Larga and Negra lakes (G2) and Toreadora lake (G6)); when analysing the PTU, the highest value in the category is found in the Llaviucu end moraine (G13), while the lowest value in this category belongs to volcanic flows (G4) (Table 7).

Table 6. List of geosites and geomorphosites in the study area, typological, primary geological interest and main features.

No.	Name	Type of Site	Type of Primary Geological Interest	Type of Secondary Geological Interest	Main Features
G1	Tres Cruces peak	Viewpoint	Geomorphological	Hydrological, glacial	(695563 E;9692860 N) It presents glacial valley views as well as rocky sub-vertical outcrops and highlights the highest elevations in the western part of the geosite, constituting the watershed between the Pacific and Atlantic hydrographic basins. Due to the wind currents crossing from both systems, there are landforms by wind erosion, such as the "Cerro Amarillo". The erosion phenomena exposed peak of this tuff hill has a yellow colour that gives it its name. The site has an additional cultural/historical value due to the presence of "apachetas" (stone mounds that mark milestones along the route and are related to religious offerings).
G2	Larga and Negra lakes	Viewpoint	Glacial	Hydrological, geomorphological	(695528 E; 9692725 N) The geosite shows late Pleistocene glacial modelling, such as glacial cirques, hanging valleys, ridges and several lakes. The staggered geomorphological arrangement of the lakes (paternoster lake) represents the erosive action of glacial advance and retreat that characterised the place. The most representative lakes are Larga lake (24 ha.) and Negra lake (2.5 ha.). In addition, there are several rocky outcrops, the product of natural erosion of the highest parts of the elevation where they are located. Due to the proximity of the lakes, the space constitutes a point of high biological diversity.
G3	Rocky outcrop Larga and Negra lakes	Point	Lithological	Hydrological, geomorphological, glacial	(695743 E; 9692562 N) It constitutes a vertical rocky outcrop on an arête that separates two valleys; one houses the Larga and Negra (West) lakes. According to Dunkley and Gaibor [62], the area is within the Chulo unit (Eocene), composed of sequences of lithologies of volcanic origin, such as rhyolitic tuffs and breccias.
G4	Volcanic flows	Point	Lithological	Glacial, geomorphological, hydrological	(695860 E; 9693813 N) It is in the highest areas (4102 m.a.s.l.) of CNP. An outcrop is presented, showing a volcanic flow of andesitic tuffs. In the surroundings, there are rocks with a marked andesitic composition. In addition, there are panoramic views of lakes of glacial origin (e.g., Palcacocha), hanging valleys and roches moutonnées.
G5	Drumlins camp	Viewpoint	Glacial	Hydrological, geomorphological, landscape	(698949 E; 9691621 N) The geosite located at the foot of the main road offers a panoramic view of an extensive field of asymmetric mounds of drumlins-type landforms. In addition, there are paternoster type lakes and fluvial slopes to the west. Finally, at the bottom of the valley there are examples of roches moutonnées.
G6	Toreadora lake	Point	Glacial	Hydrological, erosional	(697359 E; 9692361 N) It is in the central part of the main tourist attractions of the park, consisting of a 19-hectare lake of glacial origin. You can see the peaks of Cerro San Luis (4295 m.a.s.l.), one of the highest elevations in CNP. The area has a natural interest due to the present examples of the endemic flora and fauna of the Andean Paramo. In addition, it presents a recognised regional historical value due to the García Moreno trail, one of the first modern transport routes between the Coastal and Andean regions.

Table 6. *Cont.*

No.	Name	Type of Site	Type of Primary Geological Interest	Type of Secondary Geological Interest	Main Features
G7	Miguir meteorite	Point	Lithological	Hydrological, geomorphological	(698370 E; 9692187 N) The geosite is an example of impact metamorphism; it constitutes a block of andesite metamorphosed by the impact caused by a meteorite fragment a few centimetres in size, which occurred in 1995 [87]. The block physically presents radial fissures around a 7–10 cm diameter crater.
G8	Tomebamba hanged valley and glacial groove zone	Viewpoint	Glacial	Fluvial, geomorphological	(703276 E; 9692966 N) It is located in a section of the main road, where there is evidence of the glacier's passage through grooves generated by the transport of an ice mass on the slopes of a hill located to the east, taking into account the direction of Cuenca–CNP. In addition, there is one of the best examples of hanging valleys in the southern part of the park.
G9	Llaviucu valley	Area	Glacial	Fluvial, geomorphological	(708968 E; 9685563 N) The geosite has a characteristic parabolic geometry or "U-shaped" valley. In addition, fluvial modelling can be observed, caused by the rivers that flow from the lakes located at higher altitudes.
G10	Camp of erratic boulders/ Llaviucu river	Area	Glacial	Fluvial, geomorphological, lithological	(708089 E; 9685467 N) The site presents a field of erratic blocks arranged on the flood plain formed by the Llaviucu river, which comes from the lake of the same name. In addition, there is part of the meandering system of the Llaviucu river.
G11	Llaviucu lake	Area	Glacial	Hydrological, geomorphological	(706065 N; 9685420 N) Lake of glacial origin located at the end of the valley of the same name. The chain of lakes found at higher altitudes (e.g., Taitachugo and Osohuaycu) supply Llaviucu lake. It presents on the sides of the valley, where vertical rocky outcrops are a product of the last stages of glacial erosion in the area.
G12	End part of glacial valley Llaviucu	Area	Glacial	Geomorphological	(705571 E; 9685621 N) The geosite is a representative example of a terminal moraine, which signifies the maximum glacier passage. Additionally, a segment of a meandering stream of high sinuosity is the product of a postglacial stage. In addition to G9 and G11, this site is part of the ancient Inca Trail, which connected several places across South America in pre-Hispanic times.
G13	Burines route peaks	Viewpoint	Glacial	Geomorphological, hydrological	(698307 E; 9691400 N) Geosite constitutes eutrophic lakes, which connect by small streams with a smaller lake at a lower elevation than the previous one. There are also views of hanging valleys, peaks and a small valley with a stationary lake.
G14	Burines route periglacial	Area	Periglacial	Geomorphological, glacial, hydrological, erosional	(698054 E; 9691342 N) Periglacial landforms with swampy plains, which in some sections are confused with the course of the creeks that come from the high-altitude elevations surrounding them. Likewise, it presents a landslide of about 20 to 30 m in height, extending vertically from the small glacial valley base. It exhibits examples of periglacial morphogenesis where there is highlighted hummock.

