

Proposal for Assessment and Inventory of the Landscape as Geoheritage

Proposta de Avaliação e Inventariação da Paisagem como Geopatrimônio

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Abstract

Methods for quantitatively assessing geological heritage have been used in a variety of settings and for different purposes, such as environmental impact assessment, inventory of natural heritage, tourism promotion, and conservation unit management. In this sense, there are adaptations to each study in relation to the methodology and the regional context in which the research is developed, and the final objective. This research proposes a methodology for taking inventory with the goal of analyzing the landscape while adhering to the concepts and parameters that allow for the assessment of geoheritage. In addition to reviewing the literature, the Delphi method was used in 2020 email consultations with 76 experts on geoheritage and landscape. It is expected that, when using the proposed inventory, managers will be able to identify places with better scientific possibilities in the use of landscape in relation to geoheritage, which will be useful when reviewing city planning and management planning of conservation units under the scope of geoconservation.

Keywords: Geomorphology; Geoconservation; Delphi

Resumo

Os métodos para avaliação quantitativa do geopatrimônio têm sido aplicados em diferentes lugares e com objetivos diversos, como na avaliação de impacto ambiental, inventário de patrimônio natural, promoção turística e gestão de unidades de conservação. Neste sentido, existem adaptações para cada estudo, tanto em relação a metodologia quanto em relação ao contexto regional onde se desenvolve a pesquisa e ao objetivo final. Este trabalho propõe uma metodologia de inventariação com o objetivo de analisar a paisagem seguindo os conceitos e parâmetros que permitem a avaliação do geopatrimônio. Além da revisão de literatura, foi utilizado o método Delphi na consulta por e-mail em 2020 a 76 especialistas na temática do geopatrimônio realizada em duas etapas para determinação de quais critérios e suas relevâncias para avaliação do geopatrimônio em relação a paisagem. Espera-se que, com a aplicação do inventário aqui proposto, a identificação dos locais com maiores potencialidades científicas de uso da paisagem em relação ao geopatrimônio sirva a gestores na revisão de planos diretores dos municípios e planos de manejo das unidades de conservação, sob a ótica da geoconservação.

Palavras-chave: Geomorfologia; Geoconservação; Delphi

1 Introduction

Landscape studies, from the standpoint of natural and Earth sciences, are approached in a variety of fields, including geography, geology, and biology, to name a few. According to Bastian (2014), the German school generally defends that the landscape can be divided into two categories: natural and biophysical, in which a section of the Earth's crust is characterized by a uniform structure that follows certain natural laws.

Therefore, the landscape consists of the abiotic complex, which includes the geological and geomorphological structure, soil, water, and climate; the biotic complex, which consists of fauna and flora, and the relationships between the geosphere and biosphere (Haase & Mannsfeld 2002).

Morin (1977) defends that the landscape must be thought of as a system in which the relationship between the configuration of natural elements and the processes that build it, interwoven in a temporal and spatial scale. Santos (2002) explores the spatial scale and states that, as the landscape is a set of shapes (natural physical elements), it should, at a temporal scale, express the constant transformations of the relations between society, environment, and time.

Despite the definition of landscape being studied in different contexts, a single definitive meaning is far from being adopted by the scientific community as whole, as it would involve questions that are still under discussion. In this study, the definition adopted for the assessment of landscape is what proposed Coelho Netto (1992 apud Dantas et al. 2015) and Dantas and Coelho Netto (1995), in which the landscape related to geomorphology can be understood as a spatial result of the interaction between several different variables in relation to the geo-biophysical setting and, therefore, it regards the dynamic of the geomorphological processes at different spatial and temporal scales.

The objective of this research is the analysis of the landscape with a focus on its abiotic component, viewing to insert it in geoheritage studies. For the enhanced development of protocols that include the assessment of landscape beyond the literature review, which is scarce on this subject, methods that aid in the determination of which criteria are important are utilized.

Thus, in this study, the criteria proposed by previous studies are considered, with the goal of identifying which of them fit the assessment of the landscape in relation to geoheritage. Therefore, in addition to the presented literature, we sought to assess what is significant in the concept of landscape as a component of regional geoheritage, by consulting with experts.

2 Landscape and Geoheritage

In studies relating to geoheritage, the landscape has been assessed from a cultural and/or tourist perspective by Luger et al. (2012), Niculiță and Mărgărint (2018), Portal and Kerguillec (2018), and Reynard and Giusti (2018). Furthermore, Pereira et al. (2015) approached landscape assessment using criteria proposed by Pereira and Pereira (2010), such as rarity, representativeness, integrity, diversity, and scientific knowledge.

In this sense, landscapes are recognized as components of the geoheritage defined by Lopes (2017) as a set of places in a determined area, of abiotic origin, with scientific, cultural, didactic, touristic, aesthetic, ecological value, among others, obtained from the assessment and that are recognized by the scientific community and the local community.

