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Environmental management and inferences in hydrological resources: a diagnosis of the Rio Espraiado in Soledade/RS

Gestão ambiental e as inferências nos recursos hídricos: um diagnóstico do Rio Espraiado em Soledade/RS

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Abstract
We sought to analyze the inferences of regional development and environmental management, based on the mapping and environmental diagnosis, in the quality of Rio Espraiado in Soledade/RS. The research is descriptive and the methodology used was research-action. For the environmental diagnosis, data on the characteristics of the municipality were evaluated. For hydrographic mapping, the Arcgis software was used with the Geographic Information System to obtain maps and geographic information. It was possible to observe the partial absence of the circumference of native vegetation, absence of undergrowth and erosive processes, presence of waste and tailings on the banks of the tributary, dense ciliary forest of difficult access, critical position environmentally for the occupation on the banks of the river and the margins are severely degraded. Actions to reestablish the PPA are suggested to maintain quality and water flow, as well as investment in public policies to preserve the areas bordering the river.
Keywords: Environmental management. Hydrographic mapping. Water Resources.

Resumo
Buscou-se analisar as inferências do desenvolvimento regional e gestão ambiental, a partir do mapeamento e diagnóstico ambiental, na qualidade do Rio Espraiado em Soledade/RS. A pesquisa é descritiva e a metodologia utilizada foi a pesquisa-ação. Para o diagnóstico ambiental, foram avaliados dados sobre a característica do município. Para o mapeamento hidrográfico, utilizou-se o *software* ArcGis junto ao Sistema de Informações Geográfica, para obter mapas e informações geográficas. Foi possível observar a ausência parcial da circunferência de vegetação nativa, ausência de sub-bosque e processos erosivos, presença de resíduos e rejeitos nas margens do afluente, mata ciliar densa de difícil acesso, posição crítica ambientalmente pela ocupação nas margens do rio e, as margens apresentam-se fortemente degradadas. Sugere-se ações de restabelecimento da APP para manter a qualidade e o fluxo hídrico, assim como, investimento em políticas públicas para preservação das áreas que margeiam o rio.
Palavras-chave: Gestão Ambiental. Mapeamento Hidrográfico. Recursos Hídricos.

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1 Introduction

Water is a natural good of common use and fundamental to life, being indispensable in virtually all human activities. One of the greatest challenges of the population in the coming years will be to reconcile water scarcity, because with anthropic activities that influence water quality, such as disorderly population growth, lack of basic sanitation and increased water consumption in various human and industrial activities, the situation worsens and such actions can cause major impacts on water resources (OLIVEIRA; CARVALHO, 2018).

Moreover, the continuous processes of human population growth and urbanization and the constant pressure on fragmented areas of natural vegetation for agricultural practices lead directly to the degradation of natural environments. These areas are evidenced in the study area and further strengthen its relevance.

According to Rebouças, Braga and Tundisi (2006) and Santos, Dias and Balestieri (2021), the surface of the planet has 71% of its territory recognized as water, and 97% is not suitable for consumption, leaving only 3% of freshwater. However, Mukate et al. (2020) point out that about 2.5% of the Earth's freshwater is not available for consumption because it is: trapped in glaciers, icecaps, atmosphere, soil; highly polluted; or too far below the Earth's surface to be extracted at an affordable cost. Thus, less than one-third is available for human use, industrial, agricultural, irrigation, and other uses.

In order to protect this rare natural resource, many countries have environmental legislation to ensure preservation. In Brazil, the Brazilian Forest Code determines specific areas to be maintained with natural vegetation cover, known as permanent preservation areas (SANTOS et al., 2016).

The Permanent Preservation Areas (APP's) are responsible for maintaining the quality and quantity of water resources and are classified according to the law 12.651/2012, which are called marginal strips of any natural watercourse, being these perennial or intermittent, with or without coverage of native vegetation (BRASIL, 2012).

Water resources have a very relevant social role, considering that the lack of potability can be a means of disease proliferation. Given this anomaly, it is intended to demonstrate in real or approximate dimension the reality of how the level of preservation, degradation and importance of this body of water for the Soledadense population and region, because the water course is responsible for the water supply of this municipality.

Given the facts, the concern with the protection of springs and springs has increased in recent years, being the target of many researches aiming to ensure the water quality (BASTOS et al., 2018; BORGES et al., 2011; FIORE et al., 2017; FOLETO, 2018; MARMONTEL et al, 2018; MORAES et al., 2018), conservation of permanent preservation areas and the protection of water resources in Brazil (BRASIL; FERREIRA; CARDOSO, 2020; OLIVEIRA; BORGES; ACERBI JUNIOR, 2018; SCHWANTZ et al., 2019; SANTOS et al., 2021).

From this perspective, this study aims to analyze the inferences of regional development and environmental management in the quality of water resources from an environmental diagnosis of the situation of the Rio Espraiado (Soledade, Rio Grande do Sul) providing data for decision-making and goal setting to ensure the improvement of quality and water preservation for the region. The motivations for the realization of this research arose through the concern with the conservation of the quality of this hydric resource, once the Espraiado River is the only one that supplies the city of Soledade.

Furthermore, Municipal Law No. 4.078/2019 defines the macro area of protection of springs corresponding to the portion of the watershed of the Rio Espraiado located upstream of the water withdrawal point for the supply of the city of Soledade. Supported by this law, the delimitation of the macro-area of protection of springs aims at the preservation of the springs of the Rio Espraiado basin as it is the source of water supply of the city of Soledade, the protection of natural resources and the adequacy of rural productive activities with the conditions of environmental water preservation and also the promotion of rural activities in order to contribute to the sustainable development of the municipality (PREFEITURA MUNICIPAL DE SOLEDADE, 2019). All these goals corroborate the 2030 Agenda, especially the sixth Sustainable Development Goal (SDG), which deals with ensuring the availability and sustainable management of water and sanitation for all. For Brazil, the goal is to achieve universal and equitable access to safe and affordable water for human consumption for all by 2030. Such points justify the relevance of this research, which is still under development and seeks to analyze complementary parameters and indicators in order to monitor the environmental conditions of this water resource.

For this, we sought to develop mechanisms that were effective and capable of minimizing the environmental impacts of anthropic actions in the areas surrounding the Rio Espraiado. Linked to this, the mapping and environmental diagnosis were the first steps of the study and were based on the photographic survey and location of geographical coordinates of the springs. Also, data such as altitude, type of spring, degree of conservation of the surrounding vegetation, proximity to residences, degree of difficulty of access to the site, as well as the presence of waste and refuse in their surroundings were planned. The use of geotechnologies becomes an indispensable tool in helping the location, mapping and verification of the use and coverage of the PPA areas of riparian properties, showing which anthropic activities developed in the region can influence the degradation of the spring.

