Landscape Research

ISSN: 0142-6397 (Print) 1469-9710 (Online) Journal homepage: www.tandfonline.com/journals/clar20

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To cite this article: António Almeida, Irene Prieto & Beatriz García Fernández (15 May 2025): Biodiversity vs. geodiversity in landscape appreciation: what do Portuguese and Spanish pre-service teachers value?, Landscape Research, DOI: 10.1080/01426397.2025.2505022

To link to this article: https://doi.org/10.1080/01426397.2025.2505022

LANDSCAPE RESEARCH
https://doi.org/10.1080/01426397.2025.2505022

Biodiversity vs. geodiversity in landscape appreciation: what do Portuguese and Spanish pre-service teachers value?

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ABSTRACT

This study aimed to identify, via questionnaire, the landscape preferences of 336 pre-service teachers—219 from a metropolitan area in Portugal and 117 from a rural area in Spain. Eight natural landscapes were assessed, each characterised by geodiversity, biodiversity, and cultural features. Overall, Portuguese students showed stronger preferences, possibly due to Spanish students' familiarity with natural surroundings. Landscapes featuring geodiversity with water bodies (such as cascades and caldera lakes) were most favoured, while biodiversity-rich landscapes were preferred over those with only geodiversity. Both groups expressed a stronger commitment to landscape preservation than to their preferences, showing a moderate to weak correlation between these factors. Animals significantly attracted interest, and when various natural elements were present, geodiversity features tended to be less noticed. Positive emotions were generally associated with the landscapes, though some geological features and educational values were underappreciated. Suggestions for integrating these insights into teacher training are included.

ARTICLE HISTORY
Received 24 November 2024
Accepted 14 April 2025

KEYWORDS
Geodiversity; biodiversity; landscape appreciation; landscape preservation; pre-service teachers

Introduction

Concerns about the health of planet Earth have been growing due to the persistent environmental impacts of human activities. Climate change is a prominent example, with wide-ranging consequences for both biodiversity and geodiversity. Nevertheless, biodiversity loss tends to receive more attention, even though habitat destruction and alteration, land fragmentation, pollution, resource overexploitation, and human encroachment into natural areas have caused deep transformations across all components of landscapes.

According to Sarkar (2002), the term biodiversity emerged in the mid-1980s and gained prominence with the publication of a book edited by Edward Wilson in 1988. This influential book, which features articles from various authors, presents biodiversity as inherently linked to the urgent need for its preservation (Wilson & Peter, 1988).

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Supplemental data for this article can be accessed online at https://doi.org/10.1080/01426397.2025.2505022.

The term biodiversity may have emerged relatively late, as global concern for life on Earth was already evident in earlier decades. Almeida (2020) points to several international conservation initiatives as evidence of this early commitment, including the Ramsar Convention on Wetlands (1971), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (1973), and the Convention on the Conservation of Migratory Species of Wild Animals (1973).

The concept of biodiversity is more complex than the prefix "bio" might imply. In addition to species diversity, it encompasses genetic diversity within species, as well as ecosystemic and functional diversity, associated with flows of matter and energy necessary for the survival of biotic communities (Miller & Spoolman, 2019). This inclusion of ecosystemic and functional dimensions suggests that the non-living components of ecosystems would also be a focus of preservation efforts. However, it seems undeniable that these efforts have primarily concentrated on the biotic aspects of ecosystems, with "nature's diversity" typically understood as diversity of the living world (Milton, 2002).

Emerging from the need to highlight the significance of the non-living components of ecosystems, the concept of geodiversity was introduced in the 1990s. Gray (2004) defines geodiversity as the variety of Earth's physical materials (such as rocks, soils, and water), landscapes (such as mountains, glaciers, and lakes), and dynamic processes (including erosion, soil formation, and the transport of rocks and sediments). Years earlier, Stanley (2004) offered a similar definition, emphasising not only the diversity of Earth's materials but also the interconnections between geodiversity, people, landscapes, and cultural heritage.

It is irrefutable that geodynamic agents, both endogenous and exogenous, exert constructive and destructive influences on geodiversity. Although these non-living entities lack individuality and organic integrity, many possess distinctive characteristics such as symmetry, harmony, grace, and spatiotemporal unity, which are manifestations of the creative dynamics of nature (Rolston III, 1994). Consequently, these features are highlighted in favour of the non-living world, an endeavour that inextricably links geodiversity with geoconservation.

This defence is driven not by the inherent dynamics of ecosystems but by anthropogenic threats. While renewable abiotic resources, such as water, may be replenished, and landscapes can potentially recover from quarrying, numerous examples exist of irreversible damage caused by extractive industries, agriculture, urbanisation, and recreational activities. Furthermore, natural processes, including river regimes and sediment cycles, can be significantly altered or disrupted. Indirectly, geodiversity is also threatened by chemical pollution, climate change, and sea-level rise (Hjort et al., 2015).

However, concern for geoconservation is not recent, as the late emergence of the concept of geodiversity might suggest. According to Gray (2004), examples of geoconservation can be traced back to the 19th century, such as the establishment of the first geological reserve in Siebengebirge, Germany, in 1836, the creation of Yellowstone Park in the USA in 1872, and the protection of geosites in Scotland towards the end of that century. Nevertheless, it is Gray himself who asserts that geoconservation is less developed than biodiversity conservation in most countries.

What, then, justifies the lesser attention given to geodiversity and, consequently, to geoconservation?

Several explanatory reasons can be mentioned. Wilson (1984, 1993) proposed that humans possess a genetic predisposition, reinforced by cultural dimensions, to affiliate with life and life-like forms, which he termed "biophilia," and which developed over the course of human evolutionary history, shaped by millennia of interaction with the natural world. In developing the foundation of this hypothesis, the relational dimension of human beings with the non-living world is not clearly addressed, as Wilson focuses on the advantages and dangers associated with contact with biotic nature during evolution (biophilia and biophobia).

Furthermore, within the fields of educational research and evolutionary psychology, studies specifically examining interest and enjoyment in geodiversity, relative to other aspects of nature, remain scarce. Examples of this lack of concern are the lines of research that highlight the tendency of human beings to ignore plants (plant blindness) or those that seek to identify human preferences for certain types of landscapes, lines about which it is important to analyse their assumptions.

