



Quantitative evaluation of the geosites and geodiversity sites of João Dourado Municipality (Bahia—Brazil)

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Abstract

Geological aspects of certain sites can help understand the history of a region and reveal discoveries in regard to the planet. Geodiversity in situ is expressed in geosites, with occurrences of geological features of scientific value, and geodiversity sites, places where other values prevail, such as education, culture, and tourism. In addition, such locations can generate socioeconomic benefits for the local population through management based on education and geotourism. João Dourado is a municipality located in the central north of the state of Bahia, in Chapada Diamantina. It is inserted in the Irecê Basin, coinciding with lithotypes of the Salitre Formation, which presents carbonate rocks of a shallow marine environment. The municipality is yet to be the subject of a detailed study carrying out inventory and assessment of its geodiversity. The objective of this study was to investigate the geodiversity of the municipality through quantitative evaluation and classification of the relevance of geosites and geodiversity sites. In this context, the inventory and quantification of sixteen sites of interest were carried out using the GEOSSIT application of the Geological Survey of Brazil (CPRM). Five geosites were found, one of international relevance and four of national relevance, as well as eleven geodiversity sites, whereby nine are of national relevance and two of regional/local relevance. Understanding and disseminating the geodiversity of João Dourado provides a basis for territorial management actions by public authorities and brings the population into closer contact with geosciences.

Keywords Geodiversity · Geosites · Geodiversity sites · Geoheritage · João Dourado

Introduction

Brazil is an exceptional country from the point of view of its geological diversity (Schobbenhaus and Silva 2012), and the municipality of João Dourado is a territory where remarkable

geodiversity can be found. The area presents features of karstic relief characterized by structures of superficial and subterranean dissolution (karren, caves, and dolines). The superficial structures generally occur in calcarenites, being associated with fractures, forming small caves or large extended dolines (CPRM 1985). The groundwater, originating in the discontinuity surfaces of limestone rocks, provides porosity and permeability enabling conditions for the occurrence of large reservoirs (Silva 2005).

The municipality of João Dourado is located in the central north of the state of Bahia, 452 km from Salvador, the state capital. It is located in the “Polígono das Secas,” an area recognized as subject to repeated crises of prolonged drought, and subject to special measures of the public sector (Brasil 1951). Nevertheless, due to its hydrogeological context based on the occurrence of an important karstic aquifer supplying numerous wells, the municipality’s economy is based on irrigated cultivation of onion, carrot, beet, and beans—being known on the regional scene as the onion capital.

Tourism is still incipient in the region and is concentrated in the Environmental Protection Area of Lapa dos Brejões—

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Vereda do Romão Gramacho, created for the preservation of Lapa dos Brejões, archeological and paleontological sites, ecosystems, and local culture (Bahia 1985). The municipality of João Dourado partially integrates the proposed Morro do Chapéu Geopark (Rocha and Pedreira 2013), which also includes the municipalities of Morro do Chapéu, Cafarnaum, América Dourada, São Gabriel, Várzea Nova, Jacobina, and Miguel Calmon.

The natural diversity encompassing biotic and abiotic elements forms the basis for sustainability of society. Most national and international agreements and policies emphasize the biotic nature and include almost no abiotic elements in their programs, which undermines an integrated and sustainable approach to managing the environmental resources of the planet (Brilha et al. 2018).

In a general view, Gray (2008) considers geodiversity as the abiotic equivalent to biodiversity. Gray (2013) discusses geodiversity as geological diversity (rocks, minerals, fossils), geomorphological diversity (relief, topography, physical processes), soil characteristics, and hydrological characteristics that include assemblies, structures, systems, and contributions to the landscape.

Brilha (2016) defines geosites as in situ occurrences of geological elements with scientific value, and places where geodiversity presents other values, such as education and tourism, as geodiversity sites. Pereira (2010) states that conservation of geodiversity as a whole is not a feasible task, and it is necessary to survey the relevant and significant aspects of a given region, from a scientific, educational, tourist, recreational, to natural heritage conservation points of view.

Geosites and geodiversity sites tell the geological history of a region and can lead scientists to revealing studies on the planet. Moreover, they can generate social and economic benefits for the population through education and geotourism (Brilha 2016). However, often geological knowledge is left to the margins of the population and does not reach the average citizen, being restricted only to the scientific community. This is due to the fact that geological terms are not present in everyday language (Mondejar and Remo 2004), or because their temporal scale and spatial concept are very extensive (Dias 2011).

Brazilian territory has wide-ranging geodiversity with the potential for geopark creation. In addition to the already recognized Araripe Geopark, thirty-seven proposals to create new geoparks are underway in the country (CPRM 2018). The Geoparks Project, created by the Brazilian Geological Survey (CPRM) in 2006, plays an important role in identifying, surveying, describing, conducting inventories, diagnosing, and disseminating areas with potential for future geoparks. Geoparks are unique geographical areas where sites and landscapes of international geological significance are managed with a holistic concept of protection, education, and sustainable development (GGN 2018).

As a result of natural and anthropogenic factors, geodiversity, with its scientific value and its benefits to education and tourism, may face threats to its integrity. Salvan (1994) points out that the main threat looming over geological heritage is the lack of knowledge as to its existence. Prior to the present study, the municipality of João Dourado had not been the subject of an exclusive study to carry out the inventory and valuation of its geodiversity. In this context, the objective of this research was to investigate the geodiversity of the municipality, as well as the existence of geosites and geodiversity sites, in order to carry out a quantitative evaluation and rank their relevance. This procedure aims to demonstrate which places are suitable for scientific, tourist, or educational purposes and which places should be preserved.

Methods

The general survey of places of interest was based on information from the inhabitants of the municipality, who have considerable knowledge on the natural aspects of the area. Geologists, engineers, environmental inspectors, teachers, and people with traditional knowledge were consulted and contributed to the survey.

