FRAGILITY AND ENVIRONMENTAL RELEVANCE OF AN AREA OF THE CERRADO IN THE DF: PEDOGEOMORPHOLOGICAL SUBSIDIES FOR THE PROTECTION OF DIFFUSE RIGHTS

FRAGILIDADE E RELEVÂNCIA AMBIENTAL DE UMA ÁREA DE CERRADO NO DF: SUBSÍDIOS PEDOGEOMORFOLÓGICOS PARA A PROTEÇÃO DE DIREITOS DIFUSO

FRAGILIDAD Y RELEVANCIA AMBIENTAL DE UNA ZONA DEL CERRADO EN EL DF: SUBSIDIOS PEDOGEOMORFOLÓGICOS PARA LA PROTECCIÓN DE DERECHOS DIFUSOS

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ABSTRACT

This article investigates both foundational technical skills and broader socio-cultural literacy practices among Mebêngôkre/Kayapó indigenous students, taking as its locus the Municipal Elementary School Marechal Rondon, located in São Félix do Xingu, in the state of Pará. The discussion begins with a historical and political analysis of indigenous school education in Brazil, highlighting the provision of bilingual and intercultural education to indigenous peoples. It examines the factors that motivate indigenous families to migrate from their traditional communities to urban areas, the participation of these communities in the formal school environment, the teaching methodologies applied to students, and the main everyday challenges faced by both teachers and students. Drawing on a qualitative approach that included semi-structured interviews and participant observation, a case study was conducted, revealing the primary obstacles to ensuring bilingual and intercultural education for the Mebêngôkre/Kayapó people: the lack of bilingual teaching materials (Portuguese-Mebêngôkre/Kayapó), the absence of teacher-training programs (both basic and continuing), and the lack of consistent public policies. The study concludes with recommendations

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focused on teacher training, the production of intercultural teaching materials, the centrality of family participation in indigenous school education, and the formulation of more inclusive evaluative pedagogical strategies.

Keywords: Brazilian Cerrado.

RESUMO

Este artigo investiga processos de alfabetização e de letramento de estudantes indígenas da etnia Mebêngôkre/Kayapó e adota, como lócus, a Escola Municipal de Ensino Fundamental Marechal Rondon, localizada em São Félix do Xingu, no Pará. A discussão parte de uma análise histórica e política da educação escolar indígena no Brasil e enfatiza a oferta de educação bilíngue e intercultural aos povos originários. São examinados fatores que motivam a migração de famílias indígenas de suas comunidades para a zona urbana; a participação das comunidades tradicionais no ambiente escolar formal; as metodologias de ensino aplicadas aos estudantes; e os principais desafios enfrentados por professores e por estudantes no cotidiano. Por meio de uma abordagem qualitativa, que incluiu entrevistas semiestruturadas e observação participante, realizou-se um estudo de caso em que se evidenciaram, como principais entraves à garantia de educação bilíngue e intercultural aos indígenas da etnia Mebêngôkre/Kayapó, a falta de materiais didáticos bilíngues (português-Mebêngôkre/Kayapó), de programas de formação docente (básica e continuada) e de políticas públicas consistentes. A conclusão do estudo aponta para recomendações voltadas à formação de professores, para a produção de materiais didáticos interculturais, para a centralidade da participação familiar na educação escolar indígena e para a formulação de estratégias pedagógicas avaliativas mais inclusivas.

Palavras-chave: Cerrado Brasileiro.

RESUMEN

Este artículo investiga la alfabetización y los procesos de alfabetización entre estudiantes indígenas de la etnia Mebêngôkre/Kayapó, centrándose en la Escuela Primaria Municipal Marechal Rondon, ubicada en São Félix do Xingu, Pará. La discusión comienza con un análisis histórico y político de la educación escolar indígena en Brasil y enfatiza la provisión de educación bilingüe e intercultural a los pueblos indígenas. Se examinan los factores que motivan la migración de las familias indígenas desde sus comunidades hacia las zonas urbanas; la participación de las comunidades tradicionales en el entorno escolar formal; las metodologías de enseñanza aplicadas a los estudiantes; y los principales retos que enfrentan docentes y estudiantes en su vida diaria. A través de un enfoque cualitativo, que incluyó entrevistas semiestructuradas y observación participante, se realizó un estudio de caso en el que se destacaron los principales obstáculos para garantizar la educación bilingüe e intercultural al pueblo indígena de la etnia Mebêngôkre/Kayapó, a saber, la falta de materiales de enseñanza bilingües (portugués-mebêngôkre/kayapó), programas de formación docente (básica y continua) y políticas públicas consistentes. Las conclusiones del estudio apuntan a recomendaciones para la formación docente, la producción de materiales didácticos interculturales, la centralidad de la participación familiar en la educación escolar indígena y la formulación de estrategias pedagógicas evaluativas más inclusivas.

Palabras clave: Cerrado Brasileño.

1 INTRODUCTION

The Cerrado is the second largest biome in South America, being present in all Brazilian regions. It occupies about 23.3% of the national territory (IBGE, 2018). Given the endemic of its species and their threat, this biome is considered one of the world's biodiversity hotspots. It is also an important watershed, where the springs of the three important Brazilian and South American hydrographic basins (Tocantins, São Francisco and Prata) are located, resulting in a high potential for recharging surface and underground water resources, as well as for maintaining their quality. Grassland phytophysiognomies such as Campo Limpo, Campo Sujo and Campo Rupestre are found, as well as forest formations such as Cerradão, Mata Seca, Mata de Galeria and Matas Riparians (MMA, 2022). Despite its environmental importance, the Cerrado has been experiencing constant degradation over time, resulting in 22% suppression of its remaining vegetation between 1986 and 2019, increasing the number of fragments by 20%, with an increase in degradation indices such as isolation and edge effects. In addition, only 6% of these areas are on public lands, making it difficult to adopt effective conservation strategies (Pompeu et al., 2024). Nunes & Castro (2021) point out that the degradation of phytophysiognomies in the Cerrado causes impacts on water resources, such as the silting up of surface water bodies.

