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Environmental Quality of springs in a rural area, in the municipality of Pedra do Indaiá – MG

Qualidade Ambiental de nascentes na zona rural do município de Pedra do Indaiá - MG

Alysson Rodrigo Fonseca[1]; Thiago Vilela Nogueira[2]; Gabriela Barbosa Martins[3]; Mauro Cesar Cardoso Cruz[4]; Fabrízio Furtado de Sousa[5]; Clécio Eustáquio Gomides[6]

[1] Professor at State University of Minas Gerais - UEMG, Divinópolis Unit/Natural and Earth Sciences, Brazil. Email: alysson.silva@uemg.br
ORCID: https://orcid.org/0000-0002-7510-8142

[2] Student at State University of Minas Gerais - UEMG, Divinópolis Unit/Natural and Earth Sciences, Brazil. Email: thiago.1693508@discente.uemg.br
ORCID: https://orcid.org/0009-0006-2351-4081

[3] Student at State University of Minas Gerais - UEMG, Divinópolis Unit/Natural and Earth Sciences, Brazil. Email: gabriela.1655090@discente.uemg.br
ORCID: https://orcid.org/0009-0002-8356-6861

[4] Professor at State University of Minas Gerais - UEMG, Divinópolis Unit/ Engineering, Brazil. Email: mauro.cruz@uemg.br
ORCID: https://orcid.org/0009-0008-7808-1193

[5] Professor at State University of Minas Gerais - UEMG, Divinópolis Unit/ Humanities, Brazil. Email: fabrizio.sousa@uemg.br
ORCID: https://orcid.org/0000-0003-1257-862X

[6] Professor at State University of Minas Gerais - UEMG, Divinópolis Unit/ Engineering, Brazil. Email: clecio.gomides@uemg.br
ORCID: https://orcid.org/0000-0002-8566-2913

Abstract: The environmental quality of a system refers to the harmonious relationship between its constituent elements, enabling its functioning and dynamics. This case study aimed to identify, georeference and analyze the environmental and microbiological quality of existing springs in the community of *Camarão*, a rural area of the municipality of Pedra do Indaiá, MG. Environmental impacts of 13 springs were evaluated based on the "*Índice de Impacto Ambiental em Nascentes*" (IIAN; Environmental Impact on Springs Index). Water microbiology was analyzed using the Chromogenic Substrate Test (Colitest®), which indicates the presence or absence of total and thermotolerant coliforms. The tests were applied in the dry season (July 2022) and rainy season (December 2022). Classification of springs according to Degree of Preservation found three to be "Good" (Class B, four to be "Reasonable" (Class C), four to be "Bad" (Class D) and one to be "Terrible" (Class E). Microbiological analysis found all the evaluated springs to be positive for the presence of total and thermotolerant coliforms (*Escherichia coli*). The results showed a high degree of degradation of practically all the evaluated springs. As this is a case study, being carried out in only one rural community in the municipality, there is the possibility that this situation will be generalized to others, and so additional research is needed to evaluate this hypothesis

Keywords: Environmental Impact on Springs Index; Water Quality; Environmental Sanitation.

Resumo: A qualidade ambiental de um determinado sistema refere-se à relação harmônica entre os elementos que o constituem, propiciando seu funcionamento e dinâmica. Este estudo de caso teve como objetivo a identificação, georreferenciamento e análise da qualidade ambiental e microbiológica das nascentes existentes na comunidade do Camarão, zona rural do município de Pedra do Indaiá - MG. Foram avaliados impactos ambientais em 13 nascentes a partir do Índice de Impacto Ambiental em Nascentes – IIAN. A análise microbiológica da água foi realizada através do Teste do Substrato Cromogênico (Colitest®), que mostra a presença ou ausência de Coliformes Totais e Termotolerantes. A aplicação dos testes foi realizada no período seco (julho/2022) e período chuvoso (dezembro/2022). No que se refere ao Grau de Preservação das nascentes, verificou uma classificação como "Boa" (Classe B) para 3 nascentes, "Razoável" (Classe C) e "Ruim" (Classe D) para 4 nascentes em ambas as classificações e "Péssima" (Classe E) para apenas uma nascente. Na análise microbiológica, constatou-se que todas as nascentes avaliadas apresentaram resultados positivos para presença de coliformes totais e termotolerantes (*Escherichia coli*). Os resultados mostraram elevado grau de degradação de praticamente todas as nascentes avaliadas. Sendo um estudo de caso, realizado em apenas uma comunidade rural do município, existe a possibilidade de que esse quadro seja generalizado para as demais, sendo necessárias pesquisas complementares para se avaliar essa hipótese

Palavras-chave: Índice de Impacto Ambiental em Nascentes; Qualidade da Água; Saneamento Ambiental.