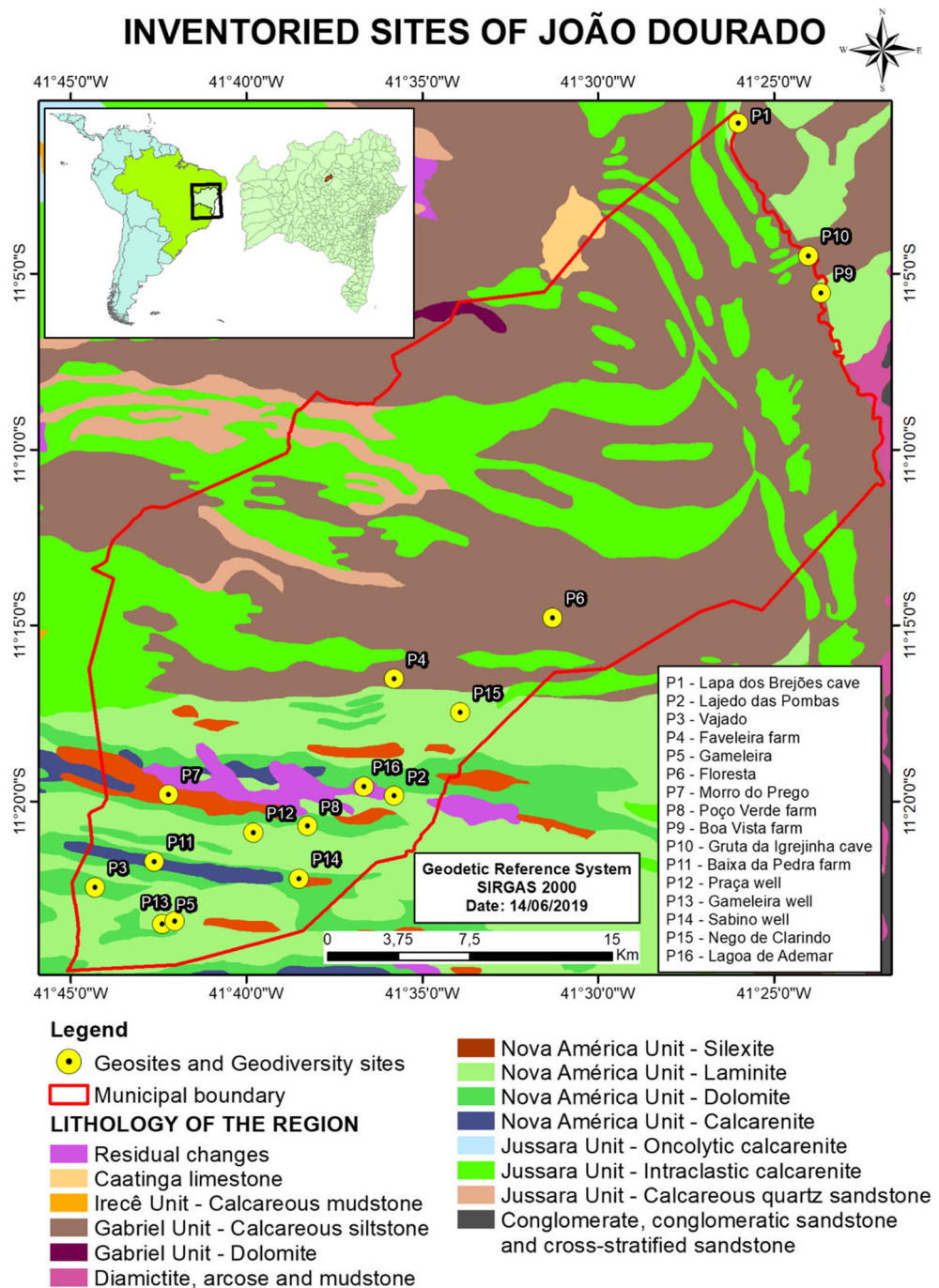
Therefore, representative locations with the potential to be used scientifically, for tourism, and/or educationally by scientists, the local population, and visitors were preferred. As a result, sixteen sites of interest were selected that enable the contemplation of various aspects related to the geodiversity of the municipality of João Dourado (Fig. 1).

The GEOSSIT application of the Geological Survey of Brazil (CPRM 2019), which combines the methods of Brilha (2016) and García-Cortés and Carcavilla (2009), is used for the inventory and quantification of sites of interest and analysis of scientific value, and value to education and tourism, besides the risk of degradation. In addition, the GEOSSIT maintains a national register of geosites and geodiversity sites on a common database available on the internet at: <https://www.cprm.gov.br/geossit/>.

The selection of potential geosites should highlight the occurrences of geodiversity that best represent a particular material, event, or geological process. Geodiversity sites correspond to occurrences that do not have significant scientific value; however, due to their relevance to education and/or tourism, they must be conserved to enable sustainable use by society (Brilha 2016). On the GEOSSIT, the maximum score the places of interest can achieve in each criterion is 400 points. According to the method used, to be a geosite, the area of interest must present a scientific value (SV) greater than or equal to 200, below which it will be characterized as a geodiversity site.

A geosite is considered to be of national relevance when its SV is equal to or greater than 200 and of international

Fig. 1 Sites of interest identified on the geological map of the municipality of João Dourado, outlined in red. Base map SC.24-Y-C Jacobina 1:250.000. Modified from CPRM (1998)



relevance when this value is equal to or greater than 300. Geodiversity sites are considered of national relevance when

the potential educational use (PEU) and/or potential tourist use (PTU) has a value equal to or greater than 200. Values below 200 characterize geodiversity sites of regional or local relevance.

Table 1 Final value of the degradation risk of João Dourado sites of interest. Adapted from García-Cortés and Carcavilla (2009) and Brilha (2016)

Final value	Degradation risk
$0 \leq \text{value} \leq 200$	Low
$200 \leq \text{value} \leq 300$	Medium
$300 \leq \text{value} \leq 400$	High

Quantitative evaluation of the SV of the sites of interest follows seven criteria: representativity, local-type, scientific knowledge, integrity, geological diversity, rarity, and limitations to use. Each site was rated 0, 1, 2, or 4 points according to the indicators for each criterion. The final scientific value is the weighted sum of these seven criteria.

Table 2 Brief characterization of the 16 sites of interest identified in the municipality of João Dourado