The Cerrado biome is located mainly in the Brazilian Central Plateau. It is naturally formed by vegetation such as Campo Cerrado, Cerrado Sensu Stricto, Cerradão and Veredas, highly adapted to less fertile soils and the frequent occurrence of fire. It is the second largest Brazilian biome, occupying about 21% of the country's area. The historical climate of the region is characterized by mild temperatures, ranging between 22ºC and 27ºC, and total annual rainfall often around 1500 mm. The weathering mantle is deep and presents strong modification, which results in acidic, not very fertile, rich in exchangeable aluminum and deep soils (Klink & Machado, 2005; de Oliveira et al., 2023). Physical characteristics of the soils of this biome, such as the abundant presence of gravel and concretions, hydromorphism, high stony or rocky soil, low water retention capacity, sandy or medium texture, and reduced depths confer limitations to plant development. An exception can be made to the Oxisols, which are mostly present in the plateaus. Latosols are the most abundant soils in the Cerrado and present, among other common characteristics, texture ranging from medium to very clayey, acric character (high levels of iron and aluminum oxides), positive ΔpH, low natural fertility, low cation exchange capacity and high saturation by aluminum. Geomorphologically, the Cerrado is found mainly in plateaus (Planalto Central Brasileiro - PCB), but it also occurs in dissected areas with relief ranging from gentle to mountainous. The PCB, which represents the main area of the Cerrado, is part of an ancient and stable continental landmass, unaffected by maritime invasions and glaciers, where anthropic, geological, and pedological processes allowed the formation of an extensive flat surface (de Oliveira et al., 2023).

The Federal District (DF) is part of the Cerrado biome. Martins et al. (2004), when mapping the landscape units of the Federal District at a scale of 1:100,000, divided the territory of this federation unit into 18 units. In general, in geological terms, the Bambuí and Araxá Groups are present, dating from the Neoproterozoic; in addition to the Canastra and Paranoá Groups, dated from the Meso/Neoproterozoic. Psamopellite-carbonate, clayey metarhemit, medium quartzite, sandy metarhemite, slate and metasilstone units are observed. Reatto et al. (2004), who elaborated the soil map of the Federal District at a scale of 1:100,000, found the following classes represented, compatible with those predominant in the Cerrado: Latosols, Quartzarenic Neosols, Ultisols, Nitosols, Cambisols, Chernosols, Plintosols, Gleisols, Spodosols and Fluvic Neosols. The landscape exhibited by the Federal District is complex and results from the interaction between geological, geomorphological and pedological factors, conferring a marked compartmentalization. The geological and pedological formations condition the geomorphology found, resulting in plateaus, abrupt edges and embedded valleys. These conditions reflect different degrees of dissection and stabilization of the relief, leading to the development of deep Red and Red-Yellow Latosols at the tops of the plateaus, while Cambisols, Ultisols and Plinthosols are mostly found in the enconstas (edges of plateaus). In the valleys and intermediate plateaus, Latosols, Cambisols, and hydromorphic soils can occur (Martins et al., 2004). This high heterogeneity reflects direct implications on its biodiversity, vulnerability to soil loss by erosion, hydrology and hydrogeology, being fundamental for land use and occupation planning, as well as for efficient environmental planning. It is also essential for the assessment and monitoring of environmental impacts, as well as for defining conscious and efficient urbanization strategies.

Environmental protection and conservation are not just an abstract collective interest, but a fundamental diffuse right. Diffuse rights are enshrined as third-generation rights, of solidarity and fraternity, taking care of the set of transindividual rights. Therefore, they are non-individual rights, which belong to a collectivity of people, whose ownership belongs to the whole society, whether present or future. One of the main examples of diffuse law is environmental law. In this sense, it is marked by the principle of intergenerational and transgenerational solidarity, as an ecologically balanced environment is everyone's right, covering present and future generations, as defined in Article 225 of the Federal Constitution of 1988 (Pontes, 2019).

For all the above, the present work aims to evaluate the fragility and environmental importance of an area of the Cerrado belonging to the microbasin of the Tamanduá Stream, located in Brasília – DF, currently under the possession of Embrapa (2025) Vegetables, as well as to make an assessment of the potential for degradation caused by disorderly urbanization from the perspective of diffuse rights, using Geographic Information Systems (GIS) as the main tool. Due to the large volume of data generated, the article was divided into two parts, the first having the objective of characterizing the mapping of geology, pedology, hydrogeology and land use and occupation of the study area.

2 MATERIAL AND METHODS

2.1 AREA OF STUDY

The study area is located in the Federal District, being part of the Tamanduá Creek watershed, belonging to the Descoberto River Basin. It has been in the possession of Embrapa (2025) Vegetables since 1972, during which time it has been kept preserved in almost its entirety. The delineation of the area was carried out manually using satellite imagery in Google Earth Pro. Figure 1 shows the delineated area, while Figure 2 shows a broad three-dimensional perspective of the region.

Figure 1

Delineation of the polygon referring to the study area (in yellow).

Figure 2

Three-dimensional perspective (East-West direction) of the study area.

2.2 DATA AND SOURCES USED

The following secondary databases were used to conduct this work:

Google Satellite images with a spatial resolution of 0.5 m x 0.5 m, obtained through Google Earth Pro.

SRTM (Shuttle Radar Topography Mission) images with a spatial resolution of 30 m x 30 m, obtained in raster format (GeoTiff).

Vector layers (shapefile) of soil classification, soil depth, soil texture, soil infiltration capacity, slope, geomorphological compartmentalization, fractured and porous hydrogeology, lithostatigraphy, risks of contamination and recharge of aquifers and land use and occupation, obtained from the SISDIA – DF database.

Vector layers (shapefile) referring to lithostatigraphy and hydrogeology obtained from the RIGEO database.

Raster layer (GeoTiff) referring to Land Use and Occupation, at a scale of 1:100,000, obtained from the MapBiomas database, referring to the year 2023.

A set of primary data related to the physicochemical analysis of soil samples collected in the study area was also used.

2.3 SPATIAL DATA PROCESSING

All geospatial data processing was conducted using the open access software QGIS in its version 4.42.3. The main procedures adopted were:

2.3.1 Clipping and overlapping layers

The vector and raster layers were added to QGIS and cropped by the extension using the Clip tool. Subsequently, overlaps were performed for integrated analysis of the evaluated factors.

2.3.2 Generation of contour lines and establishment of slope classes.

Initially, a mosaic of SRTM images was constituted, obtained at Topodata/INPE, with the following sheets: 15S48ZN, 15S49ZN, 16S48ZN, 16S495ZN. Subsequently, the Raster path > Contour Extraction was used, with equidistance equal >to 5 m, for the design of the contour lines. The contour lines were determined for the enlarged terrain and later cut to represent the studied area, with an equidistance of 5 m. To generate the map of slope classes, the MDE was first redesigned in metric coordinates (SIRGAS 2000/UTM). Then the following path was used: Raster > Analysis > Slope. The slope values were determined as a percentage and then reclassified according to SIBICS (2025) using the raster calculator. Finally, all the generated maps have been customized in order to be more visible when making maps and the analyses that require them.