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1. Introduction

Water is a valuable resource that is present in many human activities. With population and economic development, the use of water resources is increasingly needed by society and in different applications, strictly connected to human needs, whether personal, economic, and/or social (GOMES et al. 2005; FELIPPE, 2009; SANTOS e SANTOS, 2021).

In rural and urban areas of Brazilian municipalities, changes in water quality and volume in rivers, streams and lakes, whether due to pollution, degradation of the riparian forest, or other degrading factors, have been a concerning factor for debate and discussion. Similar issues can also be seen in relation to springs, which are often not recognized as important by public authorities and society.

Conceptually, springs are an environmental system in which groundwater naturally emerges temporarily or perennially and is integrated into the surface drainage network (FELIPPE, 2009). Rainwater, when it hits the ground, infiltrates and percolates into deeper aquifers or flows superficially, in which case it drains out of the system (basin) under the action of gravity into hydrographic channels. Groundwater, on the other hand, has a slower dynamic than surface water and is therefore better distributed over time. After reaching the aquifers, the water is gradually redistributed to the surface by underground flows, which also culminate in its outflow. Many of these flows do not cease even during prolonged droughts, as they are constantly fed by the water stored in aquifers, giving rise to perennial springs (FELIPPE e MAGALHÃES-JUNIOR, 2009).

Considering the importance of springs, it is important that they be understood from the perspective of environmental dynamics, based on the identification of emergences and flows that connect to the river banks, and that they be seen as part of the hydrographic systems responsible for shaping river channels. (CHRISTOFOLETTI, 1981)0. Therefore, they become important systems for maintaining the environmental balance of watersheds in the strict sense of the word (CHRISTOFOLETTI, 1980; FELIPPE e MAGALHÃES-JUNIOR, 2012; PINTO et al. 2012; FELIPPE et al. 2014). Furthermore, they have multiple purposes, such as human and animal consumption ("drinking water"), water use for irrigation ("generating food and income"), enabling people to stay in rural areas, among other benefits (DENNEDY-FRANK et al., 2016).

Considering this relevance, the emergence of the issue of protecting springs must be addressed both in urban areas, but particularly in rural areas, where most springs are located and also where significant environmental changes have been noticed, as agroforestry production has focused almost entirely on the economic dimension, often failing to take into account technical, planning and regulatory aspects regarding land use, particularly when considering Federal Law No. 12.651/2012 (BRAZIL, 2012), which establishes spring areas as of restricted use (PORFÍRIO et al. 2018). Thus, under Article 4 of the aforementioned law, Permanent Preservation Areas (APP, acronym in Portuguese) are those around springs and perennial waterholes, regardless of their topographical situation, within a minimum radius of 50 (fifty) meters (BRAZIL, 2012, Article 4, IV).

Ensuring the quality of the springs is therefore the first step towards maintaining the balance of the environmental dynamics of the entire river system. Changes in the processes that affect the springs invariably have consequences downstream. The first and most obvious effect is qualitative, as it involves disturbances in the physical, chemical or biological parameters of river water. Quantitative effects can also be seen, from a reduction in downstream flows to changes in the seasonal distribution of flows throughout the basin (TEODORO et al., 2007).

The municipality of Pedra do Indaiá, located in the central-western region of the state of Minas Gerais, did not escape this context, with major transformations in recent decades and most of its natural vegetation replaced by pastures, crops and forestry (*Eucalyptus* ssp.). Empirically, there has been a significant reduction in the volume of water in rivers and streams in the region, especially during the dry season. At the same time, local residents have reported a reduction in the volume of water flowing from springs and, in some cases, their complete drying up. Thus, due to the lack of official and/or scientific data attesting to the exact number, location and environmental conditions of the springs in the rural areas of the municipality, this work aims to identify and geo-reference the springs in one of its rural areas and also to carry out microbiological analyses of the water and assessing the environmental quality of these springs.

2. Methodology

2.1 Study Area

The study was carried out in the municipality of Pedra do Indaiá, located in the Midwest region of the state of Minas Gerais, Brazil, with a territorial extension of 347.920 km² and a population of 4,112 inhabitants (IBGE, 2024). Its climate is classified as Cwa - Humid subtropical, with warm summers and dry winters (ALVARES et al. 2013). The warmest period of the year corresponds to the January/February/March quarter, with October to December occurring sporadically as the warmest months. The average annual temperature is around 21.8 °C, with extreme average temperatures ranging from a minimum of 15.8 °C to a maximum of 28.7 °C.

