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GEODIVERSITY OF THE MUNICIPALITY OF JARDIM, IN THE STATE OF CEARÁ, BRAZIL

Geodiversidade do municipío de Jardim, no estado do Ceará, Brasil

Geodiversidad del municipio de Jardim, en el estado de Ceará, Brasil

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ABSTRACT

Considering the importance of Geodiversity for its values, this article aims to evaluate the scientific and didactic potential present in the geodiversity of the municipality of Jardim, in the state of Ceará. In the field stage, places of relevant interest in the municipality's geodiversity were selected, which were visited and field work was carried out in each one, going through the stages of inventorying, qualification and quantification. The inventory of the geodiversity of the municipality of Jardim, consisted of 7 (seven) places of relevant interest, which were: the Boca da Mata Springs, the Bica da Boa Vista, the Cruzeiro do Padre Cícero, the Pontal Mãe Baióca, the Science Museum Natural and History Barra do Jardim, the Cruzeiro São José and Sobradinho and a quantification based on scientific and didactic values.

Keywords: Geoconservation; Inventory; Cariri.

RESUMO

Considerando a importância da Geodiversidade por seus valores, esse artigo tem por objetivo avaliar o potencial científico e didático presente na geodiversidade do município de Jardim, no estado do Ceará. Na etapa de campo foram selecionados locais de relevante interesse da geodiversidade do município os quais foram passando pelas etapas de inventariação, qualificação e quantificação. O inventário da geodiversidade do município de Jardim, constou com 7 (sete) locais de relevante interesse, que foram: as Nascentes Boca da Mata, a Bica da Boa Vista, o Cruzeiro do Padre Cícero, o Pontal Mãe Baióca, o Museu de Ciências Naturais e de História Barra do Jardim, o Cruzeiro São José e Sobradinho e uma quantificação baseada nos valores científicos e didáticos.

Palavras-chave: Geoconservação; Inventário; Cariri.

RESUMEN

Considerando la importancia de la Geodiversidad por sus valores, este artículo tiene como objetivo evaluar el potencial científico y didáctico presente en la geodiversidad del municipio de Jardim, en el estado de Ceará. En la etapa de campo se seleccionaron lugares de interés relevante en la geodiversidad del municipio, los cuales fueron visitados y se realizó trabajo de campo en cada uno, pasando por las etapas de inventariado, calificación y cuantificación. El inventario de la geodiversidad del municipio de Jardim, constó de 7 (siete) lugares de interés relevante, que fueron: el Naciente de Boca da Mata, el Bica da Boa Vista, el Cruzeiro do Padre Cícero, el Pontal Mãe Baióca, el Science Museo Natural e Historia Barra do Jardim, el Cruzeiro São José y Sobradinho y una cuantificación basada en valores científicos y didácticos.

Palabras llave: Geoconservación; Inventario; Cariri.

1 INTRODUCTION

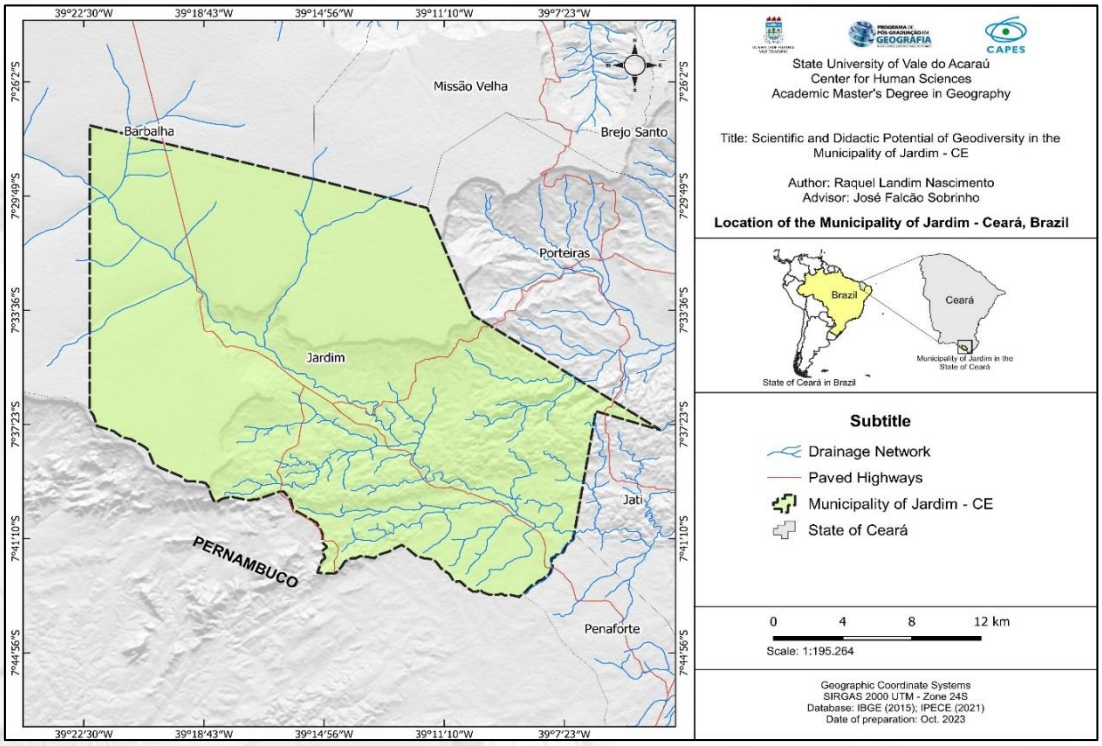
The Cariri Region in Ceará has a widely known uniqueness, considering its insertion in the semiarid northeastern Brazil. Such recognition is due to the areas and sub-areas of hydroclimatic exception (Guerra, 2019), which receive a direct influence from the Araripe Plateau. The latter, in turn, is one of Ceará's most prominent morphostructural units, characterized by its geological complexity, originating in the Araripe Sedimentary Basin (Meireles, 2005).

However, the municipality of Jardim, which stands out (Figure 01) in the middle of this remarkable setting, remains relatively underexplored concerning studies and research. Jardim is notable for its geodiversity, which encompasses several minerals, rocks, fossils, and landscapes. Developing effective strategies for protection and enhancement is necessary due to the geological and geomorphological heritage.

The municipality of Jardim in southern Ceará has 544,980 km² inside the Cariri Metropolitan Region (CMR), 537 km away from the capital Fortaleza. Porteiras, Missão Velha, and Barbalha border it to the North, Pernambuco to the South, Penaforte, Jati, and Porteiras to the East, and Barbalha to the West.

The geodiversity in Jardim represents a natural resource of great relevance and potential, although it has remained little explored regarding research and management. The situation raises the question: "How can Jardim's geodiversity be properly valued and managed sustainably, considering its geological, geomorphological, and hydro-geological aspects?"

Figure 01 – Location map of the municipality of Jardim - CE



Elaboration: The authors.

Geodiversity is a significant component of the natural environment with direct impacts on the quality of life of local communities and the preservation of ecosystems. In Jardim, the geological and geomorphological wealth offers a valuable scientific heritage and socio-economic opportunities, including the development of geological tourism and the sustainable use of mineral resources.

Despite its potential, Jardim's geodiversity faces significant challenges due to the lack of in-depth studies and effective management strategies. The lack of detailed information on geological and geomorphological resources limits the planning and decision-making for the conservation and responsible use of such elements.

Therefore, studies and actions promoting appreciation and responsible management of the local geodiversity would contribute to preserving nature and stimulating sustainable development, which would provide economic, cultural, and environmental benefits.

In this context, intending to promote the conservation and enhancement of geodiversity, the research attributes various values, including intrinsic, ecological, human, economic, functional, aesthetic, scientific, educational, and cultural ones (Sharples, 2002; Gray, 2004; 2005; Brilha, 2005).

The main aim of this study is to assess the scientific and educational potential of the geodiversity of the municipality of Jardim in Ceará.