Historically, there is a public interest in following trails with unique geological and geomorphological features, using these natural attractive aspects as a tourism activity. Geotourism, according to Moreira (2014), can be defined as “a sustainable touristic segment, taken by people interested in knowing more about the geological and geomorphological aspects of a certain place, this being their main motivation of the trip”.

Geotourism must be linked to geoconservation, as its practices are related to the promotion of geoheritage, encouraging its protection. (Rodrigues & Carvalho 2010). Degrandi (2011) sustain that activities related to geotourism go beyond the contemplation of natural landscape but are directly related to the interpretation of processes of geological and geomorphological origins in the formation of these landscapes, as well as its environmental preservation. Moura-Fé (2015) highlights that both the interpretation of the landscape and the possibility of environmental education promoted by geotourism facilitate the understanding of the marks geological and geomorphological processes leave at different temporal scales.

Landscapes are categorized within geoheritage as part of geomorphological heritage and Oliveira and Rodrigues (2014) point out the importance of their preservation, as well as the assessment of the touristic potential of these areas. Reynard (2008) and Kubalíková (2016) determine strategies and case studies for the promotion of geotourism of geomorphological heritage.

One of the most common tools used in geoconservation research, quantitative and qualitative assessments of geoheritage have been carried out using various methods and in the most diverse locations on the planet, with a variety of goals in mind, including

the assessment of environmental impact, inventory of natural heritage, tourism promotion, and management of conservation units (CUs).

Romão and Garcia (2017) present a history of inventories at national and international scales in the last decades, and the several methods of local and regional assessments that have been developed according to the specificities of the regions studied and the objectives of each assessment. Among them, we can cite: Rivas et al. (1997), Uceda (2000), Brilha (2005, 2016), Pereira (2006), Pereira (2010), García-Cortés and Carcavilla-Urquí (2009), Lima, Brilha and Salamuni (2010), Santos et al. (2020), among others.

Regarding geomorphological heritage, Figueiró, Vieira and Cunha (2014) point out that places of geomorphological interests must be assessed according to the scientific/educational value associated with ecological value, following the recommendation of Coratza and Giusti (2005). The assessment, according to Figueiró, Vieira and Cunha (2014), must be composed by the inventory (identification, classification, description, and representation) and valuation (singularity, rarity, representativity, grandiose, vulnerability, and ecological support). The definition of the criteria to be considered depends on the study's context, but as indicated by Reynard et al. (2007), the most recurring are: rarity, representativity, and integrity. However, Lima, Brilha and Salamuni (2010) propose that, when taking inventory, four criteria must be observed: subject, value, scale, and usage. The unification of these criteria poses a difficulty to researchers working on this subject.

Mucivuna, Reynard and Garcia (2019) go further in the research of methodological questions that provide the creation of inventories and the qualitative and quantitative assessment of places of geomorphological interest. The authors reach the conclusion that the methods should be more systematic, to enable its reproduction in different contexts, and that the criteria, oftentimes, are used incorrectly, resulting in the overlapping of interests according to the objectives of the research.

The works that approach the geomorphological heritage in Brazil often use classical methods of geoheritage assessment (e.g., Brilha, 2005, 2016). Nevertheless, some research propose a more specific assessment to this heritage, like Pereira (2010), at Chapada Diamantina; Lopes (2017) in a study on the coastal region of the state of Piauí, and Santos et al. (2020), in a southeastern coast of the state of Rio de Janeiro.

3 Methodology and Data

The material used in this research include scientific publications with subjects involving the concepts of geoconservation, inventory, regional and local geology, landscape, geomorphology, geodiversity, and geoheritage. Additionally, the Delphi method was used for the assessment of criteria for the classification of landscapes, of which the techniques and applications are well-founded in Linstone and Turoff (1975).

The Delphi method consists of anonymous consulting with experts in two or more steps. To choose the experts, we checked national and international scientific journals for available works related to the subject-matter, with keywords like “geoheritage”, “geoconservation”, “geodiversity”, “geotourism”, “natural heritage”, “geological heritage”, and “geomorphological heritage”. From these works, we checked the Lattes Platform of the National Council for Scientific and Technological Development (CNPq) to identify researchers who have worked with the subject of geoheritage in Brazil.

In this sense, 116 experts were selected and the central subject of research during Masters or Doctorates programs had the aforementioned keywords. We also chose 14 researchers who possess some kind of guidance on the subject-matter within the context of geoheritage in their curriculum.

Considering the context of the COVID-19 pandemic, contact with the experts was carried out remotely via e-mail from July-October of 2020, in which a form was presented on the online platform *Google Forms*, proposing parameters to be considered in the assessment of landscapes according to concepts involving geoheritage. The use of the tool enabled the anonymous participation (without identifying the surveyee) of experts across Brazil.

Then, two rounds of consults with experts were carried out. For the first step, between July and August 2020, we proposed to the participants that they define the categories they believe to be important for analyzing landscapes and places of geomorphological interests, and how much weight each category should be given, as well as category suggestions.