The municipality is part of the Atlantic Forest biome, but in an area of transition with the Cerrado domain (IDE - SISEMA, 2024), whose environment has been greatly altered by agricultural, forestry and livestock activities. As such, there are very few remnants of the original conditions of the vegetation, as most of it has been degraded by extensive pastoral activity in the municipality and also by unsuitable agricultural practices, deforestation and fire.

Concerning its water heritage, the municipality has springs in its rural and urban areas that contribute significantly to the flow of the Lambari River micro-basin, which is part of the Pará River Basin, which in turn is part of the São Francisco River Basin (IDE - SISEMA, 2022). It should be noted that the Lambari River micro-basin alone includes six municipalities, with a total population of 113,426 inhabitants. (IBGE, 2024).

2.2 Environmental impact assessment in the spring areas

In this study, the environmental impacts on springs were assessed using the Environmental Impact Index for Springs - IIAN (acronym in Portuguese), adapted from Gomes et al. (2005). According to these authors, the purpose of this procedure is to qualitatively verify the degree of protection the springs are in, through a sensory - macroscopic - and comparative evaluation technique of some key elements in the identification of environmental impacts and their consequences on springs quality. This study covers springs in a rural area called Camarão, in the municipality of Pedra do Indaiá - MG, with geographical coordinates of 20º 27' 15" south latitude and 45º 16' 01" west longitude. The choice of this area was due to the fact that one of the project members knew the region and its residents well, which made it easier to find the springs that had already been detected, as well as to obtain permission to enter the properties, as they were all on private property. Twelve springs were identified in the study area, one of which could not be tested due to its inaccessibility.

For the environmental characterization of springs and the assessment of macroscopic parameters, which are listed in Table 1, they were analyzed according to the methodology used in the studies carried out by Gomes et al. (2005). The macroscopic parameters must be categorized into standards in order to quantify them and enable the subsequent summation of the points obtained, using the score indicated for each environmental parameter assessed. Therefore, the attribute defined (good, average or bad) must be converted into a score and the index results from the sum of the scores credited for each parameter. Thus, the maximum possible value of the index is 39 points - when all the parameters are considered "good" - and the minimum is 13 points, when all the parameters are considered "bad". Table 2 presents the ranking of the springs in terms of macroscopic impacts.

Primary data was obtained during field visits organized to ensure that all the identified springs were visited. On site, the analyzed springs were georeferenced using a Global Positioning System (GPS), navigation type - Garmin MAP 78, and then their geographical coordinates were transferred to the QGIS system version 2.8.1 and Google Earth, to generate a map of the assessed rural area, with the springs identified and plotted. This information was supplemented by photographic documentation of each spring using a Nikon D5000 camera.

Table 1 – Definition of the macroscopic environmental impact index for springs.

Macroscopic Parameter	**Qualification**		
	Bad (1)	Medium (2)	Good (3)
Color of water	Dark	Clear	Transparent
Odor of water	Strong	With odor	None
Litter around the spring	Much	Few	None
Floating materials	Much	Few	None
Foams	Much	Few	None
Oils	Much	Few	None
Sewage in the spring	Visible	Likely	None
Vegetation	Degraded or absent	Altered	Good condition
Domestic animal use	Presence	Only signs	Not detected

Human use	Presence	Only signs	Not detected
Site protection	Unprotected	Protected (but with access)	Protected (but without access)
Proximity to residence or business	Less than 50 meters	Between 50 to 100 meters	Over 100 meters
Type of insertion area	Absent	Private propety	Parks or Protected areas

Source: Adapted from GOMES et al. (2005).

Table 2 – Rating of springs in terms of macroscopic impacts (final sum)

Class	Level of Preservation	Final score
A	Great	37-39
B	Good	34-36
C	Fair	31-33
D	Bad	28-30
E	Very bad	Abaixo de 28

Source: Adapted from GOMES et al. (2005)

2.3 Microbiological analysis of water

The microbiological analyses of water were carried out during two specific periods of the year, i.e., the dry season (August/2022) and the rainy season (December/2022). The collected samples were stored in duly identified containers in Styrofoam boxes and taken immediately to the microbiology laboratory at the State University of Minas Gerais - UEMG - Divinópolis Unit.

