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Classification of land use and occupation in urban streams PPA using images from Remotely Piloted Aircraft

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Classificação de uso e ocupação do solo em APP de córregos urbanos com o uso de imagens de Aeronave Remotamente Pilotada

RESUMO

As tecnologias, cada vez mais desenvolvidas, surgem como ferramentas úteis para avaliação das mudanças, bem como suporte para propostas que visem à mitigação da antropização. O trabalho objetivou fazer a classificação de uso e ocupação de três córregos urbanos na cidade de Cáceres-MT, com o uso de uma Aeronave Remotamente Pilotada (ARP). Os córregos Fontes, Sangradouro e Renato foram sobrevoados para a obtenção de aerofotografias e, posteriormente, com o processamento das imagens, obteve-se o ortomosaico. Este, por sua vez, foi usado para a classificação de uso e ocupação do solo dentro dos limites da Área de Preservação Permanente (APP). Com a precisão centimétrica espacial do ortomoisaico gerado, foi possível fazer uma análise precisa da ocupação local e analisar que a área de mata ciliar, bem como a deposição de efluentes ao longo dos córregos, não atende ao Código Florestal brasileiro vigente. O uso do equipamento de fotogrametria, mais especificamente a ARP, mostrou-se vantajoso pela agilidade na coleta de dados a campo, oferecendo resultados concisos e de ótima qualidade de imagem (ortomosaico), tornando possíveis as avaliações previstas de impactos ambientais sofridos, fornecendo, ainda, um banco de dados para o monitoramento da área.

PALAVRAS-CHAVE: Área de Preservação Permanente. Córregos Urbanos. Aeronave Remotamente Pilotada.

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ABSTRACT

Technologies, increasingly developed, are emerging as a useful tool for evaluating changes, as well as supporting proposals aimed at mitigating anthropization. The work aimed to classify the use and occupation of three urban streams in the city of Cáceres-MT, using an Remotely Piloted Aircraft (RPA). The streams Fontes, Sangradouro and Renato were flown over to obtain aerial photographs and later, with the processing of the images, the orthomosaic was obtained. This, in turn, was used to classify land use and occupation within the limits of the Permanent Preservation Area (PPA). With the centimetric spatial precision of the generated orthomoisaic, it was possible to carry out a precise analysis of the local occupation and analyze that the riparian forest area as well as the deposition of effluents along the streams, does not comply with the current Brazilian Forest Code. The use of photogrammetry equipment, more specifically the RPA, proved to be advantageous due to its agility in collecting data in the field, offering concise results and excellent image quality (orthomosaic), making it possible to carry out predicted assessments of environmental impacts suffered, also providing a database for monitoring the area.

KEYWORDS: Permanent preservation area. Urban river. Remotely Piloted Aircraft.

Clasificación de uso y ocupación del suelo en APP de arroyos urbanos utilizando imágenes de Aeronave Remotamente Pilotada

RESUMEN

Las tecnologías, cada vez más avanzadas, surgen como herramientas útiles para evaluar los cambios, así como para apoyar propuestas dirigidas a mitigar la antropización. Este trabajo tuvo como objetivo clasificar el uso y la ocupación del suelo en tres arroyos urbanos de la ciudad de Cáceres-MT, mediante el uso de una Aeronave Remotamente Pilotada (ARP). Los arroyos Fontes, Sangradouro y Renato fueron sobrevolados para obtener aerofotografías y, posteriormente, con el procesamiento de las imágenes, se generó el ortomosaico. Este, a su vez, se utilizó para clasificar el uso y la ocupación del suelo dentro de los límites del Área de Preservación Permanente (APP). Gracias a la precisión centimétrica espacial del ortomosaico generado, fue posible realizar un análisis preciso de la ocupación local y observar que la cobertura vegetal ribereña, así como la deposición de efluentes a lo largo de los arroyos, no cumple con el Código Forestal brasileño vigente. El uso del equipo de fotogrametría, específicamente la ARP, demostró ser ventajoso por su agilidad en la recolección de datos en campo, ofreciendo resultados concisos y de excelente calidad de imagen (ortomosaico), lo que permitió realizar evaluaciones previstas de los impactos ambientales sufridos, además de proporcionar una base de datos para el monitoreo del área.

PALABRAS CLAVE: Área de Preservación Permanente. Arroyos Urbanos. Aeronave Remotamente Pilotada.

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1 INTRODUCTION

Urban areas are modified and adapted spaces for human occupation and their activities, altering the environment and changing the landscape, as these occupations take place in an unplanned manner, suppressing watercourses and native vegetation. Only from the 20th century onwards, after the disorderly occupation, motivated by the Industrial Revolution, the concerns about urban environmental issues began.

Since the beginning of the formation of the great civilizations, bodies of water were considered synonymous with abundance, as they were the providers of resources that allowed their development, and these societies were appropriately called hydraulic due to this direct relationship with water (ALENCAR, 2017). According to Cengiz (2013), bodies of water have many functions and, among them, the most important are to promote the connection between the landscape and communities and to promote the creation of a concept of a sustainable environment (AMORIM, 2019).