2 METHODOLOGY

According to Gil (2008), scientific research depends on a set of intellectual and technical procedures. Thus, for the development of this research, the methodological process was qualitative and quantitative, following an office stage, field activities, and laboratory activities.

To study geodiversity from a theoretical and methodological perspective, a variety of authors served as guides, such as Sharples (2002), Gray (2005), Brilha (2005, 2010), Pereira (2010), and Nieto (2021).

The field activities enabled the assessment of the local geodiversity potential, which made it possible to set up the inventory by identifying the potential geological/geomorphological sites of relevant interest (SRI). A qualitative assessment and characterization happened before the quantification stage.

That said, some specific sites were chosen using the Ad Hoc technique described by Sharples (2002), based on site identification and selection according to the potential, which was possible by consulting published materials, such as Silva (2016), Nascimento and Moura Fé (2016), and Nascimento et al. (2019). Successive fieldwork and extensive conversations with actors living in the study locality happened after.

The inventory recognized the main geodiversity elements, interpreted the local geology and geomorphology, selected and descriptively described the sites, and defined cartography with photographic records.

After identifying the sites of interest for the inventory, the second stage dealt with the qualitative detailing of the SRI. To this end, systematized conversations were held with residents and tourists to obtain information on, for example, the historical and cultural values of the area. In addition, this stage of the inventory involved filling out cataloging forms (Table 01), adapted from researchers such as Pereira (2006, 2010), Oliveira (2015), and Lopes (2017), to describe and characterize the study area.

Table 01 – Field classification form to compose the qualification Places of Relevant Interest (LRI) of the municipality of Jardim - CE

CHARACTERIZATION SHEET OF PLACES OF RELEVANT INTEREST	
Date:	
GENERAL CHARACTERIZATION	
LRI Name:	
Altitude:	**Geographic Coordinates:**
Legal Framework: None ( ) Sustainable Use ( ) Full Protection ( )	
Location Type: ( ) Isolated ( ) Area ( ) Panoramic	
MAIN RATING:	
Aesthetic Value: Low ( ) Medium ( ) High ( ) Very High	
Cultural Value: Low ( ) Medium ( ) High ( ) Very High ( )	
Functional value: Low ( ) Medium ( ) High ( ) Very High ( )	
Didactic/scientific value: Low ( ) Medium ( ) High ( ) Very High ( )	
Economic value: Low ( ) Medium ( ) High ( ) Very High ( )	
Anthropogenic vulnerability: low ( ) medium ( ) high ( ) very high ( )	
Natural Vulnerability: Low ( ) Medium ( ) High ( ) Very High ( )	
Observation Condition: Good ( ) Fair ( ) Poor ( )	
Conservation Status: Good ( ) Fair ( ) Poor ( )	
Accessibility: ( ) Difficult ( ) Moderate ( ) Easy	
DESCRIPTION OF THE ELEMENTS OF GEODIVERSITY	
CURRENT USAGE	
PHOTOGRAPHS	

Source: Pereira (2006, 2010), Oliveira (2015) e Lopes (2017).

It is worth emphasizing that aiming quantification, according to Lima (2008), indicates potential uses that the geodiversity site may have, be it scientific, didactic, or recreational. In addition, this assessment can indicate the inherent nature of each site, whether due to natural or human factors. In this respect, the methodological approach considered Brilha (2015) and CPRM (2016) (Table 02), adapting them according to the central objective of the research. Therefore, the criteria for conservation strategies, especially geoeducation and geotourism, were i) scientific with six parameters and ii) didactic with eight parameters.

Table 02 – Parameters to be assessed in the quantification process.

PARAMETERS FOR QUANTIFYING SCIENTIFIC VALUE	
PARAMETER	DESCRIPTION
1. Representativeness;	the ability of a geosite to illustrate geological elements or processes (related to the geological thematic category under consideration).
2. Scientific knowledge;	existence of studies and scientific publications on the Geosite (related to the geological framework under consideration);
3. Integrity;	related to the conservation status of the main geological elements;
4. Geological diversity;	high number of different geological elements of scientific interest;
5. Rarity;	small number of similar sites in the study area;
6. Limitations of use.	existence of obstacles that could be problematic for the regular scientific use of the geosite.
PARAMETERS FOR QUANTIFYING DIDACTIC VALUE	
PARAMETER	DESCRIPTION
1. Didactic potential;	Didactic use of the site by students at different levels of education;
2. Variety of Geodiversity;	High number of different elements with didactic potential;
3. Vulnerability;	Existence of elements that could be destroyed by students;
4. Accessibility;	Where the easiest and shortest access is on foot, among the means of transportation that the site has;
5. Limitations of use;	Existence of obstacles that could be problematic for the development of educational activities and have an impact on the site;
6. Safety;	When the field activity can be carried out under low-risk conditions for the students;
7. Association with other values;	The existence of other natural or cultural elements associated with the site that could justify interdisciplinary field lessons;
8. Observation conditions.	Conditions for observing all the site's geodiversity elements.

Source: Adapted from Brilha (2015) and CPRM (2016).

Values were assigned to each of the parameters mentioned (Table 03). The assigned values for each parameter range from 1 to 3 depending on their characteristics. Thus, the researchers added them together to obtain the result, and the greater the sum, the greater the scientific and didactic potential of the evaluated SRI.

Table 03 – Parameters and values for the quantitative assessment of geodiversity sites in Jardim, Ceará.

Criterion 1 Scientific	**Assigned value 3**	**Assigned value 2**	**Assigned value 1**
Representativeness	It is the best example in the field of work to illustrate elements or processes related to the subject area in question.	It is a good example to illustrate elements or processes related to the subject area in question.	The site of interest reasonably illustrates elements or processes related to the subject area in question.

Scientific knowledge	There are articles about the site of interest in books and scientific journals.	There are articles about the site of interest in the proceedings of scientific events, or unpublished reports.	There are abstracts presented on the site of interest in the proceedings of scientific events.
Integrity	The main geological/geomorphological elements are very well preserved.	The site of interest is not very well preserved, but the main elements are still preserved.	The site of interest has preservation problems and the main elements are altered or modified.
Geological/geomorphological diversity	Site of interest with 5 or more different types of scientifically relevant features.	Site of interest with 3 or 4 different types of scientifically significant features.	Site of interest with 1 or 2 different types of scientifically relevant aspects.
Rarity	The site of interest is the only occurrence of its kind in the study area.	There are 2-3 examples of similar sites in the study area.	There are 4-5 examples of similar sites in the study area.
Limitations to use	There are no limitations (need for authorization, physical barriers, etc.) to carrying out sampling or fieldwork.	It is possible to carry out sampling or fieldwork once existing limitations have been overcome.	It is very difficult to carry out sampling or fieldwork due to the existence of limitations.
Criterion 2 Didactic value	**Value assigned 3**	**Value assigned 2**	**Value assigned 1**
Didactic potential	Can be used for didactic purposes by an audience of any level.	Can be used for teaching purposes by a specialized audience.	Low didactic relevance.
Variety of geo-diversity	High diversity	Moderate diversity	Low diversity
Vulnerability	The elements of the site of interest have no possibility of deterioration.	Possibility of deterioration of secondary elements due to human activity.	Possibility of deterioration of the main elements due to human activity.
Accessibility	The site of interest IS less than 500 m from a paved road.	Site of interest accessible by vehicle on an unpaved road.	Site of interest without direct access by road, but located less than 1 km from a road accessible by vehicle.
Limitations of use	The place of interest has no limitations for use by students and tourists.	The place of interest can be used by students and tourists, but only after overcoming certain limitations.	Use by students and tourists is very difficult to achieve due to the difficulty in overcoming certain limitations.
Safety	Site of interest with safety infrastructure and located less than 25 km from rescue services.	Place of interest with no safety infrastructure and located less than 50 km from rescue services.	Site of interest without safety infrastructure located more than 50 km from rescue services.

Association with other values	There are several ecological and cultural values within 20 km of the site of interest.	There is one ecological and cultural value within 20 km of the site of interest.	There is a cultural value within 20 km of the site of interest.
Observation conditions	All elements are observed in good condition.	Some obstacles make it difficult to observe the main elements.	Some obstacles make it practically impossible to see the main elements.