According to Wandersee and Schussler (1999), plant blindness has a biological basis, as plants become visually difficult to distinguish when not in bloom, forming a uniform chromatic whole, given that they often grow together. Consequently, this lack of human perception translates into: i) considering plants the setting where animals live; ii) inability to notice plants in the environment and what they need to flourish; iii) failing to differentiate plant and animal scales of activity; iv) devaluation of plants compared to animals; v) inability to recognise the ecosystemic importance of plants, including in the carbon cycle; vi) failure to notice plants in everyday life, being insensitive to their aesthetic qualities.

Some reasons have been pointed out to justify this situation: humans are morphologically, physiologically and behaviourally related to animals (Beck, 2014); plants are non-moving beings, at least not like animals, what helps to not notice them (Amprazis & Papadopoulou, 2020) and plants are disregarded in formal education, e.g., in classes, textbooks and curricula of different countries (Hershey, 1996; Link-Perez et al., 2010; Amprazis & Papadopoulou, 2018). Other studies are focused on the preference for animals or in the greater ability to learn about them (Kose, 2011; Schussler & Olzak, 2008; Wandersee, 1986).

However, more recently, Knapp (2019) argued that the problem is not between human attention for animals versus plants, but between animals like humans versus everything else, remembering that 99% of life on earth is invertebrate. With this statement she is not exactly proposing that this disregard can be extended to non-living world, but this extension seems to be perfectly plausible.

According to Brilha et al. (2018), "fewer people understand that our planet is also physically diverse, and that this non-living abiotic nature or geodiversity is rarely appreciated by the public yet without which our modern society could not exist" (p. 99). A similar idea had already been proposed by other authors, highlighting the neglect of the abiotic dimension of ecosystems compared to the biotic dimension (Dunson & Travis, 1991; Schowalter, 2006).

It is within this context of devaluation of geodiversity that Roemmele (2017) introduces the concept of geological blindness, characterised by: i) an inability to recognise rocks, landscapes, and geological structures; ii) aesthetic indifference towards the geological world; iii) a failure to recognise the reciprocal impacts between humans and the geological world; iv) a lack of firsthand experience with the geological dimension of nature. Grosz et al. (2017) further argue that humans have been blind to the geological order, which is, nevertheless, the most essential condition for all life forms.

The other line of research focused on the preference of landscapes has also given little visibility to the geological dimension present in them, or delved into the abiotic characteristics that can affect their preference. One of the conceptual frameworks that supports this line is based on the biophilia hypothesis presented earlier. Ulrich (1993) proposed a functionalist – evolutionary approach that considers that there is a genetic predisposition that helps to explain the positive or negative response to different landscapes. From the analysis of studies carried out in Europe, North America and Asia, it appears that natural landscapes are preferred over urban ones, being included in natural rural landscapes and others shaped by humans. In the range of natural landscapes, open ones, with little vegetation and available water tend to generate greater preference; dense forests are depreciated for causing unrest and insecurity, given the possibility of sudden attacks by dangerous animals and difficulty in escaping. In this scenario, vegetation is perceived as a whole, whose greater or lesser density translates into the perception of less or greater control of human beings in relation to the space in which they are located. Water, a component of geodiversity, has been the only abiotic element that has been highlighted in this preferential analysis of landscapes. Landscapes with water are attractive because they provoke pleasure and calm (Ulrich, 1986). More recent studies confirm that natural landscapes generate more intense emotions (Bethelmy

& Corraliza, 2019) and visually open landscapes receive greater appreciation from tourists (Kirillova et al., 2014).

It is important to note that the explanations given for the manifestation of biophilia or for preferences for certain landscapes based on a genetic predisposition should not be viewed in a deterministic manner. As Belardinelli and Pievani (2024) highlight, the possibility of any theory centred on a genetic, cross-cultural basis is difficult to prove. And if verified, it raises the question of the weight it might carry. Also, Joye and De Block (2011) consider that culturally shaped environments and social interactions had a much greater impact than any genetic predisposition. Therefore, Silva et al. (2017) argue that people's perceptions of the environment always involve a combination of cultural, social, and biological factors, which has garnered broad consensus among most researchers.

However, if geological blindness and a lower affiliation with geological landscapes are indeed present, this could lead to lower public support for the preservation of environments with geodiversity—an undervaluation that warrants close attention. Not only does inanimate nature provide landscapes that offer aesthetic and sensory experiences, but it also plays a crucial role in biodiversity and human health (Alahuhta et al., 2022). Furthermore, even if there is a tendency to undervalue the geological aspects of nature, this does not mean that such perceptions cannot be changed. As Rolston (1995) points out, we need only to consider what our grandfathers thought about mountains, which we now see as so scenic.

The present study

This study aimed to investigate whether geological blindness and a lower appreciation for landscapes rich in geodiversity are present among pre-service teachers, with the findings potentially informing adjustments in the design of their training courses. Thus, this study has the following aims:

1. To identify students' preferences for a range of landscapes differing in terms of geodiversity, biodiversity, and cultural elements.
2. To analyse the students' explanations to determine which landscape elements are highlighted and which are overlooked.
3. To assess the perceived need for landscape preservation in cases of potential destruction and examine whether preference and preservation are correlated.
4. To examine differences between students from two countries (Portugal and Spain), considering their distinct cultural backgrounds and geographic origins.
5. To discuss the implications of the results for addressing geodiversity in formal learning contexts.

Methods

The study has an exploratory character, given that there are few investigations that focus on the preference for geodiversity landscapes and the reasons that justify this preference. The study has a predominantly quantitative approach, with recourse to complementary data of a qualitative nature.

Participants

The study involved 336 pre-service teachers from two higher education institutions, one Portuguese ($n1 = 219$, 201 female) and one Spanish ($n2 = 117$, 106 female), who are pre-service teachers for primary education. The overall mean age was 22.3 (SD = 5.087), with the Portuguese group having a mean age of 23.3 (SD = 5.96) and the Spanish group 20.6 (SD = 1.819). The Portuguese institution is located in a large urban area, and the majority of students reside in it. The Spanish institution, on the other hand, is in a small urban area, and the students mainly come from rural areas nearby. The students were predominantly female, a common situation in teacher training courses in both countries, especially those preparing for the early years of schooling.

The non-higher education curricula in both countries include content from various sciences, including Biology and Geology, from primary education to secondary. At the higher school level, both institutions offer limited coverage of Geology. This happens because teacher training courses are designed to provide a wide range of disciplinary areas. As a result, in-depth exploration is not possible due to curricular limitations.

Procedure

Considering the study's aims, a questionnaire was designed with two parts. The first part requested sociodemographic data from the participants: age, sex, course, and institution; the second part presented eight photographs with dissimilar focuses in terms of biodiversity, geodiversity, and human elements. The features of each photo are presented in Table 1, and they are included in the Appendix 1.