The second step, which took place between September and October 2020, was based on the projection of the collected answers from the first round, which were composed by the assessment form and included the best reviewed categories as well as the participants' suggestions from the first step.

After completing both steps, the data was analyzed as a whole, while keeping the surveyees' initial formation in mind. To reduce the possibility of trends in parameter assessment due to surveyee diversity, the experts were divided into two knowledge groups: Applied Social Sciences and Exact and Earth Sciences. As a result, the parameters were analyzed based on the weight assigned to them in these two groups, with the final weight to be analyzed during the assessment of places of geomorphological interest being averaged.

4 Results

4.1 Application of the Delphi Method

The Delphi method was applied to the sample universe of 130 potential surveyees, with the participation sample of 76 (58.5%) surveyees. The fields of the surveyees of the first step were very diverse: Geography (50%), Geology or Engineering Geology (27%), Tourism (7%), and other fields which made up 13% of the sample. Surveyees from 22 different national organizations, especially universities and research centers, participated in this first step.

From the literature regarding the subject, 23 parameters – which appear relatively frequently in works about geoheritage and geotourism - were determined, such as: Grandgirad (1995, 1996), Rivas et al. (1997), Restrepo (2004), Coratza and Giusti (2005), Pralong (2005), Serrano and González-Trueba (2005), Pereira (2006), Brilha (2005, 2016), Pereira (2010), Paula and Castro (2016) and Lopes (2017).

The parameters were presented to the experts and assessed according to importance in relation to the scientific objective of the research. Each surveyee chose to include, exclude or give no opinion about each parameter. If the expert chose to include the parameter, we also asked that they include its weight (importance) (Likert, 1932), which varied from least to most important for each criterion, as well as criticisms and suggestions.

Figure 1 shows the obtained results about the inclusion and exclusion of the parameters to be analyzed in both rounds of expert consultations. Figure 2 represents the weight choices obtained in three moments of the research: the first round of the Delphi method, the second round, and after weighing between the groups of each field (final weight).

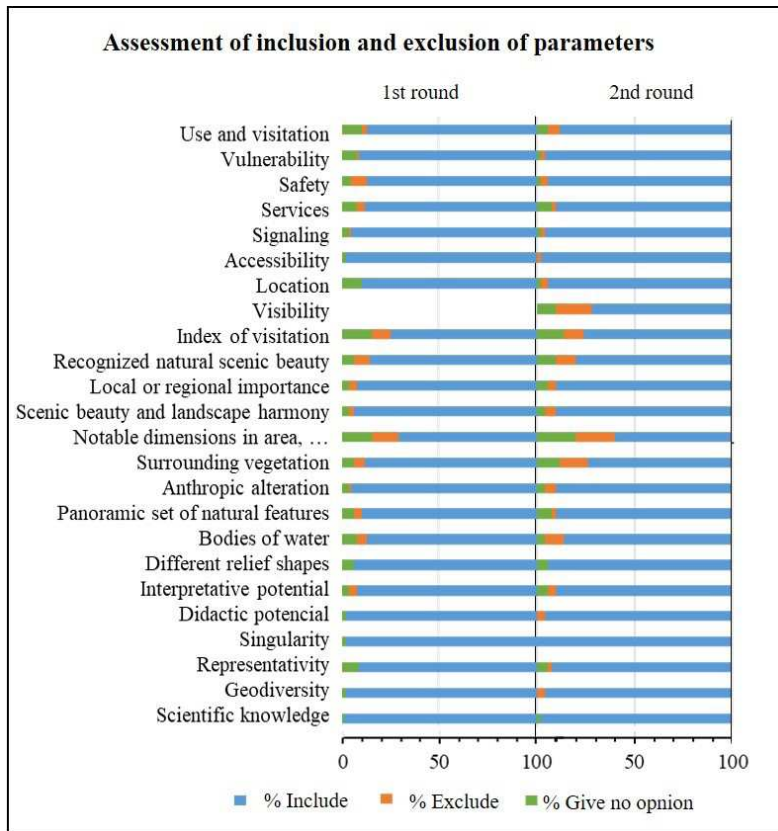


Figure 1 Assessment of inclusion and exclusion of parameters by the experts in the two rounds of the Delphi method.

Weight attributed by experts during the two rounds of the *Delphi* method and the final weight

