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Physical environment and environmental impacts on the riparian forest of the lower course of the Groaíras river, Ceará

Meio físico e impactos ambientais na mata ciliar do baixo curso do rio Groaíras, Ceará

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Abstract: Studies related to river basins should take into account not only the physical environment, but all the physiographic elements that structure the landscape. Considering the importance of research in the context of watersheds in the Brazilian semi-arid region, the aim of this study was to characterize the physiography of a stretch of the lower course of the Groaíras River, Ceará, highlighting the physical aspects and their relationship with the riparian forest, as well as the main environmental impacts observed in the area. The research was based on bibliographic surveys and field observations, from August 2020 to September 2021. Based on the results, two well-defined geomorphological units were identified for the study area: the fluvial plain and the plateau surfaces, the former associated with alluvial deposits and the latter with crystalline basement rocks. Three features were defined, characterized by the type of soil and predominant vegetation. Among the main socio-economic activities is the extraction of carnauba wax, which provides employment and income for the local population. However, its productivity is strongly threatened by the bioinvasion of the purple rubber vine (*Cryptostegia madagascariensis* Bojer). On the other hand, the demand for inputs for construction and pottery exerts strong pressure on the natural resources of the river plain, which is aggravated by the extensive cattle, goat and sheep farming. The data presented highlights the need for public policies that encourage the sustainable use of natural resources and promote actions to recover degraded areas. The conservation of riparian forest is essential, as it protects the soils and biodiversity and ensures the sustainability of local socio-economic activities.

Keywords: Geoenvironmental Analysis; Hydrographic Basin; Riparian Forest.

Resumo: Estudos relacionados às bacias hidrográficas devem levar em consideração não apenas o meio físico, mas todos os elementos fisiográficos estruturantes da paisagem. Considerando a importância de pesquisas no contexto de bacias hidrográficas do semiárido brasileiro, objetivou-se com este estudo caracterizar a fisiografia de um trecho do baixo curso do rio Groaíras, Ceará, ressaltando os aspectos físicos e sua relação com a mata ciliar, assim como os principais impactos ambientais observados na área. A pesquisa foi realizada a partir de levantamentos bibliográficos e observações de campo, durante o período de agosto de 2020 a setembro de 2021. Com base nos resultados, identificaram-se para a área de estudo duas unidades geomorfológicas bem definidas: a planície fluvial e as superfícies de aplainamento, a primeira associada aos depósitos aluvionares, e a segunda a rochas do embasamento cristalino. Foram definidas três feições caracterizadas pelo tipo de solo e vegetação predominantes. Entre as principais atividades socioeconômicas está o extrativismo vegetal da cera da carnaúba que propicia emprego e renda para a população local. Entretanto, sua produtividade está fortemente ameaçada pela bioinvasão da unha-de-bruxa (*Cryptostegia madagascariensis* Bojer). Por outro lado, as demandas por insumos para construção civil e olarias exercem forte pressão sobre os recursos naturais da planície fluvial, fato agravado pela criação extensiva de bovinos, caprinos e ovinos. Os dados apresentados ressaltam a necessidade de políticas públicas que incentivem o uso sustentável dos recursos naturais e promovam ações de recuperação de áreas degradadas. A conservação da mata ciliar é essencial, uma vez que protege os solos e a biodiversidade e assegura a sustentabilidade das atividades socioeconômicas locais.

Palavras-chave: Análise Geoambiental; Bacia Hidrográfica; Mata Ciliar.

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1. Introduction

The hydrographic basins (BH's) are considered units of geographical study and territorial planning, and these must take into account an integrated environmental analysis that considers all the structuring physiographic elements of the landscape, whose interrelationship in space and time is responsible for its characterization and evolution (Lima; Silva, 2015), as is the case of riverside areas where the elements that make up the landscape are reflections of the geological, geomorphological, climatic, hydrological and hydrographic characteristics involved (Rodrigues, 2004).

The BH's inserted in the Caatingas Domain, considering its entire drainage network, are particularly important areas, since the river channels provide the formation and existence of differentiated ecological niches in the surroundings (Claudino-Sales; Lima; Diniz, 2020), given the best existing humidity conditions. Along these river courses, riparian forests stand out with their important ecosystems (Ferreira et al., 2