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Conflictive Use of Permanent Preservation Areas (Brazilian Forest Code, 2012) in the Sub-basin of Riacho do Ipiranga, Presidente Tancredo Neves, BA

Uso conflitivo das áreas de preservação permanentes (Código florestal brasileiro, 2012) na Sub-bacia do Riacho do Ipiranga, Presidente Tancredo Neves, BA

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Abstract: This study analyzes land use and occupation in the Riacho do Ipiranga Sub-Basin, focusing on the delimitation of Permanent Preservation Areas (APP) and their relation to the Brazilian Forest Code (Law No. 12,651/2012). Four categories of APPs were identified — around springs, riparian forest, slopes, and hilltops — totaling approximately 355 hectares, or 17% of the study area. However, 68% of these areas are inadequately occupied, with 45.3% allocated to activities that provide low or no soil protection, resulting in high environmental fragility. Additionally, 65% of riverbanks are anthropized, compromising water quality and soil stability. The analysis of springs indicates that those in areas of remaining vegetation maintain better water quality compared to those located in cultivated areas. The study highlights the need for revisions to the Forest Code to ensure the interconnectivity of APPs, which are essential for preserving ecosystem services. The results provide valuable information for environmental managers, contributing to the definition of recovery plans and environmental zoning in the region.

Keywords: Forest Code; Watershed; Conflictive use.

Resumo: Este estudo analisa o uso e a ocupação das terras na Sub-Bacia do Riacho do Ipiranga, com foco na delimitação de Áreas de Preservação Permanente (APP) e sua relação com o Código Florestal Brasileiro (Lei nº 12.651/2012). Foram identificadas quatro categorias de APPs — ao redor das nascentes, mata ciliar, encostas e topos de morro — totalizando cerca de 355 hectares, ou 17% da área de estudo. No entanto, 68% dessas áreas estão inadequadamente ocupadas, com 45,3% destinadas a atividades que oferecem baixo ou nulo grau de proteção ao solo, resultando em alta fragilidade ambiental. Adicionalmente, 65% das margens dos rios estão antropizadas, comprometendo a qualidade da água e a estabilidade dos solos. A análise das nascentes indica que aquelas em áreas de vegetação remanescente mantêm melhor qualidade hídrica em comparação às localizadas em áreas cultivadas. O estudo ressalta a necessidade de revisões no Código Florestal para garantir a interconectividade das APPs, fundamentais para a preservação dos serviços ecossistêmicos. Os resultados fornecem informações valiosas para gestores ambientais, contribuindo para a definição de planos de recuperação e zoneamento ambiental na região.

Palavras-chave: Código Florestal; Bacia hidrográfica; Uso conflitivo.

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1. Introduction

In the field of Physical Geography, it is common to conduct research that maps land use and identifies the weaknesses and vulnerabilities of natural environments (SANTOS, 2018; SILVA et al., 2020). However, areas considered vulnerable in geographic analyses do not always coincide with those protected by the Brazilian Forest Code (Law No. 12.651/12). This discrepancy reveals a gap in the legislation, which often does not reflect the ecological reality of the regions (RIBEIRO, 2020). Therefore, it is essential to understand the Forest Code and assess its applicability to the areas under study, as it defines the legally protected zones (BRASIL, 2012).

The lack of coordination between scientific data and public policy formulation results in ineffective natural resource management (SILVA & SOUZA, 2021). Thus, it is crucial that academic research aligns with management practices, enabling the data obtained to influence political and administrative decisions. The effectiveness of land management depends not only on the application of existing regulations but also on the ability to adapt and update these regulations in light of new socio-environmental realities (PEREIRA et al., 2023). Legal revisions that incorporate scientific data and consider local dynamics are therefore essential to ensure the sustainability of water resources and biodiversity conservation.

This paper aims to do precisely that: to delineate the Permanent Preservation Areas (APP) and Legal Reserves of the Riacho do Ipiranga Sub-Basin (Figure 01) and overlay this information with land cover and use mapping to identify conflicting areas in light of the Forest Code. The Riacho do Ipiranga Sub-Basin, located in the rural area of Presidente Tancredo Neves, Bahia, is crucial for supplying 54% of the local population (EMBASA, 2021). However, anthropogenic interferences, such as deforestation and urbanization, can compromise water production, highlighting the need for interventions to ensure supply and conserve local biodiversity (FERREIRA & MARTINS, 2019).

