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ORIGINAL ARTICLE

Methodology for the Semi-quantitative Evaluation of Geoheritage Applied to Coastal Geotourism in João Pessoa (Paraíba, Northest Brazil)

Luciano Schaefer Pereira[1] · Daniel Matos de Carvalho[2] · Lúcio Sobral da Cunha[3]

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Abstract
In this work, a new methodology is presented for the semi-quantitative evaluation of the coastal geotouristic potential and protection requirements of ten sites chosen in the coastline of the State of Paraíba, about 54 km from the state capital. The geotouristic potential was determined based on two indicators, whose value was estimated: the Touristic Use Potential, with ten variables, with different levels of importance, and the Additional Value, with six variables, also with different levels of importance. The Need for Protection Index was estimated taking into consideration ten variables with different levels of importance and based on the need to protect the sites once the geotouristic activity starts to generate impact in the places where it is implemented. The Imminent Risk Index applied to the sites where the level of vulnerability is greater was calculated based on the Need for Protection Index, with a weight of 1, and the Touristic Use Potential and Additional Value Index, which added also present a weight of 1. The result of the simulation done to the area was satisfactory, making it possible to apply in other areas, as long as the necessary adjustment measures to the local context are taken into consideration.

Keywords Semi-quantitative evaluation · Coastal Geotourism · Geoheritage · Paraíba

Introduction

Tourism is a secular activity; however, due to the developments, it has undergone in recent years, most of them associated with natural aspects; it has never been in the spotlight as much as it is today. Rural tourism, ecotourism, adventure tourism and geotourism are some of the examples of segments that have renewed this activity, increasing incomes, moving capital, improving the quality of life of the populations involved and, when executed in a sustainable way, prolonging the life of the environment and assisting in its preservation. This development has created new territories, in which every spatial element that is possible to be inserted into the touristic dynamics is welcomed. In this context, geotourism, by inserting geoheritage into the touristic activity, generates different physical areas of appreciation, or causes old ones to be seen with a fresher perspective. The rocks, their minerals, their tectonic deformations, the fossils, the reliefs, the soil, the water, among others, are some examples of the elements that have increased this touristic area.

Therefore, geotourism is a new segment that aims to appreciate, promote and value the geological and geomorphological heritage, or geoheritage, as a whole, including forms and processes (Dowling 2011), adding the abiotic environment to the elements of fauna and flora, while using geoheritage in a sustainable way. The pioneering definitions involving the term "geotourism" date from the mid-1990s, starting with Hose (1995, 2000). Geoheritage can then be described and interpreted in places with relevant aspects that promote its

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✉ Luciano Schaefer Pereira
lschaefer2@gmail.com

Daniel Matos de Carvalho
danielmatosc@hotmail.com

Lúcio Sobral da Cunha
luciogeo@fl.uc.pt

[1] Center of Human Sciences and its Technologies, Federal Institute of Education, Science and Technology of Paraíba, 1° de maio, 720, 58015-020 João Pessoa, Brazil

[2] Federal Institute of Education, Science and Technology of Paraíba, João Pessoa, Paraíba, Brazil

[3] Department of Geography, Faculty of Letters, University of Coimbra, Coimbra, Portugal

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interpretation, always with the objective of benefiting the local community and introducing environmental awareness to the elements involved. It is important to note that, in this work, geoheritage corresponds to the abiotic portion of Natural Heritage, which can be subdivided into Geological, Geomorphological, Pedological and Hydrological Heritage (Rodrigues and Fonseca 2008). The role of geotourism is to disseminate the geodiversity of places through its geoheritage, with the implementation of projects of scientific, educational and interpretative purposes that promote tourism in the area.

The touristic flow of João Pessoa is very low, in the Brazilian context, when compared to that of Natal and Recife, nearer capitals, respectively located north and south. According to data from the Statistical Yearbook of Tourism (2013), prepared by the Ministry of Tourism, 620 thousand passengers landed at "Castro Pinto" Airport in Bayeux, in the metropolitan region of João Pessoa, against 3.2 million in Recife and 1.3 million in Natal. At the regional level, only Teresina performed worse, with 527 thousand passengers in the same year.

Although it possesses a singular scenic beauty, when the moment comes for tourists to select a northeastern capital to visit, João Pessoa has been continuously relegated. Thus, the effort to add the abiotic environment to tourism is essential as an attempt to increase this activity in the capital. There are some methodologies in the literature directly applicable to this type of use of geoheritage (as we'll see soon) and the objective of this work is to propose a semi-quantitative evaluation methodology of the geotouristic potential of João Pessoa and of the southern coastline of the State of Paraíba, up to the "Abiaí" Depression, about 50 km from the state capital.

The mapping of the geological typology of the Historic Centre is incipient (Pereira et al. 2013a, b; Pereira and Amaral 2014), the same happening with the geoheritage of the area involved: currently the topic of study of the doctorate in Physical Geography of the first author, in the University of Coimbra, Portugal.

Area of Study

The municipality of João Pessoa is the capital of the state of Paraíba, the most eastern part of Brazil. In fact, João Pessoa is known worldwide as the "eastern end of the Americas", which, by itself, provides it with touristic potential. Its geographic coordinates are 7° 7′ S and 34° 53′ W and the proximity of Ecuador provides it with high temperatures throughout the year. It has an area of 211.5 km^2 and a population of 723.515 inhabitants (Brazil 2010), resulting in a demographic density of 3421 inhabitants/km^2, the highest in the state. As well as the capital, the southern coastline receives an important touristic flow in its beaches, with *buggies* being one of the main means of transport, which are rented in packages sold in kiosks located in the main urban beaches.

Being a coastal city, its natural landscape is essentially littoral, selling tourists an image of "sun and sea". The great estuary of the Paraíba River, which in its lower course flows parallel to the coast, is separated from the sea by an enormous scrubland. The river then forms fluvial beaches, which have become important touristic spots, like the one of "Jacaré", whose sunset to the sound of Ravel's Bolero is a must-see together with the mangrove ecosystem that stretches for tens of kilometres.