In terms of urban environmental aspects, river banks are complex environments and sites of countless socio-environmental processes, from those relating to forms of occupation and use of urban land to the systemic relationships of the natural environments that make up river basins, in which river banks are important elements (ARAGÃO; GOMES, 2019). Riparian zones are among the ecosystems most susceptible to human impacts and the main factors that influence them are the regulation and urbanization of rivers (CZORTEK et al., 2020).

The areas around rivers are protected and defined by the Brazilian Forest Code (BRASIL, 1965) as Permanent Preservation Areas (PPAs) and Legal Reserve (LR) areas and were introduced by Article 225 of the Brazilian Federal Constitution. This article gives public authorities the responsibility of defining the “territorial spaces” to be protected. In this way, Brazilian New Forest Code (Law 12,561, of May 25, 2012) defined protection areas that were already part of the previous code, but were not foreseen in the National System of Nature Conservation Units (BRASIL, 2000).

The definition of PPA is closely linked to geomorphological characteristics and/or transition areas between aquatic and terrestrial systems. They occupy territories of high fragility and environmental importance and have strong restrictions on their use, both in urban and rural areas.

Since the study of the urban environment is considered complex and multidisciplinary, especially in relation to environmental issues, it is important to highlight the use of technological tools to assist and develop methodologies for the development of urban environmental studies.

Mapping land use and vegetation cover, through the use of geoprocessing techniques, represents an important instrument for planning and managing the occupation of the physical environment, enabling it to be assessed and monitored, in order to guarantee the conservation of its natural resources (BORGES et al., 2008).

At the same level, the evolution of Geographic Information Systems (GIS) allowed these systems to be increasingly used as a tool to support spatial analysis, enabling geographic scenarios to be evaluated quickly and, consequently, to facilitate decision-making at the governmental level and in the management of water resources, among other uses (ASSIS et al., 2014).

Obtaining environmental data in urban areas has always been a major limitation in the development of more detailed studies on the different elements that compose this environment. Although remote sensing, which is currently one of the main sources of environmental information, has brought great benefits to meet these demands, especially with the evolution of sensors and the expansion of data availability, it still has limitations, mainly in terms of cost-benefit ratio, when considering the context of urban areas (BOURSCHEIDT, 2019).

In this sense, the rapid technological and computational advances of recent decades have made it possible to develop new instruments, which are gaining more and more space in the geotechnology market, as they are relatively more affordable and easy to use. These are Remotely Piloted Aircrafts (RPAs), a term used more broadly, although different terminologies are usually adopted, such as UAVs, UAVs or RPAs or even drones (BOURSCHEIDT, 2019).

Studies also suggest the use of RPAs to analyze the preservation of Permanent Preservation Areas (PPAs), which are significantly more vulnerable in urban environments, as well as extremely important in these environments, mainly due to the risk of flooding (BUFFON; DA PAZ; SAMPAIO, 2017). Monitoring PPAs in urban environments through RPAs has great potential, mainly due to cost reduction and the possibility of frequent and targeted monitoring of the most vulnerable areas.

2 OBJECTIVE

The aim of this paper was to classify land use and occupation in PPAs – Permanent Preservation Areas – in three urban streams (Fontes, Sangradouro and Renato) with the use of aerial photogrammetry, using an RPA (Remotely Piloted Aircraft) as tool.

3 METHODOLOGY

3.1 Study area

The municipality of Cáceres is located in the southwest of the state of Mato Grosso, between latitudes 15°27' and 17°37' south and longitudes 57°00' and 58°48' west and an average altitude of 118 m (SOUZA et al., 2015). According to data from IBGE (2010), in the 2010 census, the municipality had 87,942 inhabitants.

The city is known as “The Portal to the Pantanal”, as it is located at the beginning of the Pantanal region, bathed by the Paraguay River. The region is in a biome transition zone, therefore presenting floristic components from the Pantanal, Cerrado and Amazon biomes. According to the Köppen climate classification, the climate is AWa (tropical savannah), hot and humid, with dry winters (NEVES et al., 2011).

The streams studied are located entirely in the urbanized area of the city where their sources and mouths are located. They are: Fontes Stream, Sangradouro Stream and Renato Stream (Figure 1).