Geosite	Coordinates	Classification	Main features	Main threats	Remarks
P1—Lapa dos Brejões cave	11° 00' 27.2" S, 41° 26' 07.2" W	Geosite of international relevance	Numerous speleothems (Fig. 2a), large galleries and dolines (Fig. 2b), and an imposing portal 106 m high (Fig. 2c). Presents fossiliferous deposits of paleovertebrates and rock paintings	Holding of a religious feast in and around the cave, accommodation of religious offerings and candles in the speleothems, accumulation of garbage and graffiti	Need for installation of new interpretive panels and renovation of old panels; improvements in accessibility and demarcation of the trail inside the cave
P2—Lajedo das Pombas	11° 19' 50.7" S, 41° 35' 47.4" W	Geosite of national relevance	Folded rocks, some with vertical axial plane (Fig. 3a), and numerous faults (Fig. 3b–c)	Extensive livestock farming, which may cause damage to outcrops	Good conditions of observation of structures that can be used for didactic purposes
P3—Vajado	11° 22' 27.3" S, 41° 44' 18.4" W	Geosite of national relevance	Exocarcic dissolution forms of karren (Fig. 4 a and b), stromatolites (Fig. 4c), and places of temporary water accumulation	Intensive agriculture, livestock, mining, garbage disposal, and graffiti	Need to protect the area containing the stromatolites and install an interpretive panel
P4—Faveira farm	11° 16' 32.0" S, 41° 47.1" W	Geosite of national relevance	Mammalian fossils of the Quaternary megafauna (Fig. 5 a and b) and karstic relief features such as sinking dolines (Fig. 5c) and dissolution dolines	Mining for the manufacture of bricks	It is essential to conduct further studies and remove the fossil material that is in place to be displayed in a museum or a scientific institution.
P5—Gameleira	11° 23' 30.0" S, 41° 42' 23.0" W	Geosite of national relevance	Faults and folds (Fig. 6a), crystals of dissolved salt (Fig. 6b), <i>tepees</i> (Fig. 6c), cross-stratification, stromatolite, ponds, and reservoirs that store water temporarily	Intensive agriculture, livestock, mining, garbage disposal, and graffiti	Necessary installation of interpretive panels so that the population becomes aware of the importance of the site
Geodiversity site	Coordinates	Classification	Main features	Main threats	Remarks
P6—Floresta	11° 14' 47.1" S, 41° 31' 16.6" W	Geodiversity site of national relevance	Mammalian fossils of Quaternary megafauna (Fig. 7 a and b), stromatolites (Fig. 7c), and Glyptodontidae osteoderms (Fig. 7d)	Agriculture and livestock	It is relevant to collect the fossiliferous material and expose it to a museum or scientific institution
P7—Morro do Pregó	11° 19' 49.0" S, 41° 42' 13.2" W	Geodiversity site of national relevance	The highest site in the municipality (Fig. 8a), which can be used as an observatory (Fig. 8 b and c)	Installation of telephone and television antennas	It provides a privileged view of the city and the escarpment that delimits the Irecê Basin to the southeast
P8—Poço Verde farm	11° 20' 42.8" S, 41° 38' 15.1" W	Geodiversity site of national relevance	Fragments of fossilized bones (Fig. 9a) and stylolites (Fig. 9b).	Agriculture and livestock	It is imperative to conduct further studies and collect the fossils to be protected in an appropriate place
P9—Boa Vista farm	11° 05' 32.5" S, 41° 23' 38.5" W	Geodiversity site of national relevance	Valley of the Jacaré river (Fig. 10a), speleothems (Fig. 10b), and rock paintings (Fig. 10 c and d)	Vandalism.	Carry out more studies and register the rock paintings
P10—Gruta da Igrejinha cave	11° 04' 29.3" S, 41° 24' 0.0" W	Geodiversity site of national relevance	Karstic valley (Fig. 11a) and cave with speleothems (Fig. 11b)	Vandalism.	Need for more studies to know what scientific and attractive findings the cave can provide
P11—Baixa da Pedra farm	11° 21' 43.7" S, 41° 42' 37.0" W	Geodiversity site of national relevance	Doline (Fig. 12a), probably formed by the lowering of the water table used for irrigation (Fig. 12b)	Uncontrolled drilling of wells	It can serve as an example for farmers in the region who drill too many wells
P12—Praça well	11° 20' 54.2" S, 41° 39' 47.5" W	Geodiversity site of national relevance	Historical well. First well of the municipality (Fig. 13a)	Indiscriminate drilling of wells	Need to supervise the drilling of wells
P13—Gameleira well	11° 23' 25.4" S, 41° 42' 1.6" W	Geodiversity site of national relevance	Historical well (Fig. 13b)	Indiscriminate drilling of wells	Need to supervise the drilling of wells
P14—Sabino well	11° 22' 13.1" S, 41° 38' 29.4" W	Geodiversity site of national relevance	Historical well. First well of the municipality directed to irrigated agriculture (Fig. 13c).	Indiscriminate drilling of wells and use of agrochemicals	Need to inspect drilling wells and correctly use agricultural inputs
P15—Nego de Clarindo	11° 17' 29.4" S, 41° 33' 54.1" W	Geodiversity site of local/- regional relevance	Stromatolites (Fig. 14 a and b), folds, faults, and sedimentary structures of tension gashes type (Fig. 14c)	Mining	Good conditions of observation of structures, which can be used for didactic purposes
P16—Lagoa de Ademar	11° 19' 35.1" S, 41° 36' 39.2" W	Geodiversity site of local/- regional relevance	Concretions of ferruginous material (Fig. 15 a and c) and possible geological fault (Fig. 15b)	Agriculture and livestock	Recommended for didactic activities

Fig. 2 Lapa dos Brejões cave. **a** Speleothem “wedding cake.” **b** Skylight. **c** Portico with a height of 106 m, a person highlighted



Degradation risk (DR) takes into account five criteria: deterioration of geological elements, proximity to potentially degrading activities/areas, legal protection, accessibility, and population density. All are scored between 0 and 4, and the final result of the DR value is attributed based on the weighted sum of the scores for each of these five criteria.

Brilha (2016) points out that a site has maximum DR when its main geological feature and its elements are highly likely to be damaged by either natural or anthropic factors, when the site is not under legal protection, and when it is located near an area of potentially harmful activity. Considering its final value, DR can be classified as low, medium, or high (Table 1).

Quantitative evaluation of potential educational use (PEU) and potential tourist use (PTU) is based on common criteria: vulnerability, accessibility, limitations to use, safety, logistics, population density, association with other values, scenery, uniqueness, and conditions of observation. Furthermore, PEU also includes didactic potential and geological diversity. Besides the common criteria previously mentioned, PTU encompasses potential for dissemination, economic level, and proximity to recreational areas. Each criterion is scored from 0 to 4 and final PEU and PTU are the weighted sum of these criteria.

The inherent subjectivity for both inventory and quantification can never be totally eliminated (Brilha 2016). However, the method used in this study aims to reduce some of these subjectivities on the sites of interest in the municipality of João Dourado taking into consideration objectively the score of each criterion.

Results

An inventory of 16 sites of interest in the municipality of João Dourado was carried out. With the exception of the Lagoa de Ademar (P16) site, which is on cenozoic residual alterations, all the sites are located on the Salitre Formation of the Una Group, of neoproterozoic age. The location (Fig. 1), as well as the listing with names, geographical coordinates, classification, main features, main threats, and observations for each location, follows in Table 2 (see also Figs. 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, and 15).

The scoring of each criterion for the quantification of scientific value (SV), degradation risk (DR), potential educational use (PEU), and potential tourist use (PTU) of the sixteen sites surveyed follows in Table 3. Figure 16 shows the total values of SV, PEU, PTU, and DR for each location.

Discussion

Knowledge on the existence of geosites and geodiversity sites, and understanding of their importance, is a fundamental mechanism that can contribute to their conservation, regardless of where they are located. The present study identified five geosites and eleven geodiversity sites in the municipality of João Dourado with the most diverse interests: sedimentological, geomorphological, speleological, tectonic-structural,

Fig. 3 Lajedo das Pombas. **a** Fold with vertical axial plane. **b** Fault in detail. **c** Outcropping of algal laminite with fault. **d** Fault and folds

