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Papers

Evaluation of the Geotourism Potential of Serra do Rola Moça State Park, MG

Avaliação do Potencial Geoturístico do Parque Estadual Serra do Rola Moça/MG

Evaluación del Potencial Geoturístico del Parque Estatal Serra do Rola Moça/MG

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Keywords:

Geodiversity.
Geotourism.
Serra do Rola Moça State Park.

Abstract

Geodiversity is highly regarded by tourism and, in this sense, geotourism highlights the aspects and promotes the dissemination of the abiotic environment in a language accessible to a lay audience. Faced with the potential of using geodiversity, it is necessary to establish planning measures for its sustainable use. Thus, the present article has the general objective of identifying geosites located in the Serra do Rola Moça State Park, Minas Gerais, performing a quantitative evaluation and risk of degradation with an emphasis on tourism use. The methodological procedures used were bibliographic research and field data collection. For the quantitative assessment of the geosites the methodology proposed by Brilha (2015) was adapted, that is, changes were made in some of the criteria suggested by the author, considering the context of the study area. From the identification and quantification of the geosites it was evidenced that geotourism can be developed in the Serra do Rola Moça State Park, although some deficiencies in the infrastructure of the geosites have been identified. Thus, it is believed that the development of geotourism will contribute to the knowledge and conservation of the local geodiversity, but for this it is necessary to develop strategies that involve managers, local community, and academia.

Palavras-chave:

Geodiversidade.
Geoturismo.
Parque Estadual Serra do Rola Moça.

Resumo

A geodiversidade é bastante visada pelo turismo e, neste sentido, o geoturismo eviden-cia os aspectos e promove a divulgação do meio abiótico em uma linguagem acessível ao publico leigo. Diante do potencial de uso da geodiversidade, é necessário que se estabeleçam medidas de planejamento para sua utilização sustentável. Sendo assim, o presente artigo tem como objetivo geral identificar geossítios localizados no Parque Estadual Serra do Rola Moça (SRMSP), Minas Gerais, realizando avaliação quantitativa e do risco de degradação com ênfase no uso turístico. Os procedimentos metodológicos utilizados foram pesquisa bibliográfica e levantamento de dados em campo. Para a quantificação dos geossítios foi adaptada à metodologia proposta por Brilha (2015), ou seja, foram realizadas mudanças em alguns dos critérios sugeridos pelo autor, levando em consideração a realidade da área de estudo. A partir da identificação e quantifica-ção dos geossítios foi evidenciado que o geoturismo pode ser desenvolvido no SRMSP, embora se tenha identificado algumas deficiências na infraestrutura dos geossítios. Dessa forma, acredita-se que o desenvolvimento de atividades geoturísticas irá contri-buir para o conhecimento e conservação da geodiversidade local, mas para isso é necessário à elaboração de estratégias que envolvam os gestores do SRMSP, a comunidade local e acadêmica

Palabras clave:

Geodiversidad.
Geoturismo.
Parque Estatal Serra do Rola Moça.

Resumen

La geodiversidad es bastante visada por el turismo y, en este sentido, el geoturismo evidencia los aspectos y promueve la divulgación del medio abiótico en un lenguaje accesible al publico laico. Ante el potencial de uso de la geodiversidad, es necesario que se establezcan medidas de planificación para su utilización sostenible. Por lo tanto, el presente artículo tiene como objetivo general identificar geosítios localizados en el Parque Estatal Serra do Rola Moça (SRMSP), Minas Gerais, realizando evaluación cuantitativa y del riesgo de degradación con énfasis en el uso turístico. Los procedimientos metodológicos utilizados fueron investigación bibliográfica y levantamiento de datos en campo. Para la cuantificación de los geosítios fue adaptada a la metodología propuesta por Brilha (2015), o sea, se realizaron cambios en algunos de los criterios sugeridos por el autor, teniendo en cuenta la realidad del área de estudio. A partir de la identificación y cuantificación de los geosítios se evidenció que el geoturismo puede ser desarrollado en la SRMSP, aunque se han identificado algunas deficiencias en la infraestructura de los geosítios. De esta forma, se cree que el desarrollo de actividades geoturísticas contribuirá al conocimiento y conservación de la geodiversidad local, pero para ello es necesario la elaboración de estrategias que involucren a los gestores del SRMSP, la comunidad local y académica.

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1 INTRODUCTION

Geodiversity, understood as the set of abiotic elements of the natural environment, is the structural basis of the planet, since it provides materials essential for the sustenance of life and evolution of species. In general, it can be said that biodiversity is directly conditioned to set and develop in the diversity of abiotic environments (Bruschi, 2007). In this sense, geodiversity and biodiversity have complex relationships with each other and are complementary to a holistic understanding of the natural environment (Santos, 2017). Thus, some scholars have sought to produce and disseminate knowledge about geodiversity, proposing methods for its enhancement and conservation.

Thus, when values are assigned to geodiversity, we allow certain regions to be of great importance whether from the economic, scientific, educational, or tourism perspective, and these values allow these regions to be inventoried and quantified as geosites. The set of these geosites constitutes the geological heritage (Brilha, 2005).

Over time, various terms and definitions have been proposed for the sites that make up the geological heritage. The terms that have been used are: point of geological interest, place of geological interest, and geosites. Regardless of denomination, these places stand out for their value that can be scientific, educational, tourist, or other (Romão & Garcia, 2017). In this paper, the term geosites was chosen to denote the elements of geodiversity.

Geosites are occurrences of one or more elements of geodiversity resulting from natural processes or human interventions, occurring in a geographically well-defined area that has unique value from a scientific, educational, cultural, or tourist point of view, among others (Brilha, 2005).