2.3.3 Spectral classification of land use at scale 1:1,000

To obtain a detailed map of land use and occupation, on a local scale, a Google Satellite image with a spatial resolution of 0.5 m x 0.5 m was used. For this purpose, semi-automatic classification was conducted in the SCP complement in its version 8.5.0 (Congedo, 2021). The spectral patterns were determined by drawing polygons representative of each land use. Subsequently, the automatic classification was carried out using the Spectral Angle Mapping algorithm.

2.3.4 Exploratory classification and chemical, physical and physicochemical characterization of soils on a scale of 1:10,000

Based on previous knowledge about soils in the study area and the Brazilian Cerrado, especially in the Federal District (DF), as well as their relationship with the landscape and geomorphological features, representative sampling points were chosen. To this end, sampling and analysis of soils present in the lowest area of the landscape (Intermediate Plateau) and in the Borda de Chapada were carried out. The collections took place between April 8 and 15, 2024, through the opening of trenches with dimensions of 60 cm x 60 cm x 60 cm (Figure 3). The area was divided into four plots, within which eight simple samples were collected to compose a composite sample, characterizing the layers of 0-20 cm and 20-40 cm. Examples of sampling points and the landscape features they represent are shown in

Figure 4. Field visits were also carried out. In addition, a Google Satellite image of the area with a spatial resolution of 0.5 m x 0.5 m was used as the base image for the delineation of the mapping units. The MDE and the contour lines were also supported for the layout of these units. The definition of the mapping units was also aided by the use of semi-automatic sorting.

Figure 3

Image of the trenches opened for soil collection. A) Open trench for sample collection from plot 1 (AS 01); B) Open trench for sample collection from plot 2 (AS 02); C) Open trench for sample collection from plot 3 (AS 03); D) Open trench for sample collection from plot 4 (AS 04).

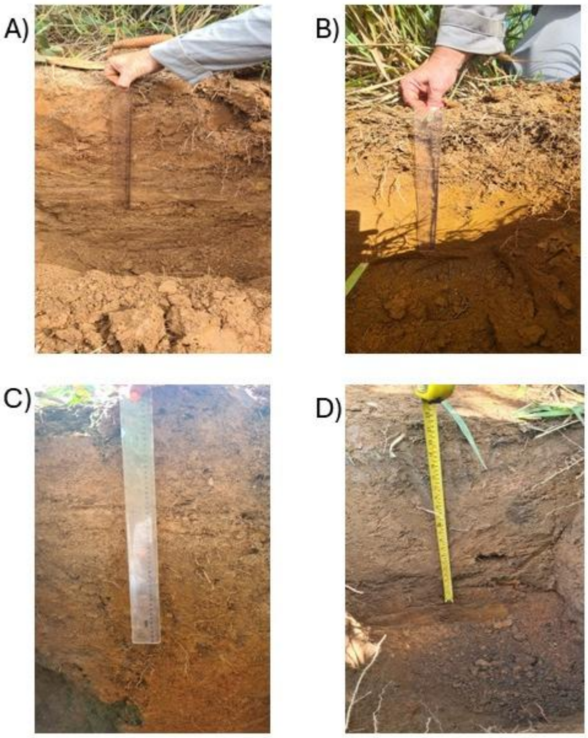
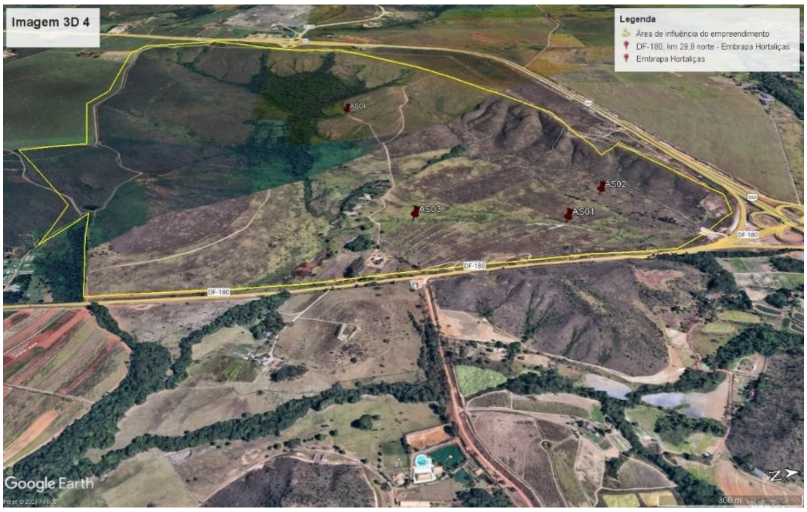


Figure 4

3D image of the study area containing the location of four examples of sampling points and their positions in the landscape in the study area.



The physicochemical characterization of the soil samples was carried out using protocols contained in Teixeira et al. (2017). Soil texture, silt/clay ratio, pH in water, available phosphorus in Melich 1, exchangeable cations (Ca, Mg, K, Na and Al), potential acidity (H+Al), sum of bases (SB), effective (t) and total (T) cation exchange capacity, base (V) and aluminum (m) saturation, sodium saturation index (IsNA), total organic carbon (TOC), organic matter (MOS) and micronutrients (B, Cu, Fe, Mn, Zn, S).

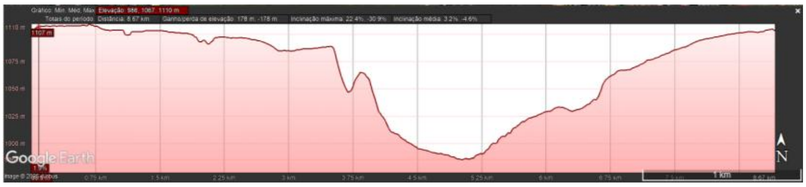
3 RESULTS AND DISCUSSION

Focusing on characterization studies of the Cerrado is necessary to increase knowledge about its physical environment and allow the improvement of public conservation policies. It is important to obtain consistent databases aiming at the construction of models of devastation and susceptibility to degradation, as well as the respective solutions to these problems. Although there is vast material produced on the physical environment of this biome, few initiatives have sought to obtain detailed products such as, for example, geomorphological maps and other cartographic assets on a local scale. Understanding the dynamics of the relief, for example, allows the determination of areas with a higher risk of degradation through water erosion, their association with vegetation classes and soil classes, their agricultural suitability and the production systems to be used. The use of semi-automated methods can reduce subjectivity and make these mappings more accurate (Rocha et al., 2022). It is in this sense that the analysis of the results of the present work will be carried out.