The selection of photos included a few with dominant geodiversity and others with dominant biodiversity, while others associate both dimensions and even include cultural elements. In this way, it was considered possible to verify the participants' appreciation for strictly geological landscapes in comparison with others dominated by biodiversity and to verify the most prominent elements highlighted in each landscape.

Alongside each landscape photo, participants were asked the following questions: 1-Based on your personal preference, please rate this landscape on a scale of 1 to 5, where 1 means "I

Table 1. Characteristics of the eight landscapes included in the questionnaire, with dissimilar relevance in terms of biodiversity, geodiversity and human elements.

Landscapes - General features	Elements included	Other features
Landscape 1. Forest (Plant biodiversity)	-Presence of tree and herbaceous layers.	-Proximity image -Medium plant density -Narrow pedestrian trail -Mossy rocks not directly observable
Landscape 2. Caldera (Dominant geodiversity)	-Traces of the volcanic apparatus -Different colour lagoons -Forest spots	-Open landscape -Human structures visible but hardly perceptible
Landscape 3. Forest with animals (Animal and plant biodiversity)	-Mammals of two different species (dear and boar) -Trees clearly visible	-Proximity image -Medium plant density -Unnoticeable road
Landscape 4. Unconformity (Dominant geodiversity)	-Folds and strata in cliffs	-Proximity image -Visualization of the geological structures without perception of the base level -Residual plant biodiversity
Landscape 5. Sheperd on the mountains (Plant biodiversity, geodiversity and cultural elements)	-Presence of cattle and a shepherd in a forest area -Rock outcrops clearly visible	-Proximity image -Medium plant density -Foggy atmosphere
Landscape 6. Glacial valley (Dominant geodiversity)	-U valley morphology -Rock outcrops in the valley	-Open landscape -Presence of plants in an undifferentiated spot in the distance -Human structures visible but hardly perceptible
Landscape 7. Waterfall on rocks (Dominant geodiversity)	-Waterfall in valley involved by rocks	-Proximity image -Plant biodiversity practically absent
Landscape 8. Volcano (Dominant geodiversity)	-Volcanic cone with clearly visible rock	-Proximity image -Absence of other elements

don't like it" and 5 means "I really like it" (Likert scale); 2-Please explain the reason for your rating; 3-If this landscape were at risk of destruction, how necessary would you consider developing a preservation program? Use a Likert scale where 1 means "not at all necessary" and 5 means "very necessary".

The administration was conducted by a researcher from each country, and the questionnaire had two equivalent versions, one in Portuguese and the other in Spanish. No difficulties in understanding the questionnaire were detected during its administration.

Validation

The questionnaire was validated by two experts in Science Education, one from each participating country, using an analysis grid. This grid included the study objectives, followed by the photos and questions, with a request for feedback on their relevance. One of the experts suggested reducing the number of photos which initially numbered ten, especially those with biodiversity; no additional critical issues were identified. The questionnaire was then tested with 5 students from each country, who were not included in the final sample. No comprehension difficulties were detected, and it was possible to determine the average administration time, which was approximately 20 minutes. The answers given to the justifications for the preference of landscapes were analysed separately by the three members of the research team who prepared a proposal for categorising them. As a team, a unified categorisation proposal was discussed and the responses to be included in each category were analysed. Thus, discrepancies were overcome as a result of this discussion.

Analysis of results

The participants' preferences for each landscape, as well as the perceived need for preservation, were analysed using descriptive and inferential statistics. For each landscape, the median, mean, and standard deviation were calculated for the overall sample and for each country-specific subsample. Although the Likert scale reflects a qualitative dimension of taste and need for preservation, it was considered that it allowed establishing an order from 1 to 5, which justified the calculation of the mean and standard deviation, in addition to the median value.

To check possible statistically significant differences between the landscape preferences expressed by participants from both countries, as well as the desire to preserve them, the Mann-Whitney U test was used for a significance value of $p < 0.05$. To verify a correlation between the preference for a landscape and the desire to preserve it, the Spearman rank correlation coefficient (rs) was calculated for the total sample and subsamples of each country. The option for this test arises from the fact that it can be applied to ordinal scales and the scale adopted to analyse the strength of the correlation was the following; 0.00 to 0.19, very weak; 0.20 to 0.39, weak; 0.40 to 0.69 moderate; 0.70 to 0.89, strong; 0.90 to 1.00, very strong (Gaciu, 2021).

The justifications for landscape preferences were subject to content analysis, with responses broken down into reasons expressing different ideas. Identical ideas, even if phrased differently, were counted as similar and assigned in the same label. It is important to note that the responses often included multiple reasons, with each reason placed into the most appropriate category. Consequently, the number of recorded reasons significantly exceeds the number of participants.

For each subsample, the absolute and relative frequency of each reason and category was calculated. However, for comparative purposes, relative frequencies were used due to the unequal sizes of the subsamples.

The reasons associated with each category were classified as positive (+) or negative (–) whenever opposing ideas were identified. For instance, in the 'biodiversity' category, some participants emphasised the type of ecosystem present (e.g., a forest or the entire environment depicted), whereas others expressed a dislike for that type. Similarly, in the 'emotions' category, some participants noted that a particular landscape conveyed tranquillity, while others felt it evoked a sense of danger. To facilitate the analysis and discussion of justifications, the landscape categories were grouped into intrinsic factors, those inherent to the landscapes and linked to natural conditions, and extrinsic factors, which are typically human-induced.

Ethical principles

A questionnaire in a digital form was administered to pre-service teachers and included information about the main aims of the study in a concise way, not to influence the answers of the respondents. The importance of the study for education was also expressed, since the results could be important to better assess the relevance of different landscapes, both for higher and non-higher education. The pre-service teachers were informed that participation in the study was completely voluntary and that they could decide not to participate or withdraw their participation at any time without explanation. The anonymity of the responses was guaranteed and none of the respondents' emails were associated when the questionnaire was submitted.

Normally, pre-service teachers of both countries understand the importance of educational studies, since they also must design and implement an educational study, a mandatory condition for the conclusion of their master's degree, which explains their high participation.