Source: Adapted from Oliveira (2015) and CPRM (2016).

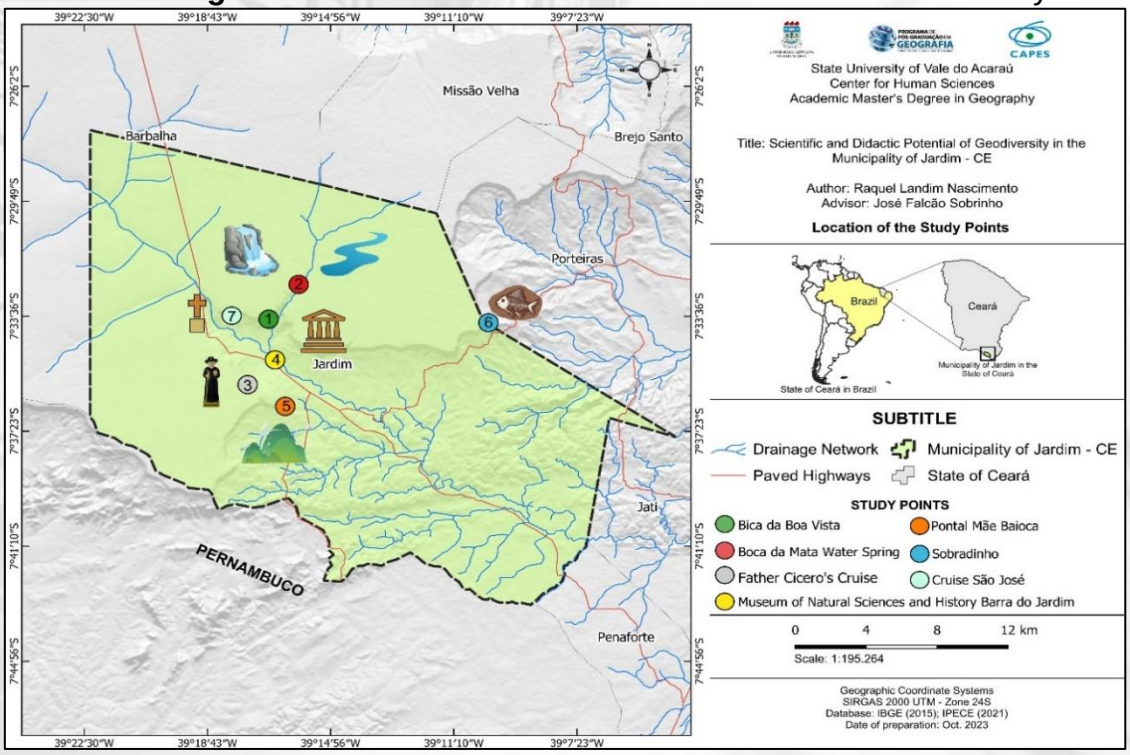
The ranking of scientific and educational potential is as follows: values from 0 to 14 = low, from 15 to 29 = medium, and from 30 to 42 = high scientific and educational potential, whereby the medium and high potential values should receive valuation and publishing. Such a stage resulted in a geodiversity ranking containing the score and position of each inventoried SRI.

3 RESULT AND DISCUSSION

3.1 Inventory stages: Qualitative assessment

The theoretical and methodological approach enabled the identification and analysis of the diversity in the geodiversity of Jardim. The points and their respective description are on the map below.

Figure 02 – Sites of Relevant Interest in Garden Geodiversity



Elaboration: the authors.

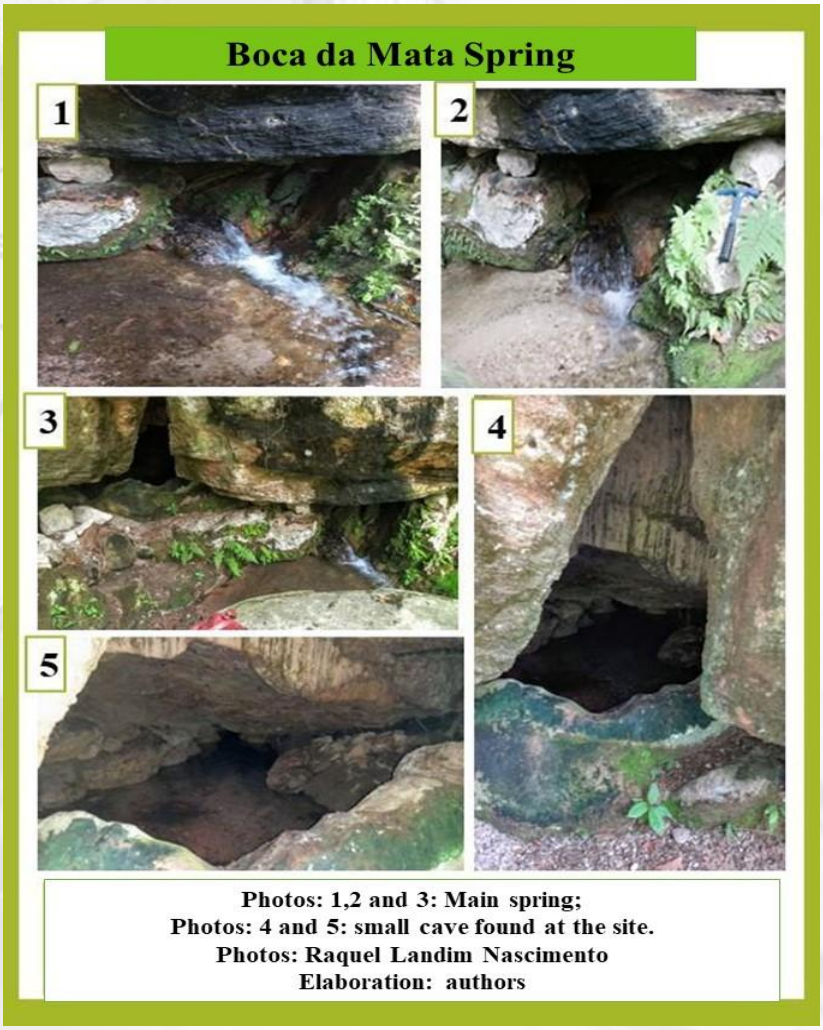
3.1.1 Boca da Mata Springs

Boca da Mata Springs is at the foot of the Boca da Mata Mountains – 4 km from the urban area of Jardim, Ceará. In addition to the relief, the local springs are significant for the public supply of the municipality and districts since it is where the highest flowing spring is.

The principal spring is home to the Serviço de Abastecimento de Água e Esgoto (Water Supply and Sewerage Service, SAAE). At an altitude of 752 meters, there are other springs besides the principal one, some of which have stopped flowing. There is also a natural underground sandstone cavity (cave), which forms the primary spring.

The spring location and its surroundings are part of a specific legal framework as a permanent preservation area (PPA) contained in the Forest Code Law No. 12.651/2012 (BRASIL, 2012), article 3, and in CONAMA resolution 303/02 (BRASIL, 2002), which consider the 50m radius around the springs as a PPA, prohibiting its use for any purpose.

Figure 03 – Boca da Mata Jardim Spring - CE



Elaboration: the authors.

Accessing the site is difficult since it is not open to the public. The poor state of conservation is due, among other things, to the lack of local supervision and a plan for water management and the springs as a whole. Anthropogenic vulnerability is high, as is natural vulnerability, and the observation conditions are poor.

Boca da Mata Mountains comprise a significant part of the site, making it possible to see the sandstone rocks in rocky walls and blocks on a path that leads to the Boca da Mata Springs. On the other hand, the lack of signposts and improvements to the trail need mention and remediation, as they make accessibility difficult.

Boca da Mata Springs has significant scientific value regarding their formation and natural and ecological importance for the local population. However, due to the inaccessibility, local fieldwork was not possible.