The elevation profile of the study area can be seen in Figure 4. Through the analysis of the average elevation profile, it is possible to determine that the area has the following minimum, average and maximum altitudes, respectively, in relation to sea level: 986 m; 1,067 m; 1,110 m. The average line drawn was 8.67 km long, with a loss of elevation between the highest point and the lowest point of 178 m, which is a significant loss of topographic gradient. The maximum slope was -30.9%, corresponding to the steepest transition between the Plateau (Chapada) and the Intermediate Plateau, referring to the feature commonly called Borda de Chapada. The valley referring to the local hydrography is clearly embedded, which increases the effects of surface runoff as an important process for recharging surface water resources. However, when using the soil non-rationally, there is a high risk of soil loss through erosion, which can lead to siltation of water bodies, as shown by the works of Baldassarini & Nunes (2014), Silva et al. (2015) and Vieira et al. (2023). Castro et al. (2017) demonstrate the importance of preserving riparian forests as a strategy to reduce the impacts of erosive processes on the quality of water resources.

Figure 5

Average elevation profile of the study area.



Figures 5 and 6, in turn, show the Digital Elevation Model (DEM) obtained from SRTM images with 30 m spatial resolution, as well as its contour lines with equidistance of 5 m. The delineation of contour lines derived from DEM with equidistance of 10 m using interpolation in QGIS, based on Landsat images with 30 m resolution, generated results consistent with conventional methods of tracing these features (Mendes et al., 2007) and the use of the COP-30 model, also with 30 m resolution, showed good accuracy (5 m) when modeling the terrain in areas of the Brazilian Midwest (DF and GO) (Cremon et al., 2022). The use of the MDE as a way to assess geomorphological features of the Cerrado has been carried out in studies such as that of Silva et al. (2015). The analysis of the DEM and the contour lines reinforces the findings of the elevation profile. The darker features (tending to black) constitute the highest part of the landscape, with an altitude of more than 1,000 m. In them, there is greater spacing between the contour lines, denoting the presence of flat relief. These correspond to the Chapadas, which have a deep mantle of weathering. The Chapadas occur in regions of the states of the following states: BA, GO, DF, MG and MS. They are characterized by altitudes above 800 m, with flat areas at the top and small slopes (around 4%). Its predominant form is concave-divergent (Rocha et al., 2022). In the study area, they occur mainly in the north, northwest, southeast and south.

Figure 6

Digital Elevation Model (DEM) - SRTM with spatial resolution of 30 m, of the study area.

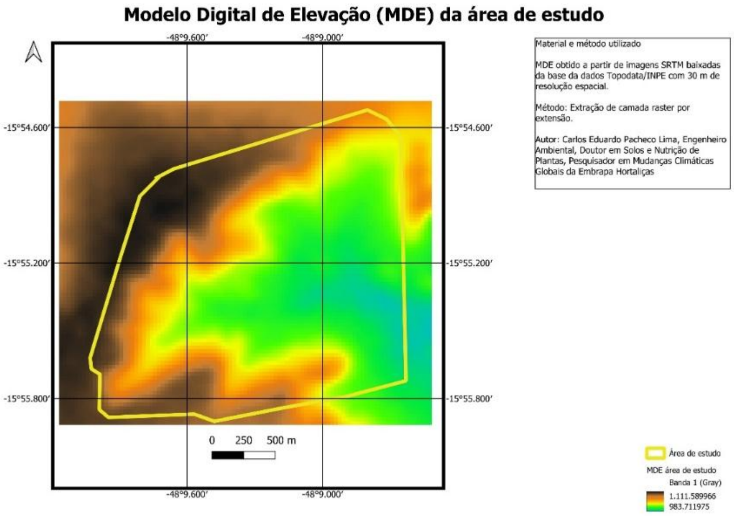
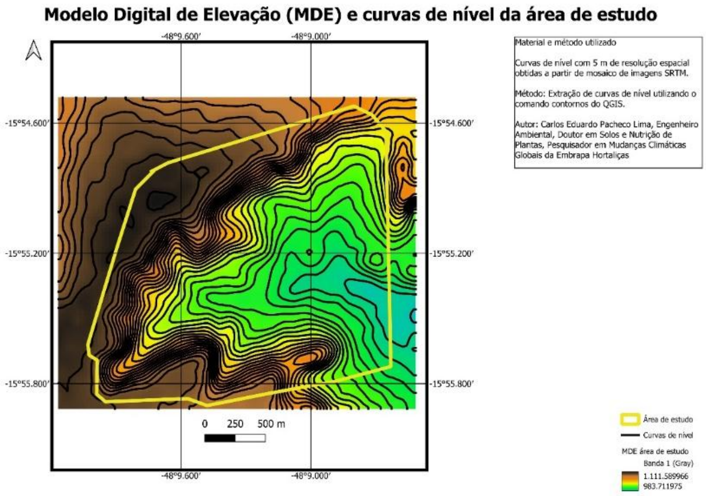


Figure 7

Superposition of the contour lines with equidistance of 5 m to the Digital Elevation Model (MDE) of the study area.



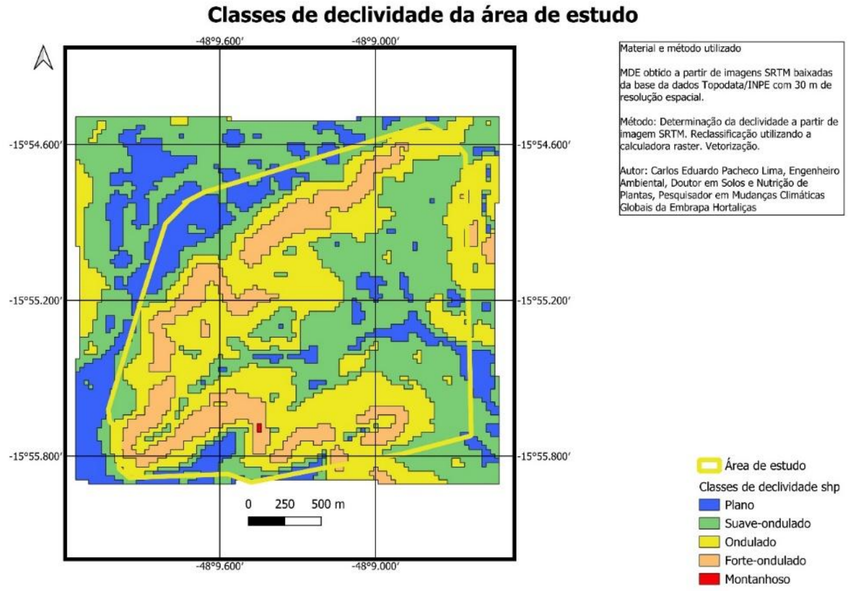
The orange and dark orange features, on the other hand, refer to the Borda de Chapada, the area of greatest slope in the region, a fact confirmed by the proximity of the contour lines. These are highly dissected areas where there is a high risk of erosive processes. The Chapada Edges are consistent with the classification of Dissected Plateaus described by Rocha et al. (2022), corresponding to areas with an altitude greater than 800 m and slopes greater than 4%. Its predominant forms are concave-divergent or convex-divergent, with the former predominating in the present study. The yellow region, in turn, marks the transition between the steeper area and the Intermediate Plateau (greenish and bluish features), and may also be linked to the concept of Dissected Plateaus previously described. In these two areas, the Serras can also be found occasionally, which also according to Rocha et al. (2022) are conceptualized as areas with a slope of more than 4%, also presenting concave-divergent and convex-divergent features.