The Fontes Stream has its source limited to the geographical coordinate South 16°03’38.7” West 057°39’52.1” and is located in the northern region in relation to the

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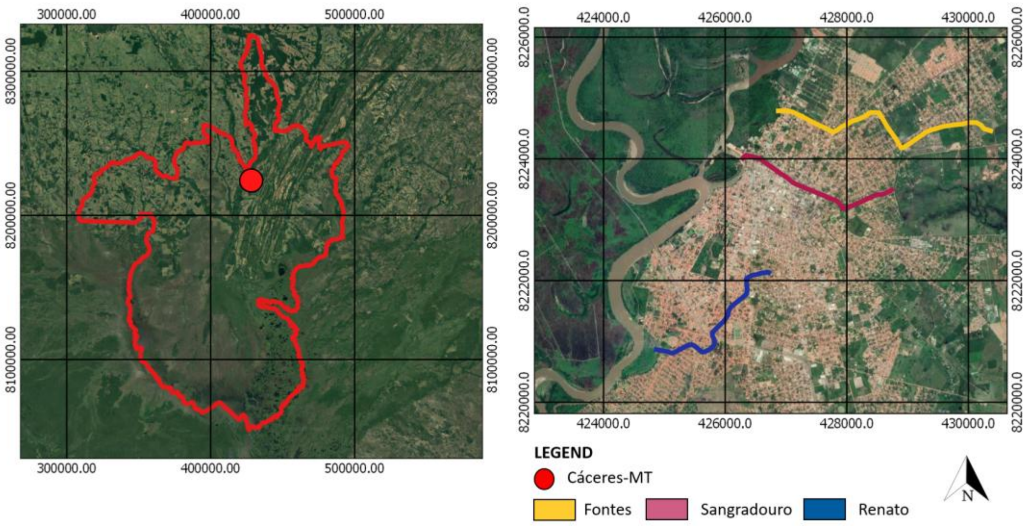
downtown. The stream course was observed from the Joaquim Murtinho neighborhood (east) to the area of native forest where its mouth is, in Malheiros Bay, flowing into the Paraguay River.

The Sangradouro Stream is in the most centralized region of Cáceres. Since its source, the river has continued its course without intervention, although, in several places, vegetation has been removed to build houses. From the Cavalhada neighborhood, the stream is channeled and covered by a concrete structure until it flows into the Paraguay River, close to Barão do Rio Branco square, one of the city's main tourist attractions. The east is limited to the geographic coordinates South 16°05’45.5” and West 57°39’10.8”.

Finally, the Renato Stream has its source limited to the geographic coordinates South 16°04’44.9” and West 057°41’05.7”, in the Vila Mariana neighborhood, which is a primarily residential location. Its source is surrounded by houses and there is no delimitation on the stream banks. Part of the river has its channel and sides preserved, without any type of interference, following its natural course. The other part is channeled in the open air, with concrete on the banks (OLIVEIRA JUNIOR et al., 2013).

Figure 1 – Location of the municipality of Cáceres and the streams (Fontes, Sangradouro and Renato) in the urban área



Source: Elaborated by the authors, 2023.

3.2 Data collection and processing

After planning and organization, data collection was organized according to the steps described in the flowchart below (Figure 2).

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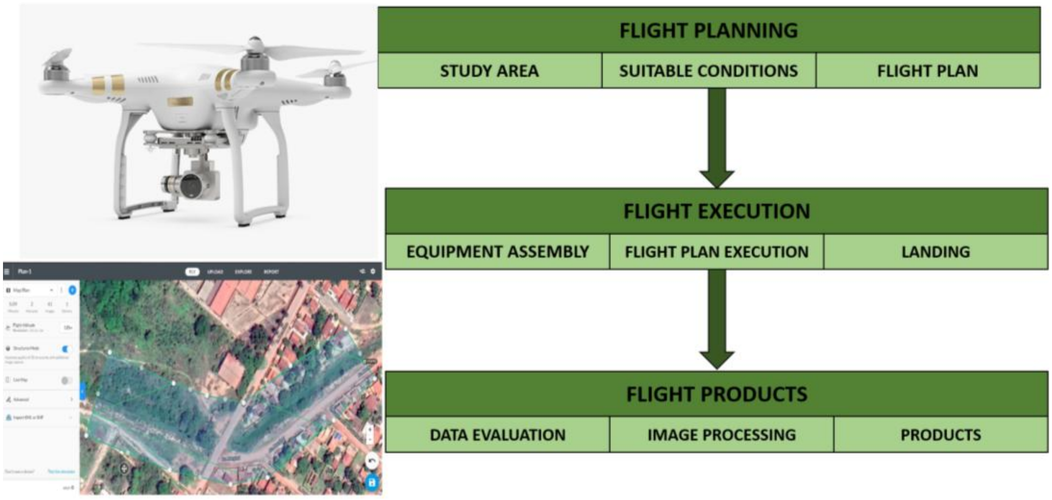
Figure 2 - Methodological flowchart



Source: Elaborated by the authors, 2023.

3.3 Aerial images acquisition

The river was vectorized and characterized in the field using GNSS Navigation points. Subsequently, this data was imported into the Google Earth program to plan support points and into the Quantum GIS to plan the areas to be imaged during flights.

To plan the flights, the DroneDeploy software (available for IOS and Android systems) was used to define the number of flights necessary and to define the routes that the RPA should follow in each section to acquire aerial photographs.