In the laboratory, the method used to analyze the biological parameters Total and Thermotolerant Coliforms was the Chromogenic Substrate Assay - Colitest® (FUNASA, 2013). In this methodology, the samples are collected from springs with a minimum of 100 ml of water in a sterile vial. In the laboratory, the contents of a vial containing the chromogenic substrate are added and incubated at 35.0 ± 0.5oC for 24 hours. After this period, samples with a yellowish color indicate the presence of Total Coliforms. When these samples are exposed to a 365nm ultraviolet lamp and there is fluorescence, it indicate the presence of Thermotolerant Coliforms. If the sample is transparent after 24 hours of incubation, this indicates that no coliforms are present.

3. Findings and discussion

The thirteen springs identified in the studied rural area, as well as the points and their respective coordinates, are shown in Table 1 and Figure 1. It was not possible to carry out the tests at spring 12, since it was in a deep cavity. It should be stressed that most of the assessed springs (n = 10) were in "grotas", which according to Guerra and Guerra (2008) are formations that are depressions or humid cavities observed at the intersections between mountains, forming deep and sometimes extensive valleys. According to IDE-SISEMA (2024), this is due to the municipality being part of the sharp homogeneous geomorphology, which, according to Cavalcante (2005), is a set of landforms with narrow, elongated tops, carved out of sediment and defined by valleys that fit into them.

Table 3 – Geographical coordinates of springs evaluated in the rural area of Camarão, municipality of Pedra do Indaiá - MG

No.	Coordinates
1	20°16'25.93"S 45°10'23.20"O
2	20°16'32.34"S 45°10'26.36"O
3	20°16'46.55"S 45°10'10.77"O
4	20°16'33.19"S 45° 9'31.38"O
5	20°16'19.61"S 45° 9'22.75"O
6	20°16'12.96"S 45° 9'14.99"O
7	20°15'50.69"S 45° 9'27.46"O
8	20°15'50.84"S 45°10'44.49"O
9	20°15'57.58"S 45°10'46.83"O
10	20°16'12.08"S 45°10'36.36"O
11	20°15'59.98"S 45°10'17.72"O
12	20°15'25.49"S 45° 9'55.55"O
13	20°15'19.93"S 45°10'6.05"O

Source: Prepared by authors (2022).

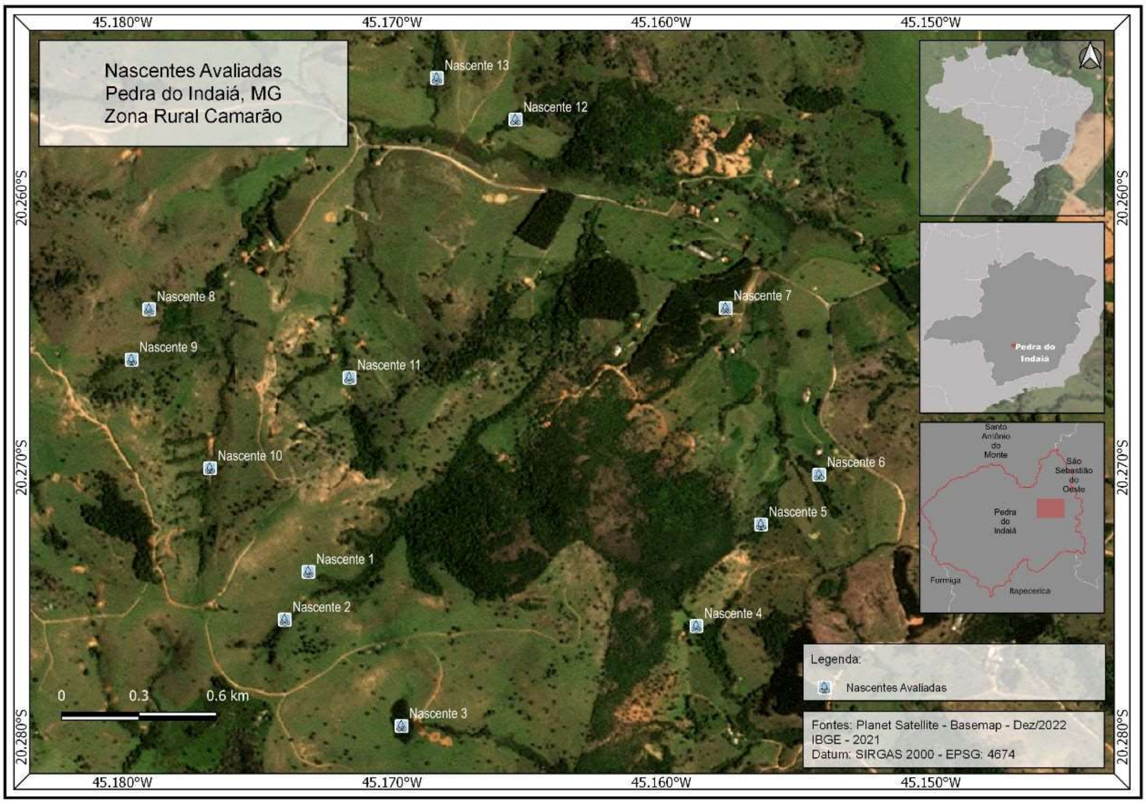

Figure 1 – Springs evaluated in the rural area of Camarão, municipality of Pedra do Indaiá - MG.
Source: Prepared by authors (2022).