Results

The results from the statistical analysis carried out are systematised in Table 2. Globally, landscapes received high appreciation from all respondents, which seems to confirm a general preference for natural landscapes. Even so, two landscapes with geodiversity received the greatest preference, landscape 2-caldera and landscape 7-waterfall on rocks, both with a median score of 5. These landscapes share a common element: the presence of water, which proved to be significant in this evaluation. It is also noteworthy that these landscapes are distinct in terms of openness, as the first provides a panoramic view, while the second allows only the observation of the rock formations on both sides of the waterfall, with biodiversity barely perceptible. The two landscapes with dominant biodiversity—landscape 1, forest and landscape 3, forest with animals—received a higher appreciation than all landscapes with geodiversity.

Still, for the global sample, landscape 4-unconformity was the least appreciated, with a median value of 3. It is a landscape with two groups of strata with a hiatus in the geological record between them, almost entirely composed of rock with a grey tonality. The results for the two subsamples generally follow the same trends, especially in the case of the Portuguese pre-service teachers. The Spanish pre-service teachers, however, expressed a lower preference for all landscapes, which resulted in statistically significant differences between groups for the following landscapes: landscape 2-caldera, landscape 3-forest with animals, landscape 5-shepherd on the mountains, landscape 6-glacial valley; and landscape 7-waterfall on rocks. It should be noted that the statistically significant differences occurred both in landscapes with dominant geodiversity or biodiversity.

In terms of the need for preservation of the landscapes presented, the values obtained were even higher in most cases, both for the global sample and for the subsamples. For the global sample, only landscape 4-unconformity received a median value of 4. Among the Portuguese pre-service teachers, the results followed a similar trend to the global sample; however, among Spanish pre-service teachers, landscape 6-glacial valley and landscape 8-volcano also received a median value of 4. Nevertheless, due to the previously mentioned differences in the results

Table 2. Preferences of pre-service teachers for eight landscapes and their expressed need for preservation (Likert scale 1-5).

	Preference							Preservation							(Correlation) r_s of Spearman		
	Total Median	Total Mean	P Median	P Mean	Sp Median	Sp Mean	*Mann-Whitney p.*	Total Median	Total Mean	P Median	P Mean	Sp Median	Sp Mean	*Mann-Whitney p.*	Total	P	Sp
Landscape 1: Forest	4	4.28	4	4.31	4	4.23	0.325	5	4.71	5	4.75	5	4.64	0.030	0.313	0.265	0.383
Landscape 2: Caldera	5	4.56	5	4.73	4	4.26	<0.001	5	4.80	5	4.86	5	4.69	0.001	0.343	0.258	0.363
Landscape 3: Forest with animals	4	4.02	4	4.16	4	3.74	<0.001	5	4.72	5	4.76	5	4.64	0.024	0.377	0.370	0.367
Landscape 4: Unconformity	3	3.09	3	3.12	3	3.03	0.424	4	3.91	4	4.03	4	3.69	0.002	0.451	0.439	0.479
Landscape 5: Sheperd on the mountains	4	3.81	4	3.88	4	3.69	0.044	5	4.49	5	4.54	5	4.39	0.009	0.481	0.500	0.416
Landscape 6: Glacial valley	4	3.88	4	4.11	4	3.46	<0.001	5	4.41	5	4.57	4	4.11	<0.001	0.547	0.495	0.548
Landscape 7: Waterfall on rocks	5	4.46	5	4.52	5	4.35	0.019	5	4.63	5	4.68	5	4.52	0.080	0.418	0.421	0.391
Landscape 8: Volcano	4	3.73	4	3.76	4	3.67	0.443	5	4.32	5	4.28	4	4.13	0.073	0.448	0.433	0.472

Median and mean scores are provided for the overall sample and for each country subsample (P - Portuguese; Sp - Spanish pre-service teachers). The Mann-Whitney test assessed statistically significant group differences, and Spearman's correlation (r_s) measured the relationship between the two variables for both total and subsample groups.

of the two subsamples, statistically significant differences were only absent for landscape 7-waterfall on rocks and landscape 8-volcano.

The correlation calculated between the preference for landscapes and the need to preserve them was always statistically significant, both for the total sample and for the subsamples of each country. However, the strength of the correlation was weak for landscapes 1-forest, 2-caldera, and 3-forest with animals, and moderate for all the others.

The reasons highlighted by students for expressing preferences for landscapes were diverse and grouped into categories, as previously mentioned, and divided by those intrinsic to the landscapes (Table 3) and those extrinsic (Table 4).

Considering the intrinsic features of the landscapes, in landscape 1-forest, landscape 3-forest with animals, and landscape 5-shepherd on the mountains, both groups highlighted the presence of biodiversity, with this component being particularly noted in the last two landscapes (73.5% and 43.4% of Portuguese pre-service and 73.5% and 87.1% of the Spanish). However, in landscapes 3 and 5, the animals were the most frequently mentioned element of biodiversity by both groups, while plant biodiversity was mentioned much less often. Even so, in landscape 3, 13.7% of Spanish students considered the presence of animals to be somewhat negative, due to their high number.

In landscapes 2-caldera, 4-unconformity, 6-glacial valley, 7-waterfall on rocks, and 8- volcano, geodiversity elements were the most highlighted in conformity with their higher visibility. In landscapes 2 and 7, hydrogeological elements were the most emphasised by both groups, although in the case of landscape 2, Portuguese pre-service teachers highlighted this aspect less (23.9% versus 59.8%).

The lack of plant biodiversity was more frequently noted by the Spanish pre-service teachers for landscapes 4-unconformity and 6-glacial valley, with a percentage slightly above 10%. In landscape 4, the Spanish students highlighted the layered rock formation more often (49.6% against 6.4%), and respondents from both groups noted the presence of rocks in a more general way (31.6% of the Spanish group and 22.8% of the Portuguese group, respectively). In landscape 8, the volcano was the most noted element, mentioned by 51.3% of the Spanish students and 30.1% of the Portuguese students, as it stood out prominently. In landscape 6, Spanish students also indicated the presence of the valley at a higher percentage (38.4% versus 24.2% of the Portuguese students). However, no student mentioned the glacial formation dynamics, only stating that it was shaped by climatic agents.

The physical characteristics of the landscapes were seldom highlighted by pre-service teachers from both groups to justify their preferences. In this regard, a noteworthy finding was that 6.8% of the Spanish students perceived the fog in Landscape 5, Shepherd on the Mountains, positively, while an equal percentage viewed it negatively.

When considering extrinsic features of the landscapes (Table 4), aesthetics was highly valued. Both Portuguese (54.3%) and Spanish students (45.3%) found landscape 2-caldera to be particularly appealing, describing it as beautiful, harmonious, and colourful. However, there was a difference in reactions to landscape 4-unconformity, which was considered ugly and dark by a higher percentage of the Spanish pre-service teachers (18.8%) when compared to the Portuguese ones (14.6%).

