Margarida Penteado
Revista de Geomorfologia

QUALI-QUANTITATIVE ASSESSMENT OF THE COASTAL GEOHERITAGE OF THE SOUTHEAST COASTAL SECTOR ON THE ISLAND OF MARANHÃO, MA-BRAZIL

AVALIAÇÃO QUALI-QUANTITATIVA DO GEOPATRIMÔNIO COSTEIRO DO SETOR SUDESTE COSTEIRO NA ILHA DO MARANHÃO, MA-BRASIL

EVALUACIÓN CUALI-CUANTITATIVA DEL GEOPATRIMONIO COSTERO DEL SECTOR COSTERO SURESTE DE LA ISLA DE MARANHÃO, MA-BRASIL

Thiara Oliveira Rabelo[1]

[1]Doutora em Geografia - Universidade Federal do Rio Grande do Norte, e-mail: thiarageo2@gmail.com
https://orcid.org/0000-0002-6786-7376

Zuleide Maria Carvalho Lima[2]

[2]Professora do Departamento de Geografia – Universidade Federal do Rio Grande do Norte,
e-mail: zuleide.lima@ufrn.br
https://orcid.org/0000-0002-6971-9801

Marcos Antônio Leite do Nascimento[3]

[3]Professor do Departamento de Geologia – Universidade Federal do Rio Grande do Norte,
e-mail: marcos.leite@ufrn.br
https://orcid.org/0000-0002-8158-7186

ABSTRACT

This research sought to evaluate the coastal geoheritage of the southeastern sector of Maranhão Island, located in the northeast of the country, based on Pereira's method (2010), which emphasizes the Scientific Use Value, the Tourist Use Value and the Conservation Value. The area has fluvial-marine plains, coastal plains, cliffs and sandy beaches of paramount importance to the ecosystem and the community. 8 geosites were inventoried, which stood out for their scientific value and conservation value. The tourist use value scored the lowest, due to the low scores for the visibility and tourist infrastructure criteria. These results indicate specific needs for local coastal management, which consider the conservation of characteristics and ecosystem services provided by geoheritage through the urban expansion of this sector on Maranhão Island.

Keywords: Geoheritage. Coastal Environment. Maranhão Island.

RESUMO

Esta pesquisa buscou avaliar o geopatrimônio costeiro do setor sudeste da Ilha do Maranhão, localizada no nordeste do país, a partir do método de Pereira (2010), que enfatiza os Valores de Uso Científico, Turístico e o Valor de Conservação. A área conta com a presença de planícies fluvio-marinhas, planícies costeiras, falésias e praias arenosas de suma importância para o ecossistema e a comunidade Foram inventariados 8 geossítios, que se destacaram por seu valor científico e valor de conservação. O valor de uso turístico teve a menor pontuação, devido as baixas pontuações para os critérios de visibilidade e infraestrutura turística. Esses resultados indicam a necessidades específicas para a gestão costeira local, que considerem a conservação de características e serviços ecossistêmicos prestados pelo geopatrimônio mediante a expansão urbana deste setor na Ilha do Maranhão.

Palavras-chave: Geopatrimônio. Ambientes Costeiros. Ilha do Maranhão.

RESUMEN

Esta investigación buscó evaluar el geopatrimonio costero del sector sudeste de la isla de Maranhão, localizada en el nordeste del país, utilizando el método de Pereira (2010), que destaca el Valor de Uso Científico, el Valor de Uso Turístico y el Valor de Conservación. El área posee planicies fluvio-marinas, planicies costeras, acantilados y playas arenosas de suma importancia para el ecosistema y la comunidad. Fueron inventariados 8 geositios, que se destacaron por su valor científico y valor de conservación. El valor de uso turístico obtuvo la puntuación más baja, debido a las bajas puntuaciones de los criterios de visibilidad e infraestructura turística. Estos resultados indican las necesidades específicas para la gestión costera local, que consideran la conservación de las características y servicios ecosistémicos proporcionados por el geopatrimonio a través de la expansión urbana de este sector en la isla de Maranhão. que necesitan atención en relación a su conservación por la expansión urbana en este sector en la isla de Maranhão.

Palabras clave: Geopatrimonio. Ambiente costero. Isla de Maranhão.

INTRODUÇÃO

The conservation of geodiversity has been gaining ground in current environmental discussions in relation to nature conservation. In recent decades, the evaluation of geoheritage has been the subject of numerous works (SHARPLES, 2011; BRILHA, 2016; BRILHA, 2018; KUBALÍKOVÁ et al, 2023; DINIZ, ARAÚJO and CHAGAS, 2022) that show the importance of specific characteristics of geodiversity that have different values for society.

We highlight the assessment of geoheritage as a tool capable of identifying the qualitative and quantitative values of areas with different geodiversity potentials, such as scientific, economic, cultural, geotourism and others. Over the last few decades, various methods for assessing geoheritage (BRILHA, 2005; ZOUROS, 2007; GÁRCIA-CÓRTEZ and ÚRQUI, 2009; PEREIRA, 2010; SANTOS et al, 2020; RABELO, LIMA and NASCIMENTO, 2021; DINIZ, ARAÚJO and CHAGAS, 2022) have been developed. These methods have different objectives that reflect the reality of different areas with different geodiversity potentials.

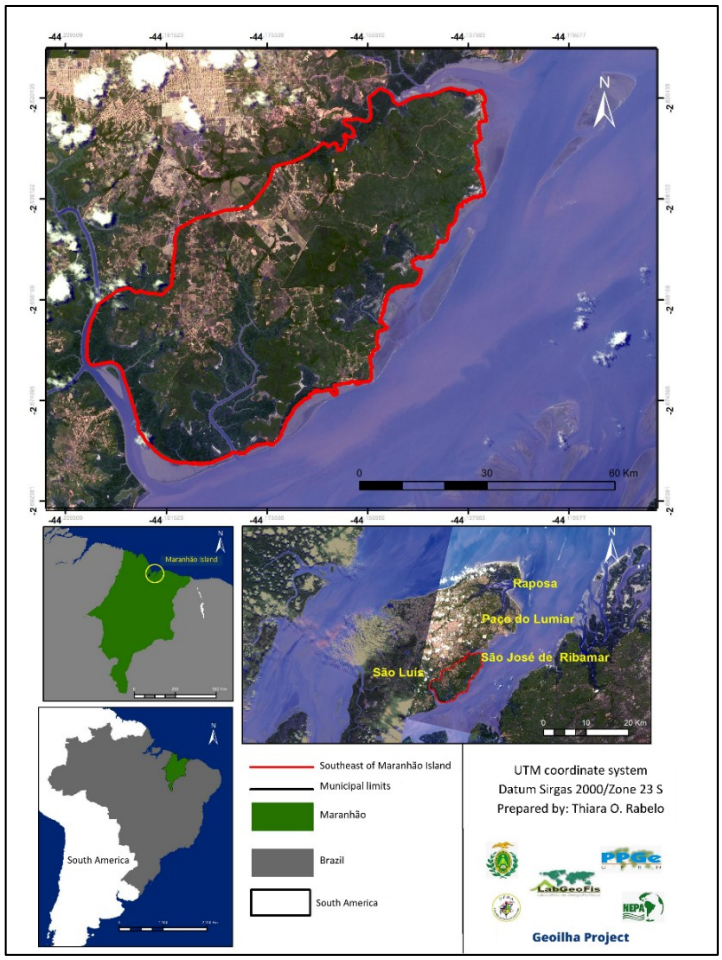
The assessment of geoheritage is highlighted for its importance in pointing out sites with specific geodiversity characteristics that need to be conserved, thinking about environmental and socioeconomic and scientific sustainability for future generations. José Brilha, one of the world's pioneers on the subject, states that these sites must be protected to allow scientific use by current and future geoscientists, as a guarantee for present and future knowledge of the functioning of the geosphere and its interaction with the other systems of the biosphere (BRILHA, 2016).

There are dozens of methods for evaluating geoheritage developed around the world, ranging from the broadest to the most specific. Regardless of the approach, geosites are valued occurrences of geodiversity that must be managed in order to protect them from degradation or destruction (SANTOS et al, 2020). We would like to highlight inventory methods proposed based on Brazilian realities, such as those by Pereira (2010), Santos et al (2020), Rabelo, Lima and Nascimento (2021), Diniz, Araújo and Chagas (2022), etc., which make use of evaluation parameters already proposed in scientific research widely disseminated around the world (BRILHA, 2005; DE WEVER, LE NECHET e CORNEE, 2006; BRILHA, 2016; GÁRCIA-CÓRTEZ e ÚRQUI, 2009, CLAUDINO-SALES; 2024) and which have brought new perspectives to the evaluation of geoheritage based on field observation of aspects of Brazilian geodiversity and its associated values.