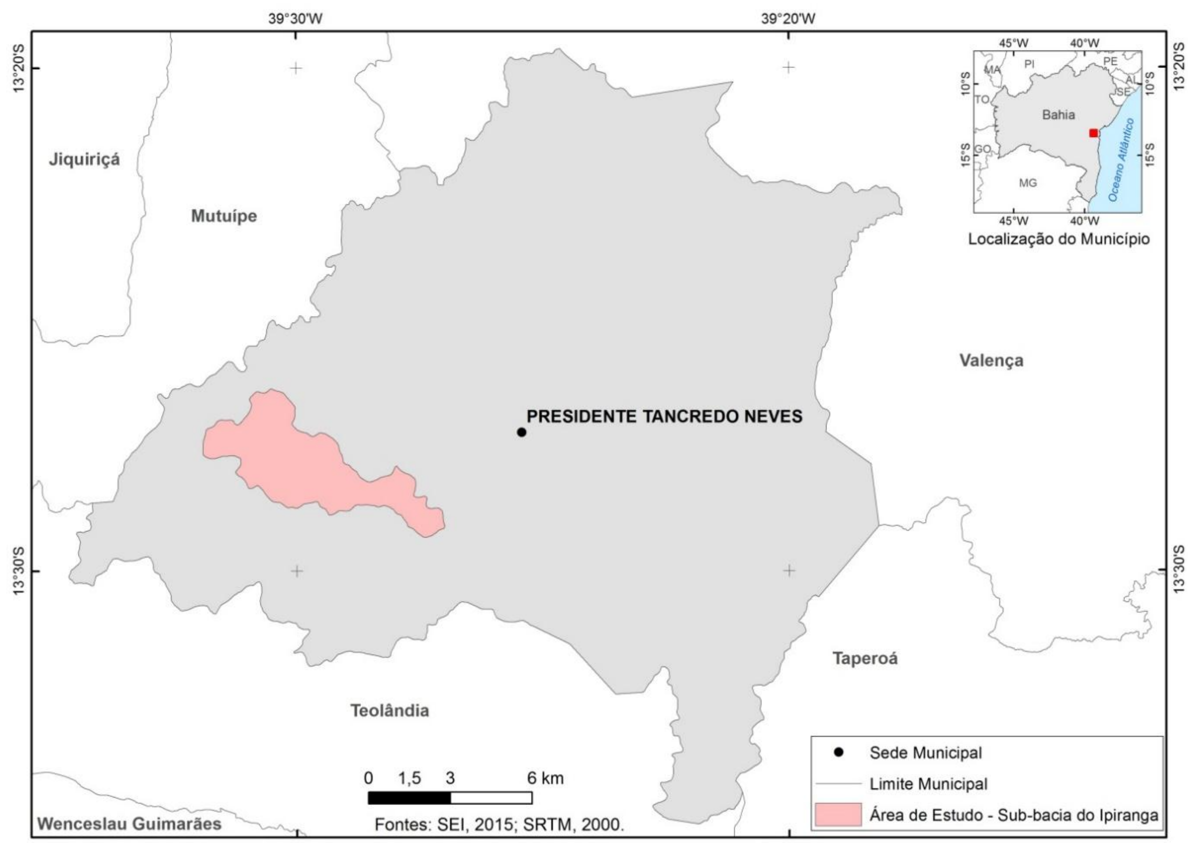

Figure 01 – Location of the Riacho do Ipiranga Sub-Basin.
Source: Author (2024).

Additionally, the geospatial approach used in this study is supported by Almeida and Santos (2019), who state that the overlay of geographic information facilitates the identification of priority areas for conservation and restoration. This strategy is particularly relevant in contexts where anthropogenic pressure is intense, such as in urban and rural areas of Brazil (MENDES, 2021).

In summary, this paper not only identifies areas that deserve greater attention but also offers a valuable tool for land management. By providing detailed data on preservation areas and their relationship with land use, this study can guide interventions that promote environmental conservation and, consequently, the maintenance of water production and the preservation of biodiversity in the sub-basin. The comparative analysis with the Forest Code highlights the need for legal and policy revisions that consider local particularities, promoting more effective and integrated natural resource management (COSTA et al., 2022).

2. Methodology

This stage was subdivided into seven parts: 1) Selection of the legal framework for identifying Permanent Preservation Areas (APP); 2) Pre-processing of topographic data; 3) Delimitation of APPs along watercourses; 4) Delimitation of APPs around springs; 5) Delimitation of APPs on slopes greater than 45°; 6) Delimitation of APPs on hilltops, and 7) Comparison of land use and occupation in APP areas.

To delineate the Permanent Preservation Areas in the Riacho do Ipiranga Sub-basin, Federal Law No. 12,651 of May 25, 2012, which established the Brazilian Forest Code, and Resolution No. 303 of March 20, 2002, of the National Environment Council (CONAMA) were used as references.

The concepts and limits defined by CONAMA (2002) and the Forest Code (2012) were applied here to assist in the delimitation of the Permanent Preservation Areas of the Riacho do Ipiranga Sub-basin. Therefore, the APPs of the Sub-basin that were delimited are shown in Table 1:

Table 1 – Characteristics of the APPs in the Riacho do Ipiranga Sub-basin.

APP’S	CHARACTERISTICS
APP1	50 meters around springs (water sources).
APP2	30 meters for rivers less than 10 meters wide.
APP3	Hilltops, hills, mountains, and ranges, with a minimum height of 100 meters and an average slope greater than 25°. The areas are delimited from the contour line corresponding to two-thirds of the minimum height of the elevation, always relative to the base.
APP4	Slopes with an inclination greater than 45°.

Source: Author (2024).

The delimitation of the APPs around springs (APP1) was based on the current Forest Code and CONAMA’s provisions. The 66 springs within the basin were spatialized as points, in shapefile format, using ArcGIS Free Trial. With these points, 50-meter buffers were created.

For the delimitation of the APPs along the drainage network (APP2) of the basin, the "Create Buffers" tool was used. The specific distance for creating the buffers along the rivers was proportional to their approximate width. Fieldwork revealed that the water bodies that make up the Riacho do Ipiranga Sub-basin have no locations where the widths exceed 10 meters. Therefore, for watercourses less than 10 meters wide, 30-meter buffers were created along the channels. These procedures were performed in ArcGIS Free Trial.

The Brazilian Forest Code (Law No. 12,651, of May 25, 2012) defines APPs as areas on slopes or parts thereof with an inclination greater than 45°, equivalent to 100% or 45° on the steepest slope.

The slope theme was generated from Shuttle Radar Topography Mission (SRTM) surface elevation data. Using ArcGIS Free Trial, the surface elevation model was converted into slope. This was reclassified into two classes: slopes less than 45° and slopes greater than 45°. The class of slopes greater than 45° was selected and later transformed into polygons. Using the "Dissolve" tool, all APP polygons were unified, excluding duplicated areas.

The steps taken to obtain the APP 4 zones were: Identification of isolated hilltops throughout the entire Sub-basin; Contoured points relative to the altitudes of the isolated peaks were selected; The base of each isolated peak was defined from the lowest depression within the respective peak's contribution area; After calculating the height of potential hills (Peak – Base), only those whose value ranged between 100 and 300 meters were kept; Among the remaining peaks, only those whose slope on at least one side exceeded 25% were considered hills; In Microsoft Excel, the altimetric quotas for the upper third were calculated using the equation: ((Peak – Base) / 3) x 2) + Base); Next, for each hill, the contour line relative to the upper third was generated on the Digital Terrain Model (DTM); This line was converted into a shapefile and transformed into a polygon using tools available in the ArcGIS Free Trial extension (Adapted from Nowatzki et al., 2009).

The comparison of areas was achieved by overlaying the APP and land use maps using the overlay technique in ArcGIS Free Trial. This allowed the quantification and determination of the percentage that each class occupies within the APP area for the entire Sub-basin.

All areas with pasture, cultivated areas, secondary vegetation, exposed soils, and degraded areas were considered under inappropriate, conflicting use. Areas occupied by intermediate vegetation and forest fragmentation were considered areas with appropriate land use. These considerations were relevant as they allowed for the verification of the degree of vegetation suppression in APPs, thus indicating the areas that need restoration.

Six field campaigns were conducted for this research: on the dates 12/07/2014, 01/04/2015, 01/07/2017, 01/10/2017, 01/16/2017, 01/17/2017, and 06/20/2017. During these visits, a Garmin Etrex GPS, a Samsung Galaxy J7 cellphone, and field sheets were used. Photos were taken with latitude and longitude coordinates using the cellphone. A total of 182 points were collected using the navigation GPS, and 991 georeferenced photographs were captured (Figure 2).