From the application of the Environmental Impact Index for Springs (IIAN), the obtained results were systematized in Chart 2.

Table 4 – Quantification of the Analysis of Macroscopic Parameters of the evaluated springs in Pedra do Indaiá - MG.

MACROSCOPIC PARAMETERS	Number of springs												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Color of water	2	1	1	3	3	2	2	2	2	2	2	-	2
Odor of water	3	2	3	3	3	3	3	3	3	3	3	-	3
Litter around the spring	2	3	3	3	3	3	3	3	3	3	3	-	2
Floating materials	1	2	1	3	3	2	2	3	3	3	3	-	2
Foams	2	3	3	3	3	3	3	3	3	3	3	-	3
Oils	2	3	3	3	3	3	3	3	3	3	3	-	3
Sewage in the spring	3	3	3	3	3	3	3	3	3	3	3	-	3
Vegetation	1	1	2	2	3	2	2	1	1	2	1	-	2
Domestic animal use	2	2	2	3	3	1	3	3	2	3	1	-	1
Human use	3	3	3	3	3	3	3	1	1	3	3	-	3
Site protection	1	1	1	1	1	1	1	2	1	1	1	-	1
Proximity to residence	3	3	3	3	3	3	3	2	3	3	3	-	3
Type of insertion area	2	2	2	2	2	2	2	2	2	2	2	-	2
TOTAL SCORE	27	29	30	35	36	31	33	31	30	34	31	-	30
RATING	E	D	D	B	B	C	C	C	D	B	C	-	D

Source: Prepared by authors (2022).

The macroscopic analysis of environmental impacts (Chart 2) showed that the color of the water was "transparent" in only two watersheds, springs 2 and 5, and "clear" in the other springs (Figures 2 and 3). According to Rocha el al. (2017), in preserved springs, a transparent coloration of the water is to be expected, which is considered a positive aesthetic parameter, since according to Botelho et al. (2001) and Ricklefs (2010), it favors light passage and the consequent photosynthesis of the existing aquatic vegetation. According to Souza (2004), light or even dark coloration can naturally occur due to rock or clay particles, the presence of added chemical elements or the decomposition of organic matter. It should be emphasized that natural erosion and/or erosion caused by anthropogenic actions can also cause changes in the color of water, and the revolving of the site by domestic animals or even wild animals cannot be ruled out.

Table 5 – Quantification of the Analysis of Macroscopic Parameters of the evaluated springs in Pedra do Indaiá - MG.

MACROSCOPIC PARAMETERS	Number of springs												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Color of water	2	1	1	3	3	2	2	2	2	2	2	-	2
Odor of water	3	2	3	3	3	3	3	3	3	3	3	-	3
Litter around the spring	2	3	3	3	3	3	3	3	3	3	3	-	2
Floating materials	1	2	1	3	3	2	2	3	3	3	3	-	2
Foams	2	3	3	3	3	3	3	3	3	3	3	-	3
Oils	2	3	3	3	3	3	3	3	3	3	3	-	3
Sewage in the spring	3	3	3	3	3	3	3	3	3	3	3	-	3
Vegetation	1	1	2	2	3	2	2	1	1	2	1	-	2
Domestic animal use	2	2	2	3	3	1	3	3	2	3	1	-	1
Human use	3	3	3	3	3	3	3	1	1	3	3	-	3
Site protection	1	1	1	1	1	1	1	2	1	1	1	-	1
Proximity to residence	3	3	3	3	3	3	3	2	3	3	3	-	3
Type of insertion area	2	2	2	2	2	2	2	2	2	2	2	-	2
TOTAL SCORE	27	29	30	35	36	31	33	31	30	34	31	-	30
RATING	E	D	D	B	B	C	C	C	D	B	C	-	D

Source: Prepared by authors (2022).

Figure 2 – Transparent water color in the spring 5
Source: Prepared by authors (2022).

Figure 3 – Color of the water, dark, in spring 3.
Source: Prepared by authors (2022).