In the greenish and bluish areas, a new distancing of the contour lines begins, denoting the smoothing of the relief that marks the end of the Borda de Chapada. They mark, therefore, the presence of flat to smooth-undulating relief which, being in the lowest part of the landscape, constitutes an area of deposition of sediments from the Chapadas, but which also present a relatively intense and deep weathering mantle, given the lasting geotectonic stability, maintained over a long period of geological time (Neves et al., 2017). These features, commonly called Intermediate Plateau, resemble the one classified by Rocha et al. (2022) as Lowered Plateau, with a slope of up to 4% and having as predominant forms those concave-divergent and convex-divergent ones.

The slope values of the study area ranged from 0.087% to 51.63%, which, at first, denotes a relief with great variation. However, when observing the map of slope classes (Figure 7), it is clear that there is a predominance of flat and smooth-undulating areas. Next, there are features with undulating and strong-undulating relief, associated with the Borda de Chapada. Finally, only a small point south of the area, also related to a Chapada Edge, was classified as having presented mountainous relief. The entire set of results observed are in line with the predominant landscape in the Brazilian Central Plateau, especially in the Federal District, as shown by Martins et al. (2004).

Figure 8

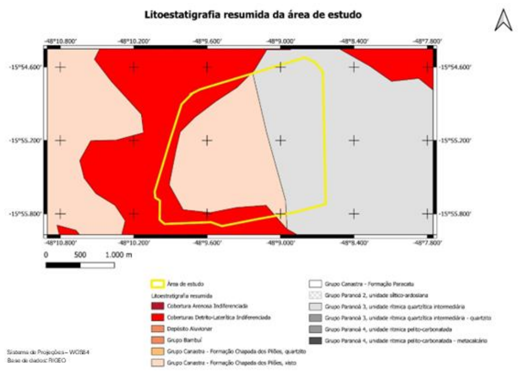
Slope classes of the study area.



The lithostatigraphy of the region is composed of undifferentiated detritus-lateritic covers on the northern, southern, eastern, northeastern and southeastern edges, by the Canastra Group – Chapada dos Pilões Formation in the center and Paranoá Group 3 – Intermediate quartzite rhythmic unit to the west, northwest and southwest (Figure 8). The predominant rocks are fine to medium quartzites with metasiltite intercalations, rare conglomerate lenses, metargillites and slates, components of the Paranoá Group 3. In the Canastra Group, schists with quartzite intercalations predominate. Finally, the undifferentiated detrito-lateritic covers are mostly composed of Oxisols with gravel levels (Figure 9) (IPE-DF, 2020).

Figure 9

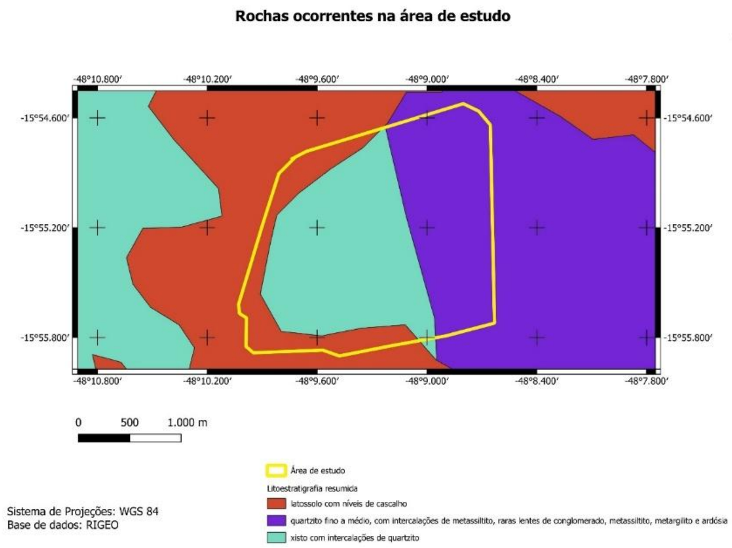
Summarized lithostatigraphy (Geology) of the study area.



Source: RIGEO.

Figure 10

Rocks and other source materials existing in the study area.



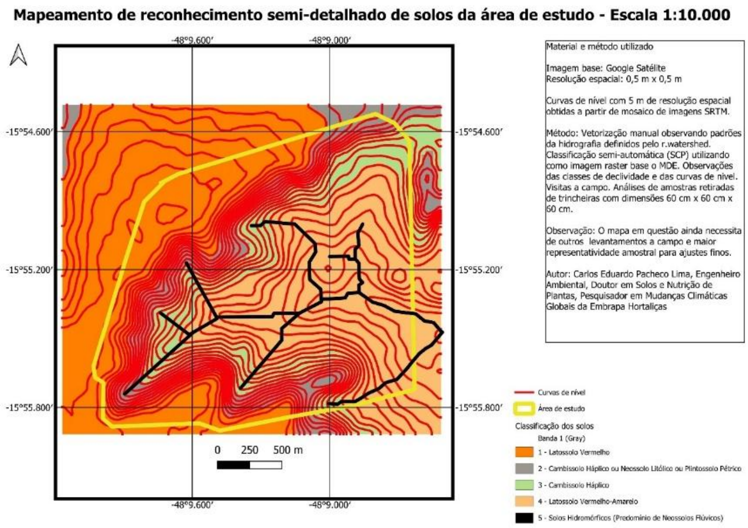
Source: RIGEO.

These features result in a geomorphological compartmentalization typical of cerrado environments, in space those constituents of the geomorphology of the Federal District. Such compartmentalization, on smaller scales than that used in the present study, is available in official materials such as those available in SISDIA (2025). The available maps are less detailed than those observed at the local level in the MDE, in the map of slope classes, in the contour lines and in the high-resolution satellite images. In this, features such as Borda de Chapada, Chapadas and Intermediate Plateaus are found, while in the official databases the entire area would be under a mapping unit classified as Intermediate Plateau.