3.1.2 Boa Vista Waterfall

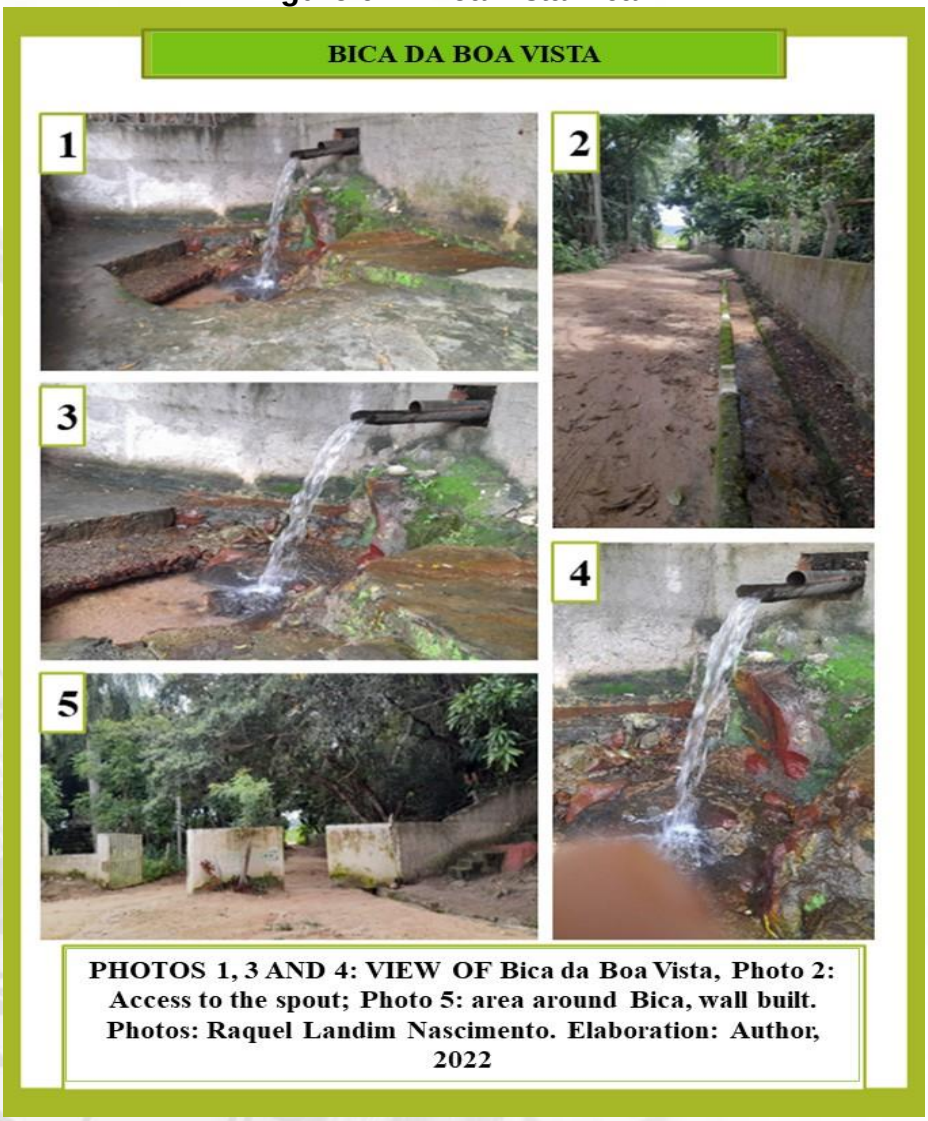
Located in Boa Vista, approximately 3 km from the urban area of the municipality of Jardim, Boa Vista Mountain is a well-known landmark not only locally but also in the surrounding areas. This highlight is due to the Boa Vista Waterfall, which originates from a spring that emerges at the foot of the mountain and has become an established tourist attraction over the decades.

Boa Vista Waterfall is at an altitude of 736 meters and receives daily visits. Its surroundings have been carefully developed with concrete structures, including a bar, offering visitors a panoramic view of the Boa Vista and Boca da Mata Mountains. In addition, a trail takes those interested in Boca da Mata Mountain and its springs.

The values associated with geodiversity in the area are remarkable. From an economic point of view, the site has high potential due to the tourism it attracts and the activities carried out there. In aesthetic terms, despite the modifications made, the local natural beauty remains an undeniable attraction. From an educational and scientific point of view, it provides a unique opportunity to understand geological and hydrological aspects related to the formation of the main spring. In cultural terms, Boa Vista Waterfall holds significant identity value for the local community.

The high anthropogenic vulnerability indicates the need for careful management to preserve this heritage. On the other hand, the natural one is medium, having observation conditions, reasonable conservation, and accessibility for visitors.

Figure 04 – Boa Vista Bica



Elaboration: The authors.

3.1.3 Padre Cícero Crossing

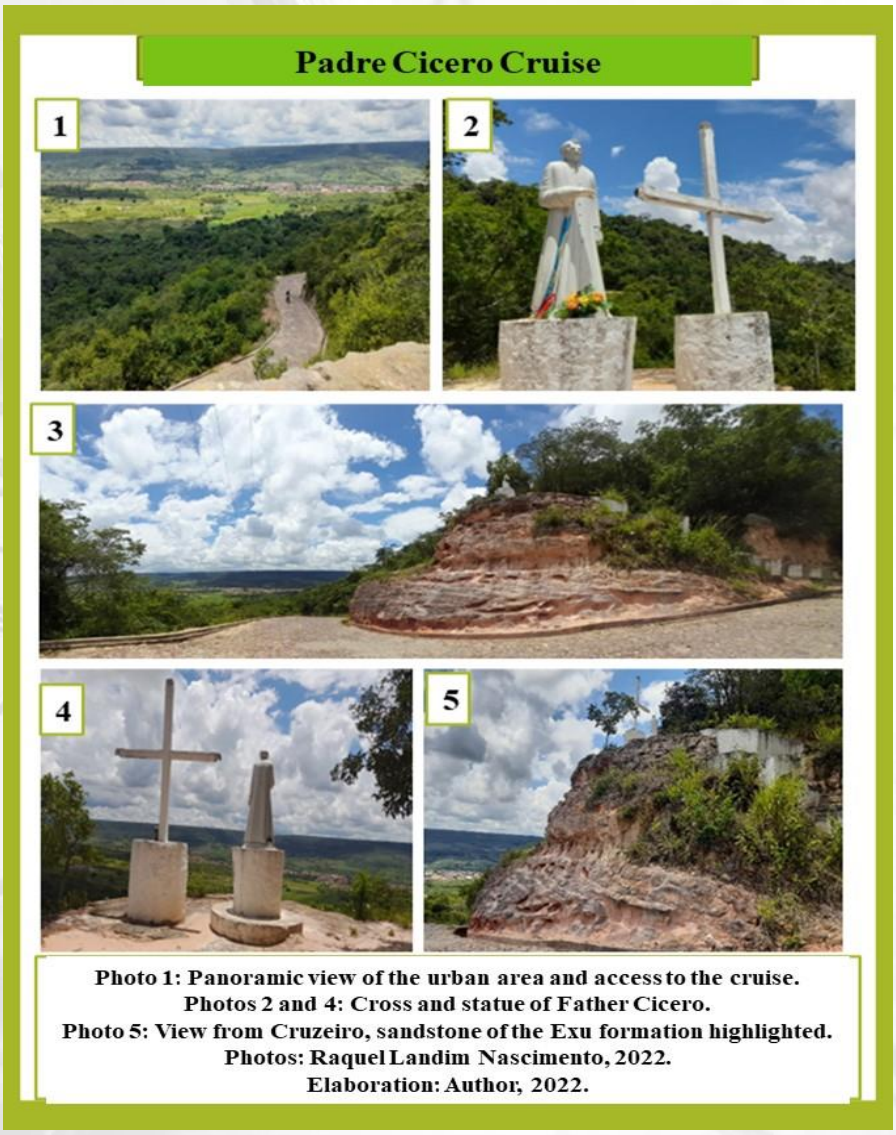
Padre Cícero Crossing is in Olho d'água Mountains, located on the site of the same name, approximately 4 km from the urban area of the municipality of Jardim, in the state of Ceará. A perennial spring that used to exist there names the place, but it is now intermittent due to improper water use.