It is important to note that although the water was clear and even transparent, the presence of water or a bottom with a ferruginous color was found in eight of the assessed springs (Figures 4 and 5). This change occurs due to geological formation and also anthropogenic actions, which can favor excess iron ions in the water and enable the development of ferruginous bacteria (CARMO, 2016).

Figure 4 – Ferruginous water from spring 10.
Source: Prepared by authors (2022).

Figure 5 – Ferruginous water from spring 13.
Source: Prepared by authors (2022).

The "odor" parameter was only detected in spring 2, which was caused by the presence of bovine carcasses in the spring, in an advanced degree of decomposition (Figure 6). In rural areas, particularly during the dry season, it is not uncommon for cattle to seek out greener pastures in areas with hydromorphic soils, which, according to Nascimento et al. (2013) have poor drainage and are thus usually flooded, which can lead the animal to get stuck and die. Santos et al. (2015) mention that, in addition to the characteristic odor, water contaminated with corpses can be microbiologically contaminated with heterotrophic and proteolytic bacteria, sulfite-reducing clostridia, enteroviruses and adenoviruses. Additionally, there is usually high oxygen consumption due to biological decomposition and chemical transformations, mainly of products containing nitrogen, phosphorus and sulfur, among others. There is also an increase in the amount of mineral salts, increasing the electrical conductivity of these waters.

Figure 6 – Presence of bovine carcasses in the water of spring 2.
Source: Prepared by authors (2022).

The "litter" parameter was detected in small quantities, consisting only of the remains of barbed wire in spring 1 and a plastic bag in spring 13, probably carried by the wind or runoffs. The presence of remains of products used by humans is more frequent in springs located in urban areas, due to their densification and proximity to buildings, as seen in the studies by Rocha et al. (2017), Fonseca et al. (2019), Fonseca et al. (2021) and Santos et al. (2021).

"Floating materials" were detected in springs 1, 3, 6, 7 and 13. These consisted of plant matter, such as parts of leaves and branches, which do not have a negative impact on the spring. According to Gomes et al. (2005) floating materials can consist of materials from household waste or from rainwater runoff, as well as elements of organic origin, such as those found in this study.

The "sewage" parameter was not detected in the springs, a result that was to be expected given that no sewage pipes or buildings were found near the springs. The presence of "foams" and "oils" in small quantities was only detected in spring 2, due to the decomposition of bovine carcasses, as previously reported.

Vegetation in a good conservation state was only found at spring 5; the other springs had their vegetation categorized as "altered" (3, 4, 6, 7, 10 and 13) or "degraded or absent" (1, 2, 8, 9 and 11). It is worth highlighting the record of deforestation in spring 6, with the suppression of large and medium-sized tree species for timber extraction (Figures 7 and 8). According to the New Forest Code (BRASIL, 2012), in the case of springs, a minimum dimension of the marginal strip of native vegetation to be preserved must be considered, regardless of its topographic condition, of at least 50 meters around the springs or 15 meters in rural areas consolidated before July 22, 2008.

Figure 7 – Degraded or absent vegetation at the spring 1.
Source: Prepared by authors (2022).

Figure 8 – Vegetation clearing at spring 6.
Source: Prepared by authors (2022).

Felippe et al. (2014), Montanarella et al. (2016), and Faria et al. (2019) emphasize that the preservation of vegetation around springs and in surrounding areas is fundamental for their maintenance, as it acts as a buffer for rainfall, preventing direct impact on the soil and its compacting. Thus, it helps to ensure that the soil remains porous and able to absorb rainwater, feeding the water table. Furthermore, it prevents excessive surface water runoff from carrying soil particles and toxic residues from agricultural activities into watercourses. Such waste can affect water quality, and soil particles can reduce the useful life of reservoirs by silting them up. In addition to these features, Silva et al. (2021) cites its importance as a regulating element for biodiversity, atmospheric composition, climate and the hydrological cycle of a river basin.

Properly installed and operational fencing was not found at any of the assessed springs (Chart 2, Figures 9 and 10). At spring 8, there was material from an old fence in a poor state of repair, with rotten posts and broken wires, which did not prevent cattle and horses from crossing (Figure 10). According to Pinto et al. (2004) and Fonseca and Gontijo (2021), fencing off spring areas is of major importance, as it delimits the space where they are located and prevents large domestic animals from entering.

Figure 9 – Fence in a poor state (notice the broken wires) at spring 8.
Source: Prepared by authors (2022).

Figure 10 – Absent fencing at spring 1.
Source: Prepared by authors (2022).