From the present study, it was possible to detail the soil mapping that existed for the area (scale 1:100,000). Figure 10 shows the semi-detailed soil map (scale 1:10,000) obtained in the present work, as well as its relationship with the local relief, represented, in this case, by the superimposition of the contour lines. The mapping was carried out based on high resolution satellite images (0.5 m x 0.5 m) and I use auxiliary tools and materials such as semi-automatic classification using the SCP complement of QGIS and the support of the MDE elaborated from SRTM images with a resolution of 30 m, contour lines drawn with an equidistance of 5 m, field visits and soil collection and analysis in 32 trenches of 60 cm x 60 cm x 60 cm, constituting four composite samples representative of four plots of the Intermediate Plateau (lower part of the landscape) and the final part of the plateau edges. Figure 16 shows examples of the location of the samples and the plots represented. All these data made up the Semi-Detailed Reconnaissance Mapping of soils in the area, at a scale of 1:10,000. Maps with large scales such as the one used in the present work are recognized as useful for local evaluations, while maps at intermediate scales such as 1:100,000, for example, provide regional information. The scale of 1:10,000, due to its detail, has a tolerable error of about 2 m (IBGE, 2018).

Figure 11

Relationships of the relief features with the semi-detailed reconnaissance map at a scale of 1:10,000 of the soils of the study area.



In Figure 10 it is possible to perceive a clear correspondence of the soil classes with the relief features found in the study area. It is observed that those features of the highest parts of the landscape (Chapada) correspond to a greater spacing of the contour lines, corresponding to the flatter part of the landscape, as can be confirmed in the MDE and in the map of slope classes. Good drainage, flattened relief and the tropical climate lead to an intense weathering mantle with a predominance of soils with a hue of 2.5 YR and chroma greater than or equal to 3, characterizing red (SIBICS, 2025). The Red Latosols may be associated with detrito-lateritic covers, according to the relationship very clearly defined in the present mapping, when the lithostatigraphy and pedology overlap. Such soils are associated with the flat to gently undulating relief found in Chapadões do Planalto Central Brasileiro (Ker, 1997). The reddish color is related to the higher levels of hematite in the clay fraction, which is made possible by the oxidation of Fe2+, a process favored in conditions of high weathering, higher levels of iron in the source material and very well-drained soils.

Figure 10 shows that the dominant soils in the study area, constituted by the yellow polygon, are the Red-Yellow Latosols. The Red-Yellow Latosols have a higher Goethite/(Goethite + Hematite) ratio, and are formed mainly under conditions that are linked to lower iron contents in the source material, low temperatures, higher moisture content and organic matter content, in addition to lower pH valres (Melo et al., 2001). Part of these conditions are present in the Intermediate Plateaus, components of the geomorphology of the landscape of the study area, which is related to a portion of the landscape closely linked to the accumulation of previously weathered sediments, in addition to the accumulation of water due to the surface runoff of the Chapadas, or even higher levels of the water table. Ker (1997) also associates the Red-Yellow Latosols as one of the dominant soil classes in the Central Plateau and Reatto et al. (2004), in addition to Martins et al. (2004) point to them as part of the landscape of the Federal District. Red-Yellow Latosols can occur on stable surfaces, but less old and intensely weathered than those occupied by Red Latosols. They can also appear in intermediate positions in the landscape, between plateaus and depressed areas (SIBICS, 2025).

The trenches opened for soil sampling have characteristics common to the Haplic Cambisols (Figure 3A), probably latosolic, such as lighter hue, structure tending from granular to subangular blocks, in addition to transition of unclear horizons, indicating intermediate levels of development. Its position in the landscape, in a steeper area, corroborates the morphological analysis. According to the Brazilian Soil Classification System (SIBICS, 2025), Haplic Cambisols are poorly weathered soils, which have an incipient B horizon, underlying any type of surface horizon that does not meet the requirements to be classified and classified into other classes. They may also have less defined color and structure. On the other hand, the latosolic happlic cambisols are those that have an incipient B horizon with morphology similar to that of the latosolic B, but with one or more physical, chemical or mineralogical attributes that do not meet the requirements to be classified as latosolic B. The presence of these soils in dissected valleys in the Federal District, as well as in Borda de Chapada, was also observed by Reatto et al., (2004) and Martins et al., (2004). In a field visit to the studied area, it was also possible to evidence the presence of these soils in their concrete form, as can be seen in Figure 18. The formation of ferruginous concretions was also found in some points of the Red-Yellow Latosol.

Figure 12

Soil with a large amount of ferruginous concretions found in the study area.

The other examples of open trenches, represented by Figures 3 (B, C and D), point to the presence of Red-Yellow Latosols in areas of the Intermediate Plateau, a statement corroborated by the position in the landscape of the samples collected and in field visits, which is common to be observed in the Federal District, as shown by Reatto et al. (2004) and Martins et al. (2004). Morphological characteristics such as structure closer to that of the granular area, a more intense color tending to reddish brown (the trenches were opened during the dry season, which may reflect, in some cases, in a color closer to yellow) and greater physical homogeneity of the soil profile were observed. The relationship between oxidic mineralogy and the granular structure of Oxisols was verified in the work of Pessoa et al. (2024).

It was also possible to observe a better defined A horizon, with dark color and more striking thickness, in samples collected under forest formations, referring to riparian vegetation in PPAs. The Red-Yellow Latosols have a latosolic B horizon and mixed colors between red and yellow, characterizing intermediate hues or color association, without the light predominance of red or yellow. These colors reflect mixed drainage and mineralogy conditions that differ them from Red Latosols or Yellow Latosols (SIBICS, 2025).

Goethite and Hematite are the main iron oxides found in tropical soils and are responsible for giving the red, red-yellow or yellow coloration, depending on their proportions (Schaefer et al., 2008). The presence of Goethite in tropical soils is favored by low Fe contents, high organic matter contents, and acidic pH (Fink et al., 2016). The position of the area in Intermediate Plateaus leads to the constant deposition of water and sediments from the Chapadas, in addition to being more susceptible to variations in the level of the water table (Silva et al., 2022). These conditions hinder the evolution of the soils there, and therefore do not happen as intensely as that observed in the Red Latosols found in the

Chapadas. The constant renewal and limiting drainage conditions are potentially forming Goethite to the detriment of Hematite, a condition that would generate the Red-Yellow coloration. Red Latosols are found only in the upper part of the landscape, in the Chapadas, where better drainage and flat to gently undulating relief favor the process of intense weathering and the formation of hematite. The flooded areas, in turn, are of small width as observed in the field, probably predominating the formation of Fluvic Neosols.