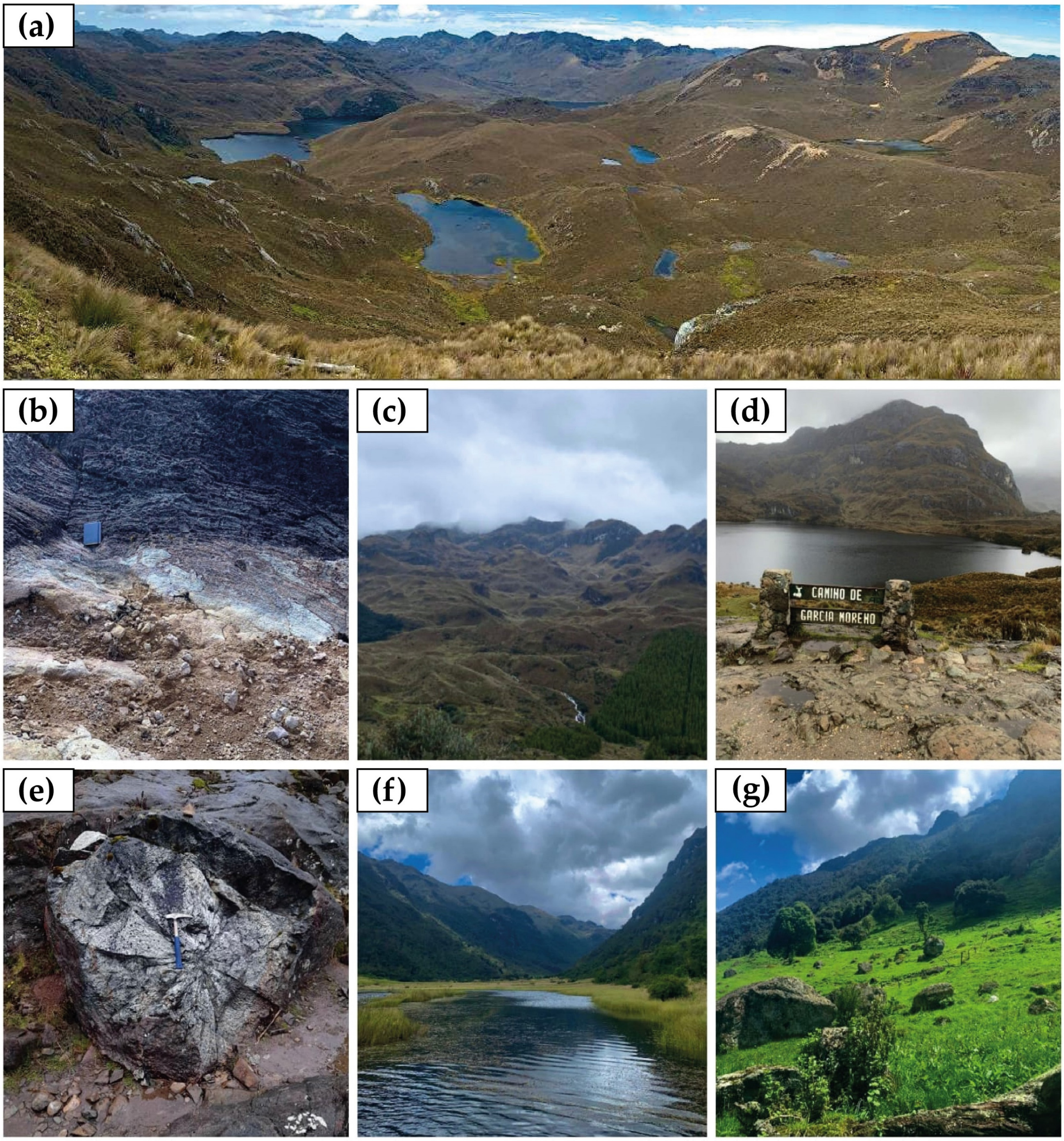

Figure 5. Geosite and geomorphosite examples of CNP according to Table 2: (**a**) Larga and Negra lakes, viewpoint (G2); (**b**) volcanic flow (G4); (**c**) Drumlins camp, viewpoint (G5); (**d**) Toreadora lake (G6); (**e**) Miguir meteorite (G7); (**f**) Llaviucu valley, viewpoint (G9); (**g**) camp of erratic boulders/Llaviucu river (G10).