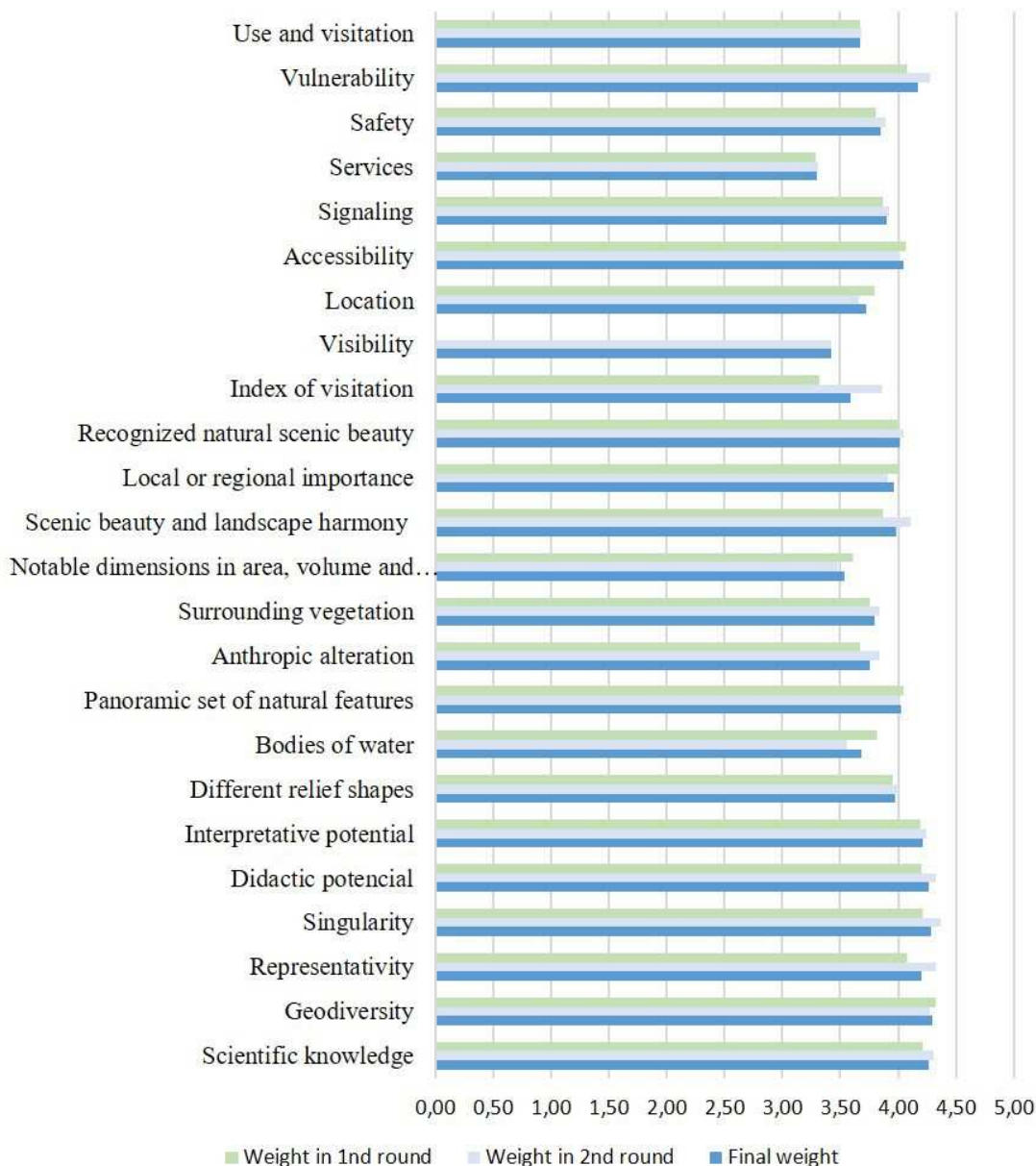


Figure 2 Weight attributed by experts during the two rounds of the Delphi method and the final weight.

The results of expert consultation during the first round indicates that, despite the lack of unanimity in either analyzed parameter, there is convergence in attributing higher weights to parameters related to geology and geomorphology in comparison to those related to landscape and tourism.

The parameter “representativity” was the one that obtained the inclusion percentage of 90.67%, while

“scientific knowledge” obtained 98.67%. The parameters “presence of bodies of water” and “panoramic set of natural features” obtained the inclusion indicators of 86.67% and 89.33%, respectively. We call attention to the inclusion percentage of the “scenic beauty and landscape harmony” (93.33%) and “local or regional importance” (92%) parameters. The “services” parameter showed an inclusion rate of 88%.

We must also highlight that parameters linked to tourism show high levels of inclusion, but, in proportion, they become average when compared to lower importance parameters.

This configuration can indicate that, when analyzing the landscape, the set of experts consider the natural characteristics of the landscape more important than access and service features to these places of geomorphological interest.

Among the suggestions - accepted for the second round -, it was pointed out that the parameters “scenic beauty”, “landscape harmony”, and “recognized natural scenic beauty” must be analyzed together, and not as separate parameters, decreasing the subjectivity of the analysis. Additionally, it was also suggested the inclusion of the parameter “visibility”, regarding how many landscapes are visible for the viewer from different positions.

The adhesion index of the second round was of 50 researchers (65.78%) in relation to the first round. In this step, the form was constructed individually, so that every expert would be able to access their answers from the previous step as well as the values generated by the group who participated in the first step.

In the second round, Figure 1, the parameter “singularity” was unanimously chosen by the experts to be included in the inventory, and “didactic potential” obtained a relative increase in importance. We also highlight the importance of the parameter “geodiversity” (average of 4.30 and inclusion rate of 96%).