Therefore, this article is organized in sections. The theoretical foundation section presents a brief discussion with grounding on the theme of the research. Subsequently, the methodology used for data collection is presented, which is subdivided into two stages. The first stage describes the methods for performing the hydrographic mapping with the production of images generated in maps, and the second stage consists of the steps for the environmental diagnosis. Finally, the results obtained and their discussion are listed, and then the final considerations of the work are presented.

2 Theoretical framework

The degradation of water resources contributes to environmental imbalance, causes extinction of species and proliferation of diseases, in addition to the water shortage that already affects several regions of the world (COUTO, 2005). The suppression of native vegetation for agricultural and livestock expansion and replacement by other types of land use exacerbate the process of forest fragmentation and, consequently, affect nature and various species of fauna and flora; therefore, negatively influencing the conservation of water sources (MARCHESAN et al., 2017).

Brasil et al. (2020) emphasize the conceptual aspect in which the APP’s are specially protected spaces, covered or not by native vegetation, with multiple social and environmental functions to protect water resources, landscape, geological stability, biodiversity, the genetic flow of fauna and flora, the soil and ensure the well-being of human populations. In addition, the environments around water bodies (rivers, lakes, ponds, springs or reservoirs), hilltops, mountains, mangroves, among other fragile environments are also included.

According to Oliveira and Francisco (2018), the Areas of Permanent Preservation (APP’s) were created by the 1965 Forest Code, and represented an important evolution of forestry activities, among other norms instituted by this code. In this sense, the preservation of areas near water resources and springs is extremely important for the conservation of local biodiversity. These areas serve as ecological corridors, having the function of transit of species, providing better food availability and maintenance of the food chain cycle. They also contribute to soil conservation, avoiding erosion and silting of rivers, providing better water quality, a natural asset essential to the life of all living beings.

Studies by Brasil et al. (2020) and Pereira et al. (2017) describe situations of watercourses by the requirements of government agencies and management of water resources regarding the need for preservation of riparian forests and in terms of quality of water resources. Brasil et al. (2020) evaluated the situation of PPAs in the Metropolitan Region of Goiânia, from the analysis of the legal text and with the help of remote sensing products and cartographic bases. The study showed noncompliance with the regulations established in the Brazilian Forest Code throughout the studied region with degradation percentages exceeding 40% of the APP's and, through the cartographic products, they identified the degree of conservation of the areas around river zones, springs, lakes and ponds.

Similarly, Pereira et al. (2017) characterized the changes in land use between the years 2002 and 2011 and the conditions of APP's and legal reserves in the Bebedouro Creek watershed (Frutal, Minas Gerais). According to the geomorphological data and the area of APP presented as a result of the authors, the Bebedouro stream had natural conditions suitable for the destination of its waters for human supply, mainly for being a river basin with low order, for having much of its riparian extension vegetated, and for being in a place of low natural vulnerability to erosive processes. However, due to the replacement of pastures by sugarcane fields near the Bebedouro stream, the need for measures to conserve water quality is evident, as well as the establishment of policies to control the use of agricultural inputs and the technical qualification of rural workers. It is noteworthy that, in both studies (BRASIL et al., 2020; PEREIRA et al., 2017), the methodological aspects covered the use of hydrographic mapping and geographic information to obtain the results presented.

In relation to the municipality of Soledade (RS), it should be noted that the evaluation of the normative aspects that govern water management is essential because they regulate the use and parceling of urban land and municipal planning, which are established through the Master Plan (PD), as provided in Law 4.078/2019, of the municipal statute (PREFEITURA MUNICIPAL DE SOLEDADE, 2019). In addition, Table 1 presents the main regulations concerning the management of water resources, APP concepts and changes in the current forest code, which are parameters to guide the cited municipal legislation.

Table 1 - Main regulations on APP's, water resource management and basic sanitation at the national, state (RS) and Soledade municipality levels.

Sphere	**Regulations**	**Guidelines**
National	Law No. 14.026, of July 15, 2020 - Basic Sanitation Framework Law.	Establishes the National Policy for Basic Sanitation by updating the legal framework for basic sanitation and amends Law No. 9984 of July 17, 2000, to assign to the National Water and Basic Sanitation Agency
National	Law 12.651/2012 - Brazilian Forest Code	Repeals the 1965 Brazilian Forest Code and defines that the protection of the natural environment is the obligation of the landowner through the maintenance of protected spaces of private property, divided between APP's and Legal Reserve (RL).

National	Law No. 12,727, of October 17, 2012 - Protection of vegetation	This Law establishes general rules on the protection of vegetation, Permanent Preservation Areas and Legal Reserve Areas; forest exploitation, supply of forest raw material, control of the origin of forest products and control and prevention of forest fires, and provides economic and financial instruments to achieve its objectives.
National	Law 11.284/2006 - Atlantic Forest Law	This norm regulates the protection and use of resources of this forest, aiming to ensure rights and duties of citizens and public agencies regarding the conscious exploitation of this biome. The law aims to safeguard biodiversity, human health, scenic values, the water regime and social stability.
National	Law No. 9984 of July 17, 2000 - Law creating the National Water Agency (ANA).	This law creates and regulates the ANA. It is the entity responsible for the implementation of the National Water Resources Policy and for the management of Singerh.
National	Law 9.985/2000 - Law of the National System of Nature Conservation Units	They establish objectives that are the conservation of varieties of biological species and genetic resources, the preservation and restoration of the diversity of natural ecosystems and the promotion of sustainable development from natural resources.
National	Law No. 9.433, of 8 January 1997 - Water Law.	Establishes the National Water Resources Policy, creates the National System for the Management of Water Resources, regulates subsection XIX of Section 21 of the Federal Constitution, and amends Section 1 of Law No. 8001 of March 13, 1990, which modified Law No. 790 of December 28, 1989.
National	Law 6.766/1979 - Land Division Law	Establishes rules for urban allotments, prohibited in ecological preservation areas, in those where pollution represents a health hazard and in flooded land.
National	CONAMA Resolution No. 429/2011	Provides on the methodology for the recovery of Areas of Permanent Preservation – APP’s
National	CONAMA Resolution 369/2006	Provides for exceptional cases of public utility, social interest or low environmental impact, which allow the intervention or suppression of vegetation in APP’s

National	Resolution CONAMA no. 302, of March 20, 2002	Complements CONAMA Resolution no 303/02 and provides on the parameters, definitions and limits of APP's of artificial reservoirs and the regime of use of the surroundings
State	CONSEMA Resolution nº 309/2016	Recognizes activities of low environmental impact in which intervention or suppression of native vegetation in APP's is allowed
State	CONSEMA Resolution nº 314/2016	Defines other occasional or low environmental impact activities in which intervention or suppression of native vegetation in APP's is allowed
State	CONSEMA Resolution No. 360/2017	Establishes environmental guidelines for the practice of sustainable pastoral activity on remnants of native grassland vegetation in APP's and Legal Reserves in the Pampa Biome
State	CONSEMA Resolution No. 361/2017	Amends Resolution 314/2016, which defines other occasional or low environmental impact activities in which intervention or suppression of native vegetation in APP's is allowed
State	Law 11.685, of November 08, 2001 - State System of Hydric Resources	Creates the State System of Water Resources, regulating article 171 of the Constitution of the State of Rio Grande do Sul.
Municipal - Soledade/RS	Municipal Law No. 4.078/2019 - Soledade Master Plan	Institutes the innovative sustainable master plan for the municipality of soledade.