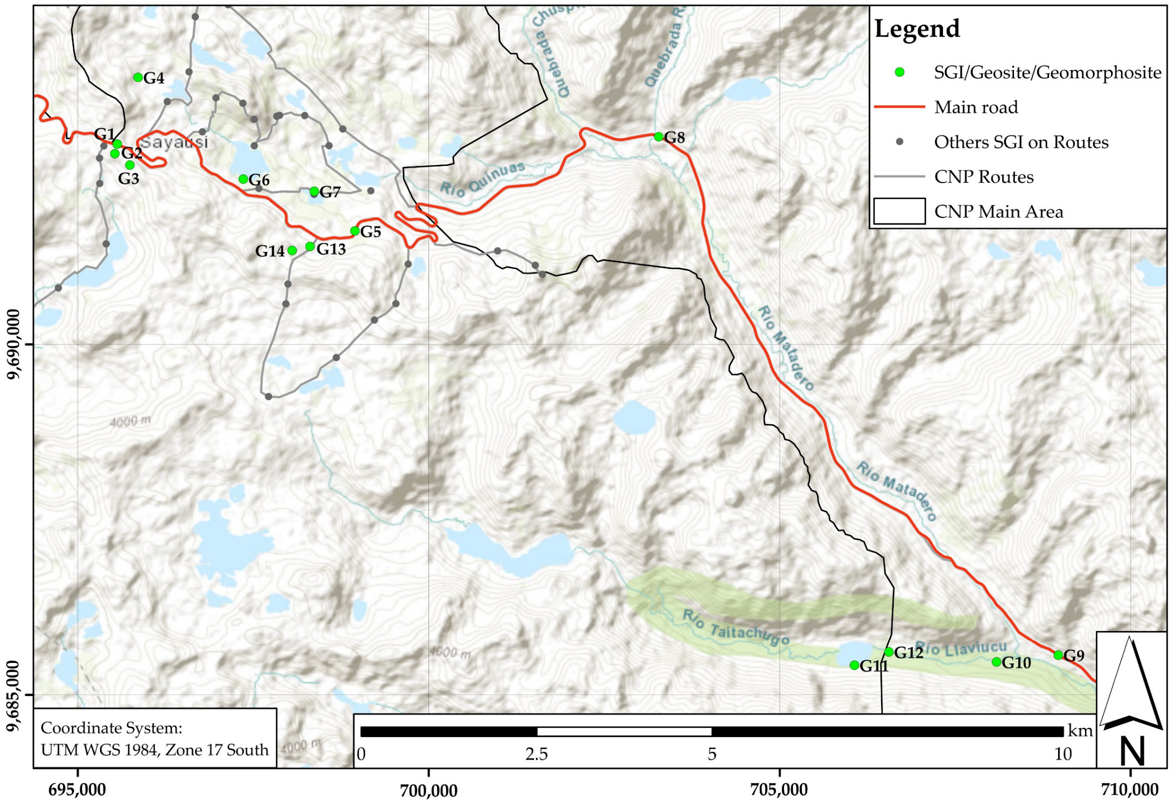

Figure 6. Geosite and geomorphosite map.

Table 7. Assessment of geosites is based on four dimensions: scientific (S), use educational potential (UEP), potential tourism use (PTU) and degradation risk (DR).

No.	Geosites	S	UEP	PTU	DR	Degradation Risk Category
G1	Tres Cruces peak	195	290	315	180	Low
G2	Larga and Negra lakes	300	330	315	215	Moderate
G3	Rocky volcanic outcrop	185	250	285	200	Moderate
G4	Volcanic flows	230	210	220	170	Low
G5	Drumlins camp	255	280	315	130	Low
G6	Toreadora lake	215	330	315	215	Moderate
G7	Miguir meteorite	315	215	240	230	Moderate
G8	Tomebamba hanged valley and glacial grooves zone	260	280	245	150	Low
G9	Llaviucu valley	320	320	285	150	Low
G10	Camp of erratic boulders/Llaviucu river	165	225	240	250	Moderate
G11	Llaviucu lake	320	315	310	210	Moderate
G12	Llaviucu end moraine	320	330	340	250	Moderate
G13	Burines peaks	210	210	255	210	Moderate
G14	Burines periglacial plains	210	220	255	135	Low

The results obtained for the degradation risk (DR) of the 14 geosites (Figure 7b) show that 57.14% of the total present values are within the "moderate" category. The remaining 42.86% falls within the "low" degradation risk category. Of the 14 geosites, the highest values of the degradation risk evaluation, with a value of 250/400, correspond to the camp of erratic boulders/Llaviucu river (G10) and Llaviucu end moraine (G12) (Table 3).