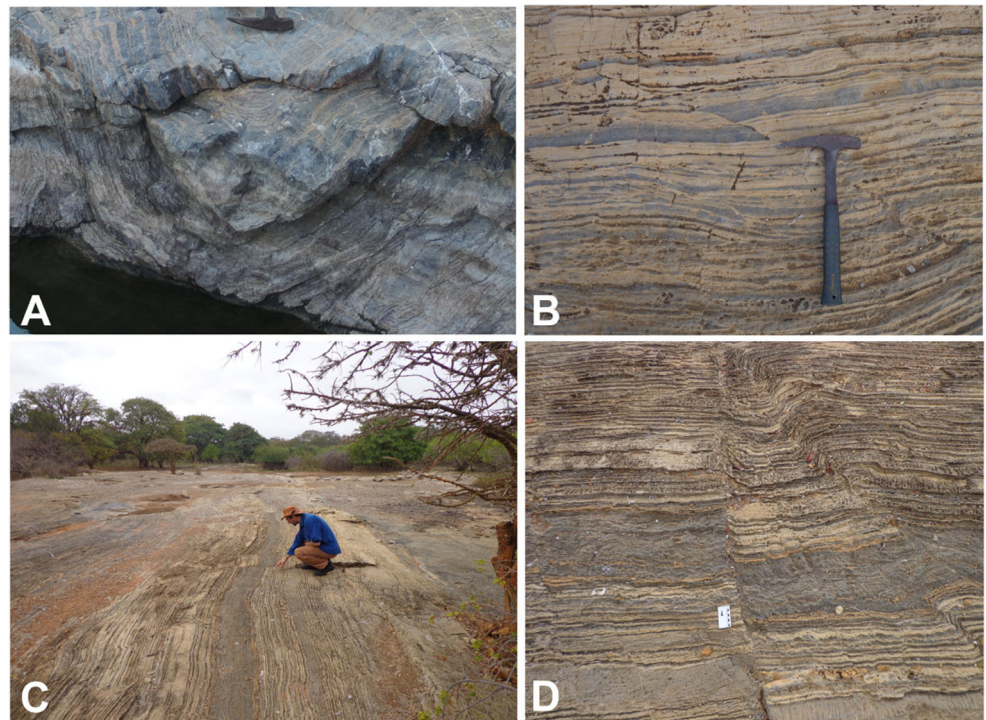


Fig. 4 Vajado. **a** Outcropping with various karren. **b** Karren seen in plant. **c** Stromatolites

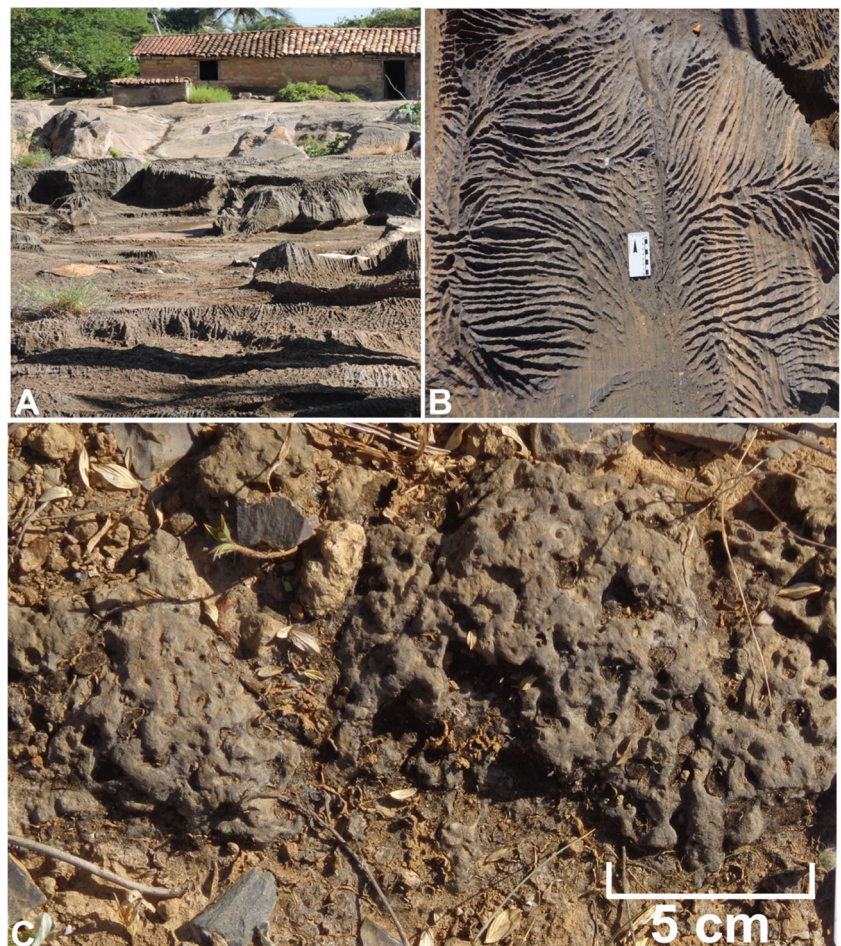




Fig. 5 Faveleira farm. **a** Tank where the fossils were found. **b** Skeletal remains of the Quaternary megafauna (Faria 2016). **c** Doline

paleontological, and hydrogeological, besides important archeological aspects, such as the rock paintings.

The only place classified as a geosite of international relevance, Lapa dos Brejões cave geosite has the highest scientific value (350) among the sixteen sites analyzed. It integrates the proposed area for the implementation of the Morro do Chapéu Geopark (Rocha and Pedreira 2013), being the best example in the study area to illustrate elements or processes related to