Landscapes evoked a variety of emotions, with landscape 1-forest receiving the highest percentage of positive assessments (35.6% among Portuguese pre-service teachers and 46.1% among the Spanish ones). It was considered to promote happiness, tranquillity, and freedom. These qualities seem to stem from the high vegetal biodiversity, an aspect that respondents highlighted as relevant for this landscape. Landscape 6-glacial valley also received similar attributes, mentioned by 14.6% of the Portuguese and 15.3% of the Spanish. The fact that it is an open landscape, as mentioned by 21.4% of the Spanish students, may have contributed to the frequency of the aforementioned emotions.

Table 3. Intrinsic features of the landscapes highlighted by the preservice teachers from both countries (P-Portuguese, n1 = 219; Sp-Spanish, n2 = 117).

LANDSCAPES	1: Forest		2: Caldera		3: Woodland		4: Discordance		5: Sheperd on the mountains		6: Glacial valley		7: Waterfall on rocks		8: Volcano	
	P	Sp	P	Sp	P	Sp	P	Sp	P	Sp	P	Sp	P	Sp	P	Sp
Biodiversity	61 (27.9)	43 (36.7)	26 (11.9)	39 (33.3)	161 **(73.5)**	102 **(87.1)**	19 **(8.7)**	22 **(18.8)**	95 **(43.4)**	71 **(60.7)**	28 **(12.8)**	29 **(24.8)**	1 **(0.5)**	6 **(5.1)**	9 **(4.1)**	7 **(6.0)**
(+) The type of ecossystem	10 (4.6)	–	7 (3.2)	2 (1.7)	52 (23.7)	27 (23.1)	–	–	20 (9.1)	15 (12.8)	–	–	–	2 (1.7)	–	–
(–) Dislike the type of ecossystem	1 (0.5)	–	–	–	–	5 (4.3)	–	–	–	–	–	1 (0.8)	–	–	–	1 (0.8)
(+) The presence of vegetation.	58 (26.5)	34 (29.0)	18 (8.2)	31 (26.5)	7 (3.2)	9 (7.7)	–	–	6 (2.7)	14 (11.9)	25 (11.4)	12 (10.2)	1 (0.5)	2 (1.7)	–	1 (0.8)
(–) Excess or lack of vegetation.	5 (2.3)	1 (0.8)	–	1 (0.8)	4 (1.8)	5 (4.3)	14 (6.4)	15 (12.8)	–	3 (2.5)	3 (1.4)	14 (11.9)	–	2 (1.7)	9 (4.1)	4 (3.4)
(+) The presence of animals.	–	5 (4.3)	2 (0.9)	7 (6.0)	145 (66.2)	81 (69.2)	–	–	79 (36.1)	60 (51.3)	1 (0.5)	1 (0.8)	–	–	–	2 (1.7)
(–) I don't like animals (too much) / lack of animals	–	4 (3.4)	–	–	5 (2.3)	16 (13.7)	4 (1.8)	5 (4.3)	–	6 (5.1)	–	4 (3.4)	–	–	–	1 (0.8)
Physical characteristics	18 (8.2)	20 (17.1)	6 (2.7)	89 (76.1)	9 (4.1)	10 (8.5)	11 (5.0)	16 (13.7)	16 (7.3)	18 (15.4)	12 (5.5)	35 (29.9)	6 (2.7)	87 (74.3)	2 (0.9)	20 (17.1)
(+) Favourable climatic characteristics (light, humidity).	10 (4.6)	8 (6.8)	3 (1.4)	1 (0.8)	–	1 (0.8)	–	1 (0.8)	9 (4.1)	8 (6.8)	–	1 (0.8)	3 (1.4)	3 (2.5)	–	3 (2.5)
(–) Unfavourable climatic characteristics (lack of excess of humidity, light, etc).	8 (3.7)	1 (0.8)	–	–	9 (4.1)	6 (5.1)	6 (2.7)	8 (6.8)	6 (2.7)	8 (6.8)	3 (1.4)	4 (3.4)	–	–	3 (1.4)	–
Physical order (open, closed, monotonous, relief, etc.)	–	5 (4.3)	3 (1.4)	6 (5.1)	–	3 (2.5)	5 (2.3)	6 (5.1)	1 (0.5)	4 (3.4)	9 (4.1)	25 (21.4)	3 (1.4)	19 (16.2)	11 (5.0)	15 (12.8)
Geodiversity	–	9 (7.7)	52 (23.7)	70 (59.8)	–	–	90 (41.1)	58 (49.6)	7 (3.2)	9 (7.7)	62 (28.3)	45 (38.4)	123 (56.2)	49 (41.9)	85 (38.8)	71 (60.7)
Topographic aspects (mountains and valleys).	–	–	4 (1.8)	14 (11.9)	–	–	–	13 (11.1)	4 (1.8)	9 (7.7)	53 (24.2)	44 (37.6)	–	3 (2.5)	–	14 (11.9)

(*Continued*)

Table 3. Continued.

LANDSCAPES	1: Forest		2: Caldera		3: Woodland		4: Discordance		5: Sheperd on the mountains		6: Glacial valley		7: Waterfall on rocks		8: Volcano	
	P	Sp	P	Sp	P	Sp	P	Sp	P	Sp	P	Sp	P	Sp	P	Sp
Hydrogeological aspects (rivers, lakes, waterfalls).	–	9 (7.7)	51 (23.9)	70 (59.8)	–	4 (3.4)	–	1 (0.8)	–	–	2 (0.9)	4 (3.4)	114 (52.1)	49 (41.9)	–	2 (1.7)
Geological structures and landscapes (volcanic cones, strata, cliffs, etc.).	–	–	2 (0.9)	1 (0.8)	–	–	14 (6.4)	58 (49.6)	–	–	1 (0.5)	1 (0.8)	1 (0.5)	5 (4.3)	66 (30.1)	60 (51.3)
Rocks / Minerals.	–	–	–	–	–	–	50 (22.8)	37 (31.6)	3 (1.4)	2 (1.7)	2 (0.9)	1 (0.8)	24 (11.0)	25 (21.3)	8 (3.7)	4 (3.4)
Geological processes.	–	–	–	2 (1.7)	–	–	10 (4.6)	11 (9.4)	–	–	9 (4.1)	7 (6.0)	7 (3.2)	19 (16.2)	12 (5.5)	15 (12.8)
Geological time.	–	–	1 (0.5)	–	–	–	15 (6.8)	4 (3.4)	–	–	3 (1.4)	2 (1.7)	1 (0.5)	6 (5.1)	8 (3.7)	2 (1.7)

Absolute frequencies and relative frequencies (in parenthesis) are included. The students gave more than one reason to justify their preference. Consequently, the number of reasons is higher than the number of participants. Negative reasons are in grey.