To exemplify the natural geotouristic potential of the city, in addition to the geomorphosite described above, we can mention the "Cabo Branco" cliff (on the beach of "Seixas", the most eastern point of the Americas), the natural pools of "Tambaba" Beach, formed in the dead water tides from the outcrops of the sandstone reefs that touch the beach, the Love Stone, which corresponds to a rare limestone outcrop of the "Maria Farinha" Formation that, through marine abrasion, eventually formed a heart-shaped cavity, "Irerês" Lagoon, popularly known only as the Lagoon (in the heart of the city, it corresponds to a *dolina*), the "Coqueirinho" Canyon that, despite its name, is in fact a large and beautiful *voçoroca* (land collapse) open in the "Barreiras" Formation, the Holocene and Pleistocene marine terraces, important testimonies of paleo-geographic and coastal dynamics, the coral reefs of "Picãozinho", among others.

In the last decades, the population increase of the municipality has resulted in a greater anthropic action on this natural landscape, which corresponds to an environment that interweaves coastal, valley and plain areas. Despite being a capital, the passage from urban area to rural area, in its periphery, is made abruptly, displaying a provincial character, with forests and mangroves being mixed with asphalt, pollution and people. Sugarcane plantations and small rural farms observe from a distance the rapid evolution of this urban site.

Geological and geomorphological context of the area

The area is located in the topographic chart of João Pessoa plane (SB-25-YC-3), scale 1:100,000, elaborated by the Army Ministry. The geology of the research area is associated with Paraíba sedimentary basin. Such sediments were deposited as the South American continent withdrew from the African continent (Françolin and Szatmari 1987), over a crystalline basement deformed by shear zones (Jardim de Sá 1994). This basin can be subdivided into three sub-basins (Fig. 1): Olinda, Alhandra and Miriri sub-basins. The study area is part of the Alhandra sub-basin, border to the north by Itabaiana fault and to the south by Goiana fault.

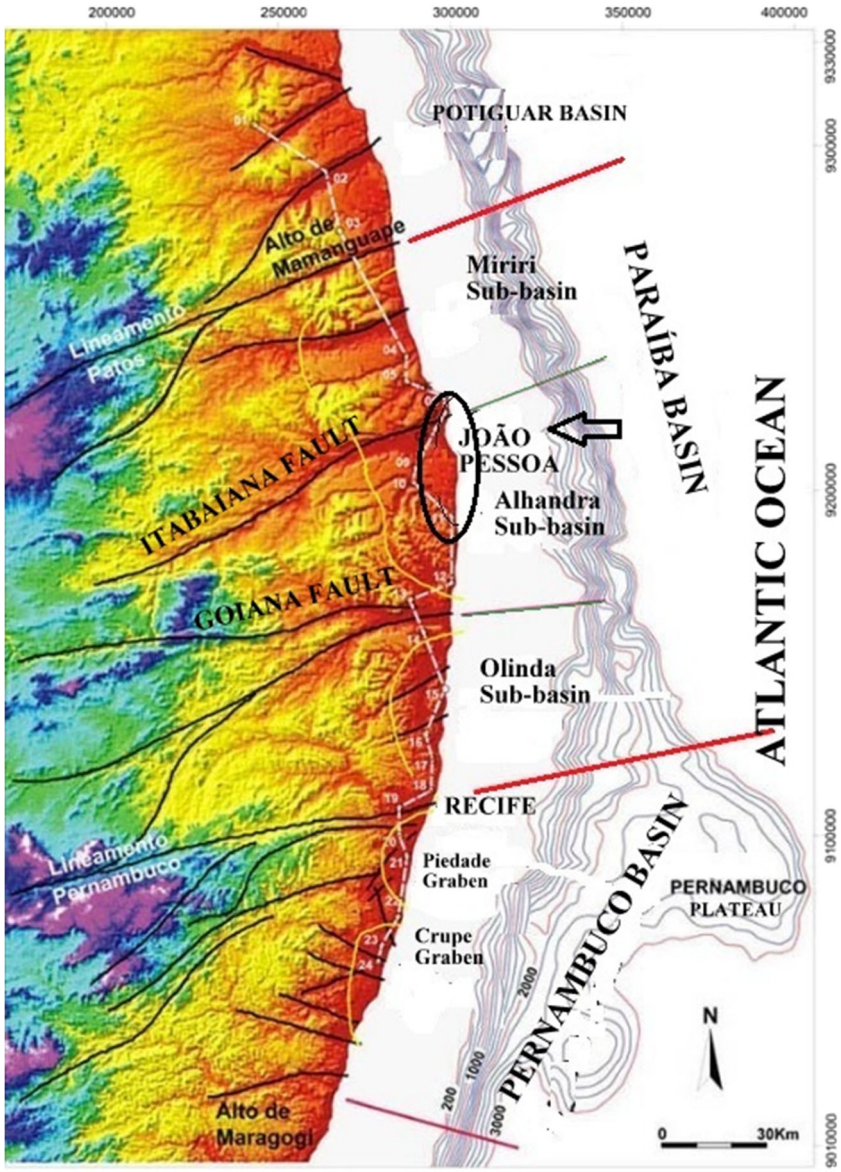

Fig. 1 Location Area (circle) in the sedimentary basins of the Northeast. (Source: modified from Barbosa and Lima Filho 2005)

The geological substrate of João Pessoa is marked by sediments that date from the end of the Triassic period to the present (Asmus 1975), on a crystalline basement called "Terrain Alto Moxotó" (orthogneisses and granite suites) that does not appear in the area. From the sedimentary sequence, we highlight the "Itamaracá"/"Beberibe" Formation (base, siliciclastic), "Gramame"/"Maria Farinha" (centre, carbonate) and "Barreiras" (platform cover), as well as quaternary sediments representative of a marine-transitional environment, all of them modelled and remodelled by exogenous agents, especially the fluvial and marine agents, resulting in a unique geoheritage.

From the Pliocene, as a result of the establishment of a stress field in the South American plate, with compression oriented E-W and N-S extension, a series of faults that hit the overlapping sediments were reactivated, having a crucial role in coastal morphology and tracing of the hydrographic network (Bezerra et al. 2001).

The research area belongs to the geomorphologic unit of Plains and Coastal Tablelands, according to Ross (1985), having direct relation with ancient tectonic movements, generated during the drift of the South American and African plates (Asmus 1975), added to Cenozoic tectonic events (Bezerra et al. 2001). We can identify three subunits to the urban site of João Pessoa and the south coast: the coastal plain, low coastal upland ("Coastal Tablelands") and floodplains, which can be still subdivided into fluvial and fluvial-marine floodplains (Rodriguez 2002).