Through preliminary studies, the average flight height and the frontal and lateral overlap pattern of the images were defined, in order to achieve the expected spatial detail. The flight was carried out at 120 meters from ground level (in relation to the take-off point), with 60% lateral and 80% frontal image overlaps.

In order for the flight product to have greater planimetric and altimetric accuracy, artificial support points were installed, in which coordinates were collected with the help of the Topcon HIPER V RTK Geodetic GNSS, providing precise coordinates to be used as supporting points.

3.4 Image processing

The images obtained from the survey were processed with the digital photogrammetry software Agisoft Photoscan, to generate the following cartographic products: three-dimensional point clouds, Digital Surface Model (DSM), Digital Terrain Model (DTM) and the orthomosaic.

The PPAs were delimited and spatialized by generating buffers in Quantum GIS on the previously obtained stream vectors. These buffers were generated considering the center of the river channel, which, according to the Brazilian Forest Code, must have 30 meters of protected área on each side, when watercourses are less than 10 meters wide, and 50 meters of protected area on each side, for the river sources. Subsequently, these spatial vector layers were used to cut the cartographic products generated by aerial photogrammetry, which were: orthomosaic, DTM and DSM.

To classify land use, six occupation categories were defined: low vegetation (< 1.3 m), shrub vegetation (< 5.3 m), tree vegetation (> 5.3 m), soil/water (streets, empty land, water), buildings up to 5.3 m and buildings above 5.3 m.

The orthomosaic consists of a raster containing the Red, Green, Blue (RGB) spectral bands, from which it is possible to segment and classify the image. From the orthomosaic, it was possible to extract the Green Leaf Index (GLI)[1] to identify what was vegetation from the rest of the classes, separating the orthomosaics into two: orthomosaic with vegetation and orthomosaic without vegetation.

$$GLI = \frac{2 * G - R - B}{2 * G + R + B} \quad (1)$$

Where: GLI: Leaf Green Index; A: Red Spectral Band; G: Green Spectral Band; B: Blue Spectral Band

By subtracting the DSM from the DTM, the Digital Height Model (DHM) is obtained and thus it is possible to know the absolute height of each “object” or “feature” contained in the orthomosaic. Then, by cutting out the DHM from the two previous orthomosaics, it can also be divided it into two: DHM with vegetation and DHM without vegetation, and, from these, classify them according to the altimetric elevations. The DHM with vegetation was classified as: low vegetation (DHM < 1.3 m), shrub (1.3 m < DHM < 5.3 m) and arboreal (DHM > 5.3 m). The DHM without vegetation was classified as: soil (DHM < 2.0 m), single-story construction (2.0 m > DHM > 5.0 m) and construction with two floors or more (DHM > 5.0 m).

Finally, the classified orthomosaics were merged to obtain the final classification orthomosaic. This orthomosaic was evaluated for its Global Accuracy (GA)[2] by stratified random sampling of 50 sample points for each of the six classes, totaling 300 cross-validation sample points. Cross-validation consists of visually checking each of the sample points, observing the classified orthomosaic versus the RGB orthomosaic to check whether the class correctly represents the defined use and occupation.

$$AG = \frac{(\sum_{i=1}^{m} n_{ii})}{N} \quad (2)$$

Where: AG: Accuracy or Global Accuracy (%); $\sum_{i=1}^{m} n_{ii}$: Sum of Correctly Classified Points; N: Total number of points evaluated

4 RESULTS AND DISCUSSION

4.1 General aspects of land use and occupation for the three streams

The function of Permanent Preservation Areas (PPA), in Brazil, aims to meet the right of every Brazilian to an "ecologically balanced environment", according to art. 225 of the

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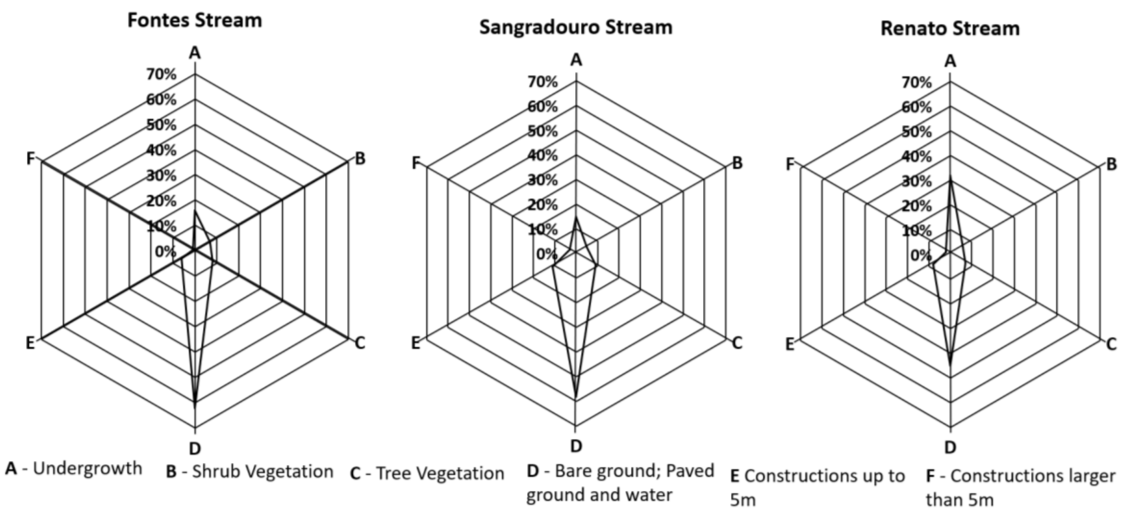
Brazilian Constitution. In general, permanent preservation areas must not be altered, allowing modification or suppression of vegetation only by law. Although much of the doctrine admits the possibility of intervention in areas of permanent preservation declared by the Public Power, Law no. 12,651/12 provides, in its articles 3, VIII, IX, the suppression of vegetation in permanent preservation areas and their use for economic purposes, in exceptional cases of public utility, social interest or low environmental impact (VIEIRA et al. 2014).