Source: Authors (2022).

Furthermore, according to the Rainfall Atlas of the CPRM (Geological Survey of Brazil), the rainfall indices in the northern region of Rio Grande do Sul, where the catchment is located, are considered good or very good when compared to other regions of the country. The annual averages between the years 1977 and 2006 point to an average of about 1,700 mm of precipitation in the region where the watershed is located, a number considered very good (CPRM, 2006). Such index contributes to the water quality parameters, increasing the solubility and purification capacity of the organic and inorganic compounds, as well as are responsible for keeping the natural water reservoirs at levels considered very good when compared with the annual rainfall average of RS, according to the Socioeconomic Atlas of Rio Grande do Sul, the rainfall regime varies from region to region, raining about 1200 to 1500mm annually in the southern half and 1500 to 1800mm in the northern half of the state of RS (RIO GRANDE DO SUL, 2020). It should be noted that the water crisis has affected the southeastern and southern regions, including Rio Grande do Sul. In 2020 and 2021, one of the causes of the lack of rainfall in the aforementioned regions was due to the La Niña effect, a natural and periodic phenomenon that occurs due to changes in water temperature in the Pacific Ocean, causing a change in temperatures and rainfall that occurs worldwide (MACKEIZIE, 2022).

Silva et al. (2020) point out that knowing the consumption profile of a population becomes an essential management tool in the current environmental scenario, and that studies on water consumption are extremely effective for the promotion of environmental public policies. From a social perspective, Schwantz et al. (2019) and Araldi et al. (2021) point out that there are incentives in environmental preservation, such as, for example, the payment for environmental services (PES), which corroborates with effective measures in the preservation of natural resources and a financial return from the actors participating in PES actions.

Additionally, Aparecido et al. (2016) add that, in order to ensure the availability and quality of water, watershed management should guarantee the conservation of native forests, the use of soil conservation techniques, and techniques to reduce diffuse transport from urban areas. Furthermore, the literature highlights several studies that analyze the preservation of permanent areas in Brazil. Authors such as Gurgel, Farias and Oliveira (2017) present an analysis of misuse in APP’s in the municipality of Tailândia - PA, based on cross-referencing land use and coverage data with APP’s. According to the data obtained in this research, 53% of the municipality (2,347.64 km²) are occupied by anthropic activities, with pasture being the largest offender, occupying 26.65% of the APP’s.

On the other hand, for Leite et al. (2020), watersheds with strong presence of small rural properties are the most affected with the flexibility brought by the article 61-A, of the Native Vegetation Protection Law (Law n.12.651 / 2012), which can compromise the functionality of the PPAs along water courses. In the study made by Oliveira, Borges and Acerbi Junior (2020), on Permanent Preservation Areas of Rio Grande in the State of Minas Gerais, it was found the need to increase inspections and provide information on these determinations and the benefits of preservation. It is worth clarifying that the low percentage with remaining natural areas of vegetation (40.19%) and the high conflicting land use (58.89%) show that Law 12.651 is not being complied with in the analyzed locality.

Additionally, Brasil, Ferreira and Cardoso (2020) conducted an assessment of the situation of the APP’s that comprise the Metropolitan Region of Goiânia, using remote sensing and geoprocessing data. The cartographic products (maps of use and occupation, APP’s and conflict of use in APP’s) generated allowed the identification of the predominance of cultivated pastures in almost 45% of all mapped APP’s.

It is also worth noting that Vivian et al. (2019) reinforce the use of Geographic Information System (GIS) and ArcGis geoprocessing software aiming to map and analyze the environmental situation of springs in the urban perimeter of Soledade (Rio Grande do Sul, Brazil). The authors further recommend that the evaluated data become subsidies for the urban expansion planning through the definition of areas liable to occupation and delimitation of environmental preservation areas. Bianchini and Oliveira (2019) determined the most suitable areas for the implementation of Conservation Units (UCs) in Vale do Taquari, RS, Brazil, using geoprocessing tools. Using the base of remnants of the Atlantic Forest, they extracted the vegetation fragments with an area equal to or greater than 100 ha and, as a result, obtained an ordination map containing the fragments with greater suitability for deployment of UCs.

3 Methodology

The research conducted is classified as descriptive and the methodology used for investigation was research-action. According to Barros and Lehfeld (2007), descriptive research involves the study, analysis, recording and interpretation of facts of the physical world without the researcher's interference. On the other hand, for Thiollent (1997), action research describes a problem situation "based on the verbalizations of the different authors in their own languages", and the knowledge of the inferences is inserted in the preparation of strategies or actions for the development of the work.

This study was conducted in two stages. The first stage corresponds to the hydrographic mapping and the second stage corresponds to the environmental diagnosis. The steps are described below.