The study area for this research (Figure 1) is located in the southeastern sector of the island of Maranhão, located in northeastern Brazil in the state of Maranhão and covering the municipalities of São Luís, the state capital, and São José de Ribamar. The area has a coastal environment of peculiar dynamics with the presence of fluvial-marine plains, tablelands, cliffs and sandy beaches that have an accentuated aesthetic value and are of paramount importance to the local ecosystem, since human activities related mainly to agriculture and mineral extraction are carried out in these areas, which directly use the potential of the local geodiversity (RABELO, LIMA and NASCIMENTO, 2021). These characteristics linked to coastal

environments are a reminder of the importance of work aimed at assessing the geoheritage in these places in the face of climate change, given that coastal environments are areas directly threatened by these changes according to the IPCC-Intergovernmental Panel on Climate Change report of 2022.

Figure 1 - Location of the southeast sector on Maranhão Island, MA-Brazil



Source: Adapted from Rabelo (2018)

The geology of the area is mainly classified as Quaternary terrain, according to the Brazilian Geological Service (2013), with the presence of the Barreiras Formation, swamp and mangrove deposits and coastal deposits. Few studies have been carried out on the island of Maranhão focusing on assessing its geoheritage. of particular note here is the mapping of the area's geodiversity carried out by the Brazilian Geological Survey (CPRM) in 2020 (BARROS, 2020) and the research by Rabelo (2018), which discusses the assessment of coastal geodiversity in the southeastern sector of Maranhão Island. In this work, we will focus on the qualitative and quantitative assessment of the coastal geoheritage of this sector on the island of Maranhão, with an emphasis on the Scientific Use Value, Tourist Use Value and Conservation Value of the geoheritage, according to Pereira's method (2010).

It is important to note that many methods created in recent years focus on land use and management due to the increase in the use of natural resources in the last century. The southeastern sector of Ilha do Maranhão is pointed out (REIS, 2005; BURNNET, 2012) as one of the new sectors of urban expansion on Ilha do Maranhão, thus indicating the relevance of research aimed at evaluating the area's geoheritage with a view to identifying priority areas for geoconservation. This work, based on the information gathered by Rabelo (2018), seeks

to discuss and contribute to the dissemination of the importance of geoconservation of the coastal environments on the island of Maranhão.

MATERIALS AND METHODS

The geoheritage assessment of the southeast sector of Maranhão Island was based on Pereira's method (2010), which includes around 20 parameters that are present in the main geoheritage assessment proposals (BRLHA, 2006, 2018; etc). This methodology adds parameters related to the Brazilian reality, since its first application was in the Chapada Diamantina region, located in the state of Bahia, in northeastern Brazil. Other studies have used this methodology in different areas(LOPES, ARAÚJO and NASCIMENTO, 2012; FRANÇA and MARIANO, 2016; SILVA, AQUINO and OLIVEIRA, 2016 etc.).

a) Inventory

The inventory of the geoheritage of the study area was based on the method of Pereira (2010) and is presented in the research by Rabelo et al (2021) and emphasis was placed on the geological and geomorphological aspects of the area. In a macrocontext, the geology of the area is classified mainly by terrain formed in the Quaternary, according to the Brazilian Geological Service (2013) and it is possible to observe the presence of the Barreiras Formation, swamp and mangrove deposits and coastal deposits.

The Barreiras Formation extends from the Amazon region throughout the north and northeast coasts to the state of Rio de Janeiro, located in the southeast of Brazil (BANDEIRA, 2013). According to Aguiar (1971), it is composed of poorly sorted, fine to coarse, variegated, generally clayey sandstones with numerous intercalations of shales. In some places, the sediments of this formation are very weathered, ferruginized and lateritized.

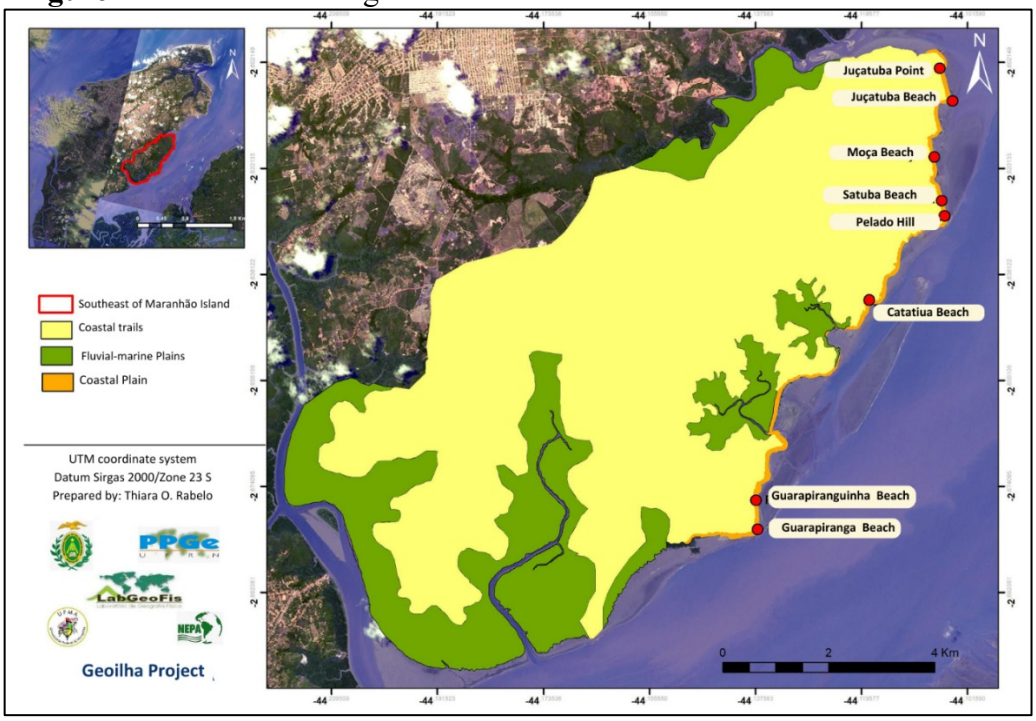
The marsh and mangrove deposits are classified by the Brazilian Geological Survey (BANDEIRA, 2013): as muddy sediments (clay and silt), gray in color and not densely packed. This geo-logical unit covers a large part of the area's watersheds and is directly associated with the area's beaches, since Maranhão Island is all cut out by rivers that dump their sediments into the sea, and it is possible to observe muddy sediments at various points on the coastal plain, mainly due to the mangroves reaching various locations in this geomorphological unit. The coastal deposits in the area are characterized by Veiga Júnior (2000) and Klein et al (2012) by the presence of fine- to medium-grained quartz sands and are also observed with the presence of biodetritus (RABELO, 2018).

In the southeastern sector of Maranhão Island, three geomorphological units stand out (BANDEIRA, 2013): the coastal tablelands, the fluvial-marine plains and the coastal plain. The coastal trails are largely associated with the occurrence of the Barreiras Formation in the area. They occur in the area in the form of dissected plains and tabular hills, carved into a network of channels of moderate density and drainage (BANDEIRA, 2013). Fluvial-marine plains occur mainly in the estuarine zones of the southeast sector and are associated with the occurrence of marsh and mangrove deposits. They are characterized by being flat surfaces and are in contact with continental and marine depositional systems, represented in the area by tidal channels (RABELO, LIMA and NASCIMENTO, 2020).

The coastal plain is the smallest geomorphological unit in the area and has geomorphological characteristics that attract the most attention for their scientific and tourist value. This unit corresponds to flat areas, closer to sea level, with the occurrence of beaches with dissipative profiles where the presence of abrasion terraces, cliffs and prairie sandstone formations parallel to the coastline can be observed, with perpendicular occurrences identified by Rabelo (2018), which may indicate past tectonic dynamics in the location.

The inventory of the geoheritage of the study area was made taking into account aspects such as: geographical location, geological setting, preliminary evaluation, legal status, land use and type of interest of the site, according to the method of Pereira (2010) and Brilha (2005). The criteria for characterizing the beach environment were also added to the inventory of the area by Rabelo (2018). In the survey, 8 geosites were identified (Figure 2), presenting scientific values associated with other values such as tourism, economic and educational.