Table 4. Extrinsic features of the landscapes highlighted by the preservice teachers from both countries (P-Portuguese, n1 = 219; Sp-Spanish, n2 = 117).

	1. Forest		2. Caldera		3. Forest with animals		4. Unconformity		5. Sheperd on the mountains		6. Glacial valley		7. Waterfall on rocks		8. Volcano	
LANDSCAPES	P	Sp	P	Sp	P	Sp	P	Sp	P	Sp	P	Sp	P	Sp	P	Sp
Aesthetics	**35 (16.0)**	**41 (35.0)**	**122 (55.7)**	**62 (53.0)**	**16 (7.3)**	**15 (12.8)**	**53 (24.2)**	**39 (33.3)**	**11 (5.0)**	**15 (12.8)**	**37 (16.9)**	**41 (35.0)**	**37 (16.9)**	**26 (22.2)**	**38 (17.4)**	**30 (25.6)**
(+) Beautiful, harmonious, with various colours, etc.	32 (14.6)	38 (32.4)	119 (54.3)	53 (45.3)	11 (5.0)	8 (6.8)	21 (9.6)	17 (14.5)	8 (3.7)	12 (10.2)	31 (14.2)	25 (21.3)	35 (16%)	24 (20.5)	27 (12.3)	22 (18.8)
(–) Ugly, dark colours, etc.	3 (1.4)	3 (2.5)	3 (1.4)	9 (7.7)	5 (2.3)	7 (6.0)	32 (14.6)	22 (18.8)	4 (1.8)	3 (2.5)	6 (2.7)	16 (13.7)	2 (0.9)	2 (1.7)	11 (5.0)	8 (6.8)
Emotions	**84 (38.4)**	**61 (52.1)**	**22 (10.0)**	**25 (21.3)**	**18 (8.2)**	**30 (25.6)**	**33 (15.1)**	**33 (28.2)**	**28 (12.8)**	**28 (23.9)**	**49 (22.4)**	**43 (36.7)**	-	**27 (23.1)**	-	**32 (27.3)**
(+) Happiness, peace, tranquillity, freedom, memory, etc.	78 (35.6)	54 (46.1)	20 (9.1)	21 (17.9)	6 (2.7)	8 (6.8)	13 (5.9)	6 (5.1)	19 (8.7)	11 (9.4)	32 (14.6)	18 (15.3)	29 (13.2)	21 (17.9)	32 (14.6)	13 (11.1)
(–) Restlessness, fear, loneliness, indifference, insecurity, danger…	6 (2.7)	7 (6.0)	2 (0.9)	4 (3.4)	12 (5.5)	22 (18.8)	30 (13.7)	27 (23.1)	9 (4.1)	17 (14.5)	17 (7.8)	25 (21.3)	12 (5.5)	6 (5.1)	24 (11.0)	19 (16.2)
Activities (Walking, fishing, bathing, leisure, etc.)	**18 (8.2)**	**15 (12.8)**	**6 (2.7)**	**10 (8.5)**	**3 (1.4)**	**6 (5.1)**	**2 (0.9)**	**4 (3.4)**	**3 (1.4)**	**48 (41.0)**	**2 (0.9)**	**7 (6.0)**	**5 (2.3)**	**2 (1.7)**	**6 (2.7)**	**5 (4.2)**
Health (Physical and mental)	**15 (6.8)**	**3 (2.5)**	**1 (0.5)**	**2 (1.7)**	**1 (0.5)**	-	-	-	**2 (0.9)**	-	**3 (1.4)**	**1 (0.8)**	**1 (0.5)**	**1 (0.8)**	-	-
Conservation	**35 (16.0)**	**11 (9.4)**	**43 (19.6)**	**28 (23.9)**	**17 (7.8)**	**25 (21.3)**	**6 (2.7)**	**2 (1.7)**	**90 (41.1)**	**69 (58.0)**	**30 (13.7)**	**3 (2.5)**	**19 (8.7)**	**20 (17.1)**	**15 (6.8)**	**4 (3.4)**
(+) Natural values (natural landscape, absence of pollution, low human presence, etc.)	34 (15.5)	11 (9.4)	36 (16.4)	13 (11.1)	15 (6.8)	18 (15.4)	6 (2.7)	2 (1.7)	9 (4.1)	5 (4.3)	30 (13.7)	2 (1.7)	19 (8.7)	19 (16.2)	14 (6.4)	3 (2.5)
(–) Affected natural values (human activities harmful to life, destructive natural forces, etc.)	–	–	4 (1.8)	13 (11.1)	2 (0.9)	6 (5.1)	_	–	–	–	–	–	–	–	1 (0.5)	1 (0.8)

(*Continued*)

Table 4. Continued.

	1. Forest		2. Caldera		3. Forest with animals		4. Unconformity		5. Sheperd on the mountains		6. Glacial valley		7. Waterfall on rocks		8. Volcano	
LANDSCAPES	P	Sp	P	Sp	P	Sp	P	Sp	P	Sp	P	Sp	P	Sp	P	Sp
(+) Cultural values (human-nature interaction, human activities, etc.)	1 (0.5)	–	4 (1.8)	2 (1.7)	–	1 (0.8)	–	–	76 (34.7)	55 (47.0)	–	1 (0.8)	–	–	–	–
(–) Negative cultural traditions destruction of heritage.	–	–	–	–	–	–	–	–	10 (4.6)	9 (7.7)	1 (0.5)	–	–	1 (0.8)	1 (0.5)	–
Didactic applications	**-**	**2 (1.7)**	**1 (0.5)**	**2 (1.7)**	**2 (0.9)**	**3 (2.5)**	**5 (2.3)**	**5 (4.3)**	**3 (1.4)**	**1 (0.8)**	**-**	**2 (1.7)**	**1 (0.5)**	**1 (0.8)**	**3 (1.4)**	**6 (5.1)**
(+) Arouses scientific or didactic interest.	–	2 (1.7)	1 (0.5)	2 (1.7)	2 (0.9)	3 (2.5)	4 (1.8)	2 (1.7)	3 (1.4)	1 (0.8)	–	2 (1.7)	1 (0.5)	1 (0.8)	3 (1.4)	5 (4.3)
(–) Without scientific or didactic interest.	–	–	–	–	–	–	1 (0.5)	3 (2.5)	–	–	–	–	–	–	–	1 (0.8)
Do not answer / do not justify (intrinsic or extrinsic reasons)	32 (14.6)	–	21 (9.6)	–	22 (10.0)	1 (0.8)	39 (17.8)	5 (4.3)	30 (13.7)	4 (3.4)	36 (16.4)	3 (2.5)	30 (13.7)	3 (2.5)	45 (20.5)	6 (5.1)

Absolute frequencies and relative frequencies (between parenthesis) are included. The students gave more than one reason to justify their preference. Consequently, the number of reasons is higher than the number of participants. Negative reasons are in grey.