The inventory is the first step in identifying and characterizing geosites. The second step consists of quantification, which consists of assigning points to various parameters according to specific criteria and sub-criteria. Then, mathematical equations are applied to calculate the final score, allowing the comparison and identification of the potential use of each element studied (Sena, 2015).

There are several quantification methodologies such as, for example, the method of Rivas et al. (1997), Brilha (2005), Pralong (2005), Pereira (2006), García-Cortés and Urquí (2009) and Brilha (2015). These methodologies were developed to quantify the European geological heritage. In the Brazilian context, we have the methods of Lima (2008), Evangelista and Travassos (2014), Sena (2015) and Santos (2017), which are

adaptations of European methodologies, where researchers add, remove, or redistribute the criteria and scores according to the context of the study area to improve and achieve their objectives.

Quantification is a fundamental method to determine the potential for use, and to establish conservation measures according to the degree of vulnerability and degradation. Since most of the threats to geodiversity come directly or indirectly from human activities such as, for example, tourist activities when carried out without proper planning (Brilha, 2005). In this sense, to minimize this type of threat we highlight the strategies of nature conservation, with emphasis on those focused on geoconservation.

Geoconservation consists of the implementation of strategies or methodologies aimed at evaluating, valuing, disseminating, and conserving elements of geodiversity that have scientific, educational, and tourist value, among others. These strategies are performed in the following sequence: inventory, quantification, classification, conservation, valuation, dissemination, and monitoring (Brilha, 2005). When applied correctly, these methods can conserve and minimize geodiversity degradation.

Geoconservation should be based on judicious strategies and awareness campaigns and, for this, geotourism can be an ally (Bento & Rodrigues, 2010). Thus, one of the consequences of geoconservation is the promotion of geotourism, which can also promote geoconservation (Moreira, 2008).

Geotourism has as its objective the tourist use of abiotic elements such as: rocks, cavities, soils, and relief. This segment can help in the promotion, dissemination, and valuation of geodiversity, through environmental education that uses interpretive means to translate the scientific language into a common language, allowing the visitors to contribute to the conservation of geodiversity elements (Moreira, 2008).

Among the areas most used by this segment are those protected by law and which people visit for recreation, contemplation, or sport. Therefore, this research was carried out in the Serra do Rola Moça State Park (SRMSP), a conservation unit located in the metropolitan area of Belo Horizonte (Minas Gerais). The SRMSP is composed of a rich association between biodiversity, which includes endemic fauna and flora, and geodiversity comprising elements of the ferruginous geosystem of the *Quadrilátero Ferrífero*, rock outcrops, water resources, caves in ferruginous rocks, geological, and geomorphological features.

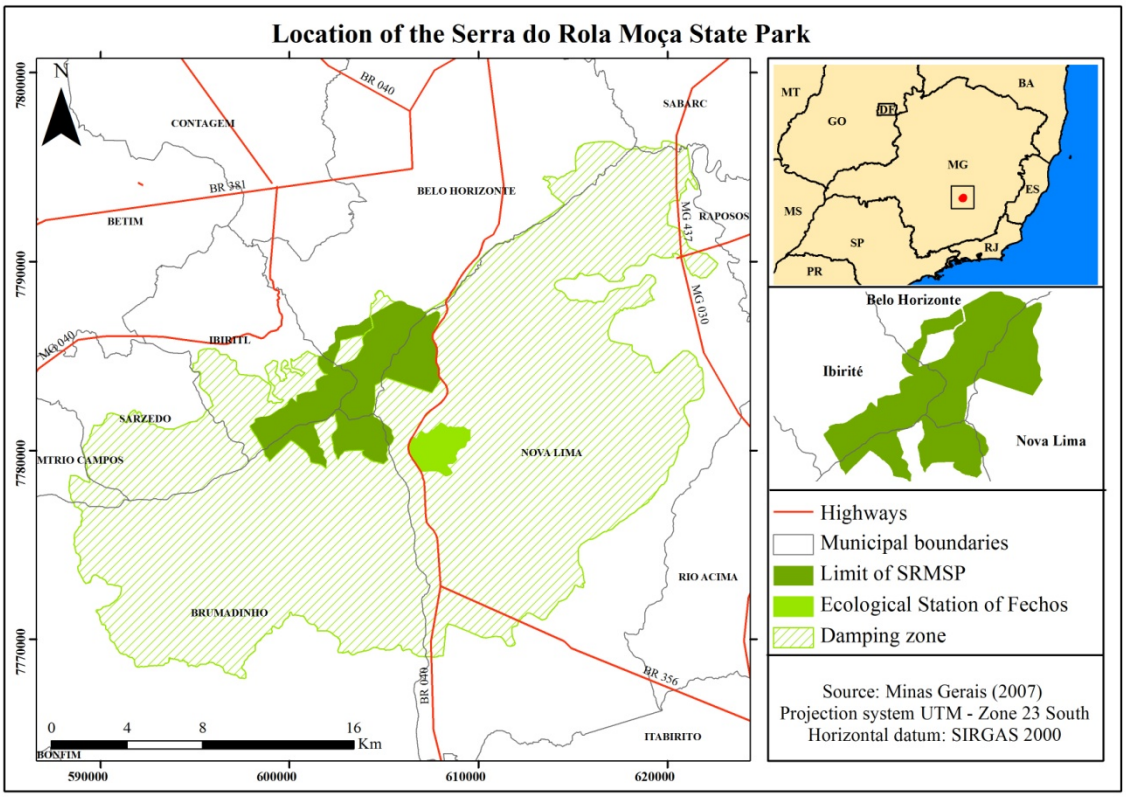
In this sense, the objective of this article is to identify geosites located in the SRMSP, carrying out a quantitative assessment and risk of degradation with emphasis on tourist use.