The Padre Cícero Crossing region, located at an altitude of 736 meters, attracts visitors daily due to its infrastructure geared towards tourism. The site has concrete walls and a small bar offering a panoramic view of the Boa Vista and Boca da Mata Mountains. A trail takes visitors to Boca da Mata Mountain and its springs.

The high anthropogenic vulnerability due to intense visitation requires careful management for preservation. On the other hand, the natural one is medium, having observation conditions, reasonable conservation, and easy accessibility for visitors.

Padre Cícero Crossing was erected in 1950 by the Gavião family and also houses the Padre Cícero and Our Lady of Sorrows Statues on the initiative of the then mayor, Dr. Fernando Luz. On the way up Olho d'água Mountain, on the red sandstone of the shallowest formation of the Araripe Plateau, there is a statue of the priest, a cross, and images of Catholic saints, all carved into the stone.

Figure 05 – Padre Cícero Cruise



Elaboration: the authors.

Padre Cícero Crossing is at an altitude of 821 meters and has no specific legal framework. It is a panoramic site with excellent observation conditions, well preserved and easily accessible, where it is possible to see the urban area of Jardim and Boca da Mata and Boa Vista Mountains. The values that stand out in this area are aesthetic due to its beauty and panoramic view, the cultural and religious, and the educational and scientific since it houses relevant rock formations and relevance in the context of the local relief.

3.1.4 Mãe Baiocá Headland

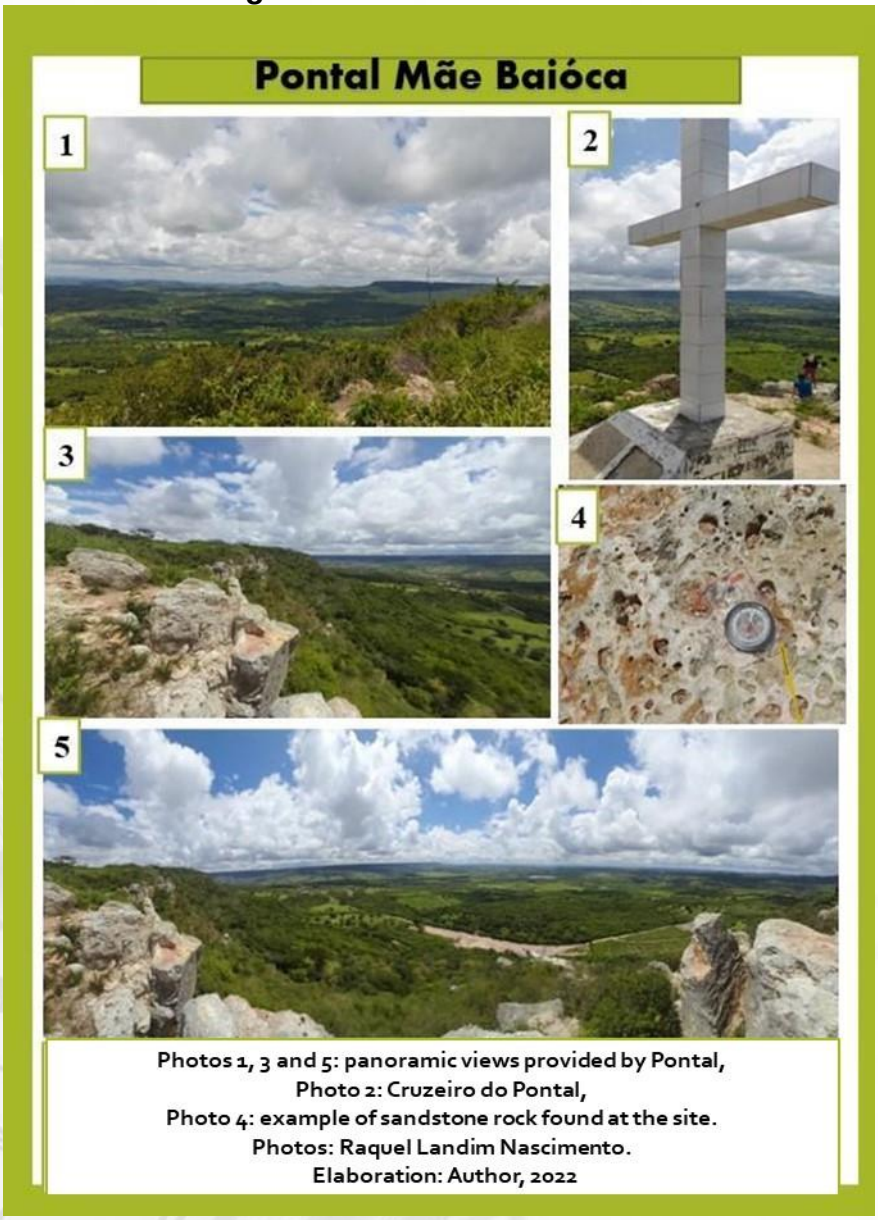
Continuing up Olho d'água Moutain, you come across Mãe Baióca Headland (Figure 06), located at an altitude of 870 meters. An influential local family, Couto, erected a cross in honor of Dona Baióca, a local respected matriarch. Oral tradition says that, after her death, the place received her name, according to residents. Dona Baióca was a caring woman who dedicated her life to helping others. The point offers breathtaking views and is ideal for free-flying.

In the headland, the geodiversity elements that stand out are mainly the relief and geology, providing a panoramic view of the urban area of Jardim, Araripe Plateau, and the flattened surface, a characteristic of the hinterland depression. Also noteworthy are the Exu Formation (sandstone) rocks, with blocks of different sizes visible on-site, and the Yellow-Red Latosol soil.

Specific legal frameworks are not visible in the headland, whose panoramic view offers observation conditions besides having easy accessibility. Concerning the geodiversity values, the aesthetic, cultural, scientific, and didactic are high, the functional values are low, and the economic values are medium.

The local conservation state is reasonable since it is open to visitors and tourists. However, the exposed soil due to the need for access has caused devastation of some of the vegetation. In addition, waste such as bottles, glass, and plastic, among others, was found scattered at various points (Figure 06), which emphasizes the need to implement geoconservation strategies. Also noticeable is the lack of signposts and information boards about the historical and natural aspects, besides the absence of garbage cans to keep the site clean and preserved.

Figure 06 – Pontal Mãe Baióca



Elaboration: the authors.

3.1.5 Sobradinho

Sobradinho, which is in the rural area of Jardim, on the edge of the Araripe Plateau, is a significant paleontological site. It has inestimable scientific value and hundreds of fossils of various species collected along the slopes and at the top of the Araripe Plateau.

During the visit, the two explored points contained preserved fossils in the sandstone and shale of the Romualdo Formation, belonging to the Santana Group, from the Lower Cretaceous of the Araripe Sedimentary Basin. Most of these fossils are in massive calcarenite concretions of three types: aphosiliferous, unifossiliferous, and multifossiliferous,

with solidified fossil organisms varying between 10 and 20 centimeters interspersed in the shale (Figure 07).

Most of these fossils go to the Barra do Jardim Museum of Natural Sciences and History (MCNHBJ), while others go to the Santana do Cariri Museum of Paleontology. Concerning the conservation state, some excavation sites require greater attention, signposting, and even surveillance, given their deterioration. The absence of specific legal frameworks characterizes the area with reasonable observation conditions but challenging access.

Figure 07 - Sobradinho Paleontological Site

Elaboration: the authors.

The most notable geodiversity values are the scientific and educational, which are high, while the others are from medium to low. Therefore, preservation and care measures

are essential to guarantee the integrity of this scientific and educational heritage of incalculable value.