Figure 2 - Location of the geosites in the southeast sector of Maranhão Island

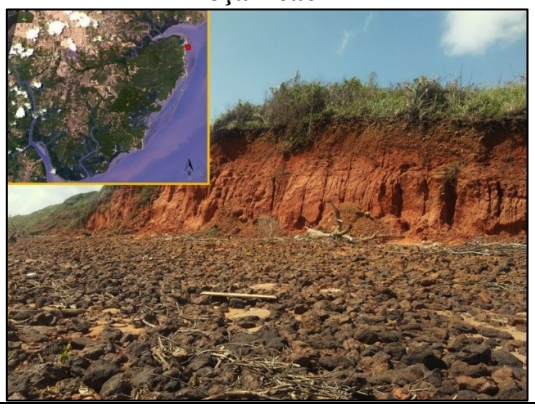
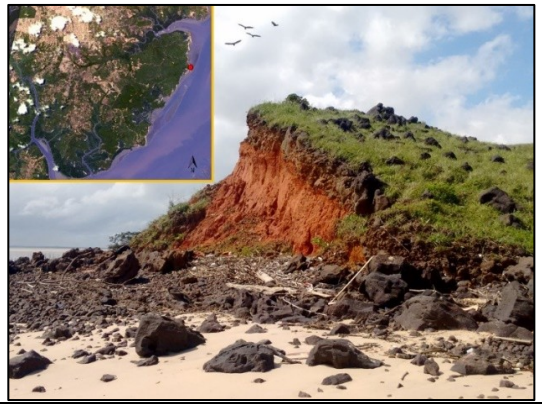


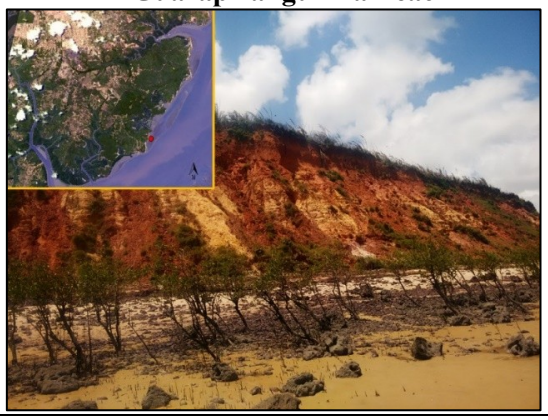
Source: Adapted from Rabelo (2018)

The geosites inventoried identified relevant aspects of the area's geoheritage, mainly related to geology, geomorphology and coastal processes, which can be seen in Table 1.

Table 1 - Outstanding characteristics of the geosites in the study area

GEOSSITES	TOPIC OF INTEREST TO GEOHERITAGE	FEATURES/ PROCESSES IN FOCUS
Juçatuba Point 	Geomorphology	-Coastal Dynamics
Juçatuba Beach	Geomorphology Geology	- Coastal Dynamics - Abrasion terrace

		- Weathering
Moça Beach 	Geomorphology Geology	- Coastal dynamics - Lithological layers - Abrasion terrace - Weathering - Erosion
Satuba Beach 	Geomorphology Geology	- Coastal Dynamics - Abrasion terrace - Cliffs - Weathering - Lithological layers
Pelado Hill 	Geomorphology Geology Neotectonism	- Coastal dynamics - Weathering -Neotectonism
Catatiua Beach	Geomorphology Geology	- Coastal dynamics - Abrasion terrace

		- Cliffs - Weathering
Guarapiranguinha Beach 	Geomorphology Geology	- Coastal Dynamics - Cliffs - Abrasion terrace - Weathering
Guarapiranga Beach 	Geomorphology Geology	Coastal Dynamics - Cliffs - Abrasion terrace - Weathering

Source: Adapted from Rabelo (2018)

In addition to the representative potential of geodiversity and the increase in human occupation, the southeast of the island of Maranhão does not yet have an intense use of its abiotic resources that presents irreversible damage to the dynamics of the environment, which allows us to observe that so far there is no major irrecoverable damage to the geo-heritage associated with human actions. Agriculture, mineral extraction and tourism, albeit to a small extent, are the main activities in the area that make direct use of these resources.

According to Rabelo, Lima and Nascimento 2021, agriculture takes place mainly in the areas of tablelands and fluvial-marine plains, with the cultivation of species such as cassava (*Manihot esculenta Crantz*), maxixe (*Cucumis anguria L*), maize (*Zea mays*), Brazilian peppertree (*Hibiscus sabdariffa*), papaya (*Carica papaya L*), okra (*Abelmoschus esculentus*). Mineral extraction takes place mainly on the coastal plain, with sand being extracted from geosites such as Guarapiranga Beach, which is used for construction. There is also the occasional extraction of fresh water on Catatiua beach at the base of one of the cliffs, which

contains a mineral called kaolin, which is friable and highly plastic. The water extracted from this site is used for washing clothes, bathing and cooking food (Figure 3)

Figure 3 - Freshwater extraction site at Catatiua Beach

Source: Authors' collection (2018).

Tourism in the area is still in its infancy, although in the last three years there has been an informal increase in some beaches in the southeast sector on local tourism pages on social networks. The places with the best facilities for receiving tourists are Juçatuba Point and Guarapiranga Beach.

b) Quantification

The quantitative results of the assessment of the area's geoheritage were obtained using the Pereira 2010 method, whose main focus is to assess the Scientific Use Value (SUV), Tourist Use Value (TUV), Conservation Value (CV) and the Local, Regional, National or International Relevance of each geosite, described in chart 2.

Chart 2 - Description of the use values proposed by Pereira (2010)

VALUE	DESCRIPTION
INTRINSIC VALUE (IV)	Parameters directly associated with aspects inherent to the point of interest, regardless of its use or a functional assessment of the site. This value is analyzed in terms of rarity, integrity, vulnerability associated with natural processes and the variety of geodiversity elements that these elements present.
SCIENTIFIC VALUE (SV)	Parameters relating to research carried out at the site, its potential to illustrate relevant aspects of the area's geodiversity. As well as its didactic relevance, and the variety of elements related to other themes of study (biology, history, archaeology). This potential is a scientific indication of the site.
TOURIST VALUE (TV)	Associated parameters that allow an assessment of the current reality regarding the use of the site. These include characteristics

	such as accessibility, the presence of infrastructures and the use of the site at the present time.
USE/MANAGEMENT VALUE (UVM)	Parameters linked to cultural relevance (legends, religion), socioeconomic conditions of the surrounding area, official level of protection, possibility of using the sites of interest and vulnerability to use. This set of criteria is indicative of the social impacts and feasibility of future use of the site, as well as the application of investments for its enhancement.

Source: Prepared by the authors

Each value presented has a set of criteria arranged in individual values that are quantified before the use of the geoheritage is assessed. These values are obtained from the data collected in the inventory process. The quantification of these criteria is directly related to the final calculation of use values. The criteria set out in Table 3 are scored from 0 to 4, where in this research 0 means the lowest weight or that the value of the criterion in question has not been identified in the area and 4 means the highest weight in relation to the quantified criterion (Chart 4), where the description of the scoring of the criteria has been adapted to the reality in question. Adaptations were made to criteria A1, A3, B2, B4, C1, C3, C4, C5, D3, D4 and D5.