This study was carried out with the purpose of assisting in the management of SRMSP public use policies, contributing to the dissemination, valuation, and conservation of geodiversity. Besides being a differentiated way of enjoying nature, and obtaining information about geodiversity, which will provide visitors with a holistic view of the area.

2 CHARACTERIZATION OF THE STUDY AREA

Serra do Rola Moça State Park (SRMSP) is an integral protection conservation unit, allowing the indirect use of natural resources, through visitation and scientific research. The SRMSP has a total area of 3,942 hectares and was created on September 27, 1994, by State Decree No. 36,071, with the objective of conserving local ecosystems and protecting six water sources (Bálsamo, Barreiro, Catarina, Mutuca, Rola-Moça, and Taboões) (Minas Gerais, 2007). The SRMSP is located in the Metropolitan Region of Belo Horizonte, encompassing part of the municipalities of Belo Horizonte, Brumadinho, Ibirité, and Nova Lima. Figure 1 shows the SRMSP location map.

Figure 1 – Location of the Serra do Rola Moça State Park, MG.



Source: The author (2018).

The SRMSP has a program of public visitation and use, which was subdivided into three categories: tourist use, technical use, and scientific use, which are under the administration of the Instituto Estadual de Floresta de Minas Gerais (IEF/MG).

Tourist use includes recreational activities and environmental education. Technical use occurs in areas of fragility of the SRMSP, and due to this reason receives only expert visitors (biologists, geologists, paleontologists, etc.). Finally, scientific use is only allowed for researchers, as it occurs in areas of extreme fragility, being prohibited for tourism and technical use (MINAS GERAIS, 2007).

For tourist use the SRMSP has three interpretive trails being: Travessia, Campo Ferruginoso and Morro III. Along the trails you can find attractions such as viewpoints, caves, springs, and waterfalls. Activities such as hiking, cycling, and sports are allowed (MINAS GERAIS, 2007).

Environmental education activities proposed in SRMSP public use are linked to the appreciation and conservation of the environment. In the SRMSP there is an interpretive panel located in Mirante dos Veados that contains information about the geodiversity present in the study area, but the panel is damaged by graffiti.

Therefore, the inclusion of geotourism in SRMSP public use activities, if well planned, may result in the awareness of visitors about the importance of conserving elements of geodiversity.

3 METHODOLOGY

In order to carry out the quantitative evaluation and the risk of degradation of the geosites of the SRMSP, the following methodological procedures were performed, as described below.

3.1 Bibliographic review

In order to reach the objectives of this research, in the first moment, the theories related to the object of study were reviewed and analyzed. The procedures used consisted of bibliographical research, being used as sources: books, articles, and dissertations that dealt with subjects on geodiversity and geotourism. In this

sense, the methodology proposed by Brilha (2015) was adapted for the quantitative evaluation and the risk of geosites degradation, which was modified with the objective of adapting to the context of the study area.

A caveat is in order here. Brilha (2015) reformulated his concept of geosites. For the author the geodiversity is divided into two large groups: sites with scientific value and sites with other values, both in situ or ex situ. Thus, geosites are composed of elements of geodiversity in situ, which have high scientific value, constituting the geological heritage. Geodiversity sites, however, are composed of natural geodiversity features and processes, which stand out because of their high educational or tourist value. In the same way as geosites, these are constituted by occurrences in situ.

However, natural heritage consists of physical and biological formations or groups of such formations with an exceptional universal value from an aesthetic, tourist, scientific, and other points of view. In this case, it is considered a loss of appropriation of the term geosites only in places of scientific importance (Meira & Morais, 2016). As this research focuses on the tourism analysis, it was adapted the methodology of Brilha (2015), however the term "geodiversity site" was not used as suggested by Brilha (2015), but the term "geosites" was used.

3.2 Identification of geosites

For the identification of potential geosites, bibliographical research was carried out, being used as source: the management plan of the SRMSP (2007). In this way, all abiotic natural resources, currently open to visitation, were considered. Next, a consultation was carried out with the specialists of the *Centro Nacional de Pesquisa e Conservação de Cavernas* (CECAV), who work at the SRMSP, to identify possible caves that could provide geosites for tourism use.

3.3 Qualitative evaluation

After the identification of the geosites, two field studies were carried out for the qualitative evaluation of sites with tourism potential, using a characterization form proposed by Brilha (2015). This author suggests that the evaluation be made based on the parameters referring to the scenery, interpretive potential, accessibility, and safety, these parameters can be understood as:

- Scenery: it is associated with the beauty of geodiversity elements;
- Interpretive potential: it is related to the ability of an element of geodiversity to be easily understood by lay people;
- Accessibility: it is associated with access conditions (roads or trails), considering the difficulties and time to reach the site;
- Safety: it is related to the conditions of visit to the site, considering the least risk to the people who access it.

According to Brilha (2015), geosites with high potential for tourist use will be those with great scenic beauty, elements of geodiversity that can be easily observed and understood by lay people, and have good conditions of safety and quick access.

3.4 Quantification of geosites

After the identification and completion of the geosites characterization sheets, a quantitative evaluation was carried out, beginning the assignment process for each site. The criteria used were adapted from the work of Brilha (2015), which presents a quantification proposal based on three factors: Potential Educational Use (PEU), Potential Touristic Use (PTU), and Degradation Risk (DR).