The parameter “services” kept the last position on the question of importance (3.30), but it once again shows great adherence regarding the importance of its assessment (90%). For Coutinho et al. (2019), one of the aspects of geotourism of this parameter is “a segment of touristic activity that seeks a sustainable way of using geological heritage as its main touristic resource, promoting the acquisition of knowledge and conservation”. Ratifying, therefore, the first definition of the term “geotourism”, by Hose (1995): “the provision of services and interpretive facilities that offer tourists the comprehension and acquisition of knowledge of a geological and geomorphological site, instead of a mere aesthetic appreciation”. The inclusion of the parameter “visibility”, to be allocated to landscape criteria, was approved by 72% of the experts and obtained an average importance assessment of 3.42.

In turn, the “visitation index”, is of little relevance for the experts in the assessment of the landscape, with an importance average of 3.59 and inclusion rate of 76%, which creates a paradigm: visitation makes the preservation of places of geological interest more difficult, but if visitation isn't possible, there is no increase in the sharing

of geosciences. The solution would be to create a harmony between the interests of researchers of geoconservation and researchers of geotourism, indicated by Williams, McHenry and Boothroyd (2020).

The combining of the parameters or “scenic beauty and landscape harmony” (inclusion rate of 90% and average of 4.11), and “recognized natural scenic beauty” (inclusion rate of 80% and average of 4.11), obtained a 72% approval rate and average of 4.18. However, there is indication that the parameters should not be assessed together, because, despite having a gain on the importance average, the inclusion rate is higher when assessed separately.

The parameters were ranked according to the averages obtained by the assessment of the surveyed experts during the second round. To avoid distortions regarding the fields of these experts, it was necessary to split them into groups based on their degrees: Exact and Earth Sciences and Applied Social Sciences. Afterwards, the weights were calculated for each group to ascertain the averages between them. The result appears in Figure 3, which shows the values obtained for each parameter, ranked from highest to lowest.

The results shown in Figure 3 represent the experts' answers within a general context of assessment of the landscape regarding geoheritage. However, the versatility of the *Delphi* method allows for the needed adaptations and modifications to produce an easily applied inventory, and avoiding the overlap and overestimation of assessment criteria, or producing subjective assessments by the observer, for instance; all that without compromising the results and opinions of the experts (Oliveira, Salgado & Lopes 2017).

After the analysis of the answers obtained from the set of experts for creating the protocol, we considered some of the adaptations to the parameters to be assessed during the process of taking inventory.

The parameters “didactic potential” and “interpretative potential”, for instance, were substituted for “didactic-scientific potential”, as both potentials presented similar importance and meaning during the assessment.

The parameters “different relief shapes”, “panoramic set of natural features”, and “notable dimensions in area, volume and extension of the relief shapes” were unified under “geomorphological diversity”. The parameter “recognized natural scenic beauty” was excluded from the assessment, as it would overlap with “local or regional importance” and “scenic beauty and landscape harmony”. We added the parameter “conditions for observation”, as utilized by Lopes (2017).

The parameters were then split into 3 values, as shown in Figure 4. To each criterion, a weight was attributed to be applied in the composition of Value of Geomorphological Landscape (VP_{Geo}).