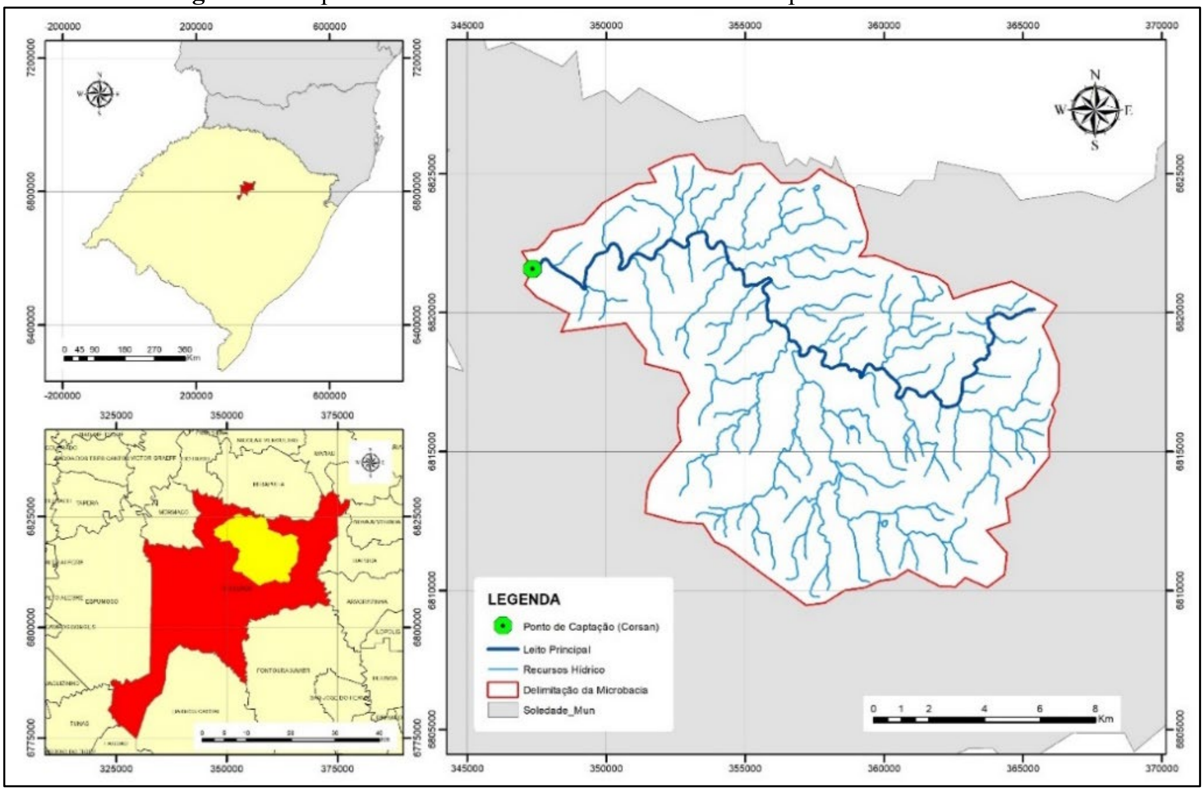
3.1 Hydrographic mapping

The hydrographic mapping was performed by obtaining maps and geographic information using ArcGis software with the Geographic Information System (GIS). Subsequently, through access to the free digital collection of INPE (National Institute for Space Research), updated Landsat 8 satellite images of the Earth's surface were sought, as well as access to the digital collection of EMBRAPA (Brazilian Agricultural Research Company) with SRTM images to generate stereoscopic altimetry maps of the Earth's surface of the location under study. Subsequently, the delimitation of the catchment microbasin of the Rio Espraiado was performed and the subdivision of the microbasin into three sections for further analysis and comparison.

The use of satellite images such as Landsat 8 and SRTM, along with shapefiles (georeferenced vector files), combined with the crossing of data, contribute valuably in studies of environmental impact assessment in the numerous current anthropic activities. Moreover, when the analyzed place is important for some activity, cartography, remote sensing and geoprocessing instruments are the necessary and basic tools for the execution of this work.

The catchment area (Figure 1) that is the focus of the study is located in the northern/northeastern part of the municipality, close to the borders with the municipalities of Mormaço and Ibirapuitã.

Figure 1 - Map of location of the micro-watershed Rio Espraiado - Soledade/RS.



Source: Authors (2022).

3.2 Environmental diagnosis

Garmin GPS and Trex 30 were used to georeference the points for the collection of water samples for physical, chemical and biological analyses, and later the classification of land use and vegetation cover in the catchment area was performed. Finally, maps were generated with data regarding the type of soil located.

It is noteworthy that the land use and vegetation cover map was obtained after classification of spectral bands 4, 5 and 6 of the Landsat 8 satellite, with an image obtained from the INPE catalog, which generated an RGB image type (*.tiff) of high resolution, which followed for the classification of 4 main elements or activities. For the classification, it was prioritized the survey of field areas, crops, forests and water. After the classification, a vector image was generated so that it was possible to measure in area (hectares) each of the activities.

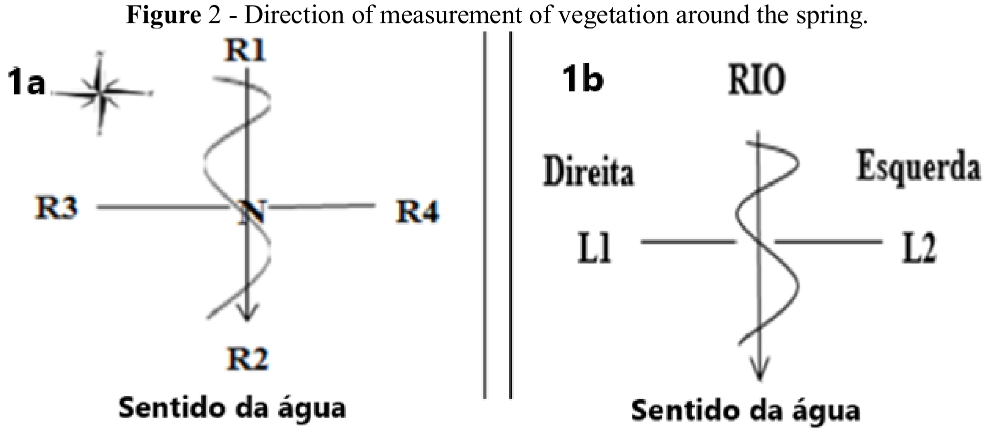
In addition, the mapping and environmental diagnosis of the PPAs of the Rio Espraiado was applied in pre-defined points, through the use of GIS (Geographic Information Systems), as well as on-site visitation. The method of analysis of the points was performed as described below.

In the diagnosis of the environmental situation of the PPAs of the Rio Espraiado, in point 1 (which refers to the spring), a photographic survey of the same was performed, and on a spreadsheet information was added about the location in geographic coordinates, altitude, type of spring, degree of conservation of the surrounding vegetation, proximity to residences, degree of difficulty of access to the site, as well as the presence of waste and refuse in its surroundings. The location in geographical coordinates and altitude of the spring was verified using a GPS.

The spring was also qualified according to the type of reservoir with which it is associated, being characterized as point or diffuse. The point springs are those that present the occurrence of water flow in a single part of the terrain, usually found on top of hills and creeks. The springs are classified as diffuse when there is no determined point on the site, i.e., there are several eyes of water, this type of spring is found in flat forests, swamps, gullies, and areas at lower altitudes (PINTO, 2003).

To evaluate the degree of conservation of the spring, the surrounding vegetation (APP) was measured with a tape measure up to a 50 meter radius, considering as (R1) the vegetation above the spring in the northern direction, (R2) the vegetation below following the direction of the water flow in the southern direction, (R3) the right in the western direction and (R4) the left in the eastern direction, as illustrated in Figure 2.