Each of the criteria was subdivided into four sub-criteria that were assigned 1 to 4 points, and for PEU and PTU, score 1 corresponded to low possibility of use and grade 4 corresponded to high possibility of use. The quantification of Brilha (2015) was designed and elaborated for educational and tourist use, but since this search focuses on tourist use, it was decided not to use the PEU criteria. And for the PTU, some adaptations were made to the criteria proposed by Brilha (2015), considering the scale of the study area.

Brilha (2015) proposes 13 criteria for the quantitative evaluation of PTU, of these, only the criterion population density was not used. This criterion was excluded because it was considered irrelevant to the study area due to the scale of analysis.

Logistics criterion was divided into two parts: lodging services and food services. These two criteria were divided to facilitate the quantitative and spatial evaluation of the sites. For the analysis of these two items, a survey of all accommodation and food establishments in the municipalities of Brumadinho, Ibirité, and Nova Lima was carried out, through the Tourist Inventory from the Secretaria de Estado de Turismo de Minas Gerais (SETUR-MG). The municipality of Belo Horizonte has no inventory, so the records of the lodging services were obtained from the *Secretaria Municipal Adjunta de Regulação Urbana* (SMARU). The food services were obtained on the website of the *Empresa Municipal de Turismo de Belo Horizonte* (BELOTUR).

These data were analyzed spatially based on the concept developed by Boullón (2002) of tourist transfer corridors, which are routes of connection between zones, areas, and attractions. For Boullón (2002), it is important that tourist facilities, such as gas stations, hotels, restaurants, among others, are in the transportation corridors. Also, according to the author there is a radius of influence of 3 kilometers between the tourist attractions and the transfer corridors. Thus, to quantify these two criteria, the distances of the sites to the lodging and food services were analyzed using the Point Distance tool of AcrGIS 10.3 software. Table 1 presents the criteria and points of the adapted quantification of Brilha (2015).

Tables 1 - Criteria for the quantitative assessment of potential touristic use (continue)

Potential Touristc Use (PTU)	
Criteria/Indicators	**Points**
A. Vulnerability	
The elements of the geodiversity of the geosite present no possible deterioration by tourism activity.	4
There is the possibility of deterioration of secondary geodiversity elements by tourism activity.	3
There is the possibility of deterioration of the main geodiversity elements by tourism activity.	2
There is the possibility of deterioration of all geodiversity elements by tourism activity.	1
B. Accessibility	
Geosite located less than 100 meters from an accessible road for ride type vehicles.	4
Geosite located less than 300 meters from an accessible road for ride type vehicles.	3
Geosite located less than 100 meters from a road accessible by 4x4 vehicle.	2
Geosite without direct access by road, being necessary to hike in trails.	1
C. Use limitations	
Geosite has no limitations on use for tourists and students.	4
Geosite can be used by students and tourists, but only occasionally.	3
Geosite can be used by students and tourists, but only after overcoming some limitations (geographical, meteorological, etc.).	2
The use by students and tourists is difficult to reach due to the difficulties of the limitations (geographical, meteorological, etc.).	1
D. Safety	
Geosite with safety facilities (fences, stairs, handrails, etc.), cell phone coverage and located within 5 km of emergency services.	4
Geosite with safety facilities (fences, stairs, handrails, etc.), cell phone coverage and located within 25 km of emergency services.	3
Geosite without safety facilities, but with cellular coverage and located within 50 km of emergency services.	2
Geosite without safety facilities, without cell phone coverage and located more than 50 km from emergency service.	1
E. Lodging Services	
There are three or more lodging establishments within 5 km.	4
There is one or more lodging establishments within 10 km.	3
There is one or more lodging establishments within 20 km.	2
There is one or more lodging establishments within 30 km.	1
F. Food Services	
There are three or more food establishments within 5 km.	4
There are three or more food establishments within 10 km.	3
There are three or more food establishments within 20 km.	2
There are three or more food establishments within 30 km.	1

Tables 1 - Criteria for the quantitative assessment of potential touristic use (conclusion)

Potential Touristc Use (PTU)	
Criteria/Indicators	**Points**
G. Uniqueness	
Geosite offers unique and unusual features in a national and international context.	4
Geosite presents unique and unusual characteristics in a national context.	3
Geosite has common characteristics in a regional context and is uncommon in the context of other regions of the country.	2
Geosite has characteristics quite common throughout the country.	1
H. Association with other values	
There are three ecological and cultural values, close to the analyzed geosite.	4
There are two ecological and cultural values, close to the analyzed geosite.	3
There is an ecological value and a cultural value, close to the analyzed geosite.	2
Ecological or cultural value is present, close to the analyzed geosite.	1
I. Scenery	
Geosite presents conditions for viewing the landscape where it is inserted and the surrounding landscape, including the insertion of other geosites.	4
Geosite presents conditions for viewing the landscape where it is inserted and the surrounding landscape.	3
Geosite presents conditions for viewing the landscape where it is inserted.	2
Geosite with poor visibility of the landscape.	1
J. Observation conditions	
All elements of geodiversity have good observation conditions.	4
There are some obstacles that make it difficult to observe some elements of geodiversity.	3
There are some obstacles that make it difficult to observe the main elements of geodiversity.	2
There are some obstacles that obstruct the observation of the main elements of geodiversity.	1
K. Interpretive potential	
Geosite presents elements of geodiversity in a clear and expressive way for all types of public.	4
The public needs to have basic knowledge to understand the elements of geodiversity of geosite.	3
The public needs solid knowledge to understand the elements of geodiversity of geosite.	2
Geosite presents elements of geodiversity understandable only by experts.	1
L. Economic level	
Geosite located in a municipality with family income higher than three minimum wages.	4
Geosite located in a municipality with a family income of three minimum wages.	3
Geosite located in a municipality with a family income of two minimum wages.	2
Geosite located in a municipality with a family income of a minimum wage.	1
M. Proximity to other geosites	
Three or more geosites occur within a radius of 1 km, in addition to the analyzed geosite.	4
Two geosites occur within a radius of 1 km, in addition to the analyzed geosite.	3
One or more geosites occur within a radius of 2 km, in addition to the analyzed geosite.	2
One or more geosites occur within a radius of 3 km, in addition to the analyzed geosite.	1