3.1.6 Barra do Jardim Museum of Natural Science and History

The Barra do Jardim Museum of Natural Sciences and History (BJMNSH), located in the urban area of Jardim, Ceará (Figure 08), opened its doors on October 27, 2001, by the Francisco de Lima Botelho Foundation. It aims to rescue and promote local memory by disseminating cultural and natural heritage, bringing together a paleontological collection with 375 listed specimens (Coutinho et al., 2021). The author argues that the assembling of fossils that make up the collection began in 1990, and most of them came from donations from the community, which, after being informed about the scientific and cultural value of natural heritage, began to appreciate the local fossils more.

Figure 08 – Some species from the MCNHBJ fossil collection

Elaboration: the authors

According to these authors, the fossil collection is:

> It consists of vertebrate fossils – fish (58%), pterosaurs (4%), and testudines (2%) –, arthropods – insects (4%), shrimp (4%), and ostracods (7%) –, plants – gymnosperms (9%) –, ichnofossils (6%), mollusks – gastropods and bivalves (3%) –, and around 3% of the collection has no information on a group (Coutinho et al., 2021 p.3).

According to Nascimento et al (2019, p.4), one of the best-known fossils is of the AraripePenaeus Timidus shrimp species, which belongs to the Romualdo Formation, more than 110 million years old, dating from the lower Cretaceous period, relevant because it is the smallest shrimp fossil found in Brazil, thus giving even more prominence to the Cariri Region, the Araripe Sedimentary Basin and the municipality of Jardim.

Fieldwork – such as recognition of areas through practice with knowledge about the history and evolution of the Earth – could happen at the museum. The high values were scientific, didactic, and cultural, while local identity and aesthetics were medium.

The museum's anthropogenic vulnerability is medium, while the natural one for the fossils is high, especially in some pieces (such as limestone concretions and preserved cartilage species), requiring care for their preservation. The museum, on the other hand, has well-preserved pieces, but it requires investment and renovation.

3.1.7 Gravatá Mountain and São José Crossing

Located on the site that bears its name, Gravatá Mountain (Figure 09) has access through the highway CE-060, which connects Jardim and Barbalha, both in Ceará. Along this route, the mountain stands out, displaying its reddish sandstone rock from the Araripe Sedimentary Basin.

Among the environments that stand out for the remarkable geodiversity are the springs and the crosses carved into the mountain slopes, such as the recently inaugurated São José Crossing (April 2022). Such a religious landmark symbolizes the Christian faith, bringing together pilgrims and tourists at different times of the year, just like the other sites already mentioned.

The values associated with such a region are distinct and relevant, especially the aesthetic – highlighted by its natural features of significant beauty – and cultural – linked to the religious presence. The scientific and educational – related to the potential for studying the geological formations present – and the economic are medium. No specific legal

frameworks were visible for the site, which is panoramic with excellent observation conditions and easy access.

São José Crossing maintains a satisfactory conservation state, even though it is open to the public. It mainly happens because the locals preserve the space. Signposts, notices prohibiting the disposal of garbage in the area, and the existence of an accessible trail contribute to its conservation. Overall, the site is suitable for educational activities, has substantial scientific value, and offers stunning views, making it a highlight in the region.

Figure 09 - San Jose Cruise

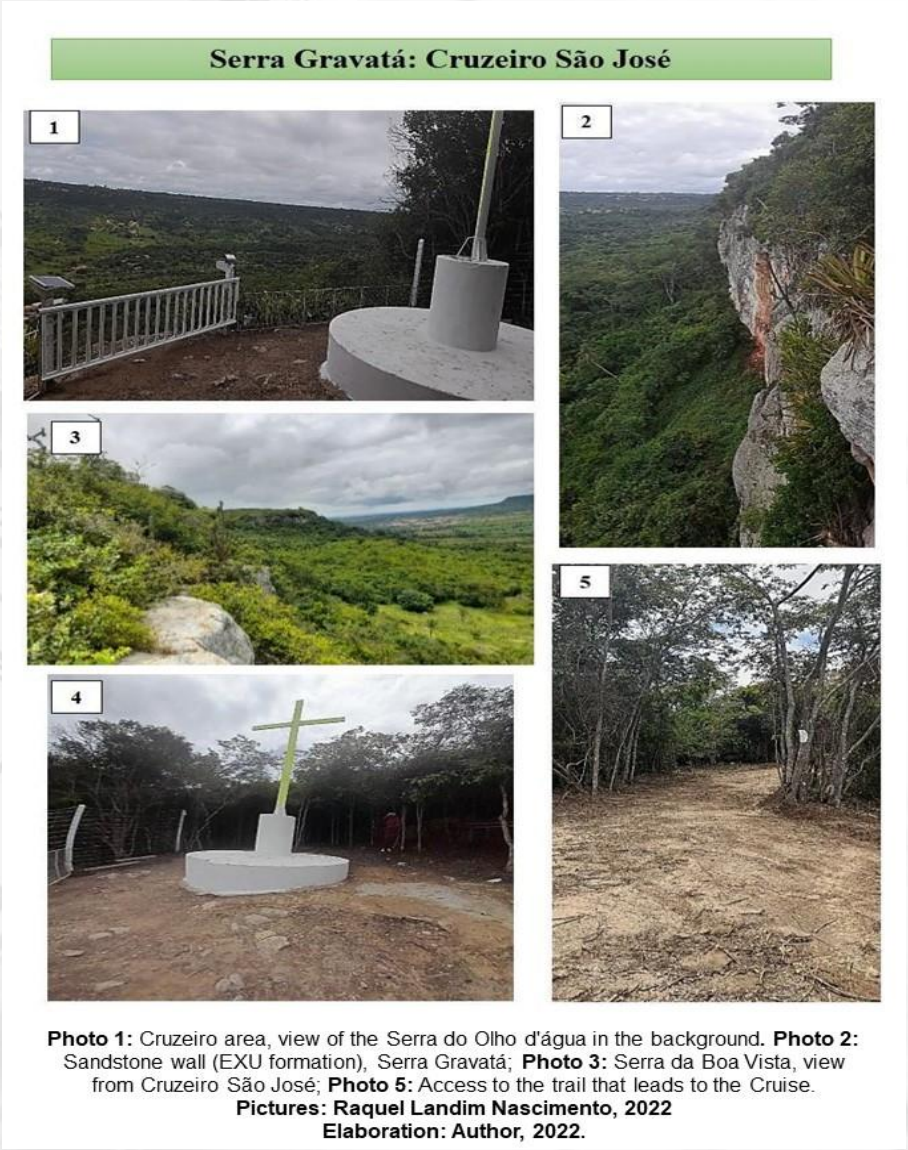


Photo 1: Cruzeiro area, view of the Serra do Olho d'água in the background. **Photo 2:** Sandstone wall (EXU formation), Serra Gravatá; **Photo 3:** Serra da Boa Vista, view from Cruzeiro São José; **Photo 5:** Access to the trail that leads to the Cruise.
Pictures: Raquel Landim Nascimento, 2022
Elaboration: Author, 2022.

Elaboration: the authors.

3.2 Quantification

According to Brilha (2005), the geodiversity sites of interest must undergo quantification and ordering right after the inventory. Thus, quantification is a tool that aids the process of managing geomorphological heritage, especially in terms of its dissemination and appreciation.

From this assumption, the quantitative evaluation of SRIs used scientific and didactic criteria, the former with six parameters and the latter with eight, receiving values from one to three. According to Oliveira (2015), sites with medium or high scientific and didactic potential should present proposals for enhancement and dissemination.