Chart 3 - Quantitative criteria for individual geoheritage assessment values

INTRINSIC VALUE (IV)		**SCORE**				
Criteria		**0**	**1**	**2**	**3**	**4**
A1	Vulnerability linked to natural processes	No vulnerability due to natural processes	Low vulnerability due to natural processes	With some natural vulnerability, but on a scale that does not compromise relevant aspects	With some natural vulnerability, but on a scale that can be mitigated through simple measures	High vulnerability, due to the activities of natural processes at the sites.
A2	Abundance / rarity	Commonly occurring point of interest (more than 10 occurrences)	Between 5 and 10 examples with similar characteristics in the area within the same geological-geomorphological context.	Existence of up to five examples with similar characteristics within the same geological-geomorphological context	Existence of up to 3 examples with similar characteristics, within the same geological-geomorphological context.	Unique example in the area
A3	Integrity	Point of interest intact and without any deterioration and no need for recovery	The site has deteriorated somewhat, but it is still possible to see aspects of interest, and it could be restored.	However, the deteriorated point still allows visualization of the aspects of interest, with the possibility of being recovered	However, the point of origin still allows the visualization of the aspects of interest, with no possibility of being recovered.	Deteriorated and uncharacterized site in such a way that the observation of the elements of interest is compromised and there is no possibility of recovery
A4	Variety of Geodiversity elements	No association with geodiversity elements.	Association with only one element of Geodiversity.	Association of only two elements of Geodiversity	Association of three elements of Geodi-versity.	Association of more than three Geodiversity elements
		SCORE				

SCIENTIFIC VALUE (SV)		0	1	2	3	4
B1	Object of bibliographic reference (degree of scientific knowledge)	No reference to the place.	Cited in technical reports or management plans	Cited in national journal article and reports or management plan.	Cited in a thesis or other technical-scientific publication	Cited in more than one academic thesis, book chapter or scientific journal article
B2	Representativeness of geological materials and processes	Absence of any relevant scientific aspect	It houses illustrative records of geodiversity, but not as local or classic examples.	It houses illustrative records of Geodiversity, little used as local examples or classics	It houses illustrative records of geodiversity, used as a local example.	It houses illustrative elements that represent types of formations or are used as classic examples of geological elements and processes.
B3	Diversity of associated interests/themes	No associations with other themes	Only one type of interest or theme	Up to 3 types of interest and/or theme	Between 4 and 5 types of interest and/or topic	More than 5 types of interest and/or theme
B4	Didactic relevance	No didactic relevance	Not very illustrative, but it can be used for teaching purposes for a specialized audience.	Illustrative and can be used for didactic purposes for a specialized audience.	Illustrative and can be used for teaching purposes by audiences at any level, from laypeople to experts.	Very illustrative and can be used for didactic purposes by audiences of all levels, from laypeople to experts
TOURIST VALUE (TV)		SCORE				
		0	1	2	3	4
C1	Aesthetic aspect	Site with no aesthetic relevance in an area with no scenic appeal.	Site with no aesthetic relevance in an area with some scenic appeal	Point of interest located in a pleasant place or with an aesthetically appealing feature	A place with spectacular aesthetics, set in a location with little scenic appeal.	Aesthetically pleasing venue in a pleasant location with scenic appeal.
C2	Acessibilidade	Accessible from a trail over 5 km long	Accessible from a 2 to 5 km long trail	Accessible from unpaved roads and trails less than 2 km long	Accessible from paved roads and a trail less than 2 km long	Directly accessible via paved main roads (federal or state)
C3	Presence of infrastructure	Lack of any infrastructure	It has a rudimentary infrastructure that provides little structure for visitors	Equipped with reasonable infrastructure to support visitors	Good infrastructure to support visitors	Equipped with a full infrastructure to support visitors
C4	Existence of current use	Point with no current use	Point with some visitation, but still incipient	Point with some visitation, mainly at local level.	Site with a high rate of visitation, but no visitor control mechanisms	Site with a high visitation rate and visitor control measures

C5	Presence of visitor control mechanisms	No control whatsoever	Existence of a non-systematic control mechanism that is still in its infancy.	The existence of a systematic control mechanism is still incipient.	Existence of systematic and efficient control of visitors from specialized groups.	Existence of systematic and efficient control of visitors from all types of groups.
USE/MANAGEMENT VALUE (UVM)		**SCORE**				
		0	**1**	**2**	**3**	**4**
D1	Cultural relevance	Unrelated to cultural elements	Indirect link to cultural elements (ruins, toponyms, cave paintings, etc.)	Direct link to cultural elements (presence of ruins or cave paintings)	Site with the presence of a cultural element that makes an ancillary contribution to the visitation or use of the site.	Close relationship with cultural elements (cultural landscape), where the cultural aspect is one of the main attractions of the area.
D2	Economic relevance	No economic potential	Point of interest with some economic potential, but where exploitation is not feasible (e.g. in a protected area)	Point with economic potential and incipient exploration in progress and regularized	Site with economic potential and incipient exploration in progress and regularized	Economically viable site, including established and organized exploratory activity
D3	Official protection level	Absence of any type of CU (Conservation units)	Inserted in CU not yet implemented	Inserted in CU not yet implemented without social outreach projects	Inserted in CU not yet implemented with some social visibility	Inserted in a not yet implemented CU with a lot of social visibility.
D4	Economically usable	Site with no restrictions on use, already equipped with some infrastructure and/or in use	Site with some restriction on use, already equipped with some infrastructure and/or with use in progress	Inserted in a CU zone or private property with the possibility of use under legal conditions, but showing signs of degradation.	Inserted in a CU zone or private property with the possibility of use under legal conditions without signs of degradation.	Inserted in a CU zone or on private property with restrictions on its use for public visitation purposes
D5	Vulnerability associated with anthropic use	Nothing vulnerable to deterioration through use or visitation, and can be used without any kind of restriction	Slightly vulnerable to deterioration through use or visitation and can be used with some restrictions	Subject to loss of characteristics through use, can be used by implementing infrastructure to minimize impacts	Slightly or not at all vulnerable, may suffer occasional deterioration due to use or visitation, may be used with occasional restrictions.	Slightly or not at all vulnerable, it should not suffer from deterioration through use or visitation and can be used without any kind of restriction
D6	Population of the nearest	5000 residents within a 25 km radius.	5000 to 10,000 residents within a 25 km radius	10,000 to 15,000 residents within a 25 km radius	15,000 to 20,000 residents within a 25 km radius	More than 20,000 residents within a 25 km radius

	urban center					
D7	Socioeconomic conditions of the nearest urban centers	Not applicable	Human Development Index (HDI) lower than the average HDI for the area	HDI lower than the average HDI for the area	HDI higher than the average HDI for the area.	HDI higher than national average

Source: Adapted by the authors from Pereira (2010)

All the parameters included in the application result in a score, by means of an arithmetic mean taking into account two decimal places in the result, as shown below:

$$IV=: (A1 + A2 + A3 + A4)/4 \quad (1)$$

$$SV= (B1+B2+B3+B4)/4 \quad (2)$$

$$TV= (C1+C2+C3+C4+C5)/5 \quad (3)$$

$$UVM= (D1+D2+D3+D4+D5+D6+D7)/7 \quad (4)$$

Based on this proposal and based on these applications adapted to the area under study in this research, the results obtained allowed for a ranking of the points of interest for each type of intended use, as well as an indication of their relevance on a local, regional, national and international scale. In defining the relevance of the selected points, Pereira [8] establishes the following criteria for ranking the results:

- Local relevance: sites where R = < 10;
- Regional relevance: locations where 10 < R < the average value obtained for the relevance of all the points evaluated;
- National relevance: locations where R > the average value obtained for the relevance of all the points evaluated;
- International Relevance: locations where R > the average value obtained for the relevance of the set of points of interest and where, simultaneously, parameters A-02 and A-03 are greater than or equal to three and parameters B-01, B-02, C-02 and C-03 (Appendix 03) are greater than or equal to two.

The results of this quantification are based on data collected in field activities between August 2016 and August 2017 from Rabelo (2018) master's research.

RESULTS

The quantitative evaluation of the area's geoheritage shows values that highlight the scientific value of the area in question and indicates, according to the method applied, a ranking of relevance for the geosites evaluated of less than or less than 10 (Chart 5).

Chart 5 - Quantitative criteria for individual geoheritage assessment values

Quantifying individual values									
A)Intrinsic value (IV)	**Juçatuba Point**	**Juçatuba Beach**	**Moça Beach**	**Satuba Beach**	**Pelado Hill**	**Catatiua Beache**	**Guarapiran-guinha Beach**	**Guara pirang a Beach**	**Overall average (IV)**