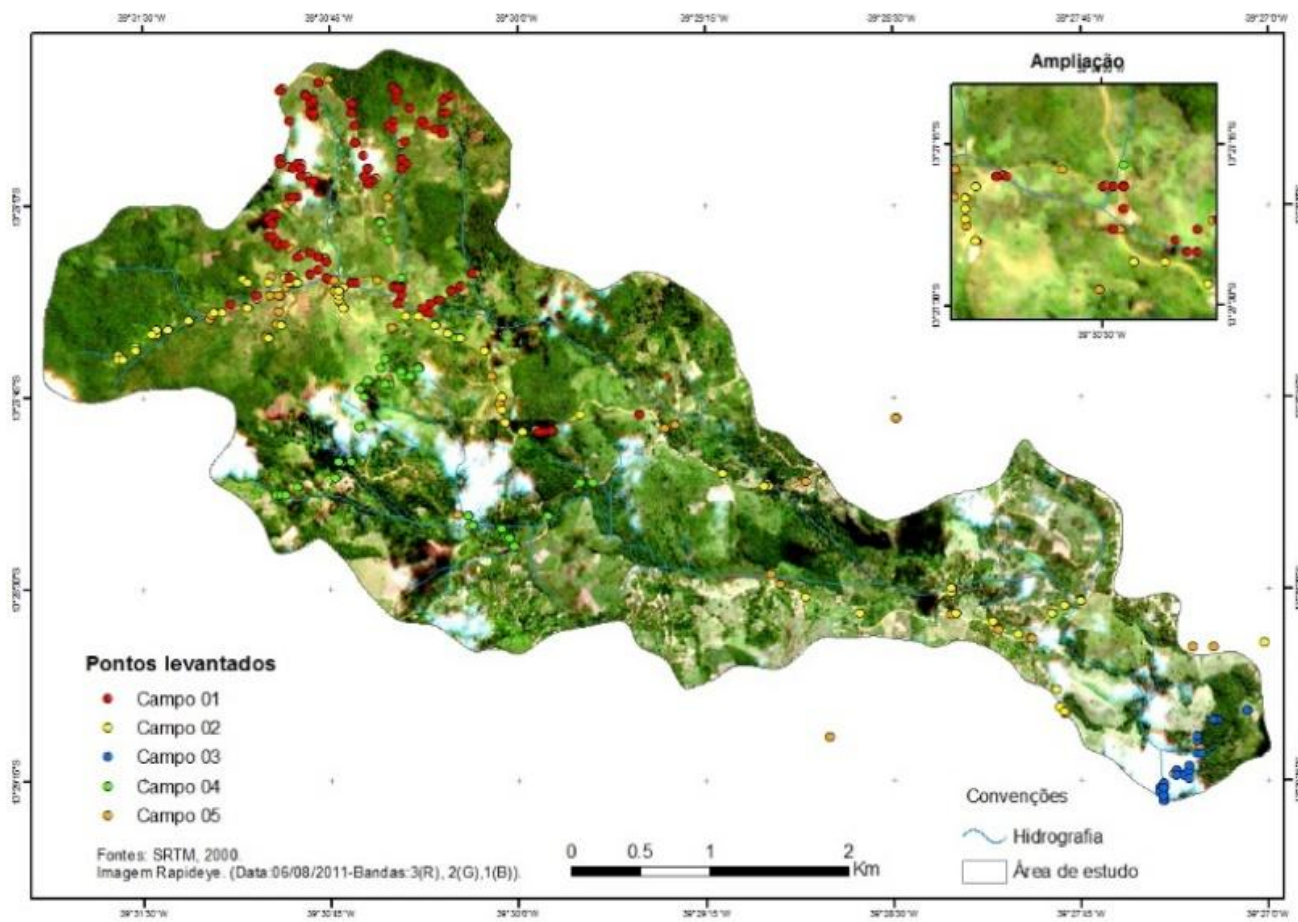

Figure 2 – Points Collected during Fieldwork in the Riacho do Ipiranga Sub-basin
Source: Author (2024).

3. Results and Discussion

The study of land use and occupation in a given area can assist in territorial planning and management. However, conflicting areas identified by such studies do not always align with the areas protected by the Brazilian Forest Code, Federal Law No. 12,651/2012, known as Permanent Preservation Areas (APP) and legal reserves. Although the legal framework presents its contradictions and needs reforms, it is important to know the Forest Code and verify its applicability in the areas under study, as these are the areas legally protected.

After studying the Brazilian Forest Code, Federal Law No. 12,651, dated May 25, 2012, and conducting fieldwork (2015, 2016, 2017), the following Permanent Preservation Areas in the Sub-Basin of the Ipiranga Creek were identified: marginal strips of any natural perennial and intermittent watercourse, excluding ephemeral ones, from the edge of the regular bed, with a minimum width of: a) 30 (thirty) meters for watercourses less than 10 (ten) meters wide;b) areas surrounding perennial springs and water sources, regardless of their topographic situation, with a minimum radius of 50 (fifty) meters;

Slopes or parts of these with a slope greater than 45°, equivalent to 100% on the steepest line;Hilltops, hills, mountains, and ridges, with a minimum height of 100 (one hundred) meters and an average slope greater than 25°, with areas delimited from the contour line corresponding to 2/3 (two-thirds) of the minimum elevation height relative to the base, defined by the horizontal plane determined by a plain or adjacent water body or, in undulating terrain, by the elevation point nearest the saddle.

In this sense, four categories of APPs were delineated in the study area: along watercourses, around springs, on slopes above 45°, and on hilltops (Figure 34). The APPs cover an approximate area of 340 ha (17% of the study area). This value is less than the sum of the APP areas because some APPs overlap in certain points. The areas occupied by each class of APPs can be seen in Table 2:

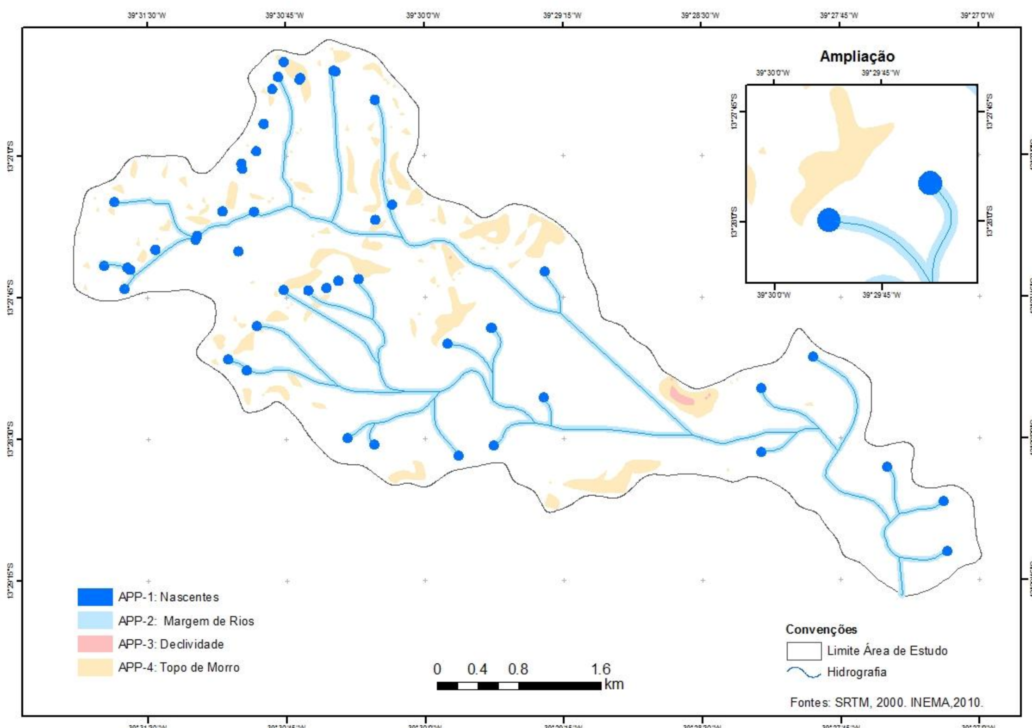

Figure 3 – Permanent Preservation Areas (APP) in the Sub-Basin of the Ipiranga Creek. Source: Author (2024).

Table 2 – Extension of Permanent Preservation Areas (APPs) by category in the Sub-Basin of the Ipiranga Creek.

Code	Characteristics	Area (ha)	Percentage of Sub-Basin Occupied %

APP-1	50m radius	38	1.8%
APP-2	30m buffer	189	9.3%
APP-3	Above 45º	2	1%
APP-4	Upper third of hill	126	6.2%
	Total	**355**	**18.3%**

Source: Author's own elaboration (2024).

The conflicting use of the Sub-Basin indicates that the APP areas listed above are occupied by (Table 3):

Table 3 – Land Cover and Use in Permanent Preservation Areas of the Ipiranga Creek Sub-Basin.

Types of Cover and Use	**Área/ha**	**%**
Forest Area	53.32	31%
Secondary Vegetation	15.48	9%
Permanent Cultivation	23.65	13.7%
Temporary Cultivation	33.97	19.7%
Pasture	30.53	17.9%
Bare Soil	13.33	7.7%
Rock Outcrop	1.72	1%
Total	**172**	**100%**

Source: Author (2024).

The analysis was then divided into four topics to better address the APPs and conflicting uses of each.

3.1 Coverage and Use of APPs around Springs

The Brazilian Forest Code, Law No. 12,651, of May 25, 2012, defines APPs around springs as a 50-meter radius surrounding perennial water sources, regardless of their topographic situation, as the necessary area for the spring to maintain its functionality of regulating water flows from the aquifer to the surface.

Regarding the definition of springs, the literature offers some attempts to define them for different study areas. This lack of consensus limits its applicability in the field. For this study, some concepts that best suit the research proposal were considered, which focuses on spatializing and delineating these areas. In geographic terms and for the sake of environmental education and protection, these concepts should be expanded to understand more than just exfiltration.

According to Valente and Gomes (2011, p. 111), springs are "superficial manifestations of underground aquifers," meaning they are contact zones where the water table meets the topographic surface, where water emerges, potentially creating a downstream drainage channel. Goudie (2004) concurs with this view. For Felippe and Magalhães Jr. (2009), a spring is an environmental system marked by a geomorphological feature or geological structure where water exfiltrates, either temporarily or permanently, forming downstream drainage channels. Guerra (1996) asserts that a spring is the head of a river, usually not a single point but a considerable area of the earth's surface.

Conama Resolution No. 303/2002, Article 2, Paragraph II, defines a spring or water source as "a location where underground water naturally emerges, even intermittently" (BRAZIL, 2002). Hence, when working with environmental legislation, this Conama resolution and the referenced literature were used as the basis, despite acknowledging their limitations.

Through field and desk research, 66 springs were identified. These occupy 38 ha (1.8%) of the Sub-Basin of the Ipiranga Creek. The land use within these APPs around springs is depicted in Figures 4 and 5.