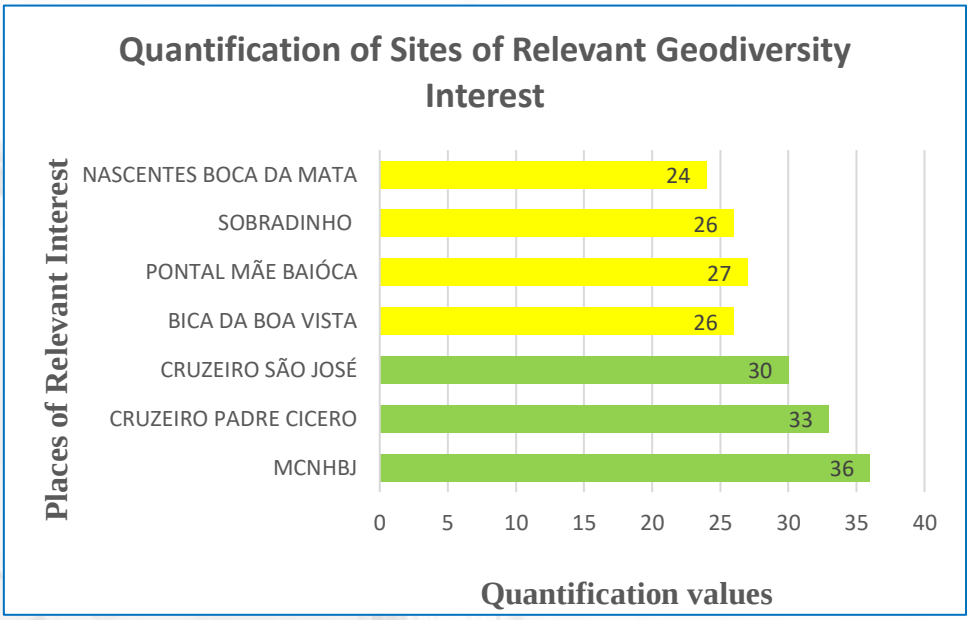
Thus, the evaluation result corresponded to the sum of the assigned values to each parameter. The organization concerning scientific and didactic potential is as follows: sites of relevant interest ranging from 0 to 14 are low (red), from 15 to 29 are medium (yellow), and from 30 to 42 are high (green).

According to table 01, a ranking of the SRI potential can be established from the highest potential to the lowest (Figure 10). Thus, most of the sites of relevant geodiversity interest (4) are classified as having medium scientific and educational potential (values from 15 to 29), namely Sobradinho (26), Mãe Baióca Headland (27), Boa Vista Waterfall (26), and Boca da Mata Springs (24). The ones with high values are Barra do Jardim Museum of Natural Sciences and History (36), Padre Cícero Crossing (33), and São José Crossing (30).

The Barra do Jardim Museum of Natural Sciences and History has a high scientific and educational potential, being the most valuable among the others due to terms of scientific criteria. Its representativeness illustrates the wealth of paleontological records found in the municipality and its scientific knowledge, which has appeared in scientific journals, in addition to the fact that the fossils in the museum are well-preserved, diverse, and rare. As far as the didactic aspect is concerned, it stands out for the possibility of being used for didactic purposes by audiences of any level: children, teenagers, and adults; it has good accessibility, safety, and association with other elements of geodiversity.

Padre Cícero Crossing is the next with high potential, standing out in the didactic criterion since it is an environment conducive to carrying out didactic activities, such as field lessons, with a diversity of rocks, highlighting the relief, accessibility, no limitations on use, and observation conditions. Concerning scientific criteria, this SRI is an example to illustrate the local soil. Articles about it in annals of scientific events reveal that elements of geodiversity are well-preserved.

Figure 10 – Quantification of scientific and didactic values of the Sites of Relevant Interest of Geodiversity in the municipality of Jardim - CE



Elaboration: the authors.

São José Crossing, which has high scientific and educational potential, had a maximum value in five parameters: two in the scientific criterion, which were integrity, the principal geological/geomorphological elements being well-preserved, and limitations of use, as there are no limitations (need for authorization, physical barriers, among others) to carry out sampling or fieldwork. As for its representativeness and scientific knowledge, the low values are due to the recent inauguration of the point, which no one knew until recently.

The criterion that stood out at São José Crossing was the didactic potential, used for such purposes by the public at any level, the limitations of use, as this SRI has no restriction for use by students or tourists, and the observation conditions, in which all the elements are in good observation conditions at the site.

Boa Vista Waterfall and Mãe Baióca Headland have medium scientific and didactic potential and stand out regarding accessibility and observation conditions. Boa Despite having limitations in access to Boa Vista Waterfall since it is inside a protected area, it is possible to carry out sampling or fieldwork after complying with existing restrictions so it can favor students and tourists.

Mãe Baióca Headland also stands out for its association with other values, such as ecological and cultural, less than 20 km from the site of interest due to its proximity to Padre Cícero Crossing. Both SRIs have already shown up in scientific articles and have a moderate diversity of geodiversity.

Sobradinho, with medium didactic scientific potential, stands out in terms of the scientific criterion concerning the first parameter, scientific knowledge, which means that there are articles about the site of interest in books and scientific journals. In addition, it is an example to illustrate the fossils, such as several specimens of rare scientific and didactic value.

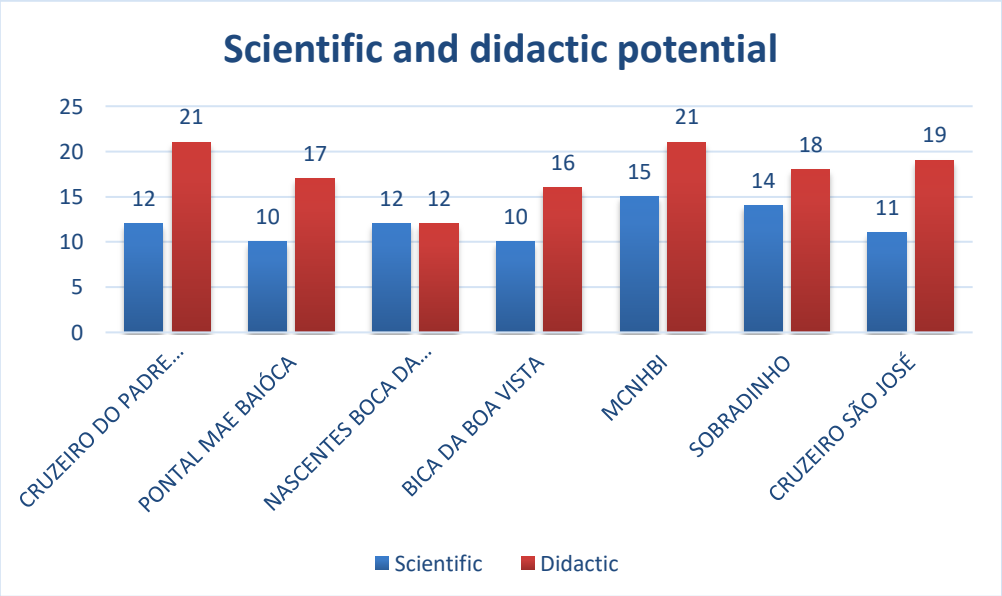
However, its low didactic potential serves only for didactic purposes by a specialized audience, but with improvements in accessibility and reduction in the limitations of use. The site could become an excellent place for didactic activities.

Finally, Boca da Mata Springs has a medium scientific and educational potential. Such a result, however, does not rule out the scientific importance since it is an example for illustrating elements or processes related to the formation of the local springs and appears in articles and chapters of books and dissertations, which reveals the scientific knowledge of the area.

It is relevant to note that, in terms of accessibility, safety, and limitations of use, Boca da Mata Springs has low values since it is not suitable for educational activities, only scientific, as it is a private area surrounded by several old tanks, which could pose a danger to students. However, it is possible to carry out sampling or fieldwork by overcoming the existing limitations.

Some sites usually stand out more in one criterion than another. Thus, in a more detailed analysis, it is possible to look at them individually and their respective values (Figure 11).

Figure 11 – Individualized graph of LRI potential



Elaboration: the authors.

The scientific and educational relevance of such sites is evident, revealing that Boca da Mata Springs, despite the scientific value lower than the others concerning geodiversity, is equal to Padre Cícero Crossing and higher than Mãe Baióca Headland, Boa Vista Waterfall, and São José Crossing. In short, it demonstrates the scientific relevance of the environment. Thus, the non-personalized interpretive media could be significant, such as self-guided trails (using printed interpretive material), folders, field guides, interpretive panels, videos, websites, games, and recreational activities.