Source: Adapted from Brilha (2015)

It is important to emphasize that the criteria and sub-criteria used in this research are subjective, that is, they were adapted to the specificities of the study area.

For each of the quantification criteria weights were assigned—according to their importance— to analyze the potential of tourist use, in this way, the second step of the process of site quantification consisted of weighting criteria. As a result of the adaptations made in the quantitative evaluation of geosites, the weight attributed to the population density criterion was redirected to the logistics criterion, which was divided into two parts (lodging and food services). The other weights were maintained according to Brilha (2015), and are presented in Table 2.

As for the indication of the sites with the greatest potential for tourist use, the classification used by Lima (2008) was followed, and three classes were established for the study area: 100 - 200 correspond to sites of low tourism potential, 201 - 300 sites of medium potential, and 301 - 400 sites of high tourism potential.

Tables 2 - Criteria of potential touristic use and respective weights

Potential Touristic Use (PTU)	
Criteria	**Weights**
A. Vulnerability	10
B. Accessibility	10
C. Use limitations	5
D. Safety	10
E. Lodging Services	5
F. Food Services	5
G. Uniqueness	5
H. Association with other values	5
I. Scenery	15
J. Observation conditions	5
K. Interpretive potential	10
L. Economic level	5
M. Proximity to other geosites	10
Total	**100**

Source: Adapted from Brilha (2015)

3.5 Quantification of degradation risk

For the evaluation and quantification of degradation risk (DR), Brilha (2015) proposes five criteria: deterioration of geological elements, proximity to areas/activities with potential to cause degradation, legal protection, accessibility, and density of population.

Each of these criteria was subdivided into four sub-criteria and were scored between 1 and 4 points, and the lower the score the lower the risk of degradation, and the higher the score the greater the risk of degradation of geosites. For this study, the population density criterion was not used, being considered irrelevant to the study area due to the scale of analysis. The criteria deterioration of the geological elements and accessibility were adapted in the indicators (sub-criteria), to better fit the context of the study.

A conceptual adjustment was made in the criterion of deterioration of the geological elements as the expression "geological elements" was replaced by "geodiversity elements", where geological and geomorphological features were also included. In this item, Brilha (2015) analyzes the vulnerability of sites based on intrinsic characteristics and anthropic activities.

The accessibility criterion was analyzed by Brilha (2015), considering that a site that has easy access is more likely to be damaged by undue use of visitors than one with difficult access. Therefore, accessibility was assessed by means of distances between geosites and paved and unpaved roads, and the smaller the distance between the site and the road, the higher the score awarded and, consequently, the greater the risk of degradation, and the higher the distance, the lower the score assigned, thus the risk of degradation will be lower. Table 3 shows the criteria and indicators used for the degradation risk.

For each of the criteria, weights were assigned according to their importance to assess the degradation risk of geosites, and thus, this stage consisted in weighing the criteria. As a result of the adaptations made in the evaluation of the risk of degradation of geosites, the weight attributed to the criterion of population density was redirected to the criterion deterioration of geodiversity elements, which now has a total weight of 45. The other weights were maintained according to Brilha (2015), and are shown in Table 4.

From the consideration of the criteria it was possible to classify if the geosites have low, medium, or high degradation risk, according to classification elaborated by Brilha (2015), which is presented in Table 5.

Table 3 – Criteria used for the quantitative assessment of degradation risk

Degradation Risk (DR)	
Criteria/Indicators	**Points**
A. Deterioration of geodiversity elements	
Geosite located in areas of very high and high degree of vulnerability.	4
Geosite located in areas with medium degree of vulnerability.	3
Geosite located in areas of low vulnerability.	2
Geosite located in areas of very low vulnerability.	1
B. Proximity to areas/activities with potential to cause degradation	
Geosite located less than 50 meters of a potential degrading area/activity.	4
Geosite located less than 200 meters of a potential degrading area/activity.	3
Geosite located less than 500 meters of a potential degrading area/activity.	2
Geosite located less than 1000 meters of a potential degrading area/activity.	1
C. Legal protection	
Geosite located in an area with no legal protection and no control of access.	4
Geosite located in an area with no legal protection but with control of access.	3
Geosite located in an area with legal protection but no control of access.	2
Geosite located in an area with legal protection and control of access.	1
D. Accessibility	
Geosite located less than 100 meters from an accessible road for ride type vehicles.	4
Geosite located less than 300 meters from an accessible road for ride type vehicles.	3
Geosite located less than 100 meters from a road accessible by 4x4 vehicle.	2
Geosite without direct access by road, being necessary to hike in trails.	1

Source: Adapted from Brilha (2015)

Table 4 - Criteria for the degradation risk and their respective weights

Degradation Risk	
Criteria	**Weights**
A. Deterioration of geodiversity elements	45
B. Proximity to areas/activities with potential cause of degradation	20
C. Legal protection	20
D. Accessibility	15
Total	**100**

Source: Adapted from Brilha (2015)

Table 5 – Classification of degradation risk.