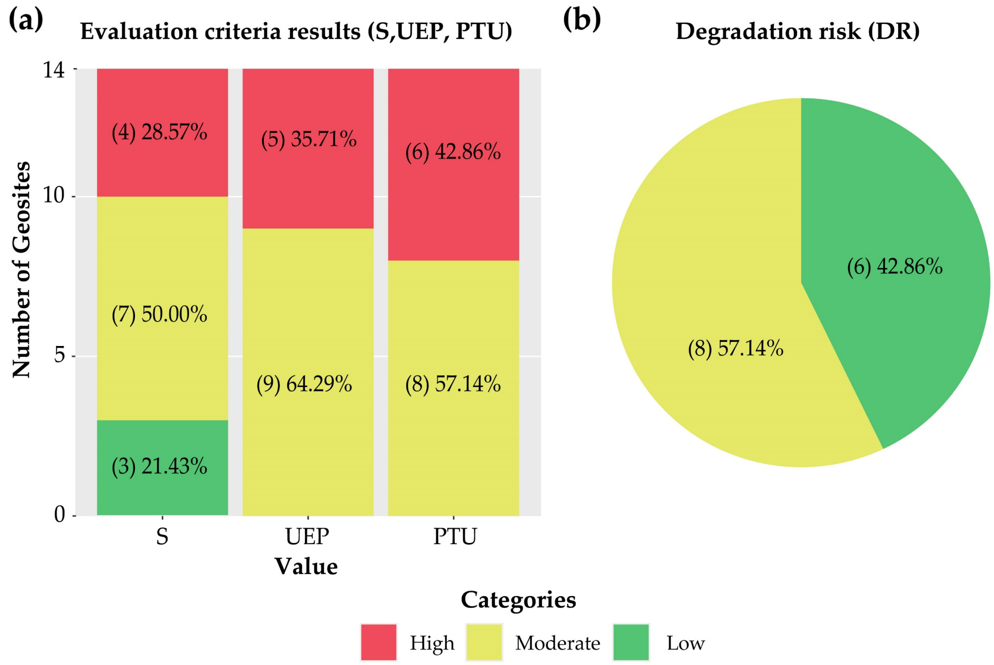

Figure 7. Assessment results according to the Brilha method: (**a**) accumulated evaluation criteria results over 14 geosites in three dimensions (S–scientific, UEP–use educational potential and PTU–potential tourism use); (**b**) degradation risk results for the 14 geosites.

3.2.2. Assessment by the IELIG Method

Table 8 presents the values obtained from the application of the IELIG method to the 14 evaluated geosites; the evaluation considered the values of the interests (S, A and T). The Llaviucu valley (310) obtained the highest average score of the indices (S, A and T), while the rocky volcanic outcrop G3 (196.67) had the lowest average score of the above indices. According to the classification suggested by García-Cortés and Carcavilla [40], in the 3 interests, the 14 evaluated geosites present values in the 2 classification categories with the highest score: "very high" and "high" (Figure 9).

On the other hand, the degree of susceptibility of the 14 geosites (Figure 8a) presented results within the categories: "high", "medium" and "low". It mostly reflected a classification within the "medium" category, with 71.43% corresponding to 10 geosites; some geosites that fall into this category are Drumlins camp G5 (19.50), Toreadora lake G6 (42.50) and Llaviucu valley viewpoint G9 (23.25). The second category with the highest proportion was "high" with 21.43%, equivalent to 3 out of 14 sites, where the rocky volcanic outcrop G3 geosite obtained the highest score (98.00). The "low" category only presents one geosite: Tres Cruces peak G1 (12.00) (Table 4), equivalent to 7.14% of all geosites.

Additionally, Table 8 shows the global protection priority (Pp) calculated for the 14 geosites. Figure 8b demonstrates that 7/14 geosites were classified within the "high" category, corresponding to 50.00% of the total evaluated. The highest value within this category was the rocky volcanic outcrop G3 geosite (23.69). Meanwhile, the remaining one constitutes 50.00% of the geosites classified within the "medium" category. Tres Cruces peak G1 (5.95) was the lowest value within this category and the total number of geosites.

3.3. Qualitative Assessment

Application of the SWOT analysis allowed us to define the park's main strengths, weak points and opportunities if geotourism is developed in the area. In addition, this study detected some natural (e.g., the risk of erosion and landslides) and anthropogenic (e.g., water and soil contamination) threats. Table 9 presents a summary of the qualitative evaluation developed.