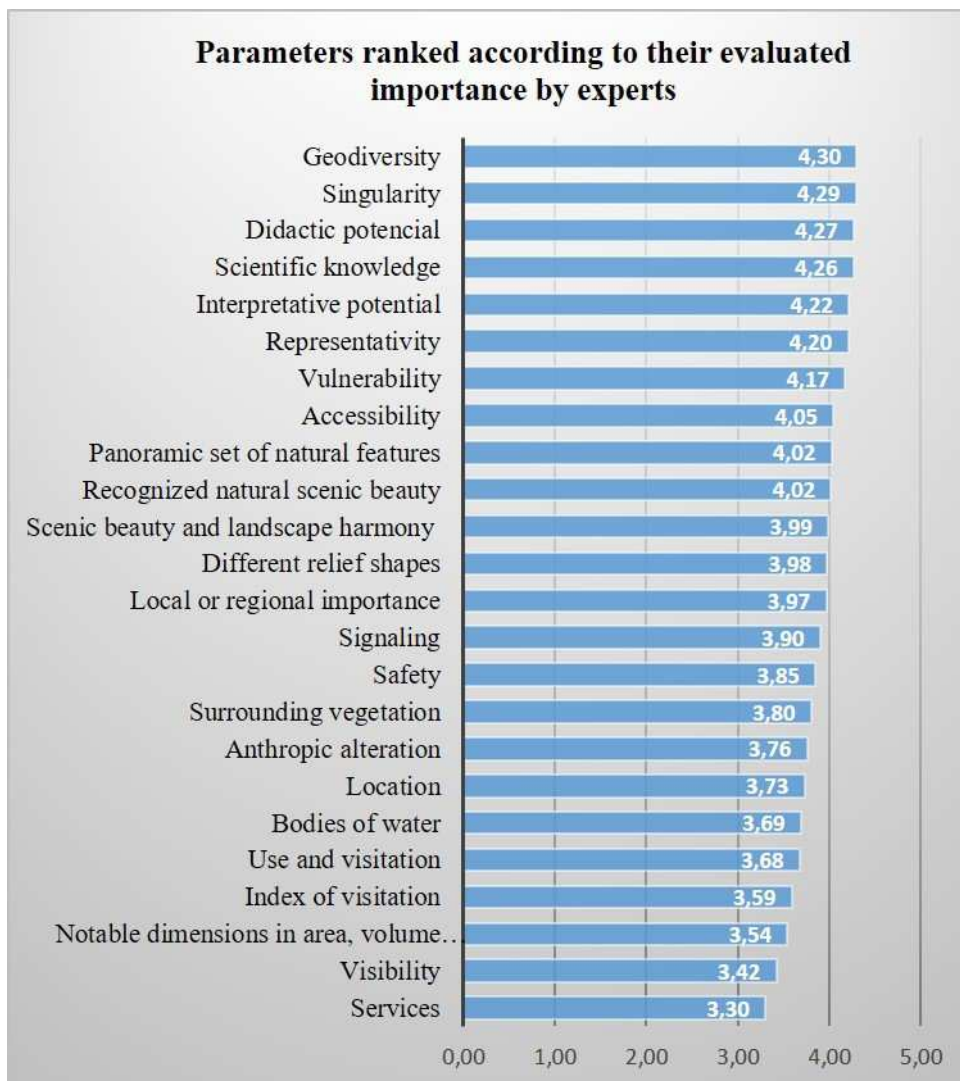


Figure 3 Parameters ranked according to their evaluated importance by experts.

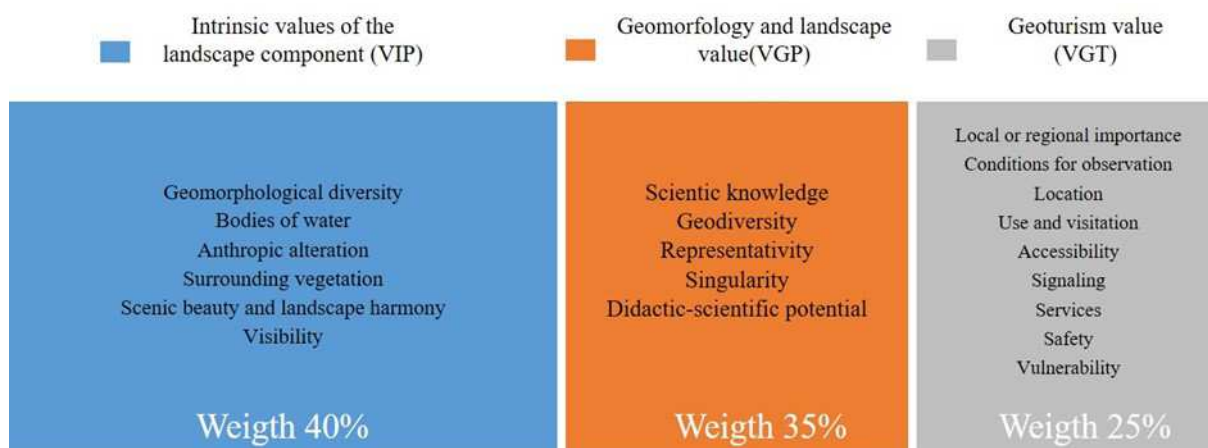


Figure 4 Values attributed to the set of parameters utilized in the assessment of landscapes as geoheritage.

The weight of each was determined through suggestions of the experts, as seen in Figure 3. It was observed that, for instance, the parameters linked to geology, geomorphology, and landscape obtained higher weight in the researchers' opinions than the parameters linked to geotourism. This happens because the determination of characteristics from the scientific perspective of the landscape does not depend on questions related to observation points, which is to say that access and visitation conditions are important for the assessment of the landscape - as seen in the

high percentage of inclusion suggested by the experts - but are not markers of the scientific importance of the landscape.

4.2 Inventory of the Assessment of the Landscape as Geoheritage

The assessment protocol of landscape (Table 1) considered for each parameter a score between 1 and 3, in a decreasing scale from most to least important - as proposed by Oliveira, Salgado and Lopes (2017).

Table 1 Inventory protocol of landscape as geoheritage.