A1	4	4	3	3	3	3	3	4	**2,09**
A2	2	1	2	2	4	2	2	2	
A3	1	1	1	1	1	1	1	1	
A4	1	2	2	3	2	2	2	1	
Average	**2**	**2**	**2**	**2,25**	**2,5**	**2**	**2**	**2**	
B)Scientific Value (SV)	**Juçatuba Point**	**Juçatuba Beach**	**Moça Beach**	**Satuba Beach**	**Pelado Hill**	**Catatiua Beach**	**Guarapiran-guinha Beach**	**Guara-piranga Beach**	**Overall average (IV)**
B1	1	2	2	2	2	2	2	3	**2,8**
B2	3	3	3	3	3	3	3	2	
B3	3	3	3	3	2	4	2	4	
B4	4	4	2	4	4	3	4	4	
Average	**2,75**	**3**	**2,5**	**3**	**2,75**	**3**	**2**	**3,25**	
C)Tourist Value (TV)	**Juçatuba Point**	**Juçatuba Beach**	**Moça Beach**	**Satuba Beach**	**Pelado Hill**	**Catatiua Beache**	**Guarapiran-guinha Beach**	**Guara pirang a Beach**	**Overall average (IV)**
C1	4	3	3	3	3	3	3	3	**1,2**
C2	2	2	1	1	1	1	2	2	
C3	3	2	0	0	0	0	1	2	
C4	1	1	0	1	0	1	1	1	
C5	0	0	0	0	0	0	0	0	
Average	**2,00**	**1,60**	**0,80**	**1,00**	**0,80**	**1,00**	**1,40**	**1,60**	
D)Use/Ma-nagement Value (UVM)	**Juçatuba Point**	**Juçatuba Beach**	**Moça Beach**	**Satuba Beach**	**Pelado Hill**	**Catatiua Beache**	**Guarapiran-guinha Beach**	**Guara pirang a Beach**	**Overall average (IV)**
D1	1	1	0	0	1	0	0	3	**0,64**
D2	1	1	0	1	0	1	1	2	
D3	0	0	0	0	0	0	0	0	
D4	2	1	1	1	0	1	1	2	
D5	2	2	2	2	0	2	2	2	
D6	0	0	0	0	0	0	0	0	
D7	0	0	0	0	0	0	0	0	
Average	**0,86**	**0,71**	**0,43**	**0,57**	**0,14**	**0,57**	**0,57**	**1,29**	

Quantifying use values

Geosites	**Juçatuba Point**	**Juçatuba Beach**	**Moça Beach**	**Satuba Beach**	**Pelado Hill**	**Catatiua Beache**	**Guarapiran-guinha Beach**	**Guara pirang a Beach**	**Overall average**
Scientific Use Value (SUV)	2,45	2,60	2,30	2,70	2,65	2,60	2,45	2,75	**2,5**
Tourist Use Value (TUV)	1,54	1,25	0,65	0,83	0,54	0,83	1,07	1,47	**1,02**
Conservation Value (VC)	1,92	1,94	1,79	2,06	2,08	1,91	1,86	2,11	**1,959**
Relevance (R)	10,74	10,74	8,75	10,38	9,73	10,05	9,95	11,62	**10,245**

Note(s): Local Relevance Point: R = < 10
Regional Relevance Point: 10 < R < average value for the relevance of the set of geosites
National Relevance Point: R > average value for the relevance of the set of geosites
Point of International Relevance: R > average value for the relevance of the group of geosites

Source: Prepared by the authors

According to the data obtained, we can see that the southeast coastal sector of Maranhão Island has higher averages for scientific use and conservation values. The tourist use value had

lower averages than the other use values, which reflects the scores given to the individual values in the TV (Tourist Value) and UMV (Use and Management Value) categories, which had the lowest scores.

It is important to emphasize that although the study area has aesthetic geodiversity potential for tourism development, it does not yet have adequate infrastructure for tourism development, which is reflected in lower averages in the evaluation of the geoheritage in question and will be discussed below.

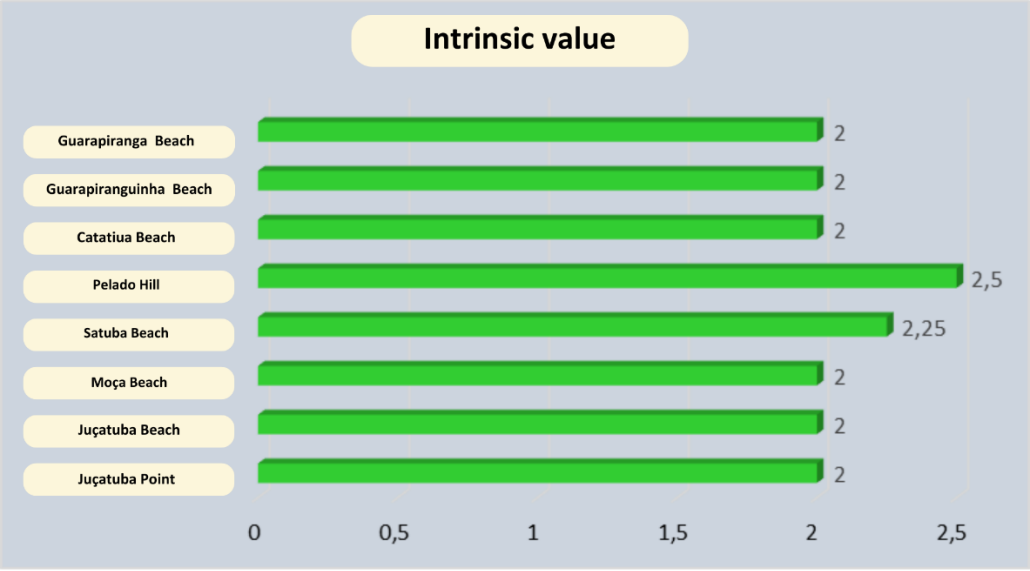
DISCUSSION

The quantified data is directly related to the information obtained from the inventoried data on the geoheritage of the area in question. The individual values supported the final use values, which reflect the state of management and conservation of the local geoheritage, which still has little visibility compared to the coastal geoheritage of the western portion of the island of Maranhão.

a) Intrinsic Value (IV)

This category is the most difficult to quantify, since according to Gray (2004) the intrinsic value of Geodiversity concerns the relationship between man and nature and his way of seeing it. None of the results obtained in this category were close to or equal to 4 (the highest score of the parameters assessed), all ranging from 2 to 2.5 (Figure 4).

Figure 4 - Intrinsic values of the geosites in the study area



Source: Prepared by the authors

The parameters analyzed to quantify intrinsic value consist of scoring which site is most vulnerable to natural processes, the level of rarity or abundance of the geodiversity analyzed in the area, the integrity (related to the level of conservation) of the point and the variety of local geodiversity.

In the coastal plain of the southeastern sector of Maranhão Island, there were no quantitative variations in this value since the area is in the same geological and geomorphological context which does not allow for so many variations in the comparisons made using the methodology applied.

The beaches in this sector are all located in a geological area made up of coastal deposits in some parts in contact with sediments from the Barreiras Formation, which are mainly provided by the trays in this sector that end in contact with the coastal plain in the form of cliffs.

In terms of geomorphology, most of the beaches have extensive abrasion terraces, with the exception of Guarapiranga Beach, and are surrounded by cliffs. We would highlight Pelado Hill and Satuba Beach, which scored more highly in terms of abundance/rarity due to their more differentiated characteristics as described in the inventory, and these were the beaches with the highest average intrinsic value values for the area.

These higher values are due to the fact that Morro Pelado Hill was identified as a unique occurrence in the coastal plain unit and that Satuba Beach presented lithological layers perpendicular to the coastline that were not observed on the other beaches (Figure 5).

Figure 5 - Sandstone lithological layers perpendicular to the coastline at SatubaBeach

Source: Authors' collection (2018).

None of the points inventoried reached a value greater than 2 for intrinsic value, as they were all located in an area of high environmental vulnerability and most of the elements of interest in relation to geodiversity are associated with geomorphology.

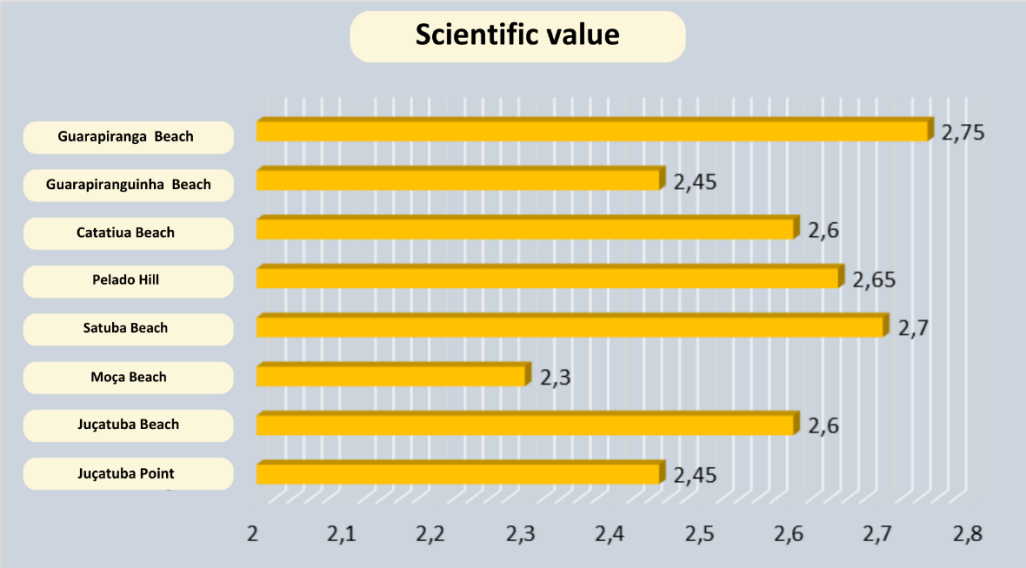
b) Scientific Value (SV)

The scientific value of the area was calculated according to the level of knowledge of the place among the population of the area and the school and scientific community in the region. In relation to the southeast coastal sector of Maranhão Island, scientific publications and technical reports are still incipient. Based on the documentary and bibliographic survey carried out for this research, it was possible to identify only the works of Silva (2012), Rabelo et al (2017), Ribeiro et al (2017) and some information made available by the GEOILHA Project (2015-2017) that discuss this area.