Figure 2 - Direction of measurement of vegetation around the spring.



Source: Adapted from Pinto (2003).

According to the measurements obtained, the spring can be classified in one of the three categories below:

Preserved: When the surrounding vegetation is at least 50 meters and in a good state of conservation.

Disturbed: When the vegetation in its surroundings does not present 50 meters, but still presents a good state of conservation.

Degraded: When there was no vegetation of any kind in the surroundings, high degree of disturbance, being identified presence of housing, domestic animals, compacted soil and garbage (PINTO, 2003).

For the diagnosis of points 2, 3, 4, 5 and 6 which are located along the banks of the Rio Espraiado and its tributaries, it was observed the region that comprises the area legally intended for APP's, for this classification the same methodology used by Pinto (2003) was adopted. In summary, the study parameters are listed in Table 2.

Table 2 - Summary of the parameters analyzed in each of the six points of the Rio Espraiado.

ENVIRONMENTAL CHARACTERISTICS/IMPACTS		
POINT CONSIDERED:		
Geographical coordinates		
Altitude:		
Type of source/river		( ) On Time ( ) Diffuse
Spring/River Conservation (As per Figure 2)		Size of the preservation areas R1:____________________ R2:____________________ R3:____________________ R4:____________________ **Comments:**
ENVIRONMENTAL ANALYSES		
1) There is waste disposed of in the assessed area:	( ) Yes	Comments:
	( ) No	Comments:
2) There are animals roaming in the assessed area:	( ) Yes	Comments:
	( ) No	Comments:
3) There are crops in the evaluated area:	( ) Yes	Comments:
	( ) No	Comments:
4)There are residences near the assessed point:	( ) Yes	Comments:
	( ) No	Comments:
5) Characteristics of the field day	( ) Temperature ( ) Rainfall (....) Relative humidity	Comments:
Comments:		
According to the data presented above, is the site considered?	( ) Preserved ( ) Disturbed ( ) Degraded	

Source: Authors (2022).

Next, the results and discussion of the research are presented.

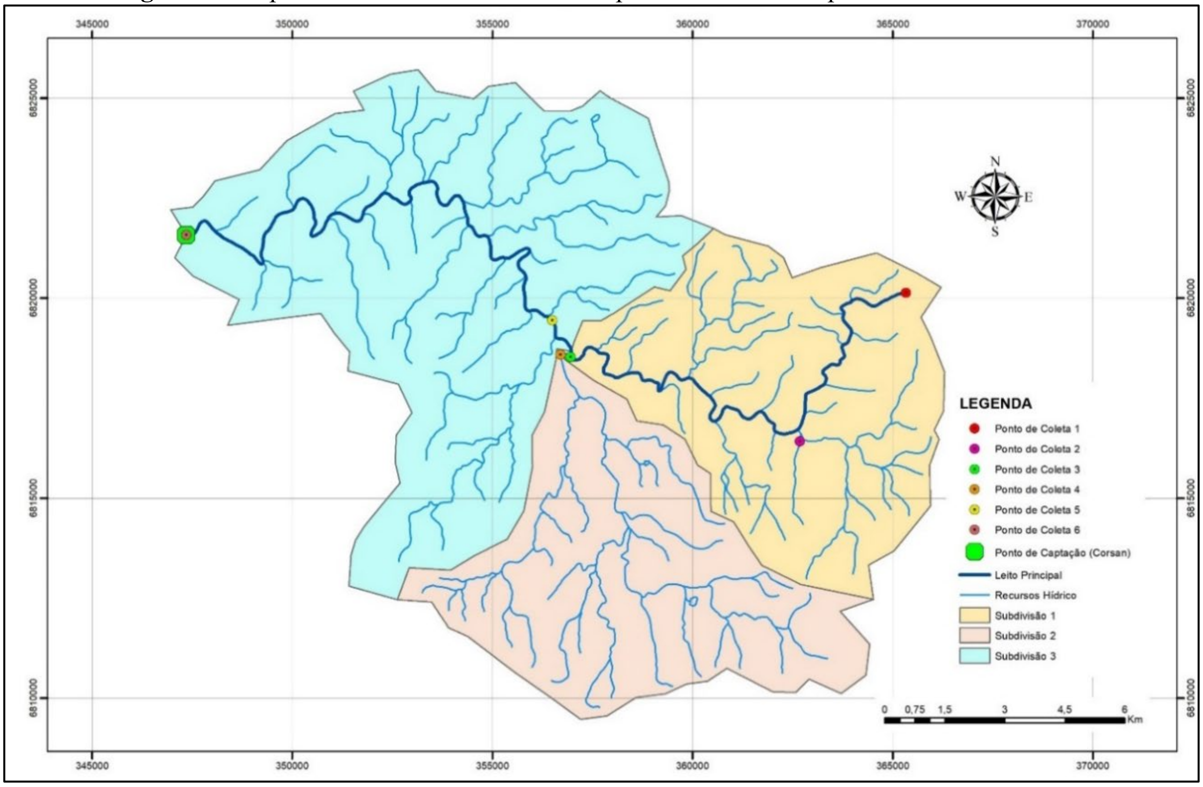
4 Results and discussions

In this topic a brief report is presented regarding the two stages of the research. Initially the data in relation to the hydrographic mapping is presented, and subsequently, the data of the environmental diagnosis is presented. It should also be noted that the water resource object of this study is located entirely within the territorial extent of the municipality of Soledade-RS, approximately 32 km in length, not extrapolating its borders.

4.1 Hydrographic mapping

The subdivision of the watershed and the location of the collection points were organized strategically so that the results would contribute to the understanding and functioning of human activities that involve the water resources, as well as their influences. The collection points were arranged in strategic locations, such as the springs, tributaries to the main riverbed, and the intake point, shown in Figure 3.

Figure 3 - Map of subdivisions and collection points of the Rio Espraiado in Soledade/RS.