Total weighted	Degradation risk
< 200	Low
201 – 300	Medium
301 – 400	High

Source: Brilha (2015)

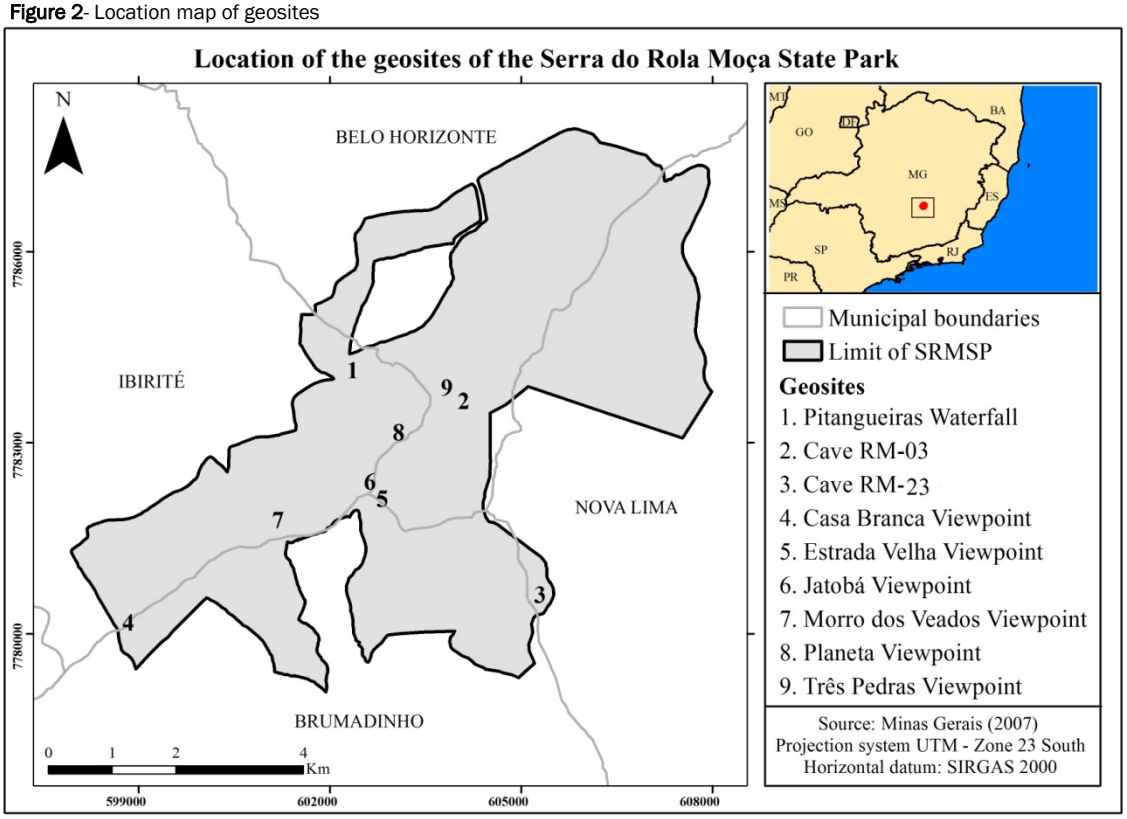
4 RESULTS AND DISCUSSIONS

4.1 Quantitative evaluation

Nine geosites have been identified for tourist use: Pitangueiras Waterfall, Cave RM-03, Cave RM-23, Casa Branca Viewpoint, Estrada Velha Viewpoint, Jatobá Viewpoint, Morro dos Veados Viewpoint, Planeta Viewpoint and Três Pedras Viewpoint. Figure 2 shows the location of geosites in the SRMSP.

The geosites Casa Branca Viewpoint, Estrada Velha Viewpoint, and Jatobá Viewpoint were identified from a bibliographical survey of published scientific articles on the SRMSP. The geosites Cave RM-03 and Cave RM-23 were suggested by experts from the *Centro Nacional de Pesquisa e Conservação de Cavernas* (CECAV) [Brazilian Center for Research and Conservation of Caves], who work on the SRMSP. And the geosites Pitangueiras Waterfall, Morro dos Veados Viewpoint, Planeta Viewpoint, and Três Pedras Viewpoint, are tourist attractions already used by visitors of the SRMSP. Figure 3 shows illustrations of geosites.

Figure 2- Location map of geosites



Source: The author (2018)

Through the quantitative assessment of geosites, the values of potential tourism use were obtained, ranging from 245 to 310. The geosites that obtained medium score were: Pitangueiras Waterfall, Cave RM-03, Cave RM-23, Casa Branca Viewpoint and Estrada Velha Viewpoint. And the geosites that obtained high score were: the Jatobá, Morro dos Veados, Planeta, and Três Pedras Viewpoints. Thus, a brief clarification is presented on the points given to the geosites according to each criterion.

In the evaluation of the criteria vulnerability (A), only the damages that are caused to the sites as a consequence of the use were considered and intentional actions to break or damage the geodiversity elements were not considered (Santos, 2017). Thus, considering the current SRMSP use and visitation situation, the nine sites were given 4 points, since during the completion of the characterization form, it was found that they did not present a risk of degradation due to tourism activities.

In the evaluation of accessibility (B), the sites Casa Branca, Jatobá, Morro dos Veados, Planeta and Três Pedras Viewpoints received the highest score (4). These geosites are less than 100 meters from a paved or unpaved road that are in good conditions of use for passenger vehicles which facilitates the visitation of the sites. The Pitangueiras Waterfall and the Cave RM-23 were given 2 points, as they are accessible only by four-wheel drive vehicles. The Cave RM-03 and Estrada Velha Viewpoint received 1 point, as they are reached only by a trail.