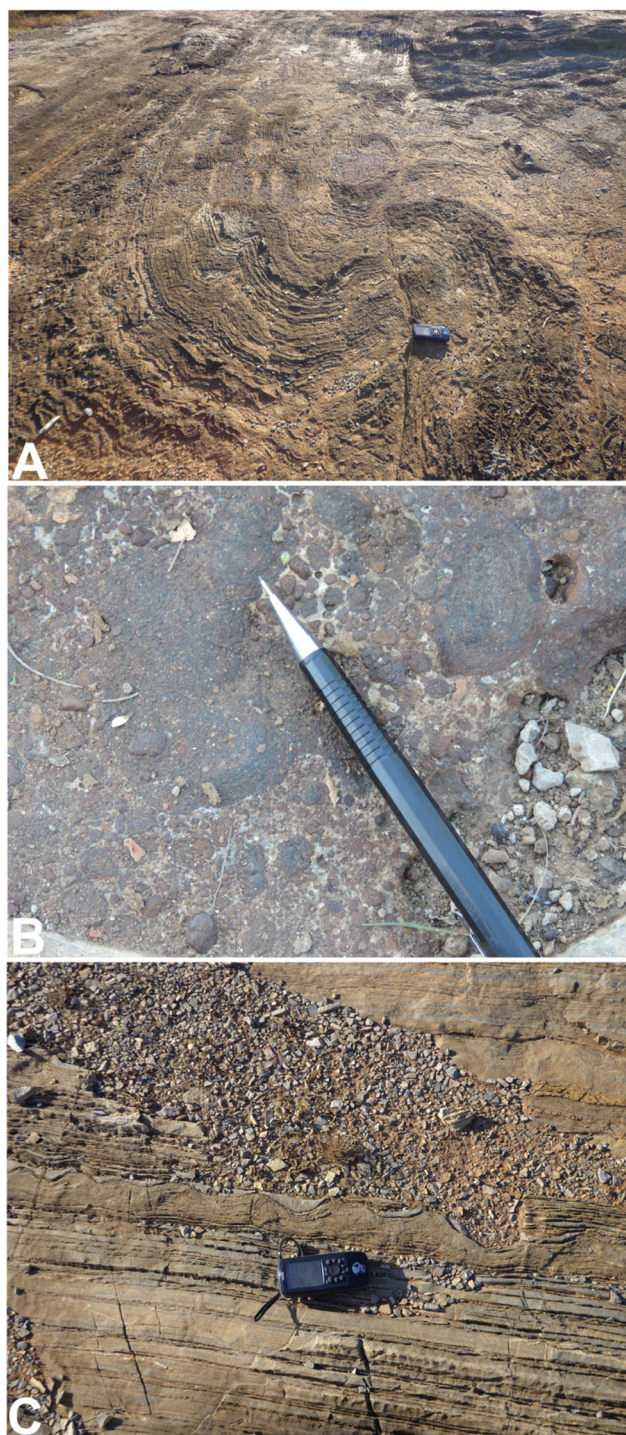


Fig. 6 Gameleira. **a** Outcropping with folds and fault. **b** Brands of dissolved salt crystals. **c** *Tepees*

Speleology. The mentioned geopark covers another seven municipalities in addition to João Dourado, and in recent years, it has been undergoing a process of development and adaptation in order to be made viable. As such, lectures have been given on the geological inventory with the aim of providing knowledge to the local population; there have been studies on possible impacts; a schedule has been prepared with

Fig. 7 Floresta. **a** Fossiliferous tank. **b** Large quantity of fossils. **c** Stromatolites. **d** Osteoderms of Glyptodontidae



steps to be established over time; and technical visits have been carried out with the help of the Araripe Geopark team for the feasibility of the main points of interest. As a result, the municipality of João Dourado may benefit from the fact that other locations, in addition to Lapa dos Brejões cave, could be part of the geopark territory.

The Lapa dos Brejões cave geosite is categorized as local type due to the occurrence of the holotype *Racekiela cavernicola* n. sp. (Volkmer-Ribeiro et al. 2010), it presents different geological aspects with scientific relevance, and the main geological elements are very well preserved. The existence of international scientific articles on the site (Courbon and Chabert 1986; Steadman et al. 2005; Barbosa and Travassos 2008; Volkmer-Ribeiro et al. 2010) also contributed to this classification.

The following places are categorized as geosites of national relevance: Lajedo das Pombas, Vajado, Faveleira farm, and Gameleira. The Lajedo das Pombas geosite has the second highest scientific value (270) and falls within this classification due mainly to the location being considered the best example in the study area to illustrate elements or processes related to structural geology. The main geological features are very well preserved; this being the only occurrence of this type in the area and presenting different types of geological aspects with scientific relevance.

Vajado geosite presents the third highest scientific value (230) and is classified in this category because there are no limitations to carrying out on-site fieldwork; presenting

different types of geological aspects with scientific relevance and being the best example currently known in the study area to illustrate elements or processes related to sedimentology.

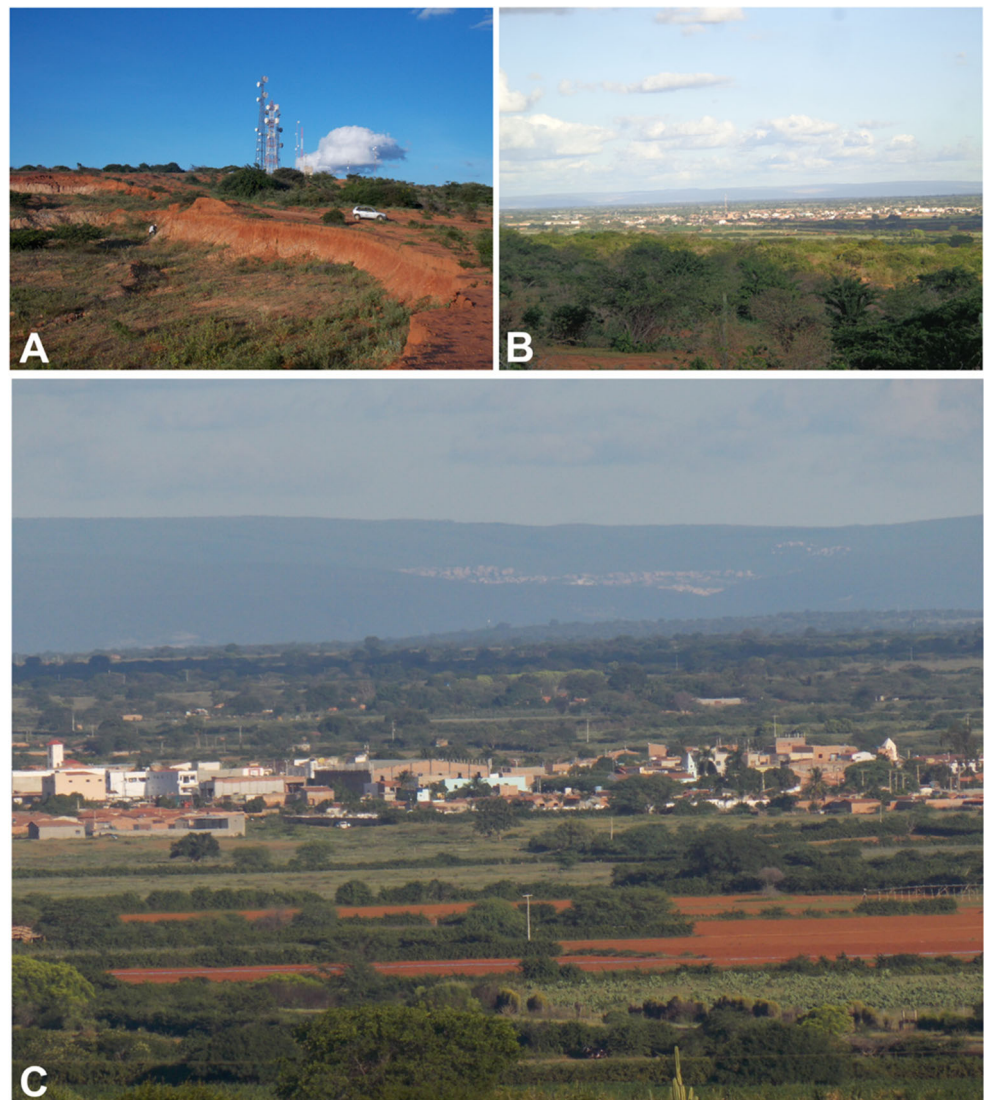
The Faveleira farm geosite has the fourth highest scientific value (220). It is in this classification because it is the best example in the municipality to illustrate elements or processes related to Paleontology, in addition to having a published dissertation (Faria 2016).

Gameleira geosite presents the fifth largest scientific value (210) and is classified in this category because its main geological elements are very well preserved, there are no limitations for sampling or fieldwork, there are different types of geological aspects with scientific relevance, and for being a good example to illustrate elements or processes related to sedimentology.