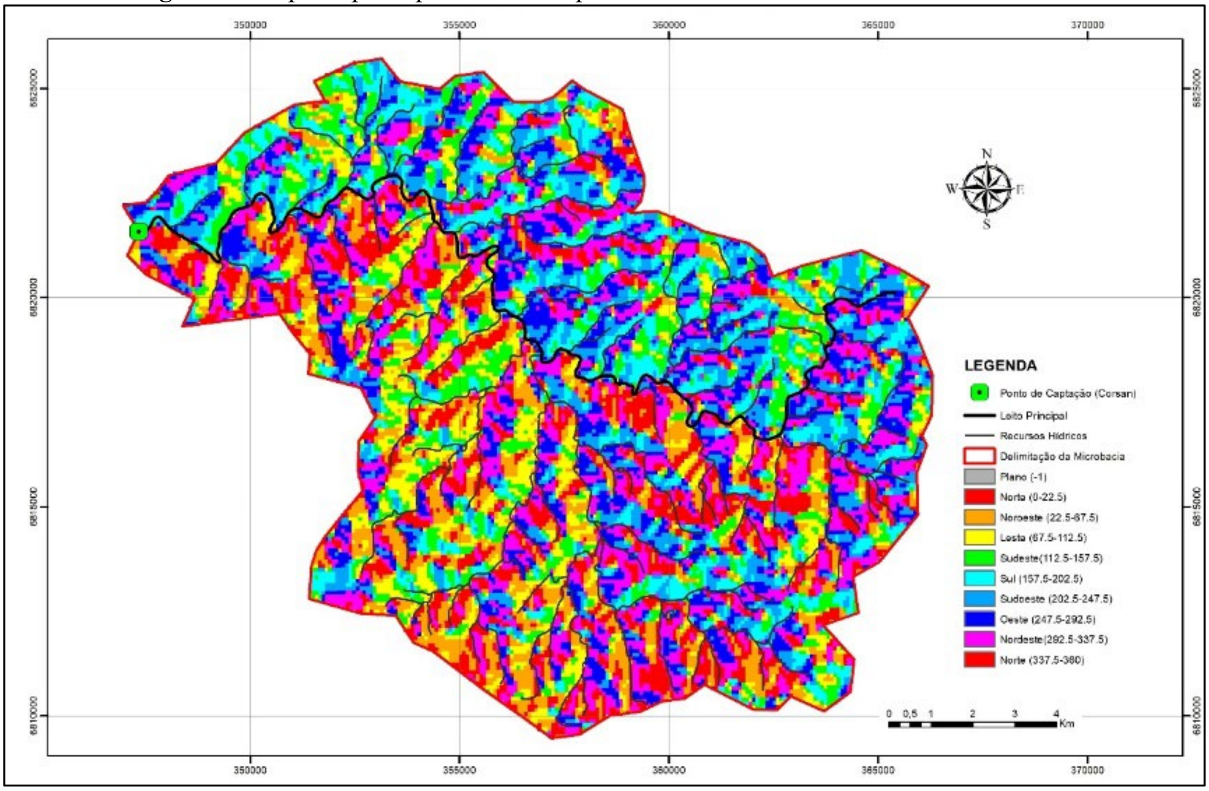


Source: Authors (2022).

The “subdivision 1”, in yellow, includes the water coming from the main sources of the Rio Espraiado to the east; “subdivision 2”, in pink, includes the sources and river contributions from the urban area of the city of Soledade/RS to the south, and “subdivision 3”, in blue, includes the final part of the water resource before the CORSAN collection point to the northwest. Subdividing the watershed into strategic points will allow for the subsequent organization of water sampling points for possible classification of the sessions and the development of mitigation actions that will improve water quality if any related problem is detected.

Subsequently, a third map of SRTM images was generated, with the orientation of the slopes (Figure 4) in the study area, these identified by bright colors that indicate each one the orientation of that face of the hill.

Figure 4 - Slope slope map of the Rio Espraiado catchment microbasin in Soledade/RS.



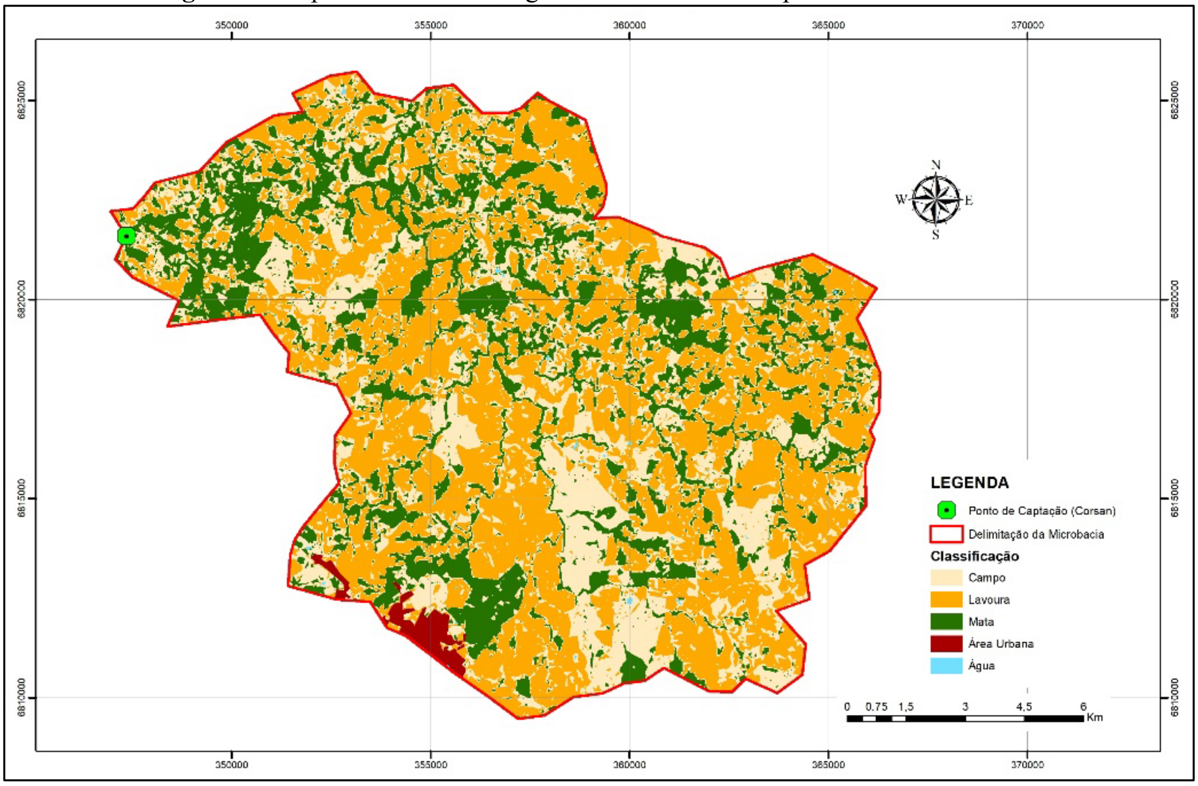
Source: Authors (2022).

When analyzing the main bed of the stream as a reference, one notices a substantial change in the color scheme, i.e., both sides point indirectly to the stream bed. Above the main bed there are mainly slopes that point to the south, southeast and southwest, while below the main bed, there is a predominance of slopes that point to the north, northeast and northwest.