The studied areas did not present a large proportion of spaces with buildings, whether single-storey or multi-storey. The percentages of built-up areas were around 10% (Figure 3). However, these constructions are within the PPA and, according to the aforementioned law, are irregular.

The biggest problem of use and occupation is in areas of land without vegetation, with a variation of 45% to 62% (Figure 3). Most of these areas represent paved or unpaved traffic roads. The roads have a major impact on the area close to the riverbed, as vehicle traffic can cause compaction of the surrounding soil and, depending on the type of soil, can cause erosion and siltation, in addition to waterproofing, causing flooding in these regions. Earth removal activities were also observed, which is a maintenance service for unpaved roads carried out by skid steer, in which the blade of the skid steer digs and removes the earth transversally towards the riverbed.

The way in which the urban development process was consolidated in Cáceres was no different from the Brazilian reality when it comes to occupation in areas adjacent to rivers or urban streams. These are negligent actions, as these rivers or streams have their beds modified, channelized, landfilled and their riparian forests suppressed, thus causing continuous densification on their banks, becoming dirty, polluted and devalued (PORATH, 2004).

Figure 3 – Classification of land use in streams



Source: Elaborated by the authors, 2023.

In relation to vegetation, which should fill the entire permanent preservation area (PPA), it reached low rates: in the arboreal stratum, 7% to 9%; in shrubs from 5% to 7% and undergrowth from 15% to 32% (Figure 3). The concept of PPA, according to Mello (2008), brings with it the principle of intangibility, that is, the impediment of human use and occupation. The principle of intangibility is contrary to traditional urban uses. Permanent preservation areas are biodiverse and fragile ecosystems in terms of susceptibility to anthropogenic impacts. These impacts have intensified in recent decades due to a lack of adequate urban planning (MEDEIROS et al., 2018).

4.2 Fontes Stream

The Fontes Stream (Figure 4) is located to the north of the downtown area. The stream was observed from its source (S16°03’38.7” W057°39’52.1”), in the Joaquim Murtinho neighborhood, to its mouth, in Malheiros Bay, located on the Paraguay River.

The most important item for the environment is vegetation. The total area covered by vegetation in the three categories (undergrowth, shrubs and trees) represented 31%. The area should be 100% preserved, if the current legislation of the Brazilian Forest Code were taken into account (BRASIL, 2012).

It is necessary to highlight that this preserved forest is a fundamental mechanism for ecosystem services, as it preserves the banks against erosion, increases soil absorption, preserves birdlife and also contributes to water quality. The artifices of urban planning in creating different spaces, which include public parks and green areas, not only contribute to the expansion of land use and its more efficient use, but also allow the improvement of quality of life, which is an essential part of the attractiveness of an urban center (CENGIZ, 2013).

The bare soil, paved and water class reached a percentage of 62%. This class includes paved and dirt roads, backyards, empty land and water. The diagnosis of each of these situations allows the public authorities to recover and transform the place for use by the general population. Urban voids (documented land or not) are potential leisure areas for a population with few resources and lacking in recreational activities.

The roads that border the streams, currently occupying this area irregularly, could be better structured or could even have a change in function, such as the creation of cycle paths, considering that the population of Cáceres uses this means of transportation (bicycle) a lot. These pathways are potential greenways. Green corridors form safe mobility networks, giving prevalence to pedestrians and to means of transportation powered by non-polluting energy, recovering native forest and incorporating the scenic value of routes and notable locations (BENEDICT; McMAHON, 2009)

In the built area class, between single-storey buildings and multi-storey buildings, a total of 7% was obtained, a relatively low percentage, given that part of the stream is in a less urbanized region of the city. However, it is important to highlight that, if public policies regarding the occupation of the area bordering the stream are not adopted, the tendency is for an increasing number of buildings to be built.

The source of the Fontes Stream is located in an area far from the city, at the end of Joaquim Murtinho street (Figure 4). It is noted that it is a very degraded area, located in a pasture field, without fence or vegetation protection and susceptible to trampling by animals (cattle), as it is located on a rural property.