Most of the places of interest surveyed in the municipality of João Dourado fit the geodiversity site classification of national relevance. They are as follows: Floresta geodiversity site, Poço Verde farm geodiversity site, Morro do Prego geodiversity site, Boa Vista farm geodiversity site, Gameleira well geodiversity site, Gruta da Igrejinha cave geodiversity site, Praça well geodiversity site, Baixa da Pedra farm geodiversity site, and Sabino well geodiversity site.

In addition, the factors that contributed to their being classified in this category are the occurrence of unique and rare aspects in the country or region (with the exception of wells and Morro do Prego) and the occurrence of geological

Fig. 8 Morro do Prego. **a** Highest point at João Dourado. **b** Vision of the municipality of João Dourado. **c** Escarp that delimits the Irecê Basin to the southeast



elements that are taught at all levels of teaching. These elements are good conditions for observation, places with good accessibility, possibility of use by students and tourists, having a mobile communications network, and being located within 50 km of a rescue service. In addition, a preponderant factor was the potential educational use equal to or above 200.

The potential tourist use had no influence, since the four places that presented this value above 200 are classified in the geosite category.

Two sites were included in the geodiversity site category of local/regional relevance. The main reason the Nego de Clarindo geodiversity site and the Lagoa de Ademar

Fig. 9 Poço Verde farm. **a** Fossilized bones. **b** Irregular surface that forms with dissolution by pressure inside rocks like limestones

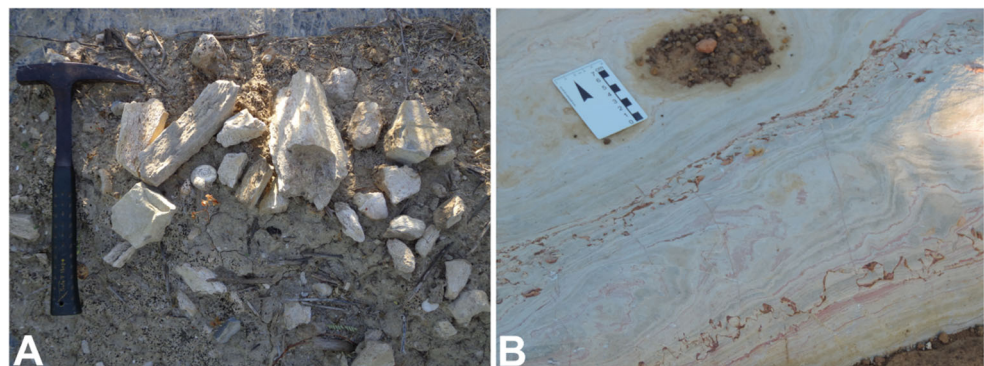
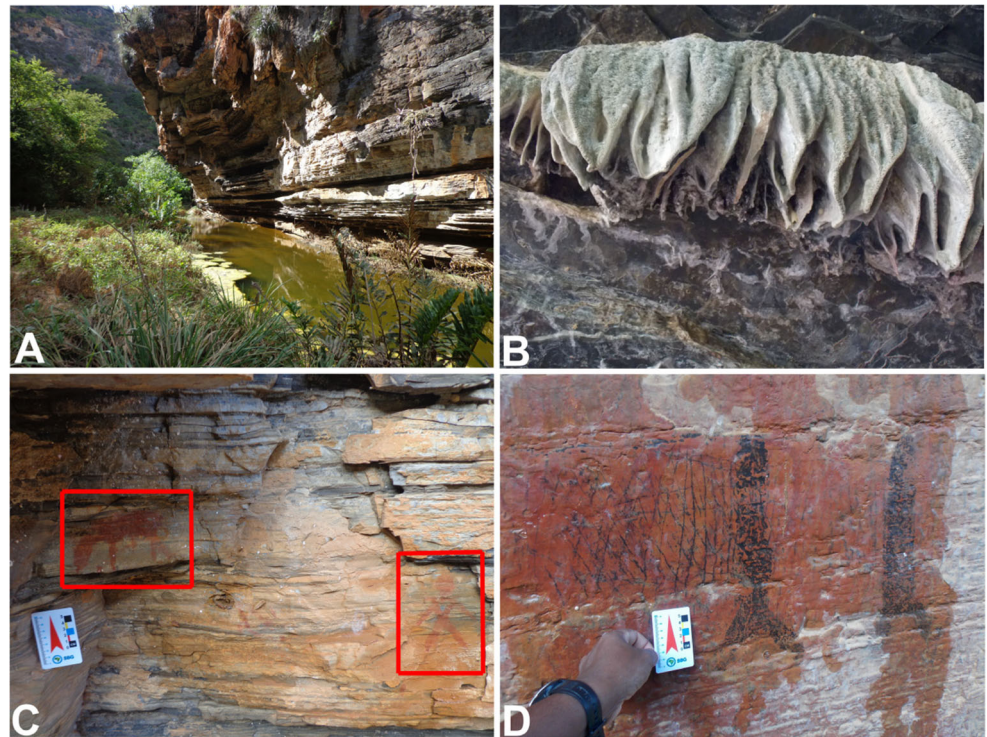


Fig. 10 Boa Vista farm. **a** Jacaré river. **b** Cascade speleothem. **c** Rock paintings depicting an animal on the left and a person on the right. **d** Representation of shapes that resemble fish



geodiversity site were in this category is that in these places, there are occurrences of geological elements that are only taught in higher education. As such, the public needs some geological knowledge to understand the complexity of the elements present in these locations.

It is important to remember that although the GEOSSIT application is based on the works of Brilha (2016) and García-Cortés and Carcavilla (2009), they do not classify the relevance of places of interest by assigning this form of quantification. In addition, the classification generated by GEOSSIT appears to be unsuitable in places of outstanding scientific interest that have not been considered “local-type” and are not the subject of published scientific papers. This fact reduces the score for scientific value and, consequently, classifies the site as a geodiversity site instead of a geosite. As is the case for the Gruta da Igrejinha cave, the Boa Vista farm, and the Floresta location, which would probably be classified

as geosites if they scored in the local type and scientific knowledge categories.

Nevertheless, it was decided to use the GEOSSIT platform as it is a tool for the standardization of the registration of geosites and geodiversity sites in Brazil. It is free to consult and feeds a national database in which the sites undergo an evaluation by the technical team of the Geological Survey of Brazil to be approved.