The use of the spring area by large domestic animals (cattle and horses), detected by their presence or marks such as footprints or droppings, was verified in 7 of the 12 springs evaluated (Chart 2, Figures 11 and 12). The presence of these animals in the Permanent Preservation Areas (PPAs) of the springs tends to have a negative impact on the vegetation and also favors soil compaction and revolving, causing silting, erosion and increased water turbidity, as well as microbiological contamination that occurs mainly through feces and urine. (FONSECA e GONTIJO, 2021). CARVALHO et al. (2020) adds that soil compaction caused by trampling reduces the spring's ability to emerge, favoring its drying out.

Figure 11 – Presence of large domestic animal traces (footprints and droppings) in spring 3.
Source: Prepared by authors (2022).

Figure 12 – Presence of large domestic animals, cattle, in the spring 11.
Source: Prepared by authors (2022).

It is important to emphasize that the absence of large domestic animals and their traces (tracks and droppings) in 5 of the assessed springs (4, 5, 7, 8 and 10) was not due to the presence of fencing, but rather to the fact that these springs have their points of resurgence in deep grottoes, which end up constituting "natural barriers" that tend to prevent these animals from accessing these areas.

The "human use" parameter was detected in only two of the assessed springs (8 and 9). Devices such as a water collection box and pipes were found in these springs, and the water used in these two springs by households is for domestic use, vegetable irrigation and animal watering. Felippe (2009) draws attention to the fact that improper use of spring water can substantially change its environmental quality. The author also emphasizes that the use of this water without prior treatment or disinfection poses a risk of water-borne diseases caused, for the most part, by microorganisms of animal or human origin, transmitted by the fecal-oral route.

In terms of "proximity to residence," only one spring was between 50 and 100 meters from a residence (spring 8), while the others were more than 100 meters away. This finding is a positive factor because, as Gomes et al. (2005) mention, the greater proximity of springs to residences or establishments increases anthropic interference, resulting in several negative environmental impacts, such as water contamination, the presence of litter, vegetation degradation, soil compacting and silting.

As far as the "insertion of area" parameter is concerned, it was found that all the assessed springs were on private property. According to information obtained from the City Hall, there are no conservation units in Pedra do Indaiá, which is a negative environmental feature, since areas of this nature are essential for the maintenance and preservation of natural ecosystems and their resources, including soil, water and biological diversity.

Concerning the preservation level of the springs, there was one rating as "Good" (Class B) for 3 springs, "Fair" (Class C) and "Poor" (Class D) for 4 springs in both ratings, and "Poor" (Class E) for only one spring. No springs were classified in category A, as "Great" (Figure 13).

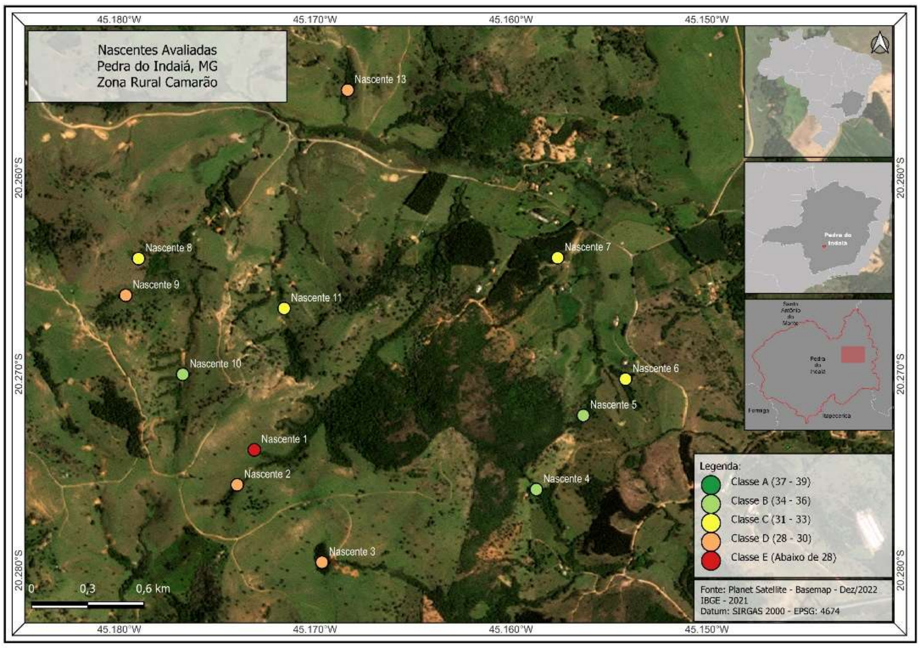

Figure 13 – Rating of Springs Preservation level assessed in the Camarão rural area, municipality of Pedra do Indaiá - MG.
Source: Prepared by authors (2022).