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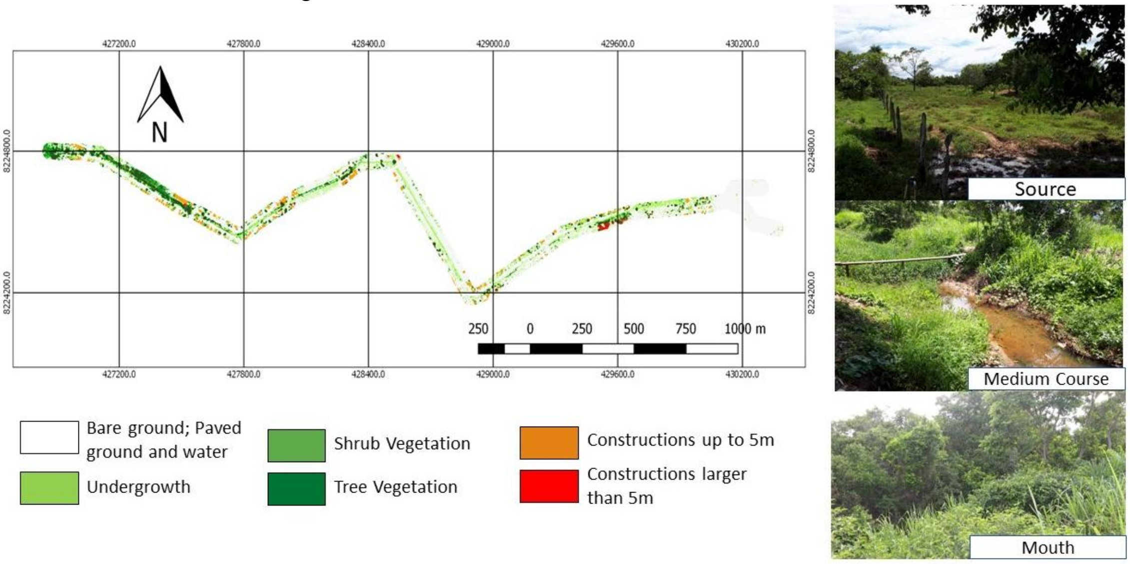
Figure 4 - Classification of land use in the Fontes Stream



Source: Elaborated by the authors, 2023.

Anthropogenic changes will continue occurring without proper planning. In the case of irregular housing, the risk lies in the occurrence of floods, in the appearance of venomous animals and in the discharge of effluents into the waters of the stream, allowing contact with diseases resulting from the lack of adequate sanitation.

According to Tucci (2008), the increase in cities causes changes in the hydrological cycle and in the natural properties of drainage. The quality of a watercourse is directly related to the changes seen in the river basin. Soil use and occupation have a fundamental influence on surface runoff into these streams and can alter their quality and quantity (GARCIA et al., 2020).

4.3 Sangradouro Stream

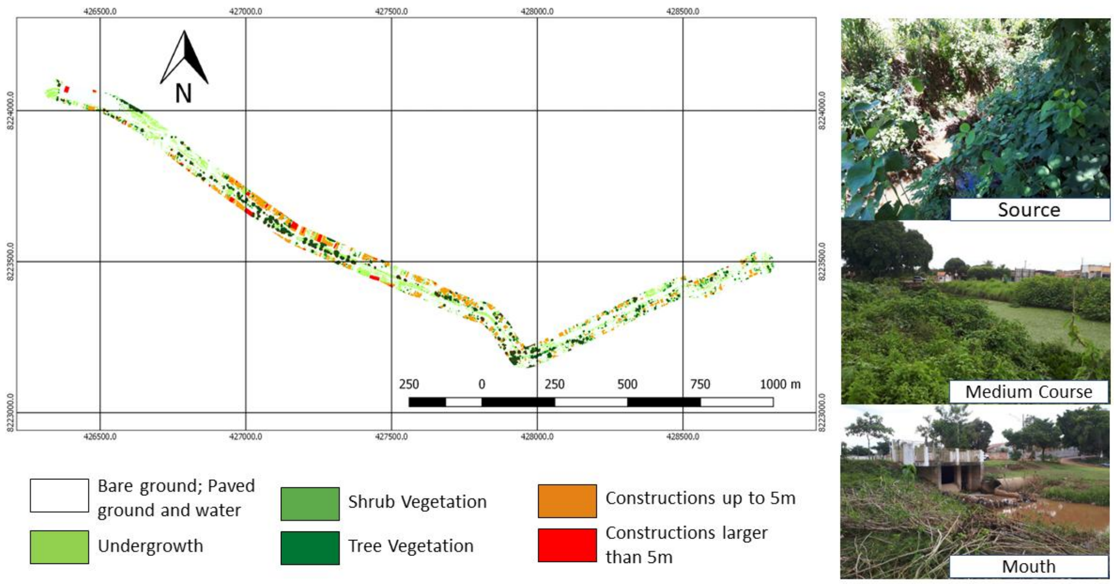
In the Sangradouro Stream, the percentage of vegetation between the three classes (undergrowth, shrub and arboreal) was 29%, with the majority (15%) being undergrowth (Figure 5), considering that the ideal would be coverage with arboreal and shrub vegetation, thus ensuring an improvement in ecosystem services, essential for conserving the watercourse. A common occurrence in deforested regions is erosion, which occurs when the soil is devoid of vegetation.