The analytical data presented in Table 1 reinforce the understanding previously reported. It is possible to see that the AS01 sample is the only one to present a high silt/clay ratio, 1.19, which suggests the presence of younger soil, which are the Haplic Cambisols. The collection of the simple samples that made up this composite sample were carried out in more sloping areas, reinforcing this statement. Chemical analysis of the composite sample indicates marked dystrophy in the superficial layer and borderline condition between dystrophy and eutrophy in the subsurface horizon. The morphological analysis showed characteristics of oxisols, such as structure and depth. Therefore, they were classified as Haplic Tb Dystrophic Latosolic Cambisols. The texture of these soils is average, which may indicate subsurface loss of clay by erosive processes. However, it is likely that in more inclined areas transitions may occur between Dystrophic Haptic Cambisols Tb, Haplic Cambisols Tb Concretionary Dystrophic (also observed in the field), Litholic Neosols or even Plinthosols. On the other hand, samples AS02, AS03 and AS04 have characteristics typical of Latosols, such as a low silt/clay ratio, 0.33, 0.10 and 0.57, respectively. The threshold for classification as this class is 0.6 for clay soils and 0.7 for soils with medium texture (SIBICS, 2025). They also have a very clayey (AS02) or clayey (AS03 AND AS04) texture. Dystrophy is pronounced, indicated by low base saturation. The exchangeable aluminum contents, however, were classified as medium to very low (Ribeiro et al., 1999), indicating a possible complexation of this cation by organic matter, which presented levels classified as medium to high (Ribeiro et al., 1999). These results are in agreement with those of soils found in the Central Plateau (Ker, 1997) and the higher levels of organic matter may be associated with the good degree of conservation of the area, with the preservation of primary or secondary vegetation being of great relevance to this fact.

Barbosa et al. (2009), when analyzing the geomorphology and its relationship with the soils of a toposequence of the Paranoá Group, in the Federal District, described the presence of Red Latosols as dominant in the Chapadas and the Red-Yellow Latosols in deposition areas, as found in the present work. These authors also determined that the differentiated color between these Latosols is linked to a higher proportion of hematite in the Red Latosols, while in the Red-Yellow Latosols this mineral is found in a smaller proportion. Goethite, in turn, is more abundant in the Red-Yellow Latosols and is associated with the geomorphological position in which the oscillation of the water table and deficient drainage favors the formation of soils in an intermediate stage of evolution, including the presence of a litholithic horizon formed mainly by ferruginous concretions (Macedo & Bryant, 1987; Barbosa et al., 2009). Bryant & Macedo (1990) and Fontes & Weed (1991), in turn, showed that Goethite has lower reductive solubility than Hematite, which is one of the predominant factors for the possible loss of Hematite and yellowing of soils found in areas with high water tables. These findings reinforce the accuracy of the present study, since one of them was conducted in a similar area (Barbosa et al., 2009) and explain the genesis of oxidic soils found in tropical environments (Macedo & Bryant, 1987; Bryant & Macedo, 1990).

Table 1

Chemical, physical and physicochemical characteristics of soil samples representative of the lower part of the landscape of the study area.

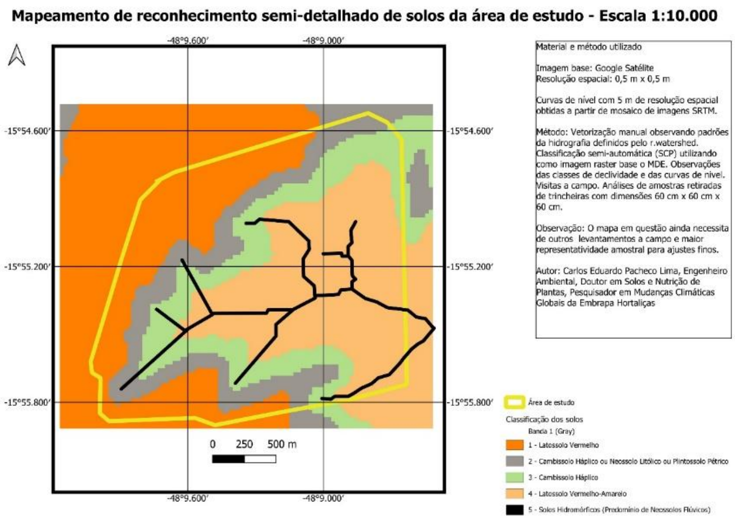
Sample/Attribute	Unit	AT 01		AT 02		AT 03		AT 04	
		0-20 Cm	20-40 cm	0-20 Cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
pH	g/kg		275		600		525		525
P (Melich 1)			400		200		425		175
Ca			325		200		50		300
Mg			1,19		0,33		0,10		0,57
K		6,1 0	6,50	5,20	5,00	5,7	5,5	5,4	5,3
Na	mg/dm³	1,20	0,90	0,70	0,60	1,8	0,7	3,8	3,1
Al	**cmolc/dm3**	0,70	1,60	0,6	0,3	2,4	2,2	2,1	1,5
(H + Al)		0,10	0,30	0,2	0,1	0,3	0,4	0,4	0,2
SUM OF BASES		0,10	0,08	0,22	0,14	0,45	0,33	0,26	0,18
T		0,03	0,03	0,04	0,04	0,04	0,04	0,04	0,04
V	**cmolc/dm3**	0,00	0,00	0,6	0,2	0,3	0,1	0,1	0,0
m		2,00	2,00	7,8	7,2	5,0	6,7	5,8	5,8
ISNa		0,90	2,00	1,1	0,6	3,2	3,0	2,8	1,9
COS		2,90	4,00	8,9	7,8	8,2	9,7	8,6	7,7
MOS	%	32,00	50,00	12	7	39	31	33	25
B		0,00	0,00	36	26	9	3	3	0
Cu		3,00	1,00	4	7	1	1	1	2
Fe	**g/kg**	6,00	3,70	17,3	17,2	26,4	19,6	26,5	18,8
Mn		10,30	6,40	29,8	29,6	45,4	33,7	45,6	32,3
Zn	**mg/dm³**	0,04	0,05	0,06	0,05	0,05	0,06	0,05	0,06

S	2,30	1,00	2,70	2,10	1,40	1,50	2,20	2,40
pH	283,30	132,00	121,8	94,9	94,2	105,4	181,9	197,2
P (Melich 1)	116,50	70,60	9,4	5,2	81,6	41,8	130,0	123,4
Ca	0,80	0,50	0,60	0,50	1,10	0,50	2,30	1,80
Mg	16,30	21,90	14,7	5,8	12,6	17,9	21,9	4,4