Three landscapes elicited feelings of fear, loneliness, insecurity, and indifference. Landscape 3-forest with animals was seen as dangerous and unsettling because of the animals present; landscape 4-unconformity was regarded with indifference and negative emotions like loneliness, possibly due to its lack of features other than rocks; landscape 8-volcano was simply described as dangerous, likely due to the risks associated with volcanic activity.

The possibility of engaging in various activities at the presented landscape sites, such as walking, swimming, or other leisure activities, was expressed for landscape 1-forest by both groups (8.2% of the Portuguese pre-service teachers and 12.8% of the Spanish) and for landscape 5-shepherd on the mountains, highlighted by a high percentage of the Spanish (41.0%). For the other landscapes, this type of justification was less prevalent. Similarly, references to the significance of landscapes for physical and mental well-being were infrequent, although some of the emotions highlighted by the students may be related to this dimension. Somewhat surprisingly, there was a lack of reference to the educational value of landscapes, given that the students will become teachers.

The perception of landscapes as natural, devoid of human presence or pollution, was an argument used by both groups for landscapes 1-forest, 2-caldera, and 6-glacial valley, and by Spanish students for landscape 3-forest with animals, with values ranging from 9.4% to 16.4%, although this perception was not always accurate. Landscape 5-shepherd on the mountains was appreciated for the interaction between humans and nature, represented by pastoral activities, an argument highlighted by 34.7% of the Portuguese students and 47% of the Spanish ones.

Discussion

The present study sought to assess preferences for diverse landscapes in terms of the prevalence of geodiversity, biodiversity, and cultural elements. Although students positively appreciated all landscapes, with a median score of 3 or higher, their preferences were expressed unevenly.

Thus, landscapes with elements of geodiversity were appreciated differently. Those that contained water were particularly appreciated, such as the volcanic caldera and the waterfall, and even received greater preference than landscapes with dominant biodiversity. These results are in line with Español-Echániz (2010), who aimed at a remaining presence of a traditional concept of beauty referred to landscapes that might be beyond these preferences, mainly connected by water presence. As Español-Echániz (2010) reflected, the dryness and heat of thermic and arid climates are in themselves aesthetics experiences, that can be close to spectacular and surprising landscapes, but the association with droughts can ruin harvests, and thus, with fear and uncertainty to peasants from a continued lack of rain, can affect the feeling and perception of the landscape. Several studies analysed by Rodríguez-Lozano (2024), involving university students or residents, show similar trends in the comparison between temporary and permanent rivers. The latter are more appreciated for their aesthetic value and considered more important in terms of biodiversity, reinforcing the importance of water as an attractive feature in landscapes for evolutionary and sociocultural reasons. Even so, in Landscape 2-Caldera, a few students, primarily from the Spanish group, perceived the water quality as poor due to its colour. This aligns with findings from other studies, which suggest that the enjoyment of landscapes with water may decrease when associated risks or visible pollution are identified (Howley, 2011; Ulrich, 1993; Zhang et al., 2022).

Landscapes centred on geological formations, such as the volcanic cone, glacial valley, and especially the one with an unconformity, were less appreciated and ranked lower in preference compared to landscapes dominated by biodiversity, such as forested areas. Similarly, the depreciation of certain geological landscapes characterised by sand and exposed rocks was identified by Corraliza et al. (2023) in a study involving more than three hundred participants from the same region in Spain as the one in the present study. Their study, one of the few analysing preferences related to the abiotic components of landscapes, also confirmed that the presence of water and vegetation are key determinants of landscape preference. This preference can be attributed to the perception of beauty influenced by natural resources, specifically biodiversity, which are vital for human life (Español-Echániz, 2010).

The presence of animals, specifically mammals, in two of the landscapes shown, also evokes positive emotions. Their appeal is further enhanced by their taxonomic classification and notable size, as mammals are the most preferred taxonomic group among people (Knapp, 2019; Prokop & Fančovičová, 2013).

Given that the less appreciated landscapes with geodiversity possess undeniable scientific value, this seems to indicate that students do not recognise it, which contributed to a lower preference. This may also explain why students overlooked the educational potential of the landscapes, choosing instead to emphasise other reasons. Carlson (2010) argues that, to move beyond a superficial aesthetic response, possessing scientific knowledge is necessary. Similarly, Brady and Prior (2020) clarify that such knowledge provides and directs the perception of certain aesthetic qualities that would otherwise go unnoticed. According to these authors, understanding that fire has beneficial ecological effects for a forest can lead to finding value in landscapes that are temporarily unattractive, grey, and lifeless. Also, observing a U-shaped valley leads to an appreciation of the geological forces that shaped it over time. Likewise, seemingly attractive landscapes with biodiversity, but where invasive species predominate, become devalued.

Rolston (1995) also argues that science is not always a necessary condition for appreciating a landscape, but in many situations, it enriches its history and brings insight into what occurs in nature. He states: "When you understand the harshness of an arid or an alpine climate, you will find the plants' clinging to life aesthetically stimulating" (p. 378). However, alternative explanations may also emerge to justify landscape preferences. Parsons and Daniel (2002) advocate for a more nuanced and affective perspective rooted in the historical behaviour of human civilisation. Even so, it is rare to find an author who completely disregards the significance of scientific knowledge in landscape appreciation, moreover considering the growing influence of science in society. However, other factors may also play a significant role, with direct contact being among the most relevant. According to Harris (2002), experiencing landscapes firsthand emphasises the importance of field trips in facilitating the reading and interpretation of landscapes.