For Machado (2007), vegetation, whether native or not, is a means of preservation due to its protective functions of water, soil, biodiversity (fauna and flora), landscape and the well-being of the local population. The permanent preservation area – PPA – is not just a favor of the law, it is an act of social and environmental intelligence.

The bare soil, paved and water class obtained a coefficient of 58%, representing the majority of the studied area. As it is not a vegetated or built area, there is a potential recovery area, specifically observing each location to determine guidelines. This area is divided between paved or unpaved roads, backyards, empty lots and urban voids; however, with a more specific study, these areas can be treated in a special way for each region where the stream is located in the city.

There is the creation of green infrastructure on various scales (squares, green corridors, parks, bioswales, among others). There is much evidence from research and practice that green infrastructure provides benefits to people and society. For example, green infrastructure can support health and well-being (FRUMKIN et al., 2017); contribute to a high quality built environment (PAYNE; BARKER, 2015); reduce the urban heat island (UHI) and support environmental quality and adaptation to climate change (ZÖLCH et al., 2016). This evidence has been important to economically justify investment in green infrastructure, demonstrating its value for public policies, urban planners, the real estate development sector and others responsible for the form and quality of the built environment.

Figure 5 - Classification of land use in the Sangradouro Stream



Source: Elaborated by the authors, 2023.

The percentage of built area, divided between single-storey and multi-storey buildings, was 14% (Figure 5), and, according to legislation, the studied area could not have any type of construction, as previously mentioned.

The region in which the stream is located has medium and high density (from 4,000 to 10,427 inhabitants/km^2), mixed residential land use, commerce and services, health services and residential. The stream has a higher level of intervention, with drainage works that have altered the channel and its configuration, with changes to its transversal profile (width and depth), with a channelized stretch, completely removed riparian vegetation and intense occupation of its banks, with an area susceptible to flooding (CRUZ; SOUZA, 2016).

Silva et al. (2008) emphasized that:

> the city of Cáceres presents disorderly territorial growth, the consequence of which is the occupation of areas located on the banks of the Paraguay River, for the construction of inns, fishing grounds and subdivisions, without any concern for Permanent Preservation Areas (PPAs), which are areas protected by environmental legislation (SILVA et al., 2008, *our translation*).

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"This situation extends to the water courses that cross the urban fabric of Cáceres to flow into the Paraguay River, such as the Sangradouro Stream" (PAIVA et al., 2015).

4.4 Renato Stream

At the water source site (Figure 6), there is a large amount of debris and the water is covered by aquatic plants, making it difficult to see the riverbed. On the banks, there are few bushes. In some places, the banks are surrounded by grass and, although they are in the urban area, there are signs of animal trampling.

The area surveyed with the RPA went from the source to the mouth of the studied stream, totaling 26.51 hectares, considering its course and its Permanent Preservation Area area, which must be 30 meters starting from its bank.

The PPA presented a low percentage of tree vegetation, with only 7% of individuals over 5.3 meters tall. This information conflicts with Law 12,651/12 (Brazilian New Forest Code), which determines that PPAs must be fully conserved. Still regarding plant occupation, 32% of vegetation less than 1.3 meters in height, called undergrowth vegetation, and 6% of shrub vegetation, considering plants smaller than 5.3 meters and larger than 1.3 meter, were calculated.

As already mentioned, permanent preservation areas must be preserved in their entirety and, therefore, should be occupied by vegetation. This does not mean that these areas cannot be visited by people and animals. It is only necessary that activities with low environmental impact be carried out (BRASIL, 2012).

Therefore, areas that have suffered suppression of native vegetation must be recovered by the area holder, with the municipal agency being responsible for proposing alternatives to mitigate environmental impacts with citizens (CÁCERES, 2016).

One of the intervention measures would be planting along its entire margin up to a distance of 30 meters, however, along its course, there are 8% of buildings below 5 meters in height and 2% of buildings above 5 meters, totaling 10 % of the entire area.

Floods and erosion in the vicinity of residences are the result of irregular occupations in PPAs, transforming them into risk areas. Linked to this are the various risks of contracting diseases, due to the dumping of waste and effluents present on site (SANTANA, 2011). The irregular occupation of areas close to watercourses, such as PPAs, generates risky situations, which can lead the municipality to declare a state of public calamity. This situation is aggravated when the drainage system is not in good condition (DA SILVA et al., 2018).