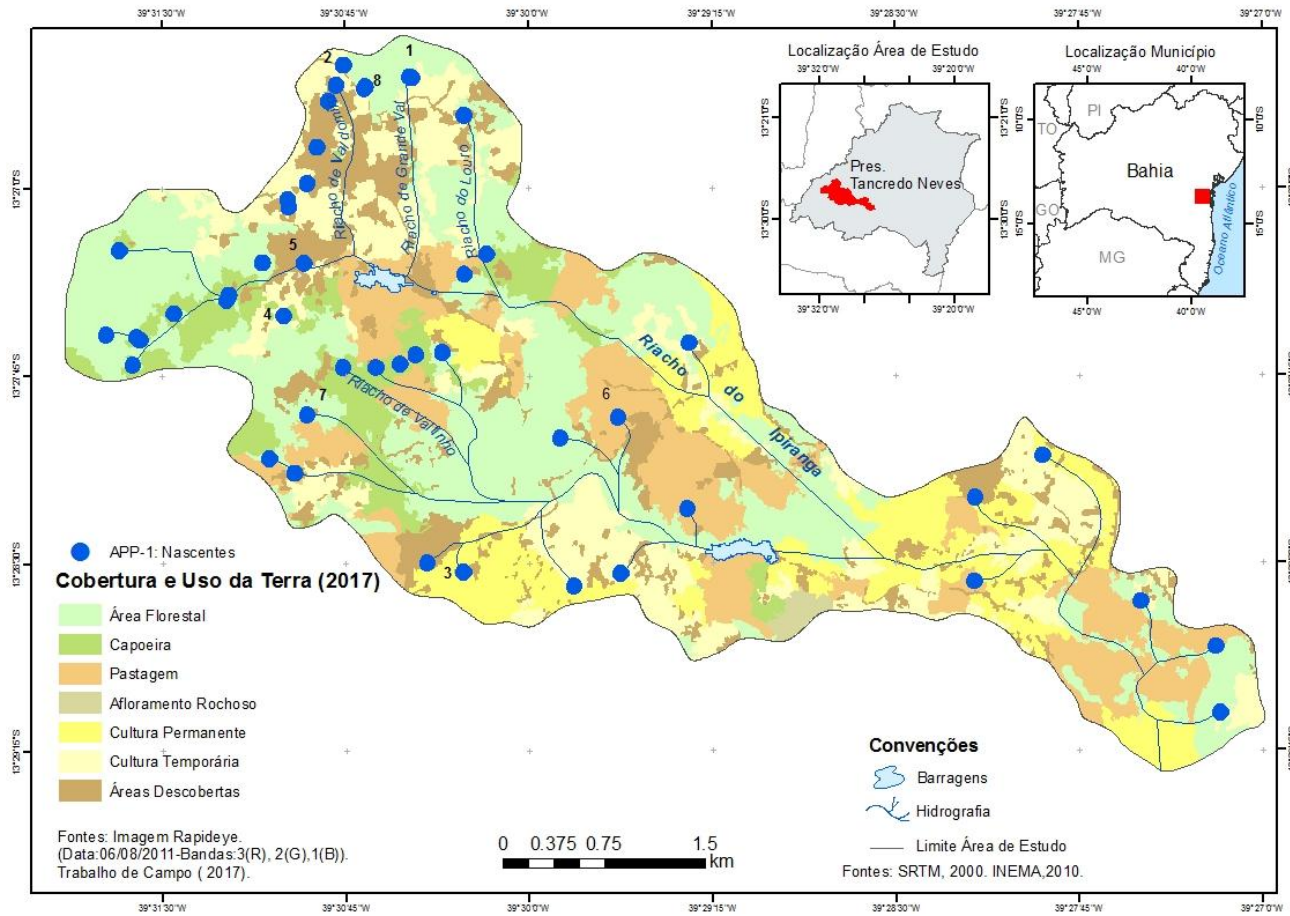

Figure 4 – Land Cover and Use in the springs APP area in the Riacho do Ipiranga Sub-Basin. The numbers on the map indicate the springs that will be illustrated in the analysis. Source: Author (2024).

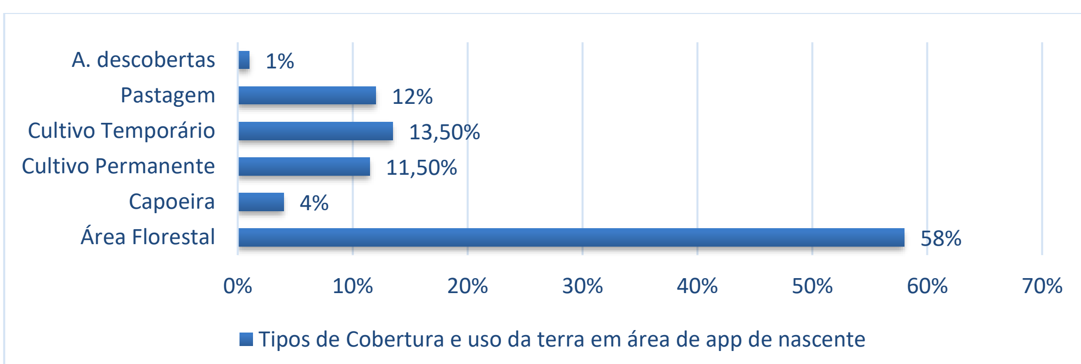

Figure 5 – Land Cover and Use in spring APP areas. Source: Author (2024).

Of the total springs mapped, 58% of these are located in areas of Atlantic Forest remnants and regeneration. The springs that have greater plant protection maintain a regular flow of water, presenting visual characteristics of potability: transparency and absence of odor. In images A and B (figure 6) it is possible to see a spring with important vegetation cover. This small outcrop of water, located in the upper part of the Sub-basin, supplies water to the entire community of

Alto Alegre, around 100 people, and nearby schools. The water collection pipes can be seen in images: A and B (Figure 6). Its spatialization can be seen in figure 4 (Spring No. 1).

Figure 6 – Spring covered by dense vegetation.
Caption: Image A: Surroundings of the spring with dense vegetation. The arrow indicates the location of the water outcrop, better detailed in image B. Image B: Spring in rocky outcrop. Presence of hoses to supply the village of Alto Alegre.
Source: Author (2017).

The spring in figure 7 is also located in the upper reaches of the Sub-Basin and is bordered by dense vegetation. Although very close to the road, to the east, it is in a good state of conservation, being perennial. The spatialization of this can be seen in figure 4 (Spring No. 2).

Figure 7 – Spring located in the upper reaches of the Sub-Basin.
Caption: Image A: Remnant of Atlantic forest in an amphitheater, arrow indicating the location of the spring. Image B: Source on a rocky outcrop on the banks of a dirt road. Bamboo used to collect water from passersby on the road.
Source: Author (2024).

In the Riacho do Ipiranga Sub-Basin, 42% of the mapped springs are found in anthropic areas. Of this total, 11.5% of springs are found in permanent cultivation areas such as cocoa and cloves. An example of this can be seen in images A, B, figure 8. The spatialization can be seen in figure 4 (Source No. 3).

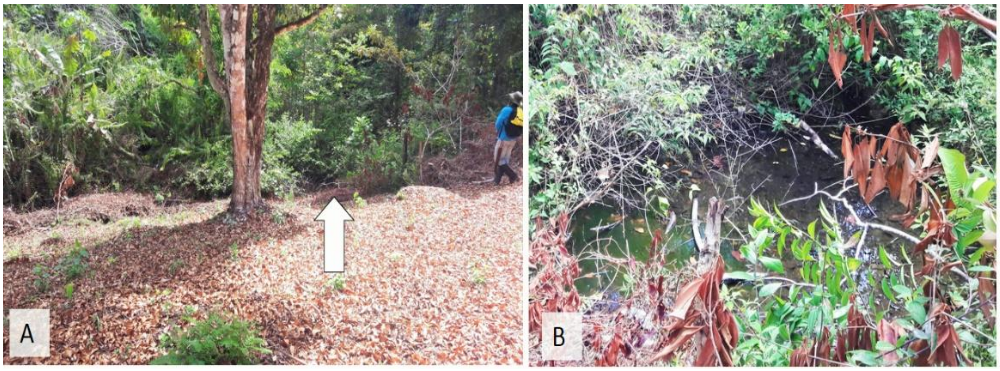

Figure 8 – Spring located within a permanent cultivation area.
Caption: Image A:Clove cultivation bordering the spring indicated by the arrow. Image B: Rising in depression. Source: Author (2017).

According to what was observed in the field, springs that are located in the midst of permanent crops have better environmental indicators than those that are in temporary crop environments.