The average values per point in this category ranged from 2.5 to 3.25 (Figure 6). The highest values identified within the quantification of this value were attributed to Juçatuba

Beach, Catatiua Beach, Satuba Beach and Guarapiranga Beach, given that they were the most cited names in scientific research published in the sum of all publications in the area.

Figure 6 - Graphical display of the scientific values of the geosites in the study area



Source: Prepared by the authors

The low values in relation to the scientific use value of the area are justified by the lack of knowledge about the points inventoried and the fact that it is still a sparsely occupied area in relation to other sectors of Maranhão Island, a factor that contributes to drawing the attention of some professionals to the area.

Guarapirangua Beach is among the points with the highest scientific use value in the area, with an average score of 3.25. This value is mainly due to the fact that Guarapiranga is one of the areas cited in a doctoral thesis, which gives it a score according to the methodology applied.

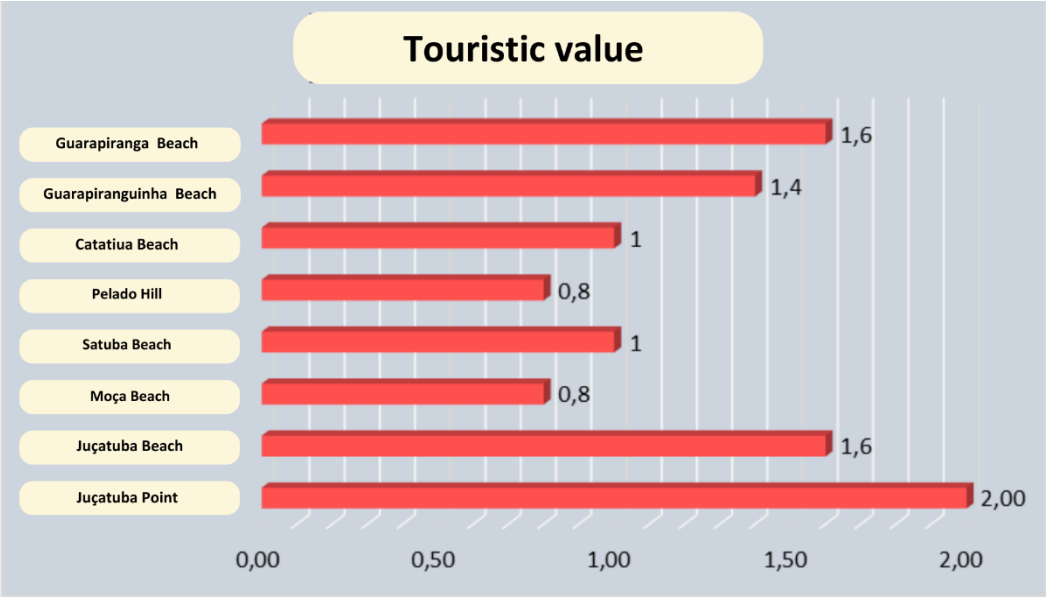
However, the potential for scientific use of the area is accentuated, since there are many particularities in this sector that have not yet been the subject of scientific studies and which may even be related to the geodiversity of the area, such as: the historical process of occupation of this sector, social relations in this area, the economic sector, characterization of the flora and fauna, identification of ecosystem services in the area, oceanographic studies, among others.

c) Tourist Value (TV)

Although it has natural potential for the development of tourism segments such as geotourism, the southeastern coastal sector of Maranhão Island does not yet have a high tourist use value, compared to the western coast of the island. In order to quantify this value, it is necessary to analyze associated parameters that allow an assessment of the reality of the location.

These characteristics include parameters such as accessibility, the presence of infrastructure and the current use of the site. The tourist use values of the points inventoried resulted in 90% of the values being below 2 (Figure 7).

Figure 7 - Graphical display of the tourism values of the geosites in the study area



Source: Prepared by the authors

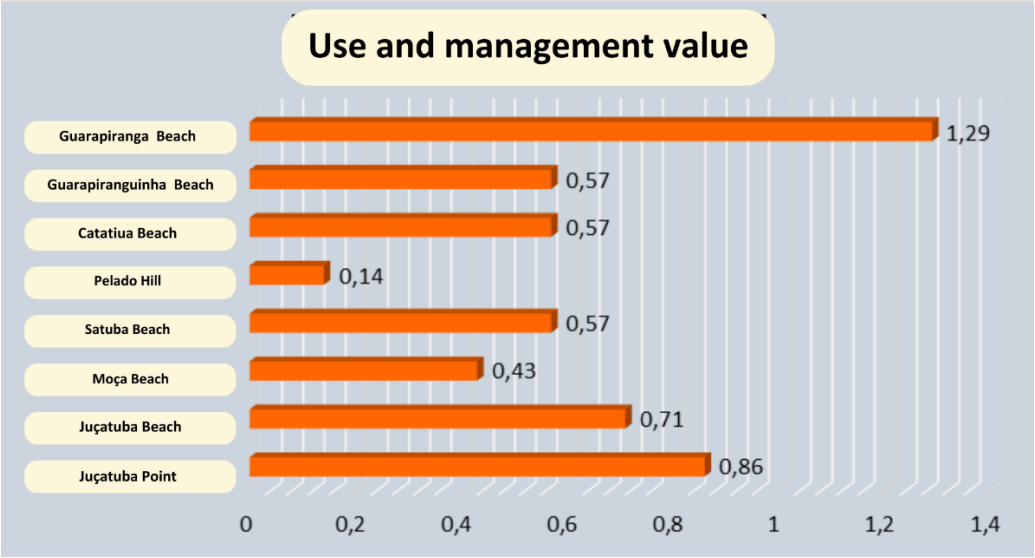
The points with the highest tourist use value were Juçatuba Point, Juçatuba Beach and Guarapiranga Beach, mainly due to the infrastructure they have. Although these points have rudimentary infrastructure, they are the most suitable areas in the southeast sector for offering basic services to visitors such as bars and restaurants and inns, the latter being offered only by Juçatuba Point.

Geosites such as Pelado Hill and Moça Beach scored less than one due to the fact that they are not as well known by people who don't live or work in the area and because the promotion of these other points is still incipient, mainly due to issues related to access and infrastructure, as is the case with Catatiua Beach, which is one of the most difficult points to access and has no structure to receive tourists or visitors.

d) Use/Management Value (UMV)

Defining the use and management value of the area according to the methodology proposed by Pereira (2010) is linked to analyses related to cultural relevance, the socioeconomic conditions of the surrounding area, the official level of protection, the possibility of using the sites of interest, and vulnerability to use. Due to factors related to precarious infrastructure in health services, sanitation services, educational services, cooperatives and others, the value of use and management in the southeastern sector indicated extremely low numbers and classified all the points inventoried in the same situation for use and management (Figure 8).

Figure 8 - Graphical display of the tourism values of the geosites in the study area



Source: Prepared by the authors

The quantified values were higher for Juçatuba Point, Juçatuba Beach and Guarapiranga Beach, which have better infrastructure than the other points surveyed, since the villages of Andiroba (a community near Ponta de Guarapiranga) and Juçatuba (a community near Juçatuba Point) have better infrastructure in terms of the presence of a school, health center, cooperatives, some paved roads, bars, restaurants, etc.

Guarapiranga Beach and Juçatuba Point were also assigned a higher value under the Use and Management Value category of cultural relevance, as these two points are currently used for cultural and sporting activities through trails made by cyclists who gather and leave the municipality of São Luís in order to reach these areas.

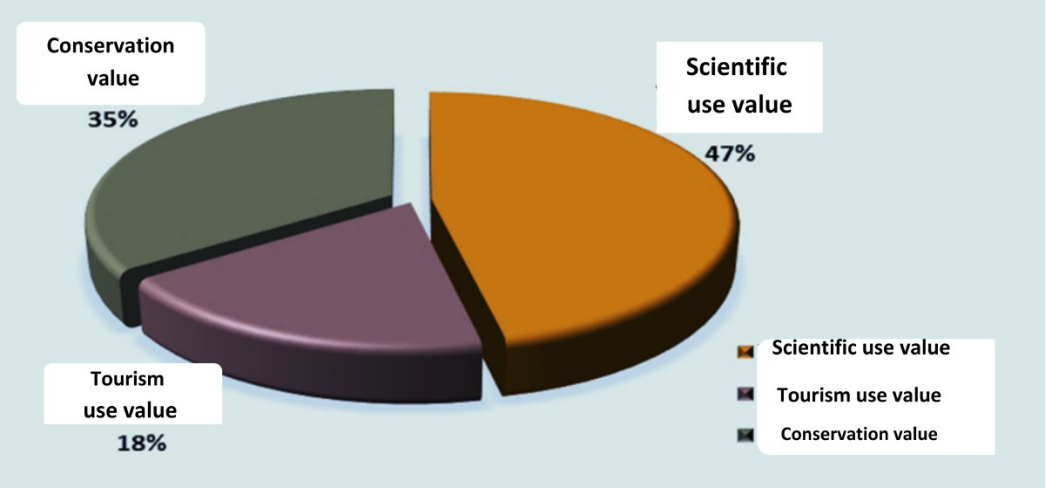
c) Scientific Use Value, Tourist Use Value, Conservation Value and Relevance

Based on the weightings made in the first quantification stage, it was possible to calculate the Scientific Use Value (SUV), Tourist Use Value (TUV), Conservation Value (CV) and Relevance (R) of the sites inventoried. The Scientific Use Value expresses the site's established or unexploited scientific potential. The Tourist Use Value expresses the ongoing use of the site and the future potential for its enhancement and dissemination.

Conservation Value expresses the importance of conserving these areas, taking into account not only their functional value, but also their intrinsic characteristics. And Relevance establishes the level of importance of the inventoried points on a local, regional, national and international scale.

Figure 9 shows the results of these values obtained for the southeast coastal sector of Maranhão Island, considering the reality of the area under study according to the parameters established by Pereira (2010). Based on the average of these values, it was possible to calculate the level of relevance of each point inventoried.

Figure 9 - Graphical display of the use values of the geosites in the study area



Source: Prepared by the authors

Even though there aren't many publications in the area, the highest average obtained was for the Scientific Use Value, which can be justified not only by the higher score given in the calculation of the Scientific Value because one of the points of interest has already been part of the research for a doctoral thesis. But also because of the association of these Geodiversity points with other themes of study and the characteristics and representation of geological/geomorphological processes that are different in some points in this sector than those observed on the western coast of the island of Maranhão.

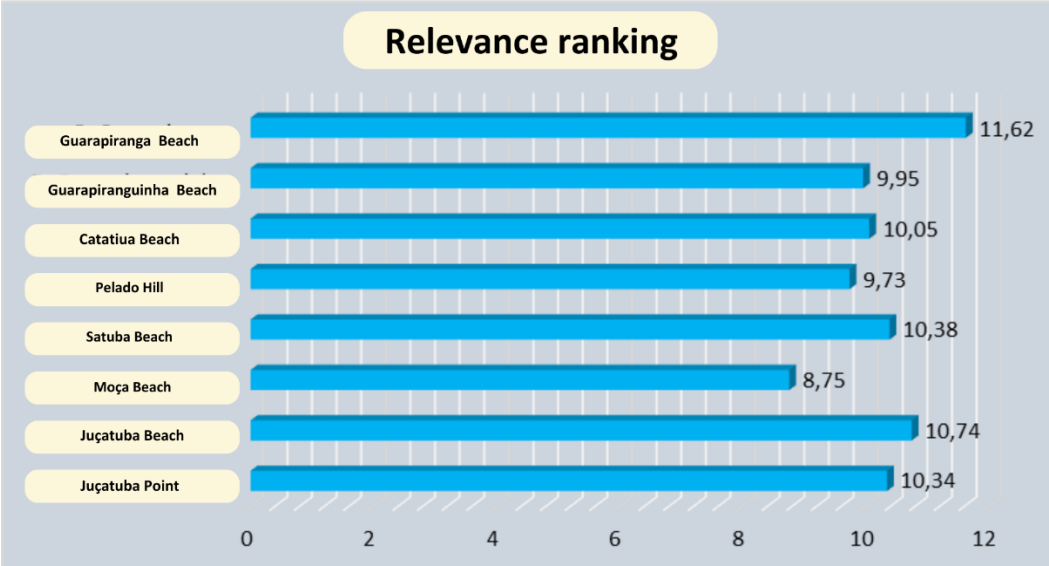
The second highest average obtained for the points inventoried in the area was Conservation Value. The fact that these points are not part of any legal environmental protection area and have high vulnerability because they are all located in the coastal plain unit, region of intense dynamics due to the "sea-continent" interface, meant that this value obtained the second highest average.

Intrinsic value also contributed to a higher Conservation Value score, as this is an important parameter in the methodology used to define VC and for the geosites defined in this research. This value obtained similar averages for all the sites, a factor that contributes to this result.

The Tourism Use Value had the lowest average percentage, accounting for 18% of all the values considered for the area. Although the area has natural potential for the development of tourism, mainly due to aspects of geodiversity that contribute to the future development of geotourism in the region, TUV had the lowest average. This result is due to the fact that the infrastructure in the area is inadequate to meet the basic needs of tourists and visitors, making it difficult to develop this economic activity in the area.

From these averages of Scientific Use Value, Tourist Use Value and Conservation Value, it was possible to arrive at the Relevance of each point inventoried in the southeast coastal sector of Ilha do Maranhão (Figure 10). The average for all the points inventoried was 10, with the exception of Guarapiranga Beach, which had an average relevance value of 11.62.

Figure 10 - Graphical display of the relevance ranking of the geosites in the study area



Source: Prepared by the authors

According to the methodology used, Relevance values equal to or less than 10 show local relevance in terms of Geodiversity. The average relevance of all the points inventoried was 10.24. Thus, Guarapiranga Beach, which had an average individual relevance value of 11.26, is also a point of local interest, since according to Pereira (2010) the average individual relevance value of a point must be lower than the average relevance value of all the points inventoried.

CONCLUSIONS

The qualitative and quantitative assessment was important for generating more specific information on the coastal geoheritage of the southeast sector of Maranhão Island, and the inventory data was fundamental to the results obtained in the quantification stage, based on the application of Pereira's method (2010). The application of this methodology to the area showed satisfactory results. The final average values for Scientific Use Value, Tourist Use Value and Conservation Value show ranked results in situations that converge with the information observed in the field and inventoried.

For the economic exploitation of mineral resources, for example, the method used to quantify use values, used in this research, is more conservationist in nature and focuses on the potential for scientific, educational and tourist use. It is important to emphasize that although the methodology applied has presented results that can contribute to the planning and management of these sites, further studies need to apply methods that also focus on the risk of degradation to which these geosites are exposed. Although the area is not intensely exposed to anthropogenic threats, the geosites inventoried are in an area of intense dynamics between the sea and the continent, which makes these points naturally more fragile.

All the points inventoried showed local relevance with slightly different averages, which indicates a similar level of importance for all geosites, taking into account the similar characteristics of geodiversity and the socioenvironmental context in which these sites are located. However, the peculiarities and limitations of each area must also be taken into account when public managers think about and plan action strategies. Moça Beach, for example, has

potential for scientific and educational use, as it has interesting geological and geomorphological features for this type of use.

Currently, the area does not have the potential for any kind of tourist use because the number of lithological layers present on the coastline and the extensive abrasion terrace that this beach has do not make it suitable for the development of "sun and beach" tourism. In addition to not having the necessary infrastructure to receive tourists, the natural characteristics of the area do not contribute to this type of economic activity, since the excess of beach rocks make it difficult for tourists to move along the beach line, for example. This discussion is just one way of showing how this information can be used by public managers to think about the best forms of use for the southeast coastal sector of Maranhão Island. Taking into account the potential, limitations and importance of these resources for the communities in the area, they can be used appropriately without threatening the local geodiversity and avoiding future environmental problems.