Even though it is relatively low, the percentage of buildings that are within the 30 meter limit is susceptible to various risks, as previously mentioned. The risk of flooding, landslides and disease is constant. These situations are aggravated in the stream because they do not receive the minimum possible care.

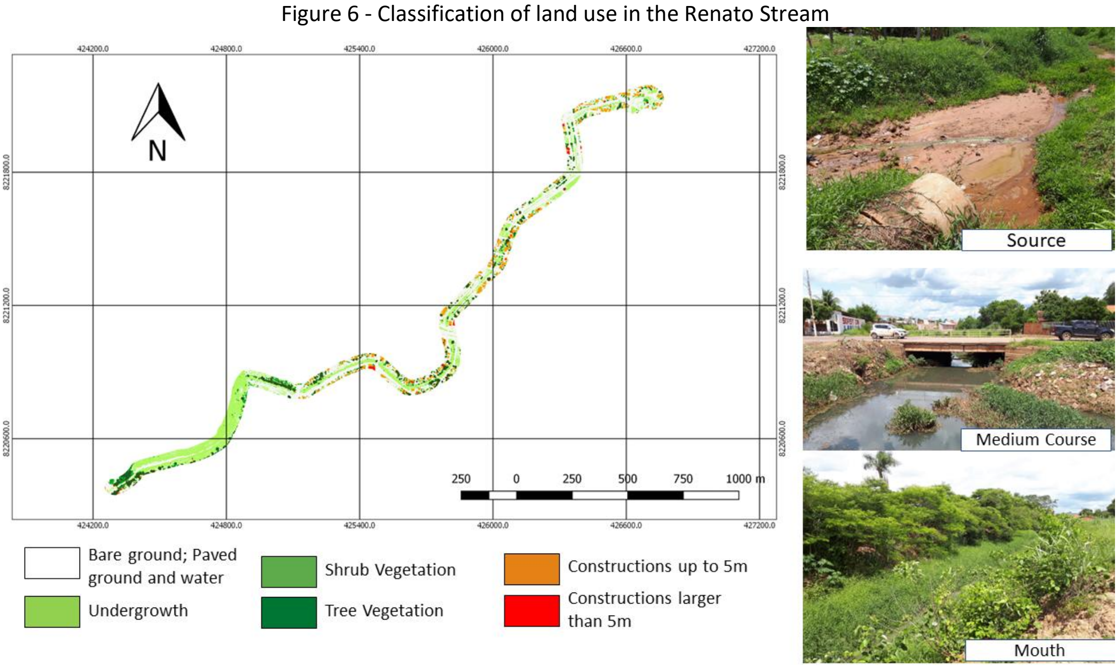
In the Environmental Code of Cáceres, Art. 55 and Art. 71 say that the release of any form of matter that causes negative impacts on the environment is prohibited, also mentioning that, if this release of effluents is authorized by the municipal environmental agency, it must undergo a treatment process (CÁCERES, 2016).

In order to avoid conflicts with residents living in these permanent preservation areas, it is recommended that, since the level of construction is relatively low, residences be maintained and intervention measures be carried out in a compensatory manner in other nearby areas.

The most worrying is the bare soil, paved and water class, with an occupancy level of 45%, which can be of public roads, paved or unpaved, backyards and sidewalk areas. This negatively contributes to the appearance of erosion and, subsequently, to the silting of the stream.

The lack of riparian forest, which leaves the soil exposed, is linked to the sedimentation of the river channel. Furthermore, the amount of garbage and sewage that is deposited influences the increase in siltation and worsens floodings and inundations (PORATH, 2004).

Figure 6 - Classification of land use in the Renato Stream



Source: Elaborated by the authors, 2023.

5 CONCLUSION

Despite the low visibility given to PPAs in urban areas and the need for more specific studies on the subject, they can be classified as one of the mechanisms to combat the degradation scenario in Brazilian cities. The conservation of native vegetation in these areas, in addition to contributing to the ecosystem balance, is also important for regulating floods and is a valuable contribution to cities, linked to reducing flooding and maintaining water supply.

However, the limits of PPAs are constantly infringed, either by irregular occupation or by channeling the banks of streams. The creation of legislation on PPAs could have created millions of square meters of green areas in Brazilian cities, as Macedo (2012) warns.

It is necessary to look for a different way of idealizing cities, looking for a new aesthetic, in which the city would not be the negation of nature. The vegetation of PPAs, in this new aesthetic, would be natural, beautiful and pleasant and the population could create a new affection for the open areas of the cities, especially the watercourses.

The survey and classification of images using RPAs (Remotely Piloted Aircraft) has a great relevance because, through images, it is possible to create control and observation strategies that would not have been possible before with only one equipment and reduced manpower. A product like orthomosaic generates precise images of vegetation, buildings, the presence of water and other elements, which guaranteed the accuracy of the classification and analysis of the PPA of the studied stream. These are instruments that facilitate forensic and environmental control actions by inspection agencies.

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