The Lapa dos Brejões cave geosite is the most suitable for tourist use because it has local guides and does not present a high risk of degradation. Despite the Vajado geosite and the Gameleira geosite leading the score for potential tourist use, these places have a high risk of degradation and therefore must be preserved. Because they house easily accessible fossils, the Faveleira farm geosite, the Floresta geodiversity site, and the Poço Verde farm geodiversity site must also be preserved, being recommended only for scientific studies. The other

Fig. 11 Gruta da Igrejinha cave. **a** Jacaré river. **b** Entrance to the cave with stalactites



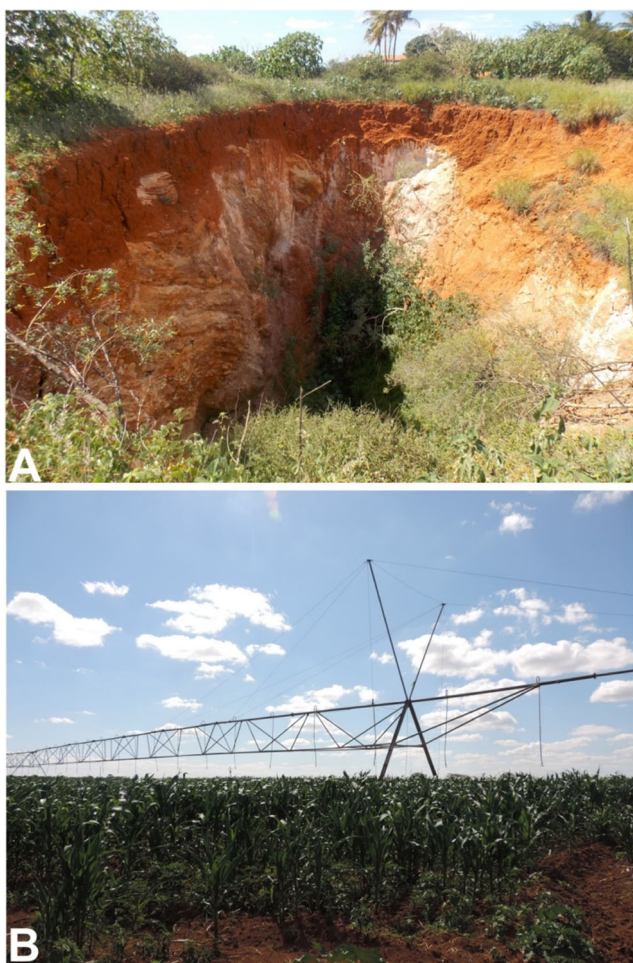


Fig. 12 Baixa da Pedra farm. **a** Sinking doline about 8 m in depth. **b** Corn crop with sprinkler irrigation pivot

locations, on the other hand, can be used responsibly for educational purposes.

Conclusions

The geosites and geodiversity sites of João Dourado are of sedimentological, geomorphological, speleological, tectonic-structural, paleontological, hydrogeological, and archeological interest. The geodiversity of the municipality is threatened mainly due to the expansion of irrigated agriculture, soil exploitation for use in pottery, rock exploitation for various uses, lack of knowledge on its importance, disposal of garbage, and the graffiti that occurs in certain locations.

In the case of sites of paleontological relevance, it is worth mentioning that the mining activity was responsible for numerous findings. However, lack of knowledge on the importance and correct handling of fossils can cause damage and lead to the loss of important information for scientists. In



Fig. 13 Wells. **a** Praça well. **b** Gameleira well. **c** Sabino well

addition, the fossils of the geodiversity sites Floresta and Poço Verde farm need further studies to identify their species.

The inventory and quantitative evaluation of the geodiversity of João Dourado provides a basis for actions on the part of public authorities, regarding planning and territorial planning, in order to contribute to the maintenance of a sustainable ecosystem and the preservation of these geosites and

Fig. 14 Nego de Clarindo locality. **a** Outcrop of algal laminite with stromatolites. **b** Block with stromatolites. **c** Sigmoidal structures originating from ductile shear filled by calcite



Fig. 15 Lagoa de Ademar. **a** Area with laterites, where ferruginous cement joins fragments of rocks, forming a sedimentary breccia. **b** Siliceous rock indicative of possible breccia failure. **c** Sedimentary breccia supported by the framework and with poorly selected sediments

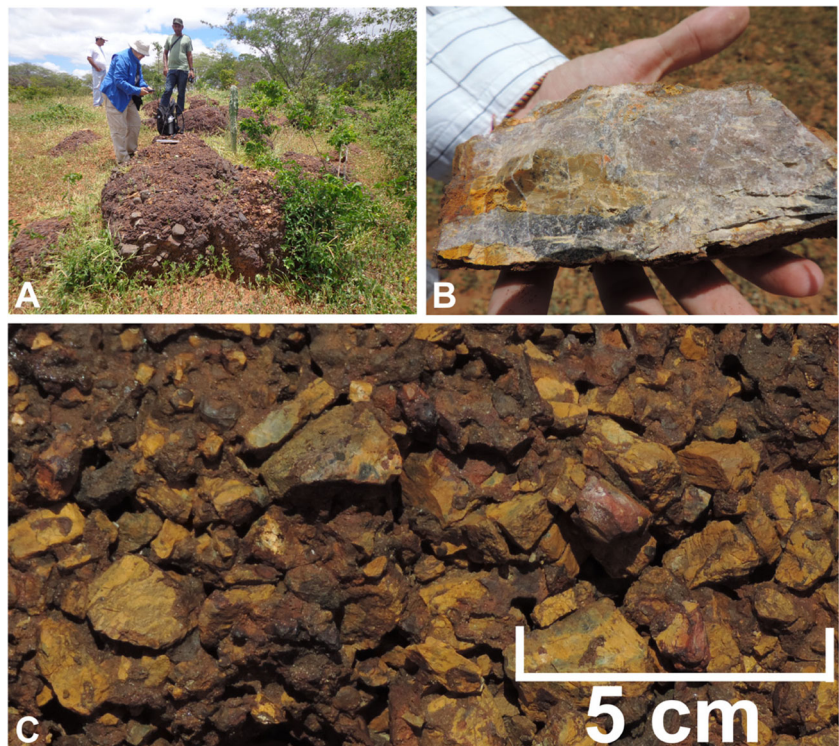


Table 3 Score of each criterion for the quantification of the 16 sites of interest of João Dourado. SV scientific value, DR degradation risk, PEU potential educational use, PTU potential tourist use

Assessment of scientific value, degradation risk, potential educational, and tourist use	Representativeness	Key location	Scientific knowledge	Integrity	Geological diversity (SV and DR)	Geological diversity (PEU and PTU)	Rarity	Use limitations (SV and DR)	Use limitations (PEU and PTU)	Deterioration of geological elements	Proximity to areas with potential to cause degradation	Legal protection	Accessibility
Lapa dos Brejões cave	4	4	4	4	4	4	2	2	3	3	2	2	1
Lajeado das Pombas	4	0	0	4	2	3	4	2	2	1	4	3	2
Vajado	4	0	0	2	2	3	2	4	4	3	3	4	4
Faveleira farm	4	0	2	2	2	3	2	2	4	3	4	3	2
Gameleira	2	0	0	4	4	4	2	4	4	3	4	4	2
Floresta	2	0	0	4	2	3	2	2	2	3	3	3	2
Morro do Prego	2	0	0	2	1	2	4	2	2	1	4	3	2
Poço Verde farm	1	0	0	1	2	3	2	2	2	3	3	3	3
Boa Vista farm	2	0	0	4	2	3	2	2	2	3	1	4	1
Gruta da Igreja cave	2	0	1	4	2	3	2	2	2	3	2	2	1
Baixa da Pedra farm	4	0	0	0	1	1	1	2	2	0	4	3	2
Praça well	2	0	0	0	1	1	1	2	2	3	4	3	4
Gameleira well	2	0	0	0	1	1	1	4	4	3	4	4	2
Sabino well	2	0	0	0	1	1	1	2	2	3	4	3	2
Nego de Clarindo	2	0	0	2	2	3	2	2	4	4	4	4	2
Lagoa de Ademar	1	0	0	4	1	2	4	2	2	3	4	3	2