Similarly, Tretinjak and Riggs (2008) found that geology-based field trips for pre-service teachers significantly enhanced their understanding of geological concepts. However, the positive impact of these trips on the appreciation of diverse landscapes depends on the strategies used for scientific exploration. Students' outdoor experiences were not surveyed in the present study, as recalling past events involves memory challenges and selective biases (Karsten, 2005). Furthermore, the institutions involved in the study offer few outdoor activities due to financial constraints.

But people's overall experiences are of course not strictly acquired in a school context. Familiarity with a landscape and the resulting sense of belonging can also positively influence appreciation (McAndrew, 1998; Twigger-Ross & Uzzell, 1996). This aspect may help explain some of the differences in the appreciation of volcanic caldera and glacial valley landscapes between the students from the two countries, given that these landscapes are in Portugal. Although only a few students explicitly mentioned memories associated with them, they might have experienced a subconscious sense of familiarity. A similar explanation could be extended to the case of forest landscape, now applicable to participants from both countries, considering some responses that referenced similarities with other landscapes they were familiar with.

The intrinsic elements of the landscapes highlighted by the respondents in their appreciation seem to follow a certain hierarchy. Thus, the presence of animal biodiversity in a landscape becomes the highlight, as happened in landscapes 3-forest with animals and 5-shepherd on the mountains. According to New et al. (2007), when people viewed photographs, they were more likely to notice the presence of animals than of inanimate objects, regardless of the objects' sizes. This tendency is believed to reflect an innate preference for animals over objects, and it seems to extend to plants in the present study.

However, this presence, although marked as positive by the majority, was depreciated in relation to landscape 3 by several Spanish students who assessed them as dangerous, perhaps due to their more frequent contact with animals such as the wild boar. The presence of humans in landscape 5 enhanced its appeal, contradicting findings from other studies that suggest that the human presence diminishes the value of natural landscapes (Kirillova et al., 2014). However, the perception of pastoralism as a natural activity may explain this positive response. It supports the integral concept of landscape proposed by Giner de los Ríos (1886) and González Bernáldez (1981), which encompasses historical and economic structures, as well as culture, as they are embedded in space upon the inorganic and organic foundations of natural environments. Interestingly, many Spanish students seemed indifferent to this landscape, suggesting that familiarity with a landscape can both increase and decrease its appeal.

Finally, pre-service teachers expressed even stronger support for the importance of preserving diverse landscapes, aligning with the view that every citizen has the right not only to adequate housing, but also to a suitable environment and a meaningful, high-quality landscape, as articulated by López Silvestre and Zusman (2008). Due to this difference, the degree of preference was positively correlated with the need for preservation, although in a moderate to weak way. It is believed that the fact that the respondents are future teachers, and thus, to some extent, more attuned to the need for nature conservation than other social groups, may help explain this result.

Conclusions

Some implications emerging from this study could be incorporated into teacher training courses with the aim of enhancing appreciation for geological landscapes. In this context, an informed interpretation of geological landscapes can contribute to broadening their aesthetic appreciation and even stimulate imagination about the processes they evoked. For instance, envisioning the movements of a glacier or the impact of plate tectonics adds a dynamic dimension that aligns closely with the present goal (Benovsky, 2016).

Ives and Carpenter (2007) suggest that emphasising the interdependence between geodiversity and biodiversity may be the most effective way to foster a deeper understanding of landscapes and their diversity. Without a more integrated approach, we risk overlooking the significance of certain geological landscapes. By focusing on subtle clues and features that, although not visually striking, enhance our understanding of systems and dynamics, we can cultivate a greater appreciation for landscapes and reduce biases (Español-Echániz, 2010). This approach also encourages a less conventional perception of beauty in relation to landscapes. Furthermore, Belardinelli and Pievani (2024) argue that broadening our love for nature to include a profound appreciation for geological features, referred to as geophilia, is essential for comprehending the complex emotional connections humans share with the natural world.

Field trips are an essential strategy to include in teacher training programs to achieve the aforementioned goals. However, as noted by Jolley et al. (2018), such trips must be immersive and foster a sense of place in students, with particular attention given to the cultural meanings embedded in landscapes. Indeed, landscapes are cultural constructs rooted in the environment, offering aesthetic experiences that arise from a complex interplay between cognition and emotion, both of which can be influenced by education (Español-Echániz, 2010). For example, many geological landscapes are associated with legends and myths (Burbery, 2023; Tepper, 1999). Some of these are inspired by actual geological events, while others are fantastical stories that can be juxtaposed with scientific "truths." Exploring this geomythological dimension can enhance students' sense of place in specific geological areas, directing their focus towards the geological features of landscapes, a strategy that warrants investigation.

Enhanced training in landscape interpretation within pre-service teacher education can lead to more effective teaching practices. This would enable future teachers to better convey the significance and complexity of landscapes to their students, a connection that also warrants further research. In this regard, the prior training of participating teachers was quite broad, and the authors did not examine its influence on landscape perceptions. Therefore, it is recommended that future research incorporate this variable into its design. Additionally, further research should explore cultural factors, which were not the focus of the present study but may significantly impact landscape perception.

This study had an exploratory character, given the scarcity of research in this field. The use of photographs presents the limitation of providing a static image of landscapes, failing to capture a broader and more diverse sensory experience. However, alternative methods appear infeasible when the objective is to appreciate landscapes often geographically distant from one another. Moreover, photographs of landscapes that offered positive aspects to emphasise were selected, rather than confronting respondents with landscapes that were more severely impacted on their ecological integrity. This approach could justify a high level of appreciation, accompanied by an equally strong need to preserve them. Additionally, a more integrated approach to geodiversity and biodiversity appears necessary within the field of preservation. While conflicts and challenges exist, it is crucial to identify ways and strategies to reconcile habitats, species, and natural processes.

Acknowledgements

The present study is part of the project IPL/IDI&CA2024/GreenLink_ESELx, supported by the Instituto Politécnico de Lisboa.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

The data presented in this study are available on request from the corresponding author.

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Appendix 1. The photographs used in the study. A: Forest with diverse species of trees (*Source*: Marc Pell. Public domain); B: Caldera in a volcanic island (*Source*: José Luís Costa. Public domain); C: Forest with animals (*Source*: Author/António Almeida); D: Geological unconformity (*Source*: Author/António Almeida); E: Sheperd on the mountains (*Source*: Paulo Azevedo. Public domain); F: Glacial valley (*Source*: Author/António Almeida); G: Waterfall on rocks (*Source*: Author/António Almeida); H: Inactive volcanic cone (*Source*: Samuel Domingos. Public domain).