Of the total springs, 13.5% of these are in areas of temporary cultivation. In figure 9 it is possible to see a spring in a banana growing area. The spatialization of this can be seen in figure 4 (Spring No. 4). The dry vegetation is the result of the application of a chemical product widely used in the region, Roundup Glyphosate. This product eliminates vegetation, reducing farm work. However, as this practice occurs close to springs, there is a risk of contamination of these and groundwater. This same situation was found on several properties in the Sub-Basin.

Figure 9 – Spring bordered by temporary cultivation.
Caption: Image A: Area deforested for banana cultivation bordering the spring. Arrow indicating direction of location of the source. Image B: Source in an amphitheater-shaped valley.
Source: Author (2024).

The springs that are found in highly anthropic areas, around 30% of the water outcrops, the banks of exposed soil, pastures and temporary crops (such as banana and cassava), according to interviews with local residents and field visits, have become present an intermittent regime and some of them dried up or showed an insignificant accumulation of water during periods of heavy rainfall (Figure 10). The spatialization of these can be found in figure 4 (Figure A-East Nº5, Figure B- East Nº 6).

Figure 10 – Springs with surroundings showing a high degree of anthropization.
Caption: Image A: Diffuse spring that has become intermittent. Image B: Place where there was a spring on the banks of banana cultivation.
Source: Author (2017).

The springs that remain perennial not only have a lower water flow, especially in the dry months, but also have a coloration that indicates the presence of sediment from the surrounding area, and in some areas of small impoundments, it is possible to notice signs of eutrophication. Some of these issues can be seen in figure 11. Their spatialization can be seen in figure 4 (Spring No. 7). Furthermore, it is necessary to monitor these springs in order to obtain more accurate information.

Figure 11 – Spring located on the banks of a pasture.
Caption: Image A: Location of spring on pasture margins, with small damming. Image B: East of image A, photographed from another angle.
Source: Author (2017).

One fact that caught our attention during the field activity was finding a surge of water in the middle of a dirt road. According to a local resident, the spring is intermittent, ceasing its flow during periods of prolonged drought. It can be inferred that the resistance of this outcrop is due to the preservation of its recharge area. The entire right margin of the road, the highest part in relation to the east, slope and top of the hill, is surrounded by remnants of the Atlantic Forest. This can be seen in figure 12. Its spatialization can be seen in figure 4 (Spring No. 8).

Figure 12 – Spring located on a dirt road.
Caption: Image A: Dirt road with arrow indicating location of water outcrop. Image B: Spring with bubbling in the middle of the dirt road.
Source: Author (2024).

This observed situation reinforces the idea of the need for a more comprehensive/systemic understanding of nature/water resources, since preserving only one area around the water outcrop cannot always guarantee its permanence, as the entire landscaped surroundings contribute to its stability, as in the example shown. For this reason, there is a need to conserve other Permanent Preservation Areas, which will be analyzed below.

It is worth noting that the areas surrounding the springs are extremely important with regard to the useful life of the rivers they supply, as without adequate protection in their surroundings it favors a process of degradation.

3.2 Coverage and use of APPs along watercourses

The forest code defines riverbank APP as the marginal strips of any perennial and intermittent natural watercourse, excluding ephemeral watercourses. According to current legislation, for the Sub-Basin under study, the riparian forest of water bodies must have 30m of marginal strips of APP, as they do not exceed 10m in width (Data collected in field work, 2015, 2016, 2017, 2023, 2024). Furthermore, this marginal strip was delimited from the edge of the regular bed channel, as required by law. The spatialization of APP2 and its occupation can be seen in figure 13.

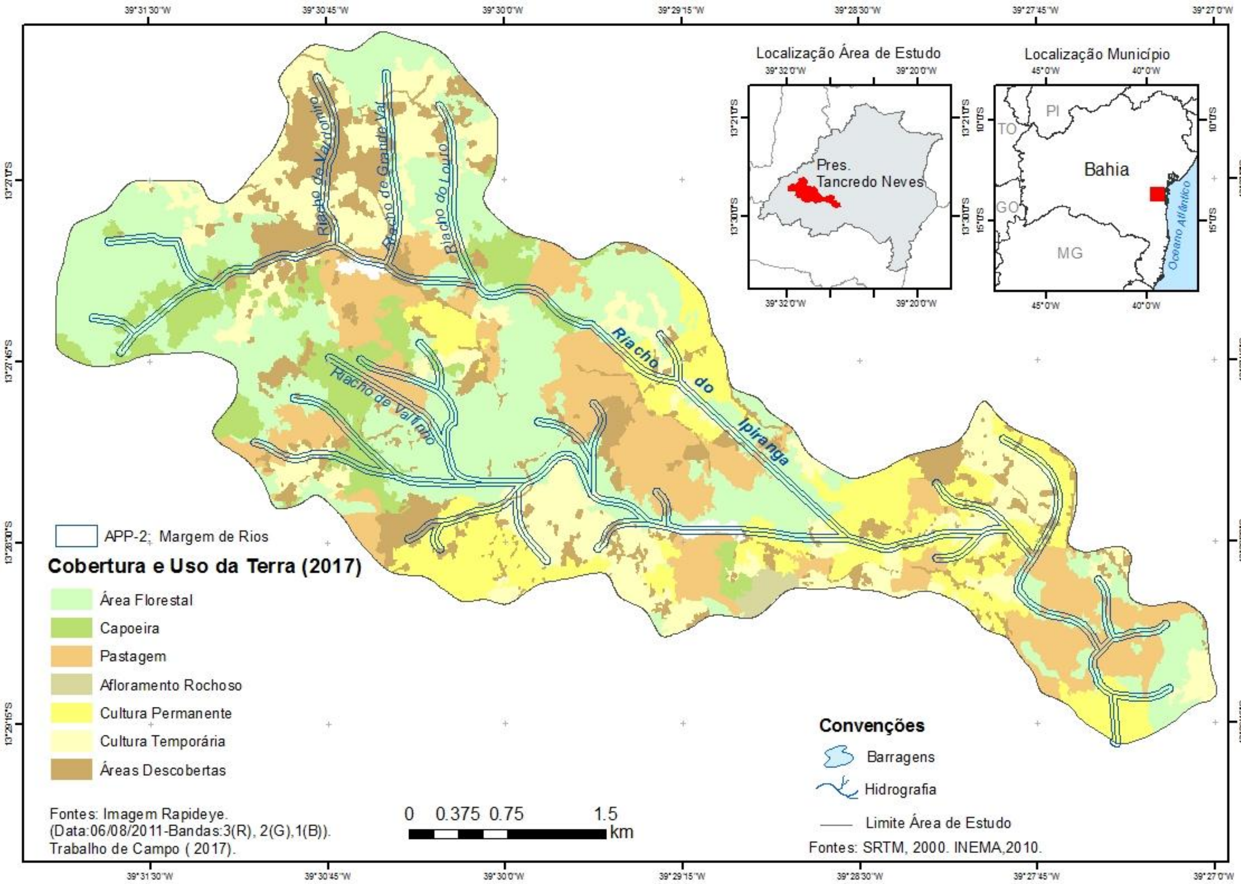

Figure 13 – Coverage and use of riverbank APPs.
Source: Author (2024).