There are few studies carried out in Minas Gerais aimed at the environmental diagnosis of springs. Pinto et al. (2004), in a study of springs in the Ribeirão Santa Cruz watershed in Lavras, Minas Gerais, found a higher number of disturbed springs than degraded springs. Resende et al. (2009), studying the conservation status of 70 springs in the Córrego-Feio watershed in Patrocínio-MG, found 63% of the springs to be disturbed, 20% classified as preserved, and 17% as degraded. Marciano et al. (2016) sought to diagnose the state of preservation of the springs located in the Vargedo stream basin, in the municipality of Santa Rita do Sapucaí, MG, in which they found a high degree of alteration of the assessed springs.

As far as the microbiological analysis is concerned, all the assessed springs tested positive for the presence of total and thermotolerant coliforms (Escherichia coli) in the two samples taken (i.e., in both the dry and rainy seasons). According to Macêdo (2003), this indicates fecal contamination, which means there is a risk of pathogens in the water and thus a risk for the two families identified in this study who use the spring water.

The environmental impacts seen in the springs, the respective classes obtained, and the finding of fecal coliforms in all the samples show that the dynamics of the studied springs have been negatively affected and could even lead to their drying up. Studies have shown that one of the main consequences of anthropogenic interventions in areas where springs are located is changes in flow (SILVA et al. 2021; SANTOS et al. 2021). In extreme cases, the reduction in flow can mean the disappearance of the spring, its transformation into a temporary spring, or its migration downstream. This is explained by the fact that hydrological systems involve a chain of interconnected processes, altering their dynamics and the characteristics of springs. Thus, the disappearance of a spring will result in a reduction in the flow in watercourses and consequently in their availability for various purposes, including for use on rural property.

Despite these factors, there is a huge contrast with the situation found in communities located around springs and rivers, which, due to their residents' lack of knowledge, deforest the permanent preservation area, enhance erosion processes and compromise water resources (JIAN et. al. 2018). Furthermore, in the case of the state of Minas Gerais, the rugged terrain in some regions, coupled with the abundance of water, contributes to small rural properties having considerably limited land use in terms of economic exploitation (ROCHA, 2009). This conflict is evident since natural areas (not exploited) are essential for sustaining wildlife and environmental dynamics, but they are also a source of livelihood when used to produce food and other basic products from agricultural activity (PORFÍRIO et al. 2018).

In view of the degradation of springs, commonly found in Brazilian rural areas, it is essential to carry out studies that can provide support for preservation and monitoring policies, as well as for the recovery of degraded spr (FONSECA e GONTIJO, 2021). The technical literature in the area has suggested that the main techniques for restoring springs are removing the degradation factor, properly isolating springs, promoting the natural regeneration of native vegetation in disturbed areas, and enriching the degraded areas by planting seedlings of native species. (SOUSA et al. 2019). In this context, Alvarenga et al. (2016) and Rodrigues et al. (2020) highlight the applicability of some strategies that can be employed, depending on the disturbance level of spring areas, such as conducting natural regeneration by isolating the area, enriching genetic diversity by introducing individuals of species that already exist on site, as facilitators of the regeneration process, using artificial perches to favor the entry of seeds, promoting dispersal and attracting seed dispersers, as well as direct planting of seedlings or direct seeding.

Porfírio et al. (2018) add that such studies and spring recovery practices can also be used as a tool for environmental education, since one of the difficulties in protecting natural environments lies in the existence of differences in perceptions of values and their importance among individuals from different cultures or socio-economic groups that perform different functions. Finally, he adds that to ensure that landowners really understand the importance of conserving the environment and protected areas, it is necessary for them to understand the co-responsibility they have for these areas on their properties, becoming the protagonists in this process.

4. Final considerations

In view of the findings of this study, the inadequacy of rural properties to comply with current environmental legislation, the inefficiency of monitoring by environmental agencies, and the carelessness of landowners related to the areas where springs are located are evident in the area under study. Therefore, public authorities need to develop policies to promote the conservation of springs and the recovery of areas that have been degraded. In parallel, environmental agencies need to ensure compliance with the legislation protecting them.

Another important factor is the development of environmental education activities designed to educate the landowners where the springs are located on environmental legislation, their rights, and their duties, with an emphasis on the importance of preserving and restoring the springs. Moreover, it is necessary for society and public authorities to recognize rural producers as guardians of this heritage by giving them proper compensation for the products they offer and the environmental services they provide, since the majority of the population living in urban areas depends on natural resources and food from the countryside.

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