These areas when associated with steeper slopes, configure points of potential instability of the surface when more significant rainfall events occur, and can trigger the installation of erosive processes, which would eventually promote a greater speed in the natural siltation in water resources (ROSA; TEIXEIRA, 2012).

For verification of land use and vegetation cover, the map represented in Figure 5 was generated after classification of spectral bands 4, 5 and 6 of the Landsat 8 satellite, with image obtained from the catalog of INPE (National Institute for Space Research), which generated an RGB image type (*.tiff) of high resolution, which followed for the classification of 5 main elements or activities. For the classification it was considered the survey of field areas, crops, native forests or reforestation, water or wetlands, and urban spot incident on the delimitation area of the watershed. After classification, a vector image was generated that could be measured in area (hectares) for each activity.

Figure 5 - Map of land use and vegetation cover in Rio Espraiado in Soledade/RS.



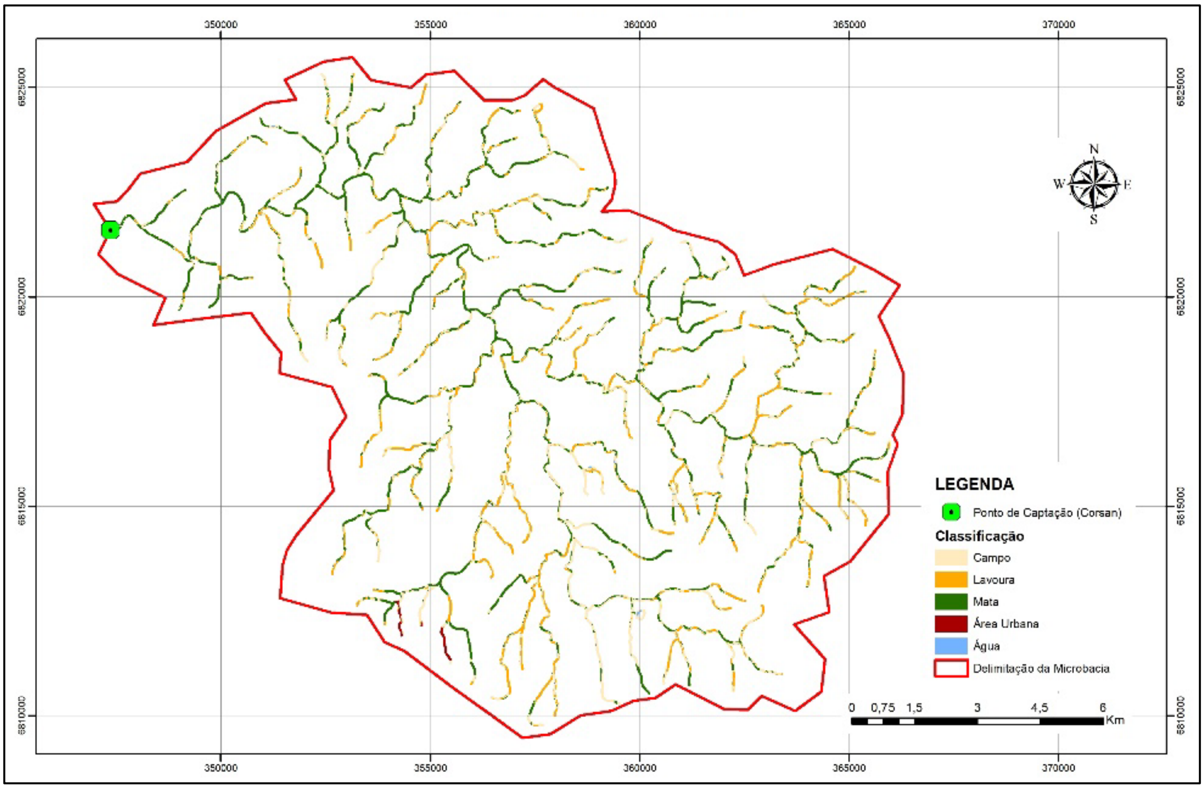
Source: Authors (2022).

From these data, the areas of each element or activity were quantified, according to the delimitation of the catchment microbasin of the Rio Espraiado. For the quantification, a total area of 18,909.02 hectares was calculated and the activities listed in the classification process resulted in the following numbers: surfaces classified as water or humid areas added up to 0.15% or 28.96 hectares, field areas added up to 29.13% or 5.509.09 hectares, farming areas totaled 46.42% or 8,776.75 hectares, areas of native forests and reforestation totaled 23.29% or 4,403.35 hectares, and finally, the urban area of the municipality that is within the limits of the watershed totaled 1.01% or 190.87 hectares.

The analysis of land use and vegetation cover was performed following the current legislation in Law nº. 12.651/2012, reaffirming that water bodies between 0 and 10 meters, must have riparian vegetation greater than or equal to 30 meters of APP. It is possible to clearly see the predominance of agriculture, which decimated the areas of native field and suppressed much of the native Atlantic Forest, as well as began to threaten the water bodies with the deforestation of APP's for the sake of economic development. The great fragmentation of native forests is also highlighted as an obstacle to the gene flow of species, whether they belong to the fauna or flora (MARCHESAN et al., 2017).

Figure 6 shows the large number of unprotected springs, APP's suppressed by human activities such as agriculture and livestock in the southern, central, eastern and northeastern regions, however, in the northwestern region, where there is a more rugged terrain, without much agricultural mechanization, the APP's are more preserved.

Figure 6 - Map of land use and vegetation cover of the APP in the catchment microbasin Arroio Espraiado - Soledade/RS.



Source: Authors (2022).

The intersection of the APP's with land use and vegetation cover within the catchment microbasin of the Rio Espraiado totaled an area of 1,534.70 hectares. Thus, it was possible to quantify the areas of each element or activity occurring within the APP.

From the activities listed in the classification process, it was possible to see that the surfaces classified as water or wetlands correspond to 0.20%, equivalent to 3.07 hectares. The field areas totaled 33.15%, equivalent to 508.73 hectares. The farming areas totaled 25.69%, equivalent to 394.34 hectares and the areas of native forests and reforestation totaled 40.32%, equivalent to 618.74 hectares. And, finally, the urban area of the municipality that is within the APP areas totaled 0.64%, equivalent to 9.82 hectares.

4.2 Environmental diagnosis

The environmental assessment was analyzed at six different points along the river. Point 01 is the source identified by CORSAN and is located in the community known as Boa União in the municipality of Soledade/RS.

It was found that Point 01 is between the geographical coordinates 28°44'20.9" and 52°22'44.7", with an altitude of 724 meters above sea level. The spring was framed as being diffuse due to its formation being within a forest fragment on flat terrain, the degree of conservation evaluated is at the disturbed level, presenting vegetation in the direction of R1 above 50 meters, R2 presents approximately 30 meters of vegetation facing an artificial water reservoir, R3 in the west direction of the spring presented forest with 28 meters in length and R4 with an extension above 50 meters.