For the evaluation of the use limitations criterion (C), it was considered that all sites could be used for tourism purposes, and there were no legal limitations, therefore they were given 4 points. The Cave RM-03 for having stretches difficult to be covered and demanding great physical effort, received 2 points.

In the evaluation of the safety criterion (D), the distances between each site and the health services were measured. Of the nine sites assessed, eight were given 2 points, since they do not have any type of safety facilities and are located less than fifty kilometers from an emergency service, but there is cell phone coverage. The Pitangueiras Waterfall received 3 points, since it has safety facilities, such as handrails and stairs, there is cell phone coverage, and it is located less than twenty-five kilometers from an emergency service.

Figure 3 – Geosites of the Serra do Rola Moça State Park.

(A) Pitangueiras Waterfall; (B) Cave RM-03; (C) Cave RM-23; (D) Casa Branca Viewpoint; (E) Estrada Velha Viewpoint; (F) Jatobá Viewpoint; (G) Morro dos Veados Viewpoint; (H) Planeta Viewpoint; (I) Três Pedras Viewpoint.
Source: Personal archive (2018)

In the criteria lodging services (E) and food services (F), the geosites were given 4 or 3 points. The high scores were due to the fact that these criteria were analyzed based on the concept of tourist transfer corridors of Boullón (2002). The sites received these scores, because they are located less than five (4 points) or ten (3 points) kilometers of one or more lodging or food establishments.

In the criterion uniqueness (G) all geosites received 1 point, since their characteristics are quite common throughout the country.

In the evaluation of the criterion association with other values (H), all sites received 1 point, since the presence of cultural values does not occur near the sites, with only ecological values occurring, and usually with the presence of a single element.

In the criterion scenery (I), all six viewpoints received 3 points, since they present conditions for viewing the landscape where it is inserted and its surroundings, however it is not possible to see other geosites. The

Pitangueiras Waterfall and the Cave RM-03 received 2 points, because they present visibility conditions only of the landscape where they are inserted. And finally, the Cave RM-23 was the only site that was given 1 point, presenting low visibility, because it is inserted in a place where the vegetation is dense, thus obstructing the view of the scenery.

In the evaluation of the criterion observation conditions (J) all the sites received a score of 4, and during the fieldwork no obstacle was found that would hinder or prevent the observation of geodiversity elements that are in good conservation status.

In the criterion interpretive potential (K), the sites were evaluated considering if the geodiversity elements are easily understood by all types of public. During the fieldwork it was observed that the geosites do not present elements of great complexity, that is, it is not required that visitors have background knowledge of geodiversity, thus, all received 4 points.

The criterion economic level (L) refers to the level of income of families living near the sites. This criterion was assessed based on the average monthly wage of the formal workers living in municipalities adjacent to the SRMSP, according to data from the Brazilian Institute of Geography and Statistics (IBGE, 2015). The sites that are located in Belo Horizonte with a means of 3.7 minimum wages received a score of 3, the sites located in Brumadinho and Ibirité received 2 points because they had a means of 2 minimum wages.

Finally, in the criterion proximity to other geosites (M), it was observed that these are close, and the shortest distance is between Estrada Velha Viewpoint and Jatobá Viewpoint (309 meters) and the greatest is between Casa Branca Viewpoint and Cave RM-23 (6,4 kilometers). Therefore, the proximity between the sites can facilitate and expedite the visitation and the time available for visitors.

From the quantification it can be observed that the potential touristic use, indicated representative results with weighting values ranging from 245 to 310. Table 6 shows the values of the PTU quantification.

The sites with the highest scores were the viewpoints, which are the most visited sites of the SRMSP, with easy access and appealing scenery. The Pitangueiras Waterfall was another place with a high score. Despite being accessed by four-wheel drive vehicles, the waterfall has safety facilities (handrails and stairs) that contributed to a medium score in the PTU. The sites that obtained the lowest scores were the Cave RM-03 (255) and the Cave RM-23 (245) which, despite having a medium tourist potential, are not much visited sites because of their remote location. Therefore, it is necessary for SRMSP managers to carry out dissemination and improvement actions on the access infrastructure of these caves, since they are suitable places to discuss genetics and speleothems.

Table 6 – Quantitative evaluation of geosites.

Sites	POTENTIAL TOURISTIC USE																									Total	Classification Lima (2008)
	Absolute values													Weighted values													
	A	B	C	D	E	F	G	H	I	J	K	L	M	A	B	C	D	E	F	G	H	I	J	K	L	M		
Pitangueiras Waterfall	4	2	4	3	3	4	1	1	2	4	4	2	4	40	20	20	30	15	20	20	5	30	20	40	10	40	280	Medium
Cave RM-03	4	1	2	2	3	4	1	1	2	4	4	3	4	40	10	10	20	15	20	20	5	30	20	40	15	40	255	Medium
Cave RM-23	4	2	4	2	3	4	1	1	1	4	4	2	2	40	20	20	20	15	20	10	5	15	20	40	10	20	245	Medium
Casa Branca Viewpoint	4	4	4	2	4	4	1	1	3	4	4	2	2	40	40	20	20	20	20	10	5	45	20	40	10	20	300	Medium
Estrada Velha Viewpoint	4	1	4	2	4	4	1	1	3	4	4	2	4	40	10	20	20	20	20	10	5	45	20	40	10	40	280	Medium
Jatobá Viewpoint	4	4	4	2	4	4	1	1	3	4	4	2	4	40	40	20	20	20	20	10	5	45	20	40	10	40	310	High
Morro dos Veados Viewpoint	4	4	4	2	4	4	1	1	3	4	4	2	3	40	40	20	20	20	20	20	5	45	20	40	10	30	305	High
Planeta Viewpoint	4	4	4	2	3	4	1	1	3	4	4	3	4	40	40	20	20	15	20	20	5	45	20	40	15	40	310	High
Três Pedras Viewpoint	4	4	4	2	3	4	1	1	3	4	4	3	4	40	40	20	20	15	20	20	5	45	20	40	15	40	310	High