Concerning the teaching potential, BJMNSH and Padre Cícero and São José Crossings stand out with equal values, demonstrating planned school activities in such environments. Thus, the personalized means – such as guided trails, folders, excursions, geological tours, and lectures, among others – stand out.

4 FINAL CONSIDERATIONS

The inventory assisted the spot of places in Jardim considering the significant geodiversity. The ad hoc technique helped to identify seven sites of relevance for interpretation (SRI), namely Boca da Mata Springs, Boa Vista Waterfall, Padre Cícero Crossing, Mãe Baióca Headland, Barra do Jardim Museum of Natural Sciences and History, São José Crossing and Sobradinho.

Most sites have an aesthetic value, although the assessment is relatively subjective. The Crossings (Padre Cícero and São José) and Mãe Baióca Headland stand out in this respect. The museum and the Sobradinho stand out for their scientific value, principally because of fossils. The springs have the same value in educational and economic aspects. Boa Vista Waterfall, for example, is a significant tourist attraction for the municipality, contributing to local income generation.

Concerning conservation state, the sites can be good, reasonable, or poor. Three of them are reasonable – Mãe Baióca Headland, Padre Cícero Crossing, and da Boa Vista Waterfall – two are good – São José Crossing and the museum – and two are bad – Sobradinho and Boca da Mata Springs. The latter requires more careful attention from the community and political entities to draw up and implement conservation strategies.

The accessibility varies among the sites, but only Boca da Mata Springs is difficult to access since its location is in a private area far from the municipality with SAAE facilities. As for Sobradinho, accessibility is moderate, and observation conditions are reasonable since it is an excavation area.

The cataloging sheets, completed and discussed here, can guide the preparation of geoeducational proposals and the management of these inventoried sites, promoting the dissemination and monitoring of their uses.

The assessment of the local geodiversity revealed that, although some SRIs assist tourism and educational activities, they still have much potential. The research represents the first step toward implementing geoconservation strategies in the municipality. May such studies bring visibility to the local geodiversity, encouraging society to know and preserve such wealth for future generations.

REFERÊNCIAS

BRILHA, J. B. R. A importância dos geoparques no ensino e divulgação das Geociências**.** **Geologia USP**: Publicação Especial, São Paulo, v. 5, 2009.

BRILHA, J. B. R., J. Inventory and Quantitative Assessment of Geosites and Geodiversity Sites: a Review. Geoheritage, **Springer Berlin Heidelberg**, v. 8. 2015. Acesso em 27 de Dez. de 2016.

BRILHA, J. B. R.. **Patrimônio geológico e geoconservação: a conservação da natureza na sua vertente geológica**. Braga: Palimage, 2005.

COUTINHO, D. L. C.; COUTINHO, C. C.; DUQUE, R.; ASAKURA, Y.; BRANDÃO, A. M.; BARBOSA, C. G.; ARARIPE, R. V. C.; ALVES JUNIOR, B. F.; DO ESPÍRITO SANTO, R. B.; PRADO, L. A. C.; BARRETO, A. M. F. A Coleção Paleontológica do Museu de Ciências Naturais e de História Barra do Jardim da Fundação Francisco de Lima Botelho, Jardim, Ceará, Brasil. **Anuário do Instituto de Geociências - UFRJ**, v. 44, p. 1-11, 2021.

CPRM. **Mapa geodiversidade do Brasil: influência da geologia dos grandes geossistemas no uso e ocupação dos terrenos**. Brasília: CPRM, 2006. 68 p., il. Color. 1 mapa. Escala 1:2.500.000. Acompanha 1 CD-ROM.

CPRM. **Geodiversidade do Estado do Rio Grande do Norte**. 2010. p. 11-14. 32- 35. 78-92. 135- 144.

CPRM - **Geodiversidade do Brasil**. 2008. p. 11-20.

GIL, A. C.. **Como elaborar projetos de pesquisa**. 4. ed. São Paulo: Atlas, 2008.

GUERRA, M. D. F. **Veredas da chapada do Araripe**: contexto ecogeográfico de subespaços de exceção no semiárido do estado do Ceará, Brasil. 2019. 210 p. Tese (Doutorado em Geografia) - Universidade Estadual do Ceará-UFC. Fortaleza/CE.

GRAY, M. **Geodiversity**: valuingandconservingabioticnature. Londres: John Wiley& Sons Ltd, 2004.

LIMA F. F. **Proposta Metodológica para a Inventariação do Patrimônio Geológico** Brasileiro. Braga, 2008. 103f. Dissertação (Mestrado em Patrimônio Geológico e Geoconservação) – Universidade do Minho.
LIMEIRELES, A. J. A. As unidades morfoestruturais do estado do Ceará. In: SILVA, J.B. et al (Org.). **Ceará: um novo olhar geográfico**. Fortaleza: Edições Demócrito Rocha, 2005. p. 141-168.

MOURA-FÉ, M. M.; PINHEIRO, M. V. A.; JACÓ, D. M.; OLIVEIRA, B. A. **Geoeducação**: a educação ambiental aplicada na geoconservação. In: Educação Ambiental & Biogeografia. 1 ed. Ituiutaba-SP: Barlavento, 2016, v. II, p. 829-842.

MOCHIUTTI, N. F.; GUIMARÃES, G. B.; MOREIRA, J. C.; LIMA, F. F.; FREITAS, F. I. Os valores da Geodiversidade: Geossítios do Geopark Araripe/CE. **Anuário do Instituto de Geociências** – UFRJ. Rio de Janeiro, v. 35, n. 1, p. 173-189. 2012.

NASCIMENTO, F. R.; FALCAO SOBRINHO, J. Geodiversidade e abordagens em estudos ambientais. In: José F. Sobrinho; Flávio R. do Nascimento; Vanda C. Sales. (Org.). **Geodiversidade: abordagens teóricas e práticas**. 1ed.Sobral: Sertão Cult, 2020, v. 1, p. 15-40.

NASCIMENTO, R. L.; SILVA, J. V. M. ; CAVALCANTE, A. E. S. ; MOURA-FÉ, M. M. Levantamento dos principais elementos da geodiversidade do município de Jardim-CE. In: PINHEIRO, L. S.; GORAYEB, A.. (Org.). **Geografia Física e as Mudanças Globais.** 2ed.Fortaleza: Editora UFC, 2019, v. 1, p. 1-5.

NIETO, L. M. Geodiversidad: propuesta de una definición integradora. **Boletín Geológico** y Minero. v. 112, n. 2. 2001.

OLIVEIRA, P. C. A. **Avaliação do patrimônio geomorfológico potencial dos municípios de Coromandel e Vazante, MG**. Uberlândia, 2015. 176f. Tese (Doutorado em Ciências Humanas) – Universidade Federal de Uberlândia.

PEREIRA, R. G. F. A. **Geoconservação e desenvolvimento sustentável na Chapada Diamantina (Bahia-Brasil)**. Tese (Doutoramento em Ciências. Área de conhecimento em Geologia). Escola de Ciências, Universidade do Minho, Portugal. 2010.

PEREIRA,R.G.F. de A.; RIOS, D. C. ; GARCIA, P. M. P. . Geodiversidade e Patrimônio Geológico: ferramentas para a divulgação e ensino das Geociências. **Terrae Didatica** (Impresso), v. 12, p. 196-208, 2016.

SHARPLES, C. **Concepts and principles of geoconservation.** Published eletronically on the Tasmanin Park & Wildlife Service web site. 3. ed. Set, 2002.

SILVA, J. V. M.; NASCIMENTO, RAQUEL LANDIM; MOURA-FÉ, M. M.. Poposta de roteiro geoturístico do município do Crato/CE: valorização e divulgação da geodiversidade.. In: PINHEIRO, L. S.; GORAYEB, A.. (Org**.). Geografia Física e as Mudanças Globais.** 1ed.Fortaleza: Editora UFC, 2019, v. 1, p. 1-12.

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