It is considered that the access to the location of the spring is difficult due to the conservation of the sobosqueak, but the access until the edge is easy, since it is surrounded by plantations. It was observed the dispersion of some solid residues in the surroundings of the spring.

In Point 02, shown in Figure 7a, was identified along the water body located next to one of the tributaries of Rio Espraiado, in the locality of Pontão, in Soledade, being between the geographical coordinates 28°46'22.2" and 52°24'24.4", at an altitude of 634 meters. The water body presented in this point width from one margin to another of 3.80 meters, with margins L1 presenting 17 meters of riparian forest and L2 of 28 meters of vegetation. Although the extent of the APP meets the values established in the Forest Code, its classification was given as degraded due to the absence of sobosqueak, silting on the banks of the stream, easy access to the site and the presence of cattle with free passage through the water body.

Also in Point 02, it was possible to observe the presence of crops on the forest edges and solid waste was found, shown in Figure 7b, resulting from chemical applications in crops. The use and occupation of the soil at this point is predominantly by crops, pastures and areas intended for forestry.

Figure 7 - Analysis point 02.

Source: Authors (2022).

The Point 03 is located between the geographical coordinates 28°45'06" and 52°28'01.3, at an altitude of 565 meters above sea level. The water body presented at this point 5.30 meters wide from one bank to another, with banks L1 presenting 30 meters of riparian forest and L2 above 30 meters of vegetation. Of difficult access to the site of evaluation, with the presence of dense forest undergrowth, vast amount of tree vegetation and strong presence of native species of araucaria, lichens and others.

The Point 04 (Figure 8) is located between the geographical coordinates 28°45'04.6" and 52°27'55.2", at an altitude of 558 meters. The water body presented in this point a width of 12 meters from one bank to another, with banks L1 presenting 15 meters of riparian forest and L2 with 30 meters of vegetation. The area is considered difficult to access, with dense riparian forest. The area was classified with disturbed preservation degree, since there is presence of residences in about 100 meters.

Figure 8 - Analysis point 04.

Source: Authors (2022).

The Point 05 is located between the geographic coordinates 28°44'40.0" and 52°28'11.6, at an altitude of 549 meters above sea level and is illustrated in Figure 9.

Figure 9 - Analysis point 05.

Source: Authors (2022).

The water body at this point was 34 meters wide from one bank to the other. Regarding the banks, L1 presents 30 meters of riparian forest and L2 presents 33 meters of vegetation, an area extremely without forest and composed of trees arranged in a dispersed way. The degree of conservation is framed in degraded, due to the existence of residences less than 50 meters from the riverbank and has easy access through a road with a bridge over the water resource of low movement. There were few residues found in this environment although it is close to the camping area.

Finally, in Point 06, located between the geographical coordinates 28°43'27.6" and 52°33'42.7" at an altitude of 487 meters above sea level, the water body was 17 meters wide from one bank to the other. Regarding the margins, L1 has 8 meters of riparian forest and L2 has no riparian forest. Point 6 can be seen in Figure 10.

Figure 10 - Analysis point 06 - uptake.

Source: Authors (2022).

The Point 6 presents easy access, with the presence of residences less than 50 meters from the banks and the occurrence of domestic animals in the surroundings, without the presence of solid waste in the area. The forest vegetation is heavily disturbed and altered, and it was possible to verify the occurrence of noise pollution at the assessment site, resulting from the CORSAN water intake pumps.

In summary, from the environmental diagnosis performed, at point 01, where the spring of the Rio Espraiado is located, it was observed the partial absence of the necessary circumference of native vegetation, as established by the Forest Code. Therefore, the restoration of the entire radius of vegetation is essential for the conservation of the spring there, as well as the adoption of sustainable and environmentally friendly practices in the area around the edge of the APP fragment, in order to preserve and maintain the quality and availability of water flow.

In points 02 and 04 there is a considerable presence of riparian forest. However, fencing is recommended in point 02, to prevent the access of cattle to the water body, significantly reducing the changes suffered in vegetation and minimizing the effects of silting of the banks. In point 03, an action is suggested for the collection of waste and tailings that have been deposited on the banks of the tributary.

In relation to point 05, it can be stated that it fits into a critical position environmentally due to the use and occupation given to the river banks. Therefore, we suggest the use of methodological tools to diagnose and evaluate the environmental impacts and, based on this, develop plans for sustainable use. At point 06, where the water catchment area is located, the banks are heavily degraded.

In view of the results presented, it is verified that, despite the existence of a master plan in the municipality of Soledade, it is still evident some impacting factors that refer to anthropic actions along the banks of the entire Rio Espraiado. Added to this, some environmental weaknesses such as, for example, the low rainfall index causing water crisis arising from the La Niña phenomenon, further exacerbating the diagnosis made. Studies conducted by Nunes (2017), Pereira et al. (2017), Gass et al. (2016), Lima, Fereira and Ferreira (2018) and Brasil et al. (2020) reinforce the factors of environmental impacts described and also highlight the importance of the preservation of APP's and meet the current legislation in municipal, state and national levels.

5 Final considerations

This study aimed to analyze the inferences of regional development and environmental management in the quality of water resources from an environmental diagnosis of the situation of the Rio Espraiado (Soledade, Rio Grande do Sul) providing data for decision making and goal setting to ensure the improvement of water quality and preservation for the region. Aligned to the established goal, the use of geotechnologies becomes an indispensable tool in helping the location, mapping and verification of the use and coverage of PPA areas of riparian properties, showing which anthropic activities developed in the region can influence the environmental degradation.

At the end of the study, a diagnosis of the situation of each point along the banks of the Rio Espraiado was presented, showing the degree of environmental conservation and issues relevant to the existence of compliance with the regulations of APP's. Still, the evidence presented allows medium and long-term actions to be implemented in the only river responsible for supplying the urban area of Soledade. At the same time, the importance of complying with current legislation at the national, state and municipal levels is highlighted, as well as keeping the municipal master plan updated.

Finally, with the data mapped at each strategic point of the river, in addition to the aforementioned legal actions, awareness-raising and environmental education activities are proposed for the communities near the water resource. It is noteworthy that the development of the project is being of great relevance for the environmental development of the municipality of Soledade, as well as for its population, through the identification of environmental impacts and the preservation of water resources.

From the development of the project in its entirety, the municipality of Soledade assumes to be committed to sustainable management, in line with Municipal Law 4.078/2019. This project has a 5-year horizon of action together with the partners of this project (Corsan, Rural Workers Union and Municipality of Soledade).

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