First of all, it is worth mentioning the definition of a "regular riverbed", since it is from this that the APP-2 is delimited. Jean Tricart (1966) apud Christofoletti (1980) classifies the types of bed as follows: Ebb bed - This is included in the minor bed and is used for the flow of low water. It constantly meanders between the banks of the smaller bed, following the talvegue, which is the line of greatest depth along the bed. The flow of water in this bed is frequent enough to prevent the growth of vegetation. Along the minor bed there are irregularities, with deeper stretches, the depressions (mouille or pools), followed by shallower parts, more rectilinear and oblique in relation to the apparent axis of the bed, called umbrails (seuils or riffles); Periodic or seasonal major bed - It is regularly occupied by floods, at least once a year; Exceptional major bed - Where the highest floods occur, the inundations. It is submerged at irregular intervals, but by definition not every year.

For Christofoletti (1994), the fact that for most of the year, the river has a configuration technically known as the "minor bed" corresponds to the flow section during the dry season, or average levels. However, in times of high rainfall, the watercourses naturally widen their domain, which is called the "larger bed", the "floodplain" or even the "floodplain". Therefore, delimiting the riverbank APP from the regular bed disregards its natural dynamics.

In the sub-basin studied, during periods of heavy rainfall, it became clear that it was important to consider the flood bed in order to delimit the APP. In a field activity (December 2015), the damage caused by the flooding of the Sub-Basin's rivers could be seen. The waters advanced about 3m from the marginal strips, sweeping away crops, water catchment pipelines and destroying roads that sectioned them off.

Some images were taken from accessible points (Figures 14, 15 and 16).

Figure 14 – Vegetation washed away during flooding of the Ipiranga Creek.
Source: Author (2015).

Figure 15 – Bridge destroyed by the waters of the creek.
Source: Fieldwork (2015).

Figure 16 – Marks of the area flooded by the river. Arrows indicating vegetation still lying after the flooding of the stream.
Source: Author (2015).

Although the delimitation from the regular bed was considered deficient, it was done as required by law. The result of this delimitation shows that the riverbank APPs occupy approximately 189 ha (9.4%) of the area of the Riacho do Ipiranga Sub-Basin. Land cover and land use in the riverbank areas show the following data (Table 4):

Table 4 – Land Cover and Use in the riverbank APP areas.

Types of Use	Area ha	%
Forest Area	68.4	35%
Capoeira	14.8	8%
Permanent Cultivation	29.8	16%
Temporary Cultivation	33.8	18%
A. discoveries	19.9	11%
Pasture	22.8	12%
Total	189.5	100%

Source: Prepared by the author (2024).

The data in Table 3 shows that 65% of the riverbanks in the Riacho do Ipiranga Sub-Basin are anthropized. Of this total, 41% of these areas are used for activities with a low, very low or zero degree of soil protection (uncovered areas, temporary crops and pastures) and are therefore included in areas of high fragility in terms of vegetation cover.

According to Barbosa (2006), riverbank riparian forests are of great importance because they regulate the flow of water, acting as natural filters that prevent sediment and pollutants from entering watercourses, as well as protecting the soil from erosion in regions with rugged topography.

The APPs of watercourses guarantee the stabilization of the banks and are therefore vitally important in controlling soil erosion and water quality, preventing sediment, nutrients and chemicals from being carried directly into the aquatic environment from the higher parts of the land, which affect water quality and reduce the useful life of reservoirs, hydroelectric installations and irrigation systems.

Therefore, areas with a higher density of native vegetation, such as the Atlantic Forest remnants in the Sub-Basin studied and areas of regeneration, capoeira, guarantee greater protection for the watercourses. Whereas the more anthropized areas leave them vulnerable. This can be seen in images 17, 18, 19 and 20.

Figure 17 – Ipiranga Creek tributary with APP area covered by cocoa cultivation.
Source: Author (2024).

Figure 18 – Ipiranga creek bordered by pastures. Banana plantations in the background.
Source: Author (2024).

Figure 19 – Residence on the banks of the upper reaches of the Riacho do Ipiranga.
Source: Author (2024).

Figure 20 **–** *Riacho do Ipiranga, near the mouth, bordered by polycultures and uncovered areas.*
Source: Fieldwork (2024).

The images illustrate some of the conflicting use of riverbank APPs. It should be noted that there is a greater concentration of forested areas in the upper part of the sub-basin, which has probably ensured the conservation of water bodies and springs.

3.3 Coverage and use of PPAs on slopes greater than 45° and hilltops

Slope APPs are found on slopes or parts of slopes with a gradient of more than 45°, equivalent to 100% of the line of greatest gradient. The area occupied by this APP covers 2 ha of the sub-basin. These areas can be seen in Figure 51 and coincide with the areas of APP-4: Hilltops. For this reason, they will be analyzed together. The APP-3 areas, Topos de Morro, make up an area of 126 ha (6.98%) of the Sub-Basin and are concentrated in the upper and middle parts of it (Figure 51).

Due to its rugged terrain, this basin has an extensive area occupied by hilltop APPs, areas that require preservation. Table 5 shows the coverage and use in APP areas 3 and 4:

Table 5 – Coverage and use in the areas of the Slope and Hilltop APPs.

Types of Use	**Área há**	**%**
Forest Area	57.96	46%
Capoeira	10.8	8%
Permanent crops	7.56	6%
Temporary crops	23.4	18%
Pasture	19.26	15%
Uncovered areas	6.3	6%
Rock outcrop	1.26	1%
Total	**126.18**	**100%**

Source: Author (2024).