The set of results so far has resulted in the semi-detailed soil reconnaissance map, at a scale of 1:10,000, presented below. A similar procedure, using MDE and satellite images for mapping soils in an area in the North of Minas Gerais, was used by Oliveira et al. (2024). This version without superimposition of contour lines (Figure 12) aims to give a better view of the distribution of soil classes that occur in the study area. It is necessary to emphasize, however, that other field visits are necessary, detailed survey through the opening of profiles, as well as a better characterization of the soils occurring in the Edges of Chapadas and in the areas of Chapadas, as well as those hydromorphic, so that an even more realistic and detailed mapping can be elaborated. According to the guidelines contained in Oliveira et al. (2019), the mapping carried out would fit, by scale, at a detailed level. However, the density of profiles is not enough for this. Also, a high-resolution satellite image was used as the main basis for the definition of the mapping units, and it is therefore more prudent to frame it as a semi-detailed Reconnaissance Mapping, according to the decision of the project team.

Figure 13

Semi-detailed reconnaissance map of soils in the study area, without overlapping contour lines.



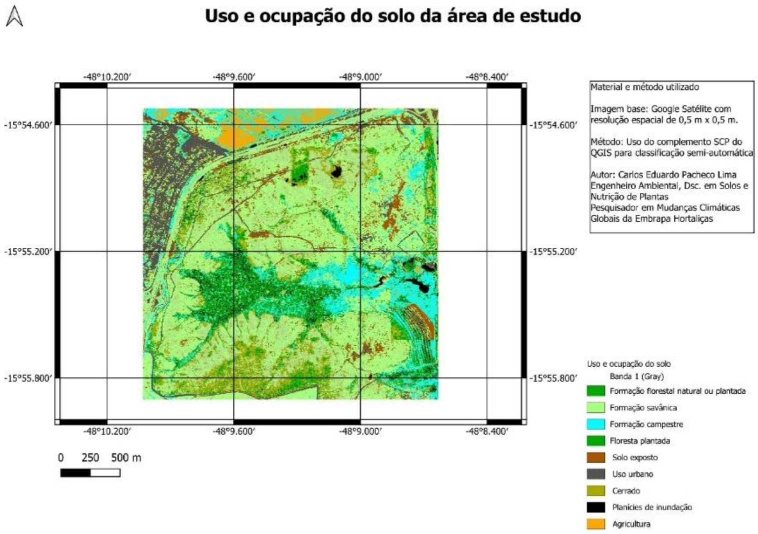
The map of land use and occupation, shown in Figure 13, confirms the low anthropization of the area, making it a conservation island in the midst of the accelerated urbanization process observed in the region. This scenario highlights the strategic importance of maintaining the conservation status of the area, with a view to maintaining environmental services such as climate regulation, protection of water resources and conservation of biodiversity, essential to the quality of life (Ribeiro & Walter, 1998) of the rural communities found locally and regionally. The savanna and grassland formations, which are predominant in the study area, are those that have suffered the greatest degradation over time in the DF (Neves et al., 2017). These authors also point out that the hilly environments and valleys, which constitute most of the studied area, found in the Federal District, constitute the landscape features with the greatest restriction to anthropic occupation due to the complexity of the relief, tending to be destined to the greater preservation of native vegetation.

It should also be noted that the area is inserted in the Environmental Protection Area (APA) of the Central Plateau, more specifically in the Sustainable Use Zone (ZUS) (ICMBIO, 2015). The APA management plan defines that the ZUS should be allocated primarily to sustainable agricultural activities, forest management and other practices compatible with the conservation of natural resources. Thus, a series of restrictions are imposed on the installation of potentially impactful projects which, however, have not been observed during the urbanization process.

In addition, the maintenance of the area in accordance with the guidelines of the APA Management Plan is essential for maintaining ecological connectivity and the formation of biodiversity corridors, which are fundamental to increase the resilience of Cerrado ecosystems in the face of anthropogenic pressures and climate change (Ribeiro & Walter, 1998). Pompeu et al. (2023) show alarming data on the degradation of the Cerrado and discuss the importance of conserving non-degraded areas or areas in stages of regeneration. These authors also report the fundamental role that areas under the possession of public institutions play in this process. Finally, it is fundamental for maintaining the collective diffuse right to environmental protection and preservation of ecosystem services, for current and future generations. Correia (2014) points out that the protection of the environment and public health must prevail over economic interests. Pontes (2019) defines diffuse rights as a category of collective rights that belong to everyone, without the possibility of individual identification of their holders. They are characterized by their indivisibility, transindividuality and indeterminacy of the subjects involved. Therefore, they are rights that concern the common interests of the community, such as a balanced environment, as determined by Article 225 of the Federal Constitution.

Figure 14

Land Use and Occupation Map on a detailed scale (1:1,000) of the study area.



4 CONCLUSIONS AND FINAL CONSIDERATIONS

The present study characterized, in a semi-detailed way, the physical environment of a Cerrado area with a good level of conservation in the Federal District. The area has been under the possession of Embrapa (2025) Vegetables since 1972 and has been under pressure related to urbanization. It is located in the micro-basin of the Tamanduá Stream, presenting relevant promotion of environmental services such as, for example, the function of cushioning negative impacts and the quantitative and qualitative maintenance of regional water resources. It is necessary to state, at this point, that the maintenance of the water quality of local water resources is of fundamental importance for the maintenance of Embrapa Vegetables' research activities, as well as for the maintenance of agricultural activities by the ranchers, who, for the most part, are family farmers. The conservation of this area, therefore, constitutes a necessity for the maintenance of the diffuse rights of the community, especially to that of a healthy environment for current and future generations, as highlighted in Article 225 of the Federal Constitution.

The pedo-geomorphological characterization showed that the most developed soils occur in flat to gently undulating relief in the Chapadas (Red Latosols), while soils with an intermediate degree of weathering such as the Red-Yellow Latosols were of common occurrence in the areas of water and sediment deposition with flat to smooth undulating relief in Intermediate Plateaus. These soils, which are dominant, have a high capacity for water infiltration into the soil. The sloping areas such as the Borda de Chapada have Dystrophic Haptic Cambisols and Haptic Cambisols Tb Dystrophic Concretionary as dominant classes, and Litholic Neosols and Plinthosols may also occur. Fluvic Neosols probably occur as the main hydromorphic soils. The landscape still features embedded valleys. This whole context makes the area important for water supply and susceptible to erosion, siltation and contamination in case of inadequate use and occupation of the soil.

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