Parameter	Score		
	1 point	2 points	3 points
01 – Scientific knowledge	Scientific works that deal with local landscapes are few and/or scarce. There are works whose focus is not the landscape.	There are articles in national scientific publications, dissertations, thesis, monographs, and other academic works that approach local landscapes.	There are articles about landscapes in direct relation to geology and/or local geomorphology in international scientific publications.
02 – Geodiversity	Landscape with lowest relevance regarding its diversity of geomorphological and geological features within a local context.	Landscape whose geodiversity fits within a context of distinctive and scientifically relevant geological and geomorphological features (relative to the local context).	Landscape whose geodiversity fits within a context of many distinctive and scientifically relevant geological and geomorphological features (relative to the regional context).
03 – Representativity	The landscape does not fit the representative criteria for the region. The geological and geomorphological elements or processes are insufficient for landscape analysis.	The landscape is considered a good expression of the geological and geomorphological elements and processes of the study site.	The landscape is considered the best expression of the geological and geomorphological elements and processes of the study site.
04 – Singularity	The geological and geomorphological elements and processes are found in other natural contexts fairly easily.	There are occurrences of geological and geomorphological elements and processes that can be used as reference to the local and regional context.	There are occurrences of unique geological and geomorphological elements and processes that use the landscape as the best reference to the local and regional context.
05 – Didactic-scientific potential	The landscape is limited regarding the observation, analysis, and interpretation of geological and geomorphological processes. The elements and processes that compose it do not allow for the demonstration and application of concepts linked to the landscape.	The landscape allows the observer to analyze and interpret geological and geomorphological processes, as well as the demonstration and application of concepts linked to the geological and geomorphological elements and processes that compose it.	The landscape is excellent for demonstration and application of concepts related to geological and geomorphological elements and processes, and a great example to observe, analyze, and interpret the local and regional geological and geomorphological context.
06 – Geomorphological diversity	The landscape shows little diversity in the relief shapes where the geological and geomorphological processes happen, which makes its observation and assessment difficult.	The landscape shows different shapes of relief where the geological and geomorphological processes happen, which enables its interpretation and observation.	The landscape shows high levels of diversity in relief shapes where geological and geomorphological processes happen, with a vast content of natural features and geomorphological processes.
07 – Bodies of water	Bodies of water are absent or do not define the formation processes of the landscape.	Bodies of water are present and compose the landscape, altering and promoting geomorphological processes.	Bodies of water are markers of the formation processes of the landscape.
08 – Anthropic alteration	The interference caused by anthropic action promotes the development and alteration of the geological and geomorphological processes in a negative way, making its observation difficult.	The interference caused by anthropic action promotes the development and alteration of geological and geomorphological processes but makes its observation difficult.	The interference caused by anthropic action, when it occurs, promotes the development and alteration of geological and geomorphological processes, in a positive way, evidencing such processes or not altering them. Ease in observing these processes.

Table 1 Cont.

Parameter	Score		
	1 point	2 points	3 points
09 – Surrounding vegetation	The natural vegetation around the landscape is in a state of degradation.	The natural vegetation is found partially preserved, with areas of agricultural occupations, pastures, industrial occupations, etc.	The natural vegetation around the landscape is found preserved.
10 – Scenic beauty and landscape harmony	The contemplation of the landscape, when observing the geoforms, the state of conservation, the contrast of geomorphological elements and colors, and the interaction with other elements, like vegetation or cultural aspects allows us to associate, at certain times, with its description in a negative manner.	The contemplation of the landscape, when observing the geoforms, the state of conservation, the contrast of geomorphological elements and colors, and the interaction with other elements, like vegetation or cultural aspects allows us to associate it, at certain times, with its description in a negative manner, but with elements that, when individually observed, show relative beauty.	The contemplation of the landscape, when observing the geoforms, the state of conservation, the contrast of geomorphological elements and colors, and the interaction with other elements, like vegetation or cultural aspects allows us to associate it, at certain times, with its description in a positive manner.
11 – Visibility	The landscape and its composition (relief shapes and geomorphological processes) can be observed from three different points of view.	The landscape and its composition (relief shapes and geomorphological processes) can be observed from two different points of view.	The landscape and its composition (relief shapes and geomorphological processes) can be observed from a single point of view.
12 – Local or regional importance	The location is relatively little explored by geoscientists and/or tourists.	The location possesses local importance for geoscientists and/or tourists and serves as a reference in relation to the natural environment.	The location possesses regional importance for geoscientists and/or tourists and serves as a reference in relation to the natural environment.
13 – Conditions for observation	Reasonable, with obstacles to the observation and with the need to move to better observe the landscape.	Requires moving to observe the landscape in its totality.	Good conditions of observation of all geomorphological elements.
14 – Location	Location with little or no touristic possibilities in natural, historical, cultural charms, with insufficient urban infrastructure.	Location with touristic possibilities in natural, historical, cultural charms, with basic urban infrastructure.	Location with many touristic possibilities in preserved natural, historical, cultural charms, with efficient urban infrastructure and safety.
15 – Use and visitation	The landscape observed is little explored, and little visited by geoscientists, tourists, and/or the local population.	The landscape observed is little explored, and visited by geoscientists, tourists, and/or the local population	The landscape observed is explored, and frequently visited by geoscientists, tourists, and/or the local population.
16 – Accessibility	Impossible physical and/or financial access to the space, equipment, transportation, information, and the means of communication by any persons.	Limited conditions of physical and/or financial access to the spaces, with safety and autonomy, equipment, transportation, information, and means of communication.	Possibility and conditions of physical and/or financial access to the space and equipment, with safety and autonomy, transportation, information, and means of communication.
17 – Signaling	Absence of signs and symbols, internal or external, in an universal language, with indication of access and information about the region.	Signs and symbols with indication of access and information about the region.	Signs and symbols, internal and external, in a universal language with indication of access and information about the region.
18 – Services	There are no services regarding local structure, like transportation, telecommunications, food, tourism.	The services regarding local structure, like transportation, telecommunications, food, tourism are limited, requiring that the observer make more preparations upon organizing a visit.	There are services regarding local structure, like transportation, telecommunications, food, tourism.
19 – Safety	The location is not safe for groups, requiring special equipment.	The location is not safe for larger groups, but safe for smaller groups, requiring special equipment.	The location is safe and can handle a group of people without requiring special equipment.
20 – Vulnerability	Location without any sort of physical and direct or indirect legal protection. There is a density of aggressive population. There is a proximity to aggressive recreational areas.	Location without any direct or indirect legal protection, but with physical protection. There is a density of population (potential aggression). There is a proximity to recreational areas.	Preserved location, with physical and direct and indirect legal protection. No anthropic threats and the recreational areas do not cause aggression.