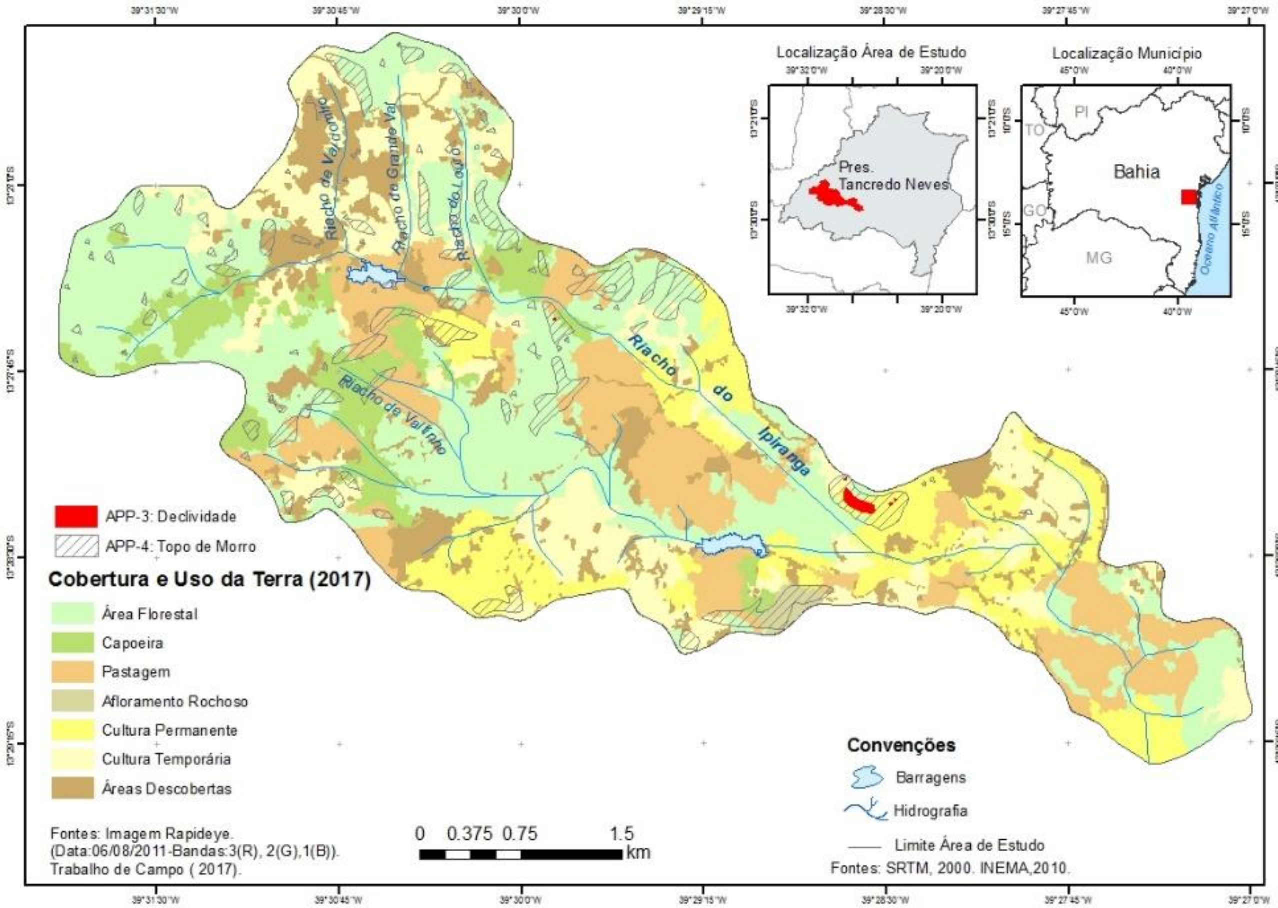

Figure 21 – Coverage and use of areas with slopes greater than 45% and hilltops.
Source: Author (2024).

Table 4 shows that 44% of the hilltop areas are used inappropriately and, of these, 39% are occupied by activities that offer a low, very low or zero degree of soil protection, thus placing these areas in a condition of high emerging fragility.

According to Skorupa (2003), on steep slopes, vegetation promotes soil stability through the tangle of plant roots, preventing its loss through erosion and protecting the lower parts of the terrain, especially watercourses. In this way, it prevents or stabilizes erosion processes, acts as a windbreak in cultivated areas and prevents siltation.

According to Santos (2007), the protection of recharge areas, including PPAs located on slopes with gradients greater than 45° and the upper third of hills, mountains and ridge lines, ensures greater infiltration of water into the soil, reducing the fragility of erosion processes and providing a greater supply of groundwater (Figure 22).

Figure 22 – Slope occupied by banana plantations and, in the background, hilltops covered by remnants of the Atlantic Forest.
Source: Author (2024).

In addition to the existence of vegetation as a stabilizing factor in the landscape, it should be noted that the type and density of vegetation cover has a direct influence on the vulnerability of soils to the development of erosion processes. In less protected areas, such as fields, pastures and agricultural areas, the kinetic energy of rainfall increases, making laminar surface erosion more intense, leading to the removal and transportation of sediment from the soil (RUHOFF, 2004).

The occurrence of areas with steep topography and the presence of soils with medium erodibility are determining factors in the triggering of erosion processes in the study area, where strong rainfall erosivity (concentrated in the summer period) creates a scenario with high levels of environmental fragility, or a high predisposition of the land to soil loss.

In the study area, what has maintained the stability of these areas is still a considerable percentage of areas covered by Atlantic Forest remnants (46%). In addition, the activities carried out favor the destabilization of slopes, generating landslides.

Another issue that should be noted is the fact that the hilltop and slope APPs have no interconnectivity between them, these areas are isolated and no longer serve as ecological corridors, requiring changes to the Code to take this into account.

4. Final considerations

In this work, the watershed was used as a spatial cut-off for environmental analysis. The use of digital image processing and mapping techniques through remote sensing and geoprocessing has demonstrated its significant contribution to knowledge of land use and cover. The study of land use and occupation in the Riacho do Ipiranga Sub-Basin can help indicate possible land use planning and management. However, the conflicting areas indicated by these studies do not always coincide with the areas protected by the Brazilian Forest Code (Federal Law No. 12.651/2012).

In this sense, we sought to delimit, based on current environmental legislation, the Permanent Preservation Areas (PPAs) around springs, riparian forests, slopes and hilltops, and to compare these results with the land use mapping in the Sub-Basin. APPs are essential for the stability of landscapes and ecosystems, especially in watershed areas, highlighting the need to conserve these areas. Despite their importance, APPs are subject to numerous anthropogenic pressures, resulting in the replacement of natural landscapes by other land uses. Disorderly land use affects water production, degrading recharge areas and the surroundings of rivers and springs, compromising the functioning of natural systems.

The results of this study show the importance of delimiting APPs as part of river basin planning. However, there are weaknesses in the Forest Code (Federal Law No. 12.651/2012) and, for this reason, there is a need for new rules to be based on scientific knowledge, taking into account the specific characteristics of each ecosystem in order to define appropriate limits and restrictions on use.

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