REFERÊNCIAS

AGUIAR, G.A. de. Geological revision of the Maranhão Basin. In: **BRAZILIAN CONGRESS OF GEOLOGY**, Proceedings. São Paulo: SBG.. v.1. p.113-122. 1971.

BARROS, J. S. e BANDEIRA, I.C.N. **Geodiversity of Maranhão Island**. CPRM, Teresina: 2020.

BANDEIRA, I.C.N. **Geodiversity of Maranhão State**. CPRM. Teresina:, 2013.

BRILHA, J. **Geological Heritage and Geoconservation:** nature conservation in its geological aspect. Ed. 1, Portugal: Palimage. 2005.

BRILHA, J. Inventory and Quantitative assessment of geosites and geodiversity sites: A review. **Geoheritage**, n. 8, p. 119–134 2016. DOI: 10.1007/s12371-014-0139-3.

BRILHA, J. Geoheritage: Inventories and evaluation. In Geoheritage; REYNARD, E., BRILHA, J., Eds.**; Elsevier**: Chennai, India, pg. 69–85, 2018. ISBN 9780128095317. DOI: https://doi.org/10.1016/B978-0-12-809531-7.00004-6

BURNNET, F.L. Metropolization and Urban Management on the Island of Maranhão: socio-environmental effects of low income real estate production. **Public Policy Journals**. UFMA, n. 16, p. 353-362. 2012.

CLAUDINO-SALES, V. **Geodiversity and Geoheritage in a geographical reading.** Journal Ecuador. n 1, p. 231-241, 2024. DOI: https://doi.org/10.26694/equador.v13i1.14421

DE WEVER, P.; Le NECHET, Y. e CORNEE, A. Vade- mecum for the inventory of the national geological heritage. - Mém. H.S. **Geology society**. Fr., p.12- 162. 2006.

DINIZ, M.T.M.; ARAÚJO, I.G.D.; CHAGAs, M.D. Comparative study of quantitative assessment of the geomorphological heritage of the coastal zone of Icapuí—Ceará, Brazil. Int. J. **Geoheritage Park**, 10, p. 124–142. 2022. DOI: https://doi.org/10.1016/j.ijgeop.2022.02.006.

FRANÇA, L.F. de O. e MARIANO, G. Quantitative assessment of geodiversity sites using the cluster analysis technique: a case study. **Geography notebook**, n. 26, p.27-54. 2016. DOI 10.5752/p.2318-2962.2016v26n.45p.27

GÁRCIA-CÓRTEZ, A. e ÚRQUI, L.C. **Methodological document for the elaboration of the Spanish inventory of places of geological interest**. Spanish Geological and Mining Institute. 11, 2009. 102 p.

GEOILHA Project. **Geoprocessing and Remote Sensing applied to the mapping of the southeast coastal sector of Maranhão Island**. COLUN-UFMA. 2015-2017.

IPCC. **Intergovernmental Panel on Climate Change. Climate Change 2022:** Impacts, Adaptation and Vulnerability. 2022. Available in:https://www.ipcc.ch/report/ar6/wg2/.

KLEIN, E.L. e SOUSA, C.S. **Geology and Mineral Resources of the State of Maranhão**. Scale: 1:750.000, Belém: CPRM., p. 11-135, 2012. Available in: http://rigeo.cprm.gov.br/xmlui/handle/doc/17861.

KUBALÍKOVÁ, L.; IRAPTA, P.N.; Pál, M.; ZWOLI´NSKI, Z.; CORATZA, P.; Van WYK DE VRIES, B. Visages of Geodiversity and Geoheritage: A Multidisciplinary Approach to Valuing, Conserving and Managing Abiotic Nature; **Geological Society**, Special Publications: London, UK, 530, p 1-12, 2023. DOI: https://doi.org/10.1144/SP530-2022-321

LOPES, L. S. de O.; ARAÚJO, J. L. L.; e NASCIMENTO, M.A.L. do. Tourist Use Values of the Geosites of Sete Cidades (PI). **Yearbook of the Geosciences Institute**, n. 35, p. 209-221. 2012. DOI: http://dx.doi.org/10.11137/2012_1_209_221.

NUNES,F.C.; SILVA, E. F. da e VILAS BOAS, G. da S. Barreiras Group: characteristics, genesis and evidence of neotectonism. **Brazilian Agricultural Research Corporation** (EMBRAPA). pp5-26, 2011.

PEREIRA, R. G. F. de A. **Geoconservation and sustainable development in the Chapada Diamantina (Bahia - Brazil)**. Doctoral Thesis in Sciences with a specialty in Geology. Minho University, Lisboa, 2010.

RABELO, T.O. **Geodiversity in coastal environments: discussions and applications in the southeast sector of Maranhão Island, MA Brazil**. Dissertation submitted to the Postgraduate Program in Geography at the Federal University of Rio Grande do Norte. UFRN. Natal. 2018.

RABELO, T,O. et al. Characterization of the Geodiversity of the southeast sector of Maranhão Island as a subsidy for environmental planning**. IV Brazilian Geological Heritage Symposium**. Ponta Grossa. 2017. Disponível em: https://www.4sbpg.com/anais.

RABELO, T.O.; LIMA, Z. M. C.; NASCIMENTO, M. A, L. do. Inventory of coastal geosites/geodiversity sites in the southeastern coastal sector of Maranhão Island, MA-Brazil. **Geography Journal**, n. 38, p.96-116. 2021. DOI: 10.51359/2238-6211.2021.248042.

RABELO, T.O.; LIMA, Z. M. C. e NASCIMENTO, M.A. L. do. Delimitation of the geoenvironmental units of the geodiversity of the southeast coastal sector of Maranhão Island, MA- Brazil. Northeast **Geosciences Journal**. 2020, v. 6. p. 236-243. DOI: https://doi.org/10.21680/2447-3359.2020v6n2ID18750.

REIS, R. de J. dos. **Southeast coast of the municipality of São Luís - MA: Analysis and proposal for Environmental Management**. Dissertation presented to the Master's Degree Course in Environmental Policy Management. Pernambuco Federal University. Recife. UFPE, 2005.

RIBEIRO, N. dos R. et al. Geodiversidade e potencial geoturístico na planície costeira do setor sudeste da Ilha do Maranhão. **IV Simpósio Brasileiro de Patrimônio Geológico. Ponta Grossa.** 2017. Disponível em: https://www.4sbpg.com/anais.

SANTOS, D. S.; MANSUR, K. L.; SEOANE, J.C.S.; MUCINUVA, V.C.; REYNARD, E. Methodological proposal for the inventory and evaluation of geomorphosites: an integrated

approach with a focus on territorial management and geoconservation. **En-viromental Management**, n. 66, p 476-497. 2020. DOI: https://doi.org/10.1007/s00267-020-01324-2.

SHARPLES, C. Potential climate change impacts on geodiversity in the Tasmanian Wilderness World Heritage Area: A management response position paper. **Resource Management and Conservation Division**, Department of Primary Industries Parks Water and Environment, Hobart, p. 1-117, 2011.

SILVA, J.F.A.; AQUINO, C.M.S. e OLIVEIRA, D.S. Evaluation and proposal for the use of the "city of stones" as a site for activities linked to environmental education and geotourism. **Proceedings of the XI National Geomorphology Symposium**. 2016. Disponível em: http://www.sinageo.org.br/2016/trabalhos/9/9-33-1535.html.

SILVA, Q. D. da. **Geomorphological mapping of Maranhão Island**. Thesis presented to the Postgraduate Program in Geography at the Paulista State University. Presidente Prudente. UNESP. 2012.

VEIGA JÚNIOR, J.P. **São Luís NE/SE, mapsheet AS 23 – X e AS 23 – Z:** states of Maranhão and Piauí. Brasília, DF. Brazil's Basic Geological Survey Programs. CPRM. 2000.

ZOUROS, N. C. Geomorphosite assessment and management in protected areas of Greece. Case study of the Lesvos island- coastal geomorphosites. **Geographic Helvetica**, n. 3. p.169-180, 2007. DOI: https://doi.org/10.5194/gh-62-169-2007.

ACKNOWLEDGMENTS

We would like to thank CAPES (Foundation for the Coordination of Improvement of Higher Education Personnel) for supporting this research through a master's scholarship within the scope of the Postgraduate Program in Geography at the Federal University of Rio Grande do Norte and the Center for Environmental Research Studies at the Federal University of Maranhão for supporting the activities of this research on Maranhão Island, state of Maranhão - Brazil.