We opted to include the value of zero, because, according to the Multi-attribute Utility Theory (Von Winterfeldt & Fischer 1975), the use of this value would accentuate the extremes of the assessment. Therefore, we utilized equations 1, 2 e 3 for the calculation of intrinsic values of the landscape component (VIP), geomorfology and landscape (VGP) and geotourism (VGT).

$$VIP = \sum_{i=1}^n p_i \quad (1)$$

$$VGP = \sum_{i=1}^n p_g \quad (2)$$

$$VGT = \sum_{i=1}^n p_t \quad (3)$$

Where, **VIP** is the intrinsic value of the landscape component; **n** is the number of parameters; **p_i** is the score of importance of each parameter. **VGP** is the geomorfology and landscape value; **n** is the number of parameters; **p_g** is the score of importance of each parameter. **VGT** is geoturismo value; **n** is the number of parameters; **p_t** is the score of importance of each parameter.

For the calculation of the value that corresponds to the analysis of landscape as geoheritage, we utilized the weighted average of the values, as observed in equation 4.

$$PGeo = \frac{VIP \times 40 + VGP \times 35 + VGT \times 25}{20} \quad (4)$$

Where, PGeo is the weighted average of the values analyzed in the landscape; **VIP** is the intrinsic value of the landscape components; **VGP** is geomorfology and landscape value; **VGT** is the geoturismo value.

To simplify the scores of each place of geomorphological interest, we suggest the normalization of data in a decimal number interval that varies between 0 and 1. To do so, we used the minimal value (32) and maximum value (64) obtained in the assessment of landscape via inventory (PGeo); the value of geomorphological landscape (VP_{Geo}) can vary between 0 and 1 and is shown in equation 5.

$$VP_{Geo} = \frac{PGeo - 32}{64} \quad (5)$$

Where, **VPGeo** is the Value of Geomorphological Landscape; **PGeo** is the score of the landscape of each place of geomorphological interest (LIGe);

The development of the methodology results in the final score of the assessment of landscape for places of geomorphological interest (VP_{Geo}), which must be applied to the site to observe the results.

According to the work of Pereira and Nogueira (2015), it is suggested that, in order to assess the geotouristic potential of the study site, a ranking chart be created in which the values are inserted in descending order and then the universe average is calculated. This data must be, therefore, split into categories that divide the geoheritage of the landscape as high potential, low potential, and no potential.

5 Conclusion

The natural landscape, while a collection of geophysical elements and processes at various space-temporal scales, has a high value in geoheritage. Nevertheless, landscapes have received little scientific attention in terms of geoheritage.

The protocol for taking inventory of the landscape as geoheritage was created through literature review and expert consultation and allows for the inventory of places of geomorphological interest which, as a group, can represent the local and/or regional geoheritage from a scientific standpoint.

There is difficulty in reaching consensus among experts about which method and parameters are to be utilized in the assessment of a region's geoheritage. Therefore, some works have in common the adaptation of methods for specific constructions according to the subject-matter, studied region, and even work scale.

The contribution of the experts accomplished through the *Delphi* method was fundamental for the construction of this inventory. Additionally, the proposal uses parameters that were already commonly applied in studies whose objectives are linked to geoconservation.

Therefore, we suggest the use of this inventory to places of geomorphological interest to promote geotourism, especially that of scientific character.

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Author contributions

Stênio Toledo Nascimento: conceptualization; methodology; validation; formal analysis; writing-original draft; visualization. **Paulo de Tarso Amorim Castro:** methodology; validation, writing – review and editing; supervision.

Conflict of interest

The authors declare no potential conflict of interest.

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