Source: The author (2018)

4.2 Degradation risk

The values obtained in the quantification of the degradation risk ranges from 180 to 300. The sites were assessed in relation to anthropic and natural threats. The absolute and weighted values of the sites are shown in Table 7.

Table 7 – Degradation risk evaluation of geosites

Sites	Degradation Risk								Total	Classification Brilha (2015)
	Absolute values				Weighted values					
	A	B	C	D	A	B	C	D		
Pitangueiras Waterfall	2	1	2	2	90	20	40	30	180	Low
Cave RM-03	4	1	2	1	180	20	40	15	255	Medium
Cave RM-23	3	2	2	2	135	40	40	30	245	Medium
Casa Branca Viewpoint	4	1	2	4	180	20	40	60	300	Medium
Estrada Velha Viewpoint	4	1	2	1	180	20	40	15	225	Medium
Jatobá Viewpoint	4	1	2	4	180	20	40	60	300	Medium
Morro dos Veados Viewpoint	4	1	2	4	180	20	40	60	300	Medium
Planeta Viewpoint	4	1	2	4	180	20	40	60	300	Medium
Três Pedras Viewpoint	4	1	2	4	180	20	40	60	300	Medium

Source: The author (2018).

From Table 7 it is possible to observe that the geosites presented a medium degradation risk, with values ranging from 255 to 300. This factor is a result of the location of these sites in areas that presented high index of environmental vulnerability (A), receiving scores of 4 or 3, only the Pitangueiras Waterfall received a lower score, with 2 points.

Another factor that influenced the result of the medium degradation risk was the criterion accessibility (D), the sites Casa Branca, Jatobá, Morro dos Veados, Planeta, and Três Pedras Viewpoints were given 4 points. These sites are very close to paved and unpaved roads that are in good conditions of conservation, being possible the use of passenger vehicles which facilitates the access of the visitors and local population and lead to degradation by misuse. The Pitangueiras Waterfall and the Cave RM-23 were given 2 points, since they are accessible only by four-wheel drive vehicles. Cave RM-03 and Estrada Velha Viewpoint received a score of 1, since access to them is done by a trail, which means less degradation.

The criterion legal protection (C) did not influence the quantification of degradation risk, since the sites are in a legally protected area, but there is no access control mechanism by the SRMSP administration. In this way, all sites received the same points (2), considering that they need awareness and monitoring of use.

In the evaluation of the criterion proximity to areas/activities with potential cause of degradation (B), such as mining, urban, and industrial areas, geosites received 1 point, since they are more than 1000 meters from any type of activity or area which may cause degradation.

It is observed that of the nine geosites analyzed, eight presented a medium degradation risk, therefore, it is necessary that the SRMSP managers define actions for the maintenance of the sites according to the use they are undergoing, carrying out periodic evaluations of the vulnerability, and raising the awareness of local people and visitors about the importance of site conservation.

5 FINAL REMARKS

The purpose of this study was to evaluate the geodiversity of the Serra do Rola Moça State Park in order to identify geosites with greater potential for tourism use, to be recipients of geotourism activities of an educational and interpretive nature. In this way, according to the results presented, it was verified that the SRMSP presents great geological and geomorphological wealth which, most of the times, is not promoted to visitors.

The quantification of the geosites showed those with better conditions for tourist use, highlighting, however, the dynamic character of this methodology. In this sense, when using quantification methodologies, the researcher needs to consider the specific context of the study area and intended objectives. This is because changes in some of the analysis criteria may alter the tourist potential of the sites.

Another point that should be considered in this research is the identification of the geosites of the SRMSP, since some sites were not considered in the identification carried out. The restrictive factor for the accomplishment of this stage of the work is related to the limitations of access to the places that are under administration of the *Companhia de Saneamento de Minas Gerais* (COPASA). This made it impossible to identify and quantify potential sites located within these areas. As a result, new studies on the geodiversity of SRMSP may be carried out and new sites will be surveyed, as there are other sites with potential for tourist use, such as the Abrigo Casa Branca, Catarina and Mutuca water springs, and Serra das Andorinhas.

The identification of the sites carried out in this research also did not consider the geodiversity elements in the SRMSP Damping Zone, being this area of great relevance in terms of geodiversity. Possibly, future works will be able to contemplate this area and new sites will be identified, therefore, it is necessary to signal for subsequent survey: the Abrigo Retiro das Pedras, located in the district of Piedade do Paraopeba, the Caminhos Antigos da Serra da Calçada, which have remains of 18th century roads, some with cobblestone pavement, and the Forte Brumadinho.

Finally, the SRMSP presents a rich geodiversity and it is believed that the development of geo-tourism activities will contribute to the knowledge, valuation, and conservation of geodiversity and biodiversity present in the SRMSP, through interpretive processes promoted by environmental education. Finally, to ensure that such activities are successful, it is necessary to develop strategies together with the local community, SRMSP managers, visitors, and the academia.

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