The top of the tablelands is linked to the plains in relatively steep slopes, in the form of cliffs, with great scenic beauty, in the shore. The coastal lowlands are in direct contact with the sea, have altitudes between 0 and 10 m, which quaternary

sedimentation of river, marine and rivermarine origin filled the coastal plain, resulting in numerous geomorphological features that can be considered potential geomorphosites for its scenic beauty and/or relevant geological/geomorphological history. On the margin of the Paraiba River, floodplains occur on higher altitudes, whose presence of mangroves, away up to 12 km of the coastline denote its ecological importance. In the northern portion of the study area, the sandbank of Cabedelo ("Restinga de Cabedelo") separates the Paraíba River from the Atlantic Ocean. The low coastal uplands, also known as "Coastal Tablelands", correspond to a higher, gently sloping portion of the land, with flat top, generally inclined to the east, result from the action of exogenous agents that carved the Barreiras Formation, including marine abrasion on cliffs, another outcrop form of this formation on the coast, at its eastern portion. Most of the urban site of João Pessoa sits on this geomorphological unit.

According Brito Neves et al. (2004), these low coastal uplands were results of large arching and a succession of steeped pediplains to inland, subordinated to paleoclimate, whose graben-horst-type structure controlled its morphology. Reactivation of basement shear zones with E–W ansd NE–SW direction, from the Early Cretaceous (Nóbrega et al. 2005), reach the sediments of the Barreiras Formation, forming fault scarps that are capped by alluvial terraces, sandstone dunes, debris slopes, soil and vegetation, and which serve as bounds of the river valleys, while the upraised portions were dissected (Lima et al. 1990).

Thus, the altimetric quotes of the urban compartment of tablelands show uplifted portions (west, whose elevations reach 70 m) and lowered portions (between Mumbaba River and Sanhauá River, a tributary of the Rio Paraiba, where altitudes do not exceed 40 m), rising again (in the upper course of the Rio Cuiá), decreasing toward the east, and denoting the structural behavior of the graben-horst type, bounded by normal faults (Bezerra et al. 2001). The substrate of municipality is represented by a Graben, called Gráben da Grande João Pessoa, according Brito Neves et al. (2004), whose sediments reach 300 m thick, when they reach the basement.

The criterion for choosing the sites was according to the presence of values, such as cultural, scientific, aesthetic, ecological, among others, and Fig. 2 shows the location of the sites in the area. These values were considered as parameters for the calculation of the Geotouristic Potential of the geosites.

Semi-quantitative evaluation methodology of geotouristic potential

Geoheritage, particularly geological and geomorphological heritage, has been semi-quantitatively evaluated since the pioneering work of Grandgirard (1995). Since then, several authors have proposed methodologies for the quantitative evaluation of geoheritage, with the purpose of doing the inventory and quantification of the geodiversity of the sites, of the potential of certain sites to be classified as geosites/geomorphosites or of the level of vulnerability to which these sites are subjected.

Inserted in these proposals, we mention Rivas et al. (1997), Lima (2008), Gacia-Cortez and Carcavilla (2009), Pereira (2010), Fassoulas et al. (2012), Figueiró et al. (2014), Brilha (2015), among others. For these authors, the mapping of geoheritage mainly aims at its geopreservation or the promotion of geosciences to a larger public. In this sense, geotouristic activities would serve as an additional tool to achieve this goal. However, mapping the geotouristic potential of these sites was not the main guideline for these methodologies. Theoretical-methodological proposals of semi-quantitative evaluation of the geotouristic potential of geosites and geomorphosites are scarce in the literature. However, a highlight should be given to the precursor work of Pralong (2005), who, in addition to the quantification of the touristic potential of sites, in the case of geomorphological sites, assessed the risks of exploring these sites in a tourist and recreational context, using as case study two mountainous areas of the Alps, Chamonix-Mont Blanc, in France and Crans MontanaSierra, in Switzerland. According to the author, this touristic potential can be quantified using four main values: scenic/aesthetic, scientific, cultural/historical and economic/social, each divided into several attributes, which were scored from 0 to 1, according to some previous works. After Pralong (2005), we cite Rybár (2010), Pereira and Pereira (2012), Pereira and Nogueira (2015), Ziemann and Figueiró (2017), Brazilian Geological Service (CPRM), among others.

In the case of the latter, CPRM developed an application for the automatic registration and quantification of geosites, called GEOSSIT, being one of the first Brazilian initiatives that enables the integration of data from the inventory records and quantification parameters for characterization of national geological heritage. It works as a tool for standardizing the registration of geosites in Brazil, from free access to visualization of existing sites. For the quantification of vulnerability and didactic, scientific and touristic values, GEOSSIT used the method of Gacia-Cortez and Carcavilla (2009), maintaining all parameters and their respective weights for the calculation of the final value.

The semi-quantitative assessment of the geotouristic potential of João Pessoa and the southern coastline of Paraíba, the baseline of this article, corresponds to an intermediate phase of the promotion process involving other sequential phases (Brilha 2005), namely: *identification* (In which geoheritage segment can the site be inserted? Geological, geomorphological, pedological or hydrological?); *inventory* (creation of a database with the heritage elements, with the completion of descriptive files, containing various information, such as absolute location, means of access, photographic register of the

Fig. 2 Location of the assessed geosites in the area

site, a detailed description of geological, geomorphological, pedological and hydrological features, considering the scale of the site, from the outcrop to the landscape); *semi-quantitative evaluation* (degree of importance of the element for geotourism, as well as the evaluation of the degree of vulnerability, aiming at the creation of geoconservation measures, based on the proposal of this work); and *promotion* (publicity of the value of heritage elements, through the elaboration of the geotouristic guide of the area and other promotion methods). This integrated methodology will be published soon.

Between December and February of the years 2014 to 2017, 237 questionnaires were given to tourists who participate in a tour through the southern coastline of the State of Paraíba, which had the duration of about 7 h and covered several sites of geotouristic interest in order to know the profile of the tourist in a geotouristic context. This questionnaire discriminated the places visited and the tourists had to make

an evaluation of the spots that marked their tour, demonstrating their perception of the landscapes and sites visited.