Assessment of scientific value, degradation risk, potential educational, and tourist use	Population and density	Vulnerability	Safety	Logistics	Association with other values	Scenery	Uniqueness	Observation conditions	Didactic potential	Interpretative potential	Economic level	Proximity of recreational areas	
Lapa dos Brejões cave	1	2	1	2	1	2	4	4	4	4	1	0	
Lajeado das Pombas	1	2	2	3	1	0	2	4	1	3	1	2	
Vajado	1	2	2	3	1	1	2	4	1	3	1	4	
Faveleira farm	1	2	2	3	1	0	4	4	4	3	1	1	
Gameleira	1	1	2	3	2	1	2	4	1	4	1	4	
Floresta	1	2	2	3	1	0	4	4	4	3	1	1	
Morro do Prego	1	3	2	3	1	0	1	4	4	4	1	1	
Poço Verde farm	1	2	2	3	2	0	2	2	4	3	1	4	
Boa Vista farm	1	2	1	2	4	0	2	4	4	3	1	0	
Gruta da Igreja cave	1	2	1	2	1	1	2	3	4	4	1	0	
Baixa da Pedra farm	1	0	2	3	2	0	2	4	4	4	1	3	
Praça well	1	1	2	3	1	0	1	2	4	3	1	4	
Gameleira well	1	1	2	3	1	0	1	4	4	3	1	4	
Sabino well	1	1	2	3	1	0	1	4	4	3	1	4	
Nego de Clarindo	1	1	2	3	1	0	1	2	4	3	1	4	
Lagoa de Ademar	1	1	2	3	1	0	2	4	1	3	1	1	
													2

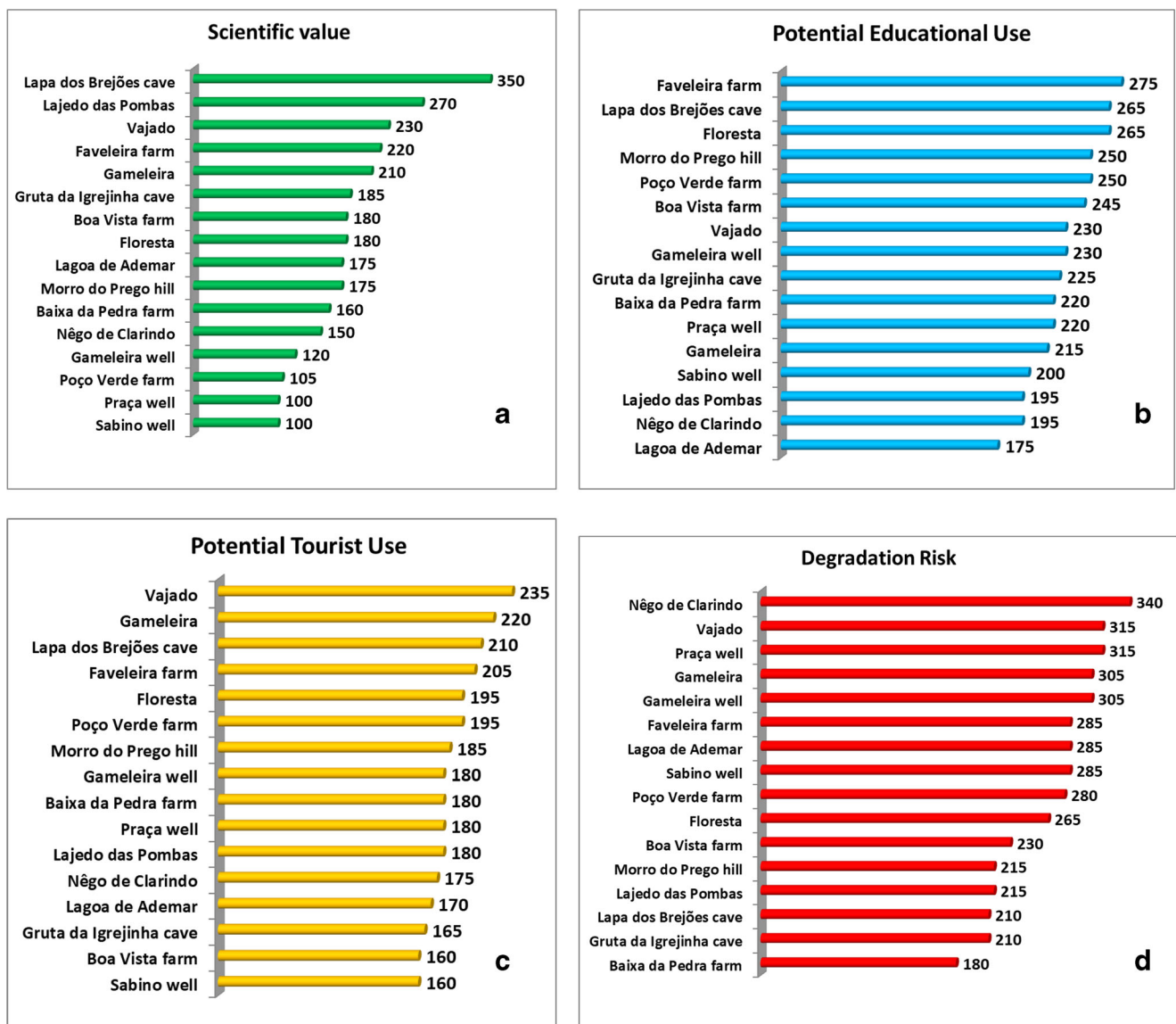


Fig. 16 Final quantification. **a** Scientific value. **b** Potential educational use. **c** Potential tourist use. **d** Degradation risk of each site of interest surveyed in João Dourado

geodiversity sites for future generations. It also favors its conservation and brings the public closer to geosciences, enabling an awareness of the need for balance in relation to the abiotic aspects of nature. This process can deepen the relationship between people and their municipality, as well as their origins and customs.

In interviews with the population of João Dourado, Albani (2017) found that the majority of the inhabitants of the municipality demonstrate confidence in the benefits that geodiversity can provide in social and economic terms, as well as the capacity to attract geotourists. With its scientific, educational, historical, and cultural importance, geosites and geodiversity sites can provide

an alternative income for the local population through geotourism and contribute to the sustainable development of the municipality.

However, it is imperative that people know the existence and importance of these places so that they can preserve them. In order to introduce these sites into the tourist scene, it is indispensable to make visitors and residents become users and guardians of these places at the same time, avoiding more damage so that in the future, they can enjoy the same attractions found today. It is also a good opportunity to bring students from the education network with the geodiversity identified in the municipality.

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