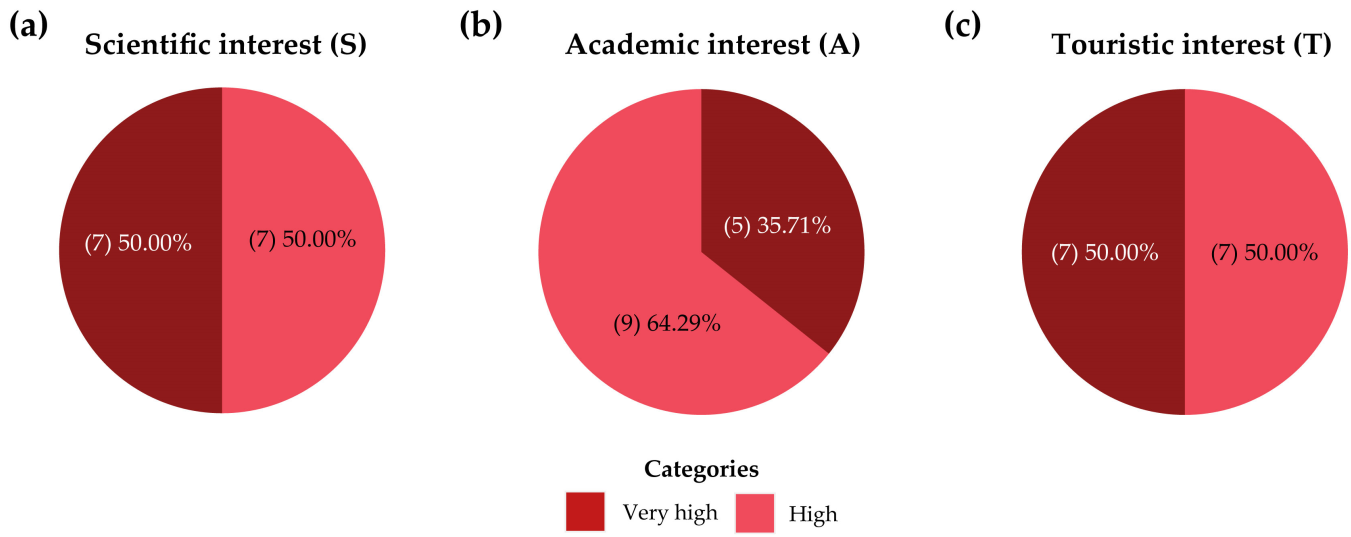

Figure 8. Assessment of degradation susceptibility (fragility and vulnerability due to anthropogenic threats) and protection priority of the geosites: (**a**) degree of susceptibility (DS); (**b**) global protection priority (Pp).

Table 8. Assessment of geosites in terms of scientific (S), academic (A), touristic (T) and average (Av.) interest, susceptibility to degradation (DS), vulnerability due to anthropic threats (Vul.), and scientific (S-Pp), academic (A-Pp), touristic (T-Pp) and global (Pp) protection priority.

No.	Geosites	S	A	T	Av.	DS	Vul	S-Pp	A-Pp	T-Pp	Pp
G1	Tres Cruces peak	235	280	330	281.67	12.00	160	4.14	5.88	8.16	5.95
G2	Larga and Negra lakes	255	240	305	266.67	27.75	185	11.28	10	16.13	12.33
G3	Rocky volcanic outcrop	190	210	190	196.67	98.00	140	22.12	27.01	22.11	23.69
G4	Volcanic flows	295	220	250	255.00	24.00	160	13.05	7.26	9.38	9.75
G5	Drumlins camp	305	255	310	290.00	19.50	130	11.34	7.92	11.71	10.25
G6	Toreadora lake	260	270	290	273.33	42.50	170	17.96	19.36	22.34	19.85
G7	Miguir meteorite	370	270	180	273.33	84.00	120	71.87	38.27	17.01	39.22
G8	Tomebamba hanged valley and glacial grooves zone	295	255	305	285.00	42.00	105	22.84	17.07	24.42	21.32
G9	Llaviucu valley	335	275	320	310.00	23.25	155	16.31	10.99	14.88	13.96
G10	Camp of erratic boulders/ Llaviucu river	235	245	300	260.00	32.50	130	11.22	12.19	18.28	13.73
G11	Llaviucu lake	335	285	265	295.00	33.75	135	23.67	17.13	14.81	18.36
G12	Llaviucu end moraine	245	225	255	241.67	70.00	140	26.26	22.15	28.45	25.56
G13	Burines peaks	180	230	260	223.33	39.00	130	7.90	12.89	16.48	12.16
G14	Burines Periglacial plains	295	225	245	255.00	42.50	85	23.12	13.45	15.94	17.27

Table 9. Strengths, weaknesses, opportunities and threats (SWOT) matrix.

Internal Environment	Strengths (S)	Weaknesses (W)
External Environment	**S_1.** A great diversity of geological elements of glacial origin. **S_2.** It has a park conservation plan based on five major programs that focus on administration and planning, control and surveillance, communication, environmental education and participation, public use and tourism and biodiversity management. **S_3.** It has a system of tourist services, marked trails and organised recreation and leisure activities. **S_4.** Infrastructure dedicated to the promotion of the natural environment of the park. **S_5.** The park has a status of protection under the national system of protected areas, and its area has two international denominations: a Ramsar site and a biosphere reserve. **S_6.** High cultural and ecological value.	**W_1.** Scarce information and promotion about the park's geoheritage. **W_2.** The trail system and other tourist facilities do not cover all sites of geological interest. **W_3.** Absence of plans dedicated to geoconservation. **W_4.** Sometimes the base information of the park may be outdated. **W_5.** There is little interaction on social media. **W_6.** Absence of scientific–informative studies and publications on the geological characterisation of the park. **W_7.** Extensive pine plantations hinder the scenic value of the sites. **W_8.** Limited community participation. **W_9.** Lack of interaction, protocol and communication on the logistics processes for the geoscientific research of the park.
Opportunities (O)	**Strategies: S + O**	**Strategies: W + O**
O_1. Creation of geotourism itineraries. **O_2.** Generation of geoproducts and activities related to the park's geoheritage for local development. **O_3.** Development of awareness of the value of geoheritage in conjunction with biodiversity values in local communities and tourists. **O_4.** Increase in the tourist value of the park.	**S_1. O_1. O_2.** Develop a geotourism approach related to glacial environments that promotes education and research. **S_1. O_1. O_3.** Establish a national and international technical–scientific cooperation network for the sustainable development of the park. **S_3. O_1. O_2.** Articulate tourist routes and other services offered by the park with geological characteristics, highlighting the value of the geological heritage.	**W_4.O_3.** Update the general information exhibited in the park's tourist infrastructure and develop and install interpretive panels of the geological–geomorphological processes of the place. **W_6.O_4.** Promote geoscientific research on geoheritage issues to add more sites of geological interest to the list of geosites–geomorphosites proposed in this study. **W_6.O_1.** Design an inventory and characterisation protocol for geosites compatible with the natural heritage inventory process. **W_7.O_1. O_4.** Generate a management plan to prohibit the advance of pine plantations that hinder the landscape value of geosites.
Threats (T)	**Strategies: S + T**	**Strategies: W + T**
T_1. Greater park promotion will increase the influx of tourists and hurt geosites and the environment. **T_2.** Alteration in certain park areas due to human activities (e.g., cattle, agriculture, mining and wildfires). **T_3.** Natural threats due to erosion and landslides.	**S_2.T_2.** Establish awareness campaigns on the conservation of geoheritage for the local community and seminars on this subject in the current interpretation centres.	**W_3.T_1. T_3.** Generate and implement a comprehensive geoconservation plan for the natural park. **W_5.T_1.** Design virtual guides on GIS [1]-based websites compatible with mobile applications that facilitate geological–geomorphological interpretation and education on geosite conservation measures.

[1] GIS: geographical information system.

Based on the SWOT analysis (Table 9), five lines of action are proposed, which focus on the characterisation, protection, promotion and monitoring of the evaluated geosites–geomorphosites.

1. Design an inventory and characterisation protocol for the park's geosites, articulated with current natural heritage inventory programs (flora and fauna), that integrates all the stakeholders dedicated to the conservation of CNP;
2. Creation and installation of geological and geomorphological interpretive panels. These panels must combine a real photograph of the geosites–geomorphosites with graphic schemes illustrating the geological process of interest. A good practice is the implementation of the ABC (abiotic, biotic and cultural) interpretive concept [88] in the CNP panel system;

3. Development of panoramic view areas, signage, information panels and safety means (e.g., installation of safety railings) at specific points where geomorphosites can be better observed and continue with the construction of trails and other facilities for tourism in some geosites (e.g., Miguir meteorite);
4. Propose pilot projects for the development of geotourism that integrate the values of cultural and natural interest present in the current tourist trails of the park with the geological value of the sites characterised in this study;
5. Include geotourism guides and descriptions of the geological value in the information brochures and other informative material promoting geoheritage and geomorphological heritage education.

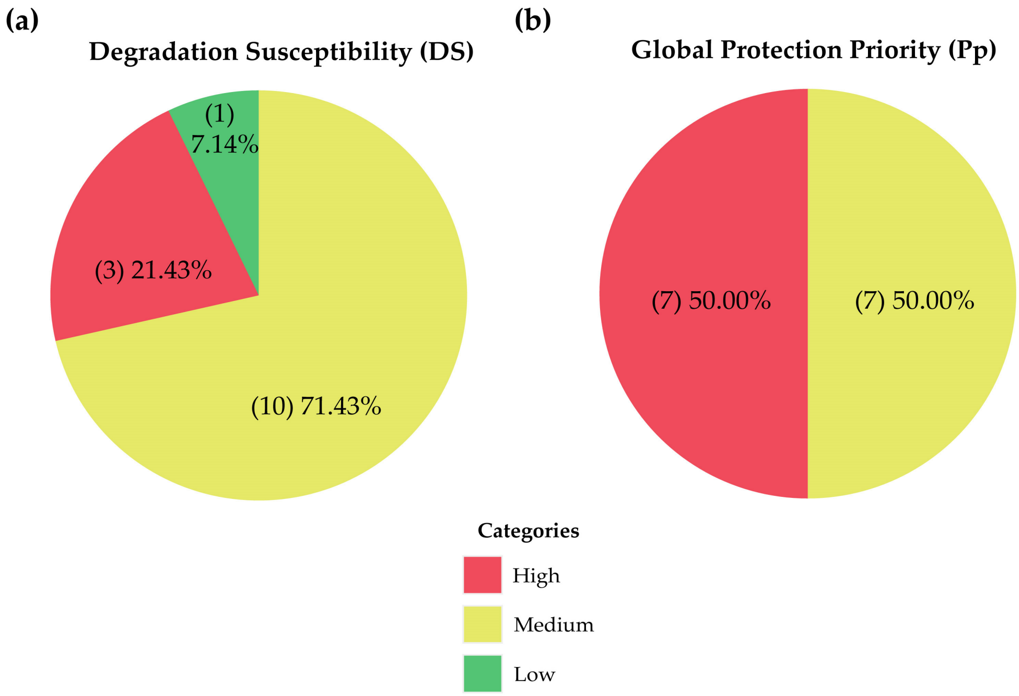

Figure 9. Classification of interests of the geosites: (**a**) scientific, (**b**) academic and (**c**) touristic.

4. Discussion

Cajas National Park has elements of geoheritage where the glacial and periglacial landscapes and landforms stand out, evidencing the glaciation and deglaciation processes that occurred during the Pleistocene. These events have left clear signs of their occurrence, represented by the sites of geological importance suggested in this study (Table 6). Depending on the type of main geological interest, the glacial interest constitutes a considerable part of the total. Additionally, the 14 evaluated sites of geological importance (Tables 7 and 8) present in both methods have predominantly scientific values, with categories mainly varying from "moderate" to "high" (Figures 7 and 9).

The results of the assessment of geological interest sites of CNP indicate that the high scientific/educational value comes from sites where a high aesthetic value is concentrated, resulting from the modelling of more than one geological–geomorphological process (e.g., Llaviucu valley). This opens up the possibility of analysing other types of studies (e.g., hydrological, climatological and biodiversity). One example is the lakes, which constitute an essential cover letter to disseminate the scientific content of the area to people of any educational level.

The tourism component reflected significant qualities for its use in recreational activities due to sports activities (e.g., hiking and recreational fishing) and cultural activities (e.g., birdwatching and religious ceremonies). There is a clear influence of sites with high landscape value over those with high scientific/educational value (e.g., volcanic flows), due to their limited promotional facilities and tourist infrastructure.

The degradation risk parameter is a key factor in evaluating geoheritage due to its influence on the level of use to develop geotourism activities and geoconservation strategies [8,89–91]. Both methods (Brilha [32] and IELIG [40]) assess similar parameters (e.g., legal status and proximity to degrading activities). However, IELIG [40] provides more detail on the indicators/sub-indicators, classifying them into fragility (natural conditions) and vulnerability due to anthropic threats.

The study area has many lakes that have historically been influenced by disturbances of the natural state of soil and water [92,93] and by the effects of climate change, which reduce the extension of water bodies within the park [75].

The assessments show that most geosites have medium levels of risk (Figures 7b and 8). This is because many geosites, such as the lakes, have a monitoring system, which is a product of the conservation plan that CNP has, and there are studies of natural threats that have led to the identification and execution of certain prevention actions by natural agents (e.g., erosion and floods).

In general, sites of geological interest, due to their characteristics, provide an opportunity to raise awareness about climate change for tourists and surrounding communities. For example, U-shaped valleys, hanging valleys, eroded relief forms, large lakes and other landforms of glacial origin are witnesses to the fluctuations of the masses of glaciers influenced by Quaternary climate change modelled in this region. Moreover, climate change constitutes one of the key aspects of the role of geology in the sustainable development goals (SDGs) [94].

Within the country, some of the few evaluations of geosites with glacial origin are those carried out in the Chimborazo Province [95] and Ruta Escondida (Quito) [96,97]. These studies presented significant values for promotion and sustainable management. Similarly to CNP, they are located within protected areas with many tourist services, thereby increasing administration opportunities under an emerging geotourism approach. At an international level, the experiences of geosite evaluations of glacial origin show that, as a whole, they present values of geological interest in the highest categories of the classification [98,99]. The geosites with the highest scores are located where aesthetic values are complemented by other topics of importance to the user (e.g., accessibility) and a level of educational and tourist use [98]. Similarly, the sites with the highest scores in both methods in this study (e.g., Llaviucu valley and Toreadora lake) are those where the administration uses greater outreach resources and tourist facilities.

Regarding the methodology applied, the first step was the selection of sites of initial geological interest recommended by several authors [40,100–102]. In this case, that meant applying the Delphi method [79,80] with the information collected in the first phase. This step is crucial to understanding the geological and geomorphological context. After this stage, the selected sites are assessed by the semi-quantitative methods of Brilha [32] and IELIG [40]; both methods integrally evaluate the geosites in the different sections that compose them. The IELIG method [40] provides the protection priority value, which is essential for establishing improvement strategies. Additionally, the chosen methods have parameters that include the types of interest of CNP and have the aesthetic value within the evaluation, which is an important factor in geomorphosites [103].

In the Brilha method, the aesthetic value is indirectly in the educational potential and potential touristic use (scenery in Table 1) [32], as the beauty of the site and its frequency of use in national and local campaigns. On the other hand, the IELIG method [40] (beauty in Table 3) assessed beauty in terms of the coincidence of three characteristics: (i) relief amplitude, (ii) mighty river courses/large sheets of water (or ice), and (iii) remarkable chromatic variety. In the first case, the indicators focus on attractiveness to be visited. The second case is on the visual quality of its features. Reynard et al. [100] highlight the subjectivity of the aesthetic value and the difficulty of measurement; it is clear that this is a limitation of the evaluations since it depends on visual perception. However, the use of both methods is adequate for the present study.

Given the difficulty of making direct comparisons between the values of geosites characterised by different methodologies [104], some studies have approached a comparative description of the values obtained with different methods. In general, for an adequate comparison, quantitative assessment values are transformed into percentages (e.g., in the IELIG and Brilha methods, 400 to 0 into 100% to 0%) in the first phase [104]. Furthermore, according to Berrezueta et al. [54], using geosites that have been assessed by more than one method allows us to calculate a factor that relates the IELIG method to the Brilha method (e.g., the Brilha to IELIG factor is 0.82 in geosites from Ecuador). In an attempt to unify the process of characterisation and assessment of sites of geological interest in Ibero-American countries, in 2018 the Association of Geological Services of Ibero-America (ASGMI in Spanish) presented [105] an action protocol based on the IELIG method [40]. As complement to this method, the Brilha method [32] was also used.

This study shows a general trend in the application of the two geosite evaluation methods. Geosites (e.g., Miguir meteorite (G7), Llaviucu valley (G9) and Llaviucu lake (G11)) are among the top 5 best scored in both methods for their scientific value (Tables 7 and 8). However, the difference lies in the sub-indicators of each method and the ranges established for their classification, as can be seen in the graphs of the global evaluations of the 14 sites in the 3 dimensions for both the Brilha method (Figure 7, whose categories range from "low", "moderate" to "high") and the IELIG method (Figure 9, which is dominated by the "high" and "very high" categories).

The SWOT analysis results recommend a protocol for the inventory and characterisation of geological and geomorphological heritage, even though CNP has national [50] and international recognition for its biotic resources [51,52]. The abiotic part of CNP requires greater visibility. This study evidences the lack of a holistic approach that integrates the abiotic, biotic and cultural domains of the natural heritage of CNP. Therefore, it is essential to encourage geoscientific research and promote geoeducation in the interpretive panels and other tourist services offered by the park. Implementing the ABC interpretive concept is an example of one approach used in geoparks (e.g., Colca and Volcanoes Andagua and Muroto geoparks) [88].

Geomorphosites are natural tourist resources with interesting economic benefits, especially in protected areas such as national parks and natural monuments [106]. Natural parks have geological characteristics relevant to the development of geotourism and geoeducation, and present opportunities for the protection of geological elements (e.g., Fforest Fawr Geopark [11] and Cilento Vallo di Diano Geopark [12]). It is important to highlight the identity of natural parks with cultural and natural aspects [11]. Articulating the abiotic axis through geotourism will complement its protection and promote sustainable development in addition to the opening of research projects, marketing, events, workshops and scientific publications.

Finally, the geosites and geomorphosites evaluated in this research make an initial contribution to the knowledge of the geological heritage of natural parks. The geoheritage examples from this investigation illustrate the unique geological features that marked the area's geological history. However, more geoheritage characterisation studies and geoheritage value information within the CNP conservation plan are needed. It is also important to highlight that the inventory and characterisation of the geomorphosites which have been carried out represent a basis for the proposal of other initiatives. For example, the creation of a UNESCO geopark [107] or the presentation of specific geological itineraries. In this study, since there were official protection figures such as national parks in the study area, the contributions have been framed within this official figure and are intended to be an example extended to other areas with existing protection figures.

5. Conclusions

The present investigation reveals the singularity of glacial and periglacial landscapes and landforms that tell the geological and geomorphological history of the ate Pleistocene of the region. This study evaluated 14 geologically significant sites using 2 international geosite evaluation methods. Four types of main geological interest were identified: (i) geomorphological, (ii) glacial, (iii) lithological and (iv) periglacial. Geosites represented scientific and educational value with exceptional aesthetic value (e.g., Llaviucu valley) and their educational value to illustrate the evolution of geological processes in CNP. In addition, the area has high geodiversity and geoheritage, as well as connections with the biotic and cultural dimensions recognised internationally.

Threats against site degradation reflect the "medium" degree of vulnerability against natural and anthropogenic events (e.g., landslides, agricultural and cattle activities). Additionally, the degree of priority of the sites was evidenced, reaching significant scores concerning the total and illustrating the priority that geosites and the CNP environment should have to protect their geoheritage.

The SWOT analysis results identified the main strengths (e.g., the existence of a system of tourist services that includes a large part of the places of geological interest) and weaknesses (e.g., the absence of studies and scientific–informative publications of geological characterisation). This qualitative analysis allowed us to establish five strategies focused on: (i) the design of an inventory protocol and characterisation of geoheritage; (ii) the establishment of interpretive panels using the ABC interpretive concept; (iii) continuing with the construction of trails and other facilities for tourists; (iv) generating pilot projects for the development of geotourism that integrate abiotic, biotic and cultural dimensions; (v) creating geological guides and including the value of the geoheritage and geomorphological heritage of the park in the informative material.

Finally, this work strengthens geological heritage, biodiversity and cultural benefits that the natural park houses, and shows us the need for more exhaustive investigations on the subject of glaciation for its application in geoheritage.

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