These tourists did not know concepts such as geotourism (59%) or geoheritage (51%), but were interested in understanding how the natural landscape of the area was formed (87%), and felt the absence of panels, posters or geo-interpretative boards in the area (77%).

Based on the profile of the area's tourist, obtained from the questionnaires carried out and presented, we are able to classify the visitors of João Pessoa and the southern coastline of Paraiba as "type 1", according to Miller (1991), "general tourist" (*sensu* Hose 1995, 2000) and "interested visitor" (*sensu* GRANT 2010), since they are unaware visitors of the geotouristic activities and concepts that involve geoheritage, and this is not the main motivation for their choice of travel destination. However, these tourists made it clear that they were curious to understand the dynamics of the landscape, and not only to appreciate it, as well as comprehend the interest of the abiotic heritage, especially in what regards the beach, the sea and the landform.

Thus, the methodological proposal of this work emphasizes the criteria that stimulate the geotouristic use of the sites mapped in the quantification of this potential, giving less importance to the scientific, ecological and cultural values, which were used as parameters to calculate the "Additional Value", and giving more importance to the aesthetic value and the indicators of the degree of tourist support that are at the base of the estimation of the "Touristic Use Value".

Different weights are attributed to the indicators of each criterion, valuing those that make the difference for a better understanding of the criterion, be it touristic or additional. These criteria were partially based on the models of quantitative evaluation presented by Uceda (1996), Brilha (2005) and Gacia-Cortez and Carcavilla (2009), to which were added some new indicators based on the local reality.

The methodology proposed here is based on the obtaining of three indices: two secondary indices (Geotouristic Potential and Vulnerability) and a general index (Imminent Risk Index—IRI), obtained by weighing the values of the two secondary indices. These indices were obtained from the authors' completion of two files containing the variables and their respective weight in the estimation. For this, it was necessary a detailed knowledge of the physical (geology, geomorphology, hydrology and pedology), socioeconomic, touristic and ecological characteristics of the catalogued sites. This knowledge was acquired in the preliminary phases of bibliographical research and field mapping.

Geotouristic Potential

The Geotouristic Potential (GeoP) is a result of the evaluation of two central characteristics: Touristic Use Potential (TUP), which combines variables that characterize elements of aesthetic value and touristic support (Table 1) and the Additional Value—AdV, in which a combination of scientific, ecological and cultural values is highlighted (Table 2).

Considering these variables and after the calculation of an average is done, the Geotouristic Potential Index—TPI and the Additional Value Index—AdVI, respectively, with the first indicator having a double weight in the calculation of the GeoP in relation to the second. Thus, Tables 1 and 2 describe the variables selected to calculate the indicators, the weight of the variable, the score associated with the mapped location (ranging from 1 to 5) and the degree of importance of the variable (weight). For a better understanding of these variables, the reading of Pereira and Nogueira (2015) is recommended.

Therefore, the GeoP, the Tourist Use Potential Index—TPI and the Additional Value Index—adVI should be obtained as follows:

$$\mathrm{TPI} = \left(\sum_{i=1}^{10} TUP_i * Weight_i\right)/100$$

$$adVI = \left(\sum_{i=1}^{10} adV_i * Weight_i\right)/50$$

where $\mathrm{TUP_i}$ is the variable i of Touristic Use Potential, $\mathrm{adV_i}$ is the variable i of the Additional Value, and $\mathrm{Weight_i}$ is the weight of variable i.

The Geotouristic Potential (GeoP) will be estimated by adding the result of these two indicators, divided by 3, to reach a value between 1 and 5, as in:

$$GeoP = (\mathrm{TPI}*2 + adVI)/3$$

It should be noted that each indicator received different weights. The construction of the indicators was based on the concept of a pondered average, where we consider the response of the variable, weighted by the degree of importance of the variable, divided by the sum of the weights.

As mentioned previously, the result of the three indicators will be between 1 and 5. If two or more sites have similar GeoP values, the site with the highest TPI, which has a higher weight in the GeoP calculation, is considered as a tie-breaking criterion.

As a standard scale of the quality of the GeoP, a scalar grid can be implemented to allow a quick perspective over the behaviour of the sites in the study (Fig. 3), where

- ✓ GeoP with values between 1 and 2: sites *without* geotouristic potential.
- ✓ GeoP with values between 2.01 and 3: sites with *weak* geotouristic potential.
- ✓ GeoP with values between 3.01 and 4: sites with *good* geotouristic potential.
- ✓ GeoP with values between 4.01 and 5: places with *high* geotouristic potential.

Table 1 Quantification variables of Tourist Use Potential (TUP) of the catalogued sites, with their respective weights

Local characteristics			
Aesthetic value			
TUP_1—spectacularity/beauty	Weight 20	TUP_2—presence of non-harmonic elements (nhe)	Weight 15
5. Very high visual and scenic quality		5. Absence of nhe in the landscape	
4. High visual and scenic quality		4. Weak impact of nhe	
3. Average visual and scenic quality		3. Average impact of nhe	
2. Low visual and scenic quality		2. Strong impact of nhe	
1. Very low visual and scenic quality		1. Nhe interfere in a very significant way in the landscape	
TUP_3—colour contrast at the site	Weight 5	TUP_4—clarity	Weight 5
5. At least five contrasting colours		5. Easily visible at least 1 km away	
4. Four contrasting colours		4. Visible at least 500 m	
3. Three contrasting colours		3. Only visible between 100 and 500 m	
2. Two contrasting colours		2. Only visible between 10 and 100 m	
1. Identical colours		1. Only visible less than 10 m away	
Access/transport			
Value of tourist use			
TUP_5—access	Weight 10	TUP_6—transport	Weight 5
5. Direct access using the main road		5. Easily reached by motor vehicle	
4. Access partially done through paved secondary road		4. Partially reached by motor vehicle and on foot—walking at least 100 m	
3. Access partly done through paved secondary road while the other part is done on non-paved road		3. Reached partially by motor vehicle and on foot—walking between 100 and 500 m	
2. Access partially done through unpaved secondary road		2. Partially reached by motor vehicle and on foot—walking more than 500 m	
1. Access requires the use of boat		1. Only reached by boat	
Tourist support			
Value of tourist use			
TUP_7—distance from the nearest town	Weight 10	TUP_8—promotion	Weight 10
5. Within a large city, with at least 100 thousand inhabitants.		5. Broad promotion by specialized media	
4. Nearest town at least 5 km/marine site		4. Great promotion	
3. Closest city between 5 and 8 km		3. Average promotion	
2. Closest city between 8 and 15 km		2. Weak promotion	
1. Nearest town more than 15 km		1. No promotion	
TUP_9—presence of hotel infrastructures	Weight 10	TUP_{10}—proximity to restaurants and bars	Weight 10
5. At least 500 m of distance		5. At least 500 m of distance	
4. Between 500 m and 1 km		4. Between 500 m and 1 km	
3. Between 1 and 5 km		3. Between 1 and 5 km	
2. Between 5 and 10 km		2. Between 5 and 10 km	
1. More than 10 km		1. More than 10 km	
Total weight			100

All sites belonging to the two upper classes will be inserted in the Geotouristic Map of João Pessoa and the Southern Coastline, a geotouristic itinerary, all the rest will be discarded. Clarity and objectivity were intended objectives in the theoretical-methodological process of semi-quantitative evaluation. However, as we were performing this exercise, it was possible to observe that a certain level of subjectivity is inherent in any quantitative evaluation methodology, since some values are intangible and/or highly dependent on the appraiser's opinion.

Need for Protection Index

Taking into consideration that the geotouristic activity generates impact where it is implemented, if not accompanied by geopreservation proposals, the Imminent Risk Index (IRI) of the sites will be calculated based on an indicator called Need for Protection (NP), subdivided into ten variables, whose score ranges from 1 to 5, partially based on Gacia-Cortez and Carcavilla (2009), according to Table 3. Thus, we repeat the proposals done for the two previous indicators, also with different weights for each variable. The higher the values assigned to the variables, the greater the need for preservation.

The Need for Protection Index (NPI) of the site will be estimated based on the variables, each one with different weights, displayed on Table 3. For this, the formula used was:

$$\mathrm{NPI} = \left(\sum_{i=1}^{10} NP_i * Weight_i\right)/100$$

Resulting in a value between 1 and 5, where NP_i is the variable i of the Need for Protection and $Weight_i$ is the weight of variable 1.

Table 2 Quantification variables of the additional value (AdV) of the inventoried sites, with their respective weights

Scientific value			
AdV_1—abundance/singularity	Weight 15	AdV_4—degree of scientific knowledge	Weight 5
5. Unique in the studied area		5. More than one doctoral/master's thesis	
4. There are only two similar locations		4. At least one doctoral/master's thesis and one article in a national newspaper	
3. There are 3 to 4 similar sites		3. Only a doctoral/master's thesis	
2. There are 5 to 6 similar sites		2. Publications are restricted to national scientific meetings or national newspapers	
1. The place is very common		1. There are virtually no publications	
AdV_5—paleogeographic and geological interest	Weight 5	AdV_6—representative/local type	Weight 5
5. Clear and visible witness of phenomena and processes		5. Stratigraphic reference	
4. -		4. It adequately illustrates a particular characteristic or represents processes	
3. Witness but not so visible		3. Illustrates a particular characteristic or represents processes	
2. -		2. Poor representative	
1. Low importance or uninteresting		1. Not representative	
Ecological value		Cultural value	
AdV_5—ecological interest	Weight 10	AdV_x—association with cultural elements	Weight 10
5. Large fluvial or marine site with reefs		5. Referenced in iconography (maps/plants) and historical textual documents, both colonial and associated with local beliefs	
4. Marine river site, small/medium size river lagoon, *dolinas* and springs		4. Referenced in iconography (maps/plants) and textual historical documents, without association with local beliefs	
3. River site or basically acts as a wildlife support		3. Referenced in colonial iconography or historical textual documents	
2. Low ecological interest		2. It has cultural value limited to local beliefs	
1. No ecological interest		1. Not relevant	
Total weight			50

Once the NPI is estimated, the Imminent Risk Index (IRI) is calculated, which will involve all the quantified parameters until then. The protection priority of the site will be the result of the GeoP added with the NPI, the latter with a greater weight.

In the end, the results will be ranked in decreasing order for a better perspective of the sites that need urgent protection in relation to others, whose need for protection will be directly proportional to the IRI value. The IRI will be calculated as follows:

$$\mathrm{IRI} = (GeoP{*}0,5 + \mathrm{NPI})/1,5$$

If two or more sites have similar IRI values, the site with the highest NPI, which has a greater weight in the IRI calculation, is considered as a tie-breaking criterion.

In the same way, the median of this sample universe is estimated and divided into classes between 1 and 5. The upper area (values between 4.01 and 5) is considered as requiring urgent care by the state; the need for protection decreases as the IRI values decline; thus, the lower class needs very low protection.

Application of the geotouristic potential to the mapped area

Ten sites (Fig. 4) were randomly selected to be evaluated from a much larger universe, after detailed studies of geology, geomorphology, tectonics and stratigraphy, and through information collected from published works about the Paraíba Basin. They are:

- "Cabo Branco" Cliff
- Holocene Marine Terrace
- "Coqueirinho" Canyon
- "Irerês" Lagoon
- "Jacaré" Beach
- Stone of Love
- Pleistocene Marine Terrace
- "Tambaba" natural pools
- Paraíba River Estuary
- "Picãozinho"

The main objective of this selection is to apply the methodology proposed here, through the previously mentioned formulas. The results are presented on Tables 4 and 5.

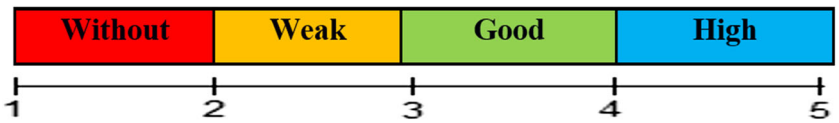

Fig. 3 Scale of the geotouristic potential of a coastal area

Table 3 Quantification variables of the Need for Protection (NP) in the catalogued sites, with their respective weights. The higher the values assigned to the parameters, the greater the need for preservation

NPI_1—anthropogenic vulnerability modality 5. Sites strongly altered by human action, with great possibility of destruction in the short-term 4. Sites strongly altered by human action, with possibilities for long-term destruction 3. Sites that, even with intense anthropization, will hardly be destroyed due to their isolation 2. Small to medium-sized sites that suffer from small human influence and small deterioration. 1. Large sites that suffer little human influence and small deterioration.	Weight 20	NPI_2—natural vulnerability 5. Affected by active processes of high intensity (marine abrasion, floods, mass movements, among others) 4. Affected by active processes of medium intensity 3. Affected by active processes of low intensity 2. Affected by active processes of very low intensity 1. Vulnerable only to chemical weathering	Weight 15
NPI_3—monthly number of visitors in high season (December to February) 5. More than 10 thousand visitors 4. Between 5 thousand and 10 thousand visitors 3. Between 1 thousand and 5 thousand visitors 2. Between 500 and 1 thousand visitors 1. Less than 500 visitors	Weight 15	NPI_4—settlement proximity 5. Within an urban nucleus with more than 50 thousand inhabitants. 4. Within an urban nucleus with more than 50 thousand inhabitants, with at least 10 km of dense area 3. Within an urban nucleus with less than 50 thousand inhabitants. 2. Distance between 10 and 50 km of an urban/marine nucleus 1. Distance greater than 50 km from an urban core or isolated from human action	Weight 10
NPI_5—protection regime 5. Does not present any legal protection level 4. Partially included in a protected area with allowed visitation 3. Partially included in a protected area with restricted visitation 2.Totally included in a protected area with allowed visitation or isolated from human action 1. Totally included in a protected area with restricted visitation	Weight 10	NPI_6—associated economic activities 5. Quarries and urbanization 4. Sand extraction and direct tourist activities on the site 3. Bars and restaurants and indirect tourist activities near the site 2. Low-impact human activity 1. No economic activity	Weight 10
NPI_7—real estate pressure 5. Distance less than 50 m from some construction/allotment 4. Distance between 50 and 500 m of some construction—allotment 3. Distance between 500 m and 1 km of some construction—allotment 2. Distance between 1 and 5 km of some construction—allotment or isolated from human action 1. Distance greater than 5 km from some construction/allotment	Weight 5	NPI_8—level of deterioration 5. Very high deterioration, which strongly masks the original characteristics of the local site 4. High deterioration 3. Average deterioration 2. Low deterioration 1. No deterioration	Weight 5
NPI_9—surface extension 5. Over 50 thousand m^2 4. Between 20 thousand and 50 thousand m^2 3. Between 10 thousand and 20 thousand m^2 2. Between 1 thousand and 10 thousand m^2 1. Less than 1 thousand m^2	Weight 5	NPI_{10}—property regime 5. Private land belonging to several owners 4. Private land owned by an owner 3. Partially public and private land 2. Predominantly municipal land 1. Predominantly state-federal land	Weight 5
Total weight			100

Considering the results obtained, with respect to the geotouristic potential (GeoP) of the sites mapped, and separating them, as proposed, in areas, we have the situation displayed in Fig. 5a. Regarding the Imminent Risk Index (IRI), the ranking resulted in the configuration of Fig. 5b.

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Discussion of the results obtained

Recently, through the interviews conducted to 602 tourists that visited João Pessoa and the region, between December 26, 2013, and January 15, 2014, the "Fecomércio" Institute of Economic and Social Research of Paraíba - IFEP (IFEP 2014) came to the conclusion that the "Cabo Branco" Cliff, with its lighthouse, the "Jacaré" Beach, the "Picãozinho" and the "Coqueirinho" Canyon are among the most visited touristic spots in the region, while the urban beaches (in descending order, "Tambaú", "Cabo Branco", "Manaíra", "Bessa" and the beaches of "Cabedelo") were the ones selected to be visited. Immediately following, the preference falls upon the southern coastline, with "Coqueirinho" and "Tambaba" standing out.

When we associate the spots selected by the tourists, sampled in the IFEP survey, with the results obtained by the semi-

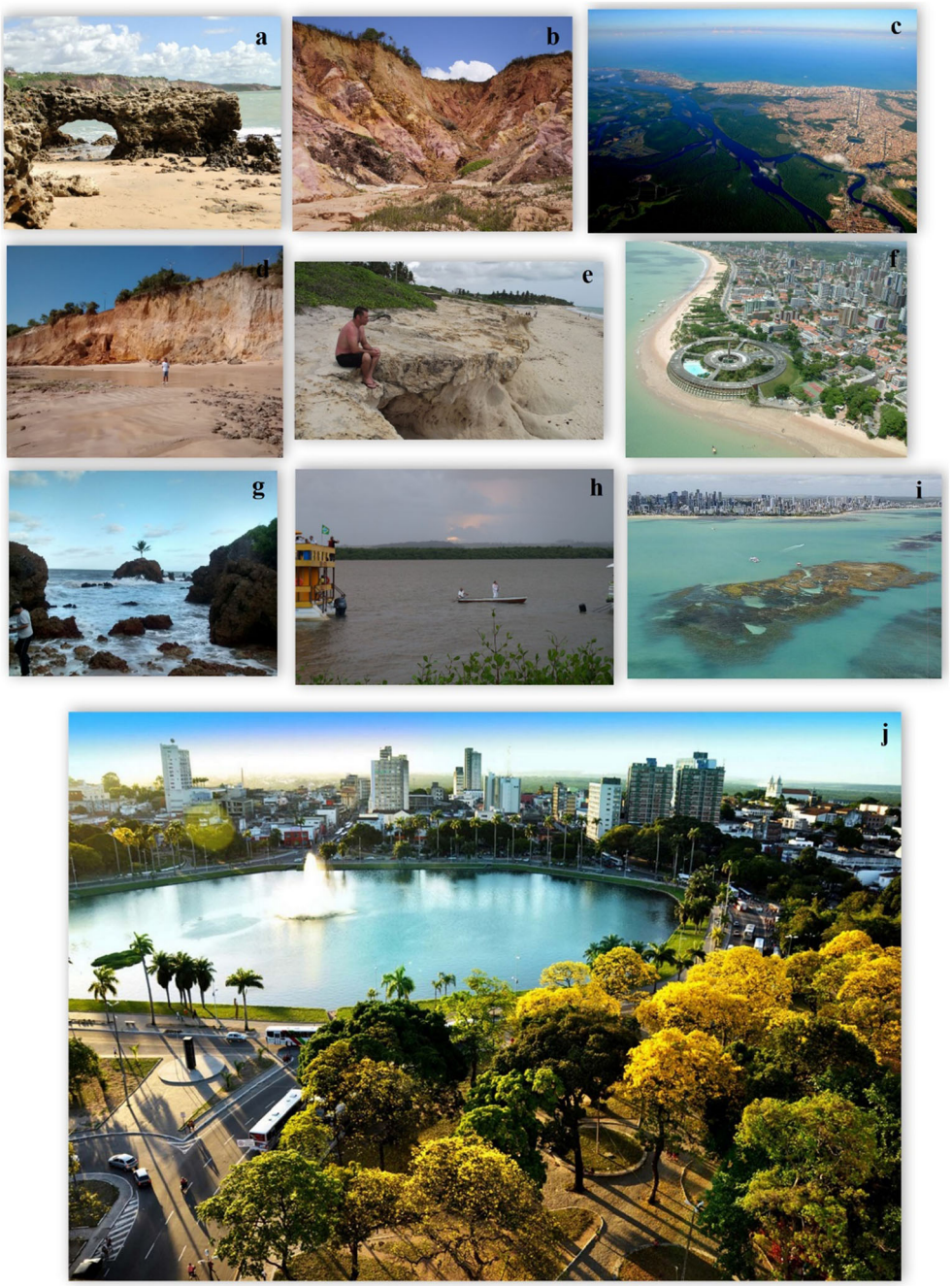

Fig. 4 Aerial and surface photos of the assessed sites: **a** Stone of Love (source: photo of the author (s), 2014); **b** "Coqueirinho" Canyon (source: photo of the author (s), 2016); **c** Estuary of the Paraíba River (source: Newsea, 2015); **d** "Cabo Branco" Cliff (source: photo of Elda Karoline, 2016); **e** Pleistocene Marine Terrace at "Tabatinga" Beach (source: photo of the author (s), 2014); **f** Holocene Marine Terrace at "Tambaú" Beach (source: photo of Ricardo Paulo, 2005); **g** "Tambaba" natural pools (source: source: photo of Thiago Farias, 2006); **h** Sunset at "Jacaré" Beach (source: photo of the author (s), 2016); **i** "Picãozinho" (source: Brasilvip, 2014); **j** "Irerês" Lagoon (source: Guia Mais, 2015)

quantitative evaluation methodology of the geotouristic potential, the results are curious. Together with the Holocene marine terraces, the "Irerês" Lagoon and the "Cabo Branco" Cliff are the only sampled sites with high geotouristic potential. The "Cabo Branco" Cliff, for example, is signalled as the "most eastern point in the Americas" and this slogan is sold to the world, although this location is really at the "Seixas" Beach—Ponta do Seixas. From this cliff, there is a spectacular view of the municipality of João Pessoa and its beaches—"Cabo Branco", "Tambaú", "Manaíra" and "Bessa", from the south to the north. At the back of these beaches, there is the geomorphosite of the Holocene marine terraces that, due to their magnitude and high occupation rate, present a serious need for protection, as well as the highest geotouristic potential of all sites. The "Cabo Branco" Cliff has its natural landscape completely modified, suffering from a high degree of deterioration due to human occupation and adjacent buildings, such as the Science Station. It has the differential of an intense marine erosion on its slopes, which resulted in its partial collapse in April 2015, as well as part of a cliff attached to it.

The "Irerês" Lagoon, in the heart of the Historic Centre of João Pessoa, stands out for its scenic beauty, as well as its

Table 4 Results of the semi-quantitative evaluation of the selected sites in João Pessoa and the Southern Coastline

Potential site	Main heritage segment	Thematic category	TPI	AdVI	TPI/ AdVI	GeoP	NPI	IRI
"Cabo Branco" Cliff	Geomorphology	Coastal geoform	4.75	3.1	1.53	4.2	3.95	3.97
Stone of Love	Geomorphology	Karstic	3.4	3.55	0.96	3.45	3.25	3.32
Holocene Marine Terrace	Geomorphology	Coastal geoform	4.75	3.45	1.38	4.32	4.05	4.14
Pleistocene Marine Terrace	Geomorphology	Coastal geoform	2.65	3.1	0.85	2.8	3.25	3.1
"Coqueirinho" Canyon	Geomorphology	Pluvial geoform	3.9	3.25	1.2	3.68	3.45	3.52
"Tambaba" natural pools	Geology	Marine	3.8	4.35	0.87	3.98	2.6	3.06
"Irerês" Lagoon	Geomorphology	Karstic geoform	4.75	3.45	1.38	4.25	3.6	3.82
Estuary of the Paraíba River	Geomorphology	Fluvial-marine	4.2	3.4	1.23	3.93	3.7	3.78
"Jacaré" Beach	Geomorphology	Fluvial	4.0	3.45	1.16	3.82	3.20	3.41
"Picãozinho"	Geomorphology	Marine	3.5	3.65	0.96	3.55	2.7	2.98

ecological, paleo-environmental-geological-geomorphological and historical importance, with records in sixteenth century iconography.

The estuary of the Paraíba River, which bathes the extremely populous João Pessoa, and other cities in the metropolitan region, such as Santa Rita, Bayeux and Cabedelo, where anthropization is intense, has resulted in an ecosystem with forms of relief that are extremely sensitive to deterioration. Their IRI assessment was inserted in the average need for protection. This is where "Jacaré" Beach is located, one of the most visited places by tourists with the existence of commercial establishments and bar-restaurants, until then in stilt construction—since these made the environment susceptible to the risk of deterioration, they were removed from this site, hence its average classification regarding the need for protection.

On the other hand, although it is inserted in the area of good geotouristic potential, "Picãozinho", one of the most visited tourist spots in the capital of Paraíba, had the third lowest GeoP. This result can be justified by the low score, from the point of view of geotouristic use value that the geomorphosite received in the categories of "access" and "transport", since it can only be reached by boat, and "clarity", since it is located about 2 km from the beach of "Tambaú". This same geomorphosite, regarding additional value, has received low scores in "association with other cultural elements", because of its geographical isolation, and in "degree of scientific knowledge", essentially restricted to the community of Biological Sciences, which study the reef ecology and its fauna and flora. The only site with low geotouristic potential was the Pleistocene Marine Terraces. Their TPI/AdVI ratios were the lowest of all mapped sites, which highlights the importance of the additional value of these sites in relation to geotourism. "Picãozinho", although fragile and susceptible to deterioration, was the only site inserted in the area of low protection needs, mainly due to the low values that it receives in "protection regime" and "property regime", since both are under legal protection and with restricted visitation. Through the Normative Instruction no. 138, of 2006, of the Brazilian Institute of the Environment and Renewable Natural

Table 5 Results of GeoP and IRI, ranked in decreasing order

Site	GeoP	Site	IRI
1. Holocene Marine Terrace	4.32	1. Holocene Marine Terrace	4.14
2. "Irerês" Lagoon	4.25	2. "Cabo Branco" Cliff	3.97
3. "Cabo Branco" Cliff	4.2	3. "Irerês" Lagoon	3.82
4. "Tambaba" natural pools	3.98	4. Estuary of the Paraíba River	3.78
5. Estuary of the Paraíba River	3.93	5. "Coqueirinho" Canyon	3.52
6. "Jacaré" Beach	3.82	6. "Jacaré" Beach	3.41
7. "Coqueirinho" Canyon	3.68	7. Stone of Love	3.32
8. "Picãozinho"	3.55	8. Pleistocene Marine Terrace	3.10
9. Stone of Love	3.45	9. "Tambaba" natural pools	3.06
10. Pleistocene Marine Terrace	2.8	10. Picãozinho	2.98
Median	3.875	Median	3.46

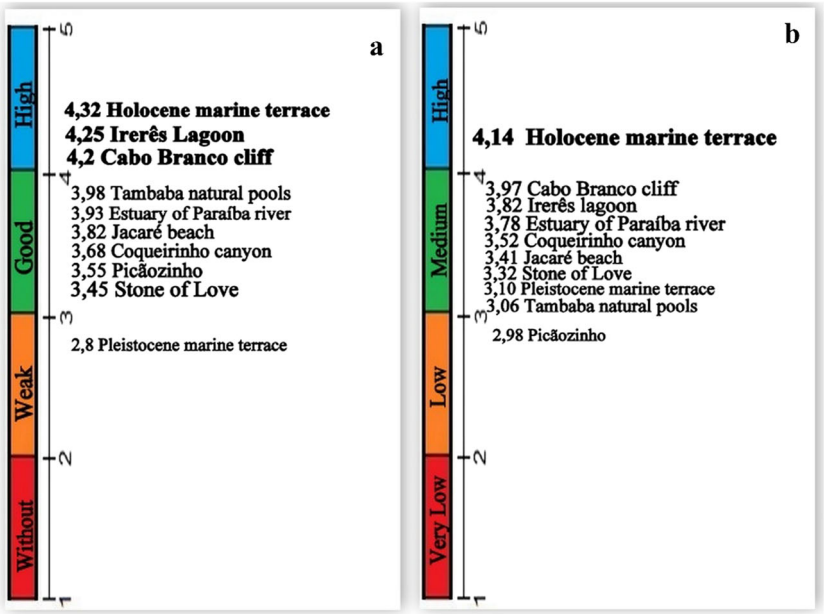

Fig. 5 **a** Quality Scale of the geotouristic potential for the surveyed area. **b** Scale of the Imminent Risk Index in the sampled sites of the area

Resources (IBAMA), its algae coral reefs are protected from extractive activities in areas of greater fragility.

Conclusions

The geotouristic potential of João Pessoa and the southern coastline is evident, but its confirmation through its semi-quantitative evaluation is still lacking. Thus, this work specifies a quantitative evaluation model, using as primary criteria the geotouristic value and the additional value of ten sites and places of interest, which were randomly selected. Once these are quantified and ranked, this proposal will allow the creation of a geotouristic guide for the region and the implementation of promotion methods for this geoheritage, such as folders, posters and signs, distributed along this itinerary in the sites with the highest geotouristic values. In addition, the protection value was considered, based on the knowledge of the protection needs of each mapped location, being pertinent for the planning of a territorial preservation management that effectively protects the most threatened areas.

Comparing the results obtained by this methodology with the practice, where several of the sites are effectively points of high tourist visitation, the results, for some points, converged, for others not, like "Picãozinho". This can be explained as the criteria used in the estimation of geotouristic potential are different from those used by conventional tourists.

According to data from the IFEP (2014), the main reason for tourists to visit João Pessoa was its beaches (57%), while only 5.5% answered that they were interested in the natural landscape. As pointed out earlier, a questionnaire was distributed between December 2014 and January 2017, and, among the basic questions included, there were the tourists' perception of the natural landscape, the semi-quantitative evaluation of some of the sites visited on the tour, and terms as "geological heritage", "geomorphologic" and "geotourism". From here, the tourist profile through the geotourism bias was known, being classified as "type 1" according to Miller (1991), "general tourist" (*sensu* Hose 1995, 2000) and "interested visitor" (*sensu* Grant 2010).

We can conclude that, even though it is a recent segment, not sufficiently promoted, particularly in Brazil, geotourism should be understood as a new asset to be introduced in the tourism market. Geotourism will help in the revitalization of the stagnant economy of the area in question, generate income and employment and provide the education of local population for the geopreservation of the abiotic environment, which serves as a resource for geotouristic attraction and the promotion of local geodiversity and geosciences.

The presence of a pre-existing tourist itinerary in the area facilitates the incorporation of the geotouristic points of observation in its structure, which provides additional value to the activity that is in a lower position when compared to the neighbouring capitals, even if its geodiversity is as exuberant as theirs is.

This methodology, after being tested and despite possessing a certain degree of subjectivity, proved to be a useful and effective form of semi-quantitatively evaluating the geotouristic potential of the places of interest, having been elaborated for the coastal region of Paraíba. It is possible to apply this method to other areas, as long as its indicators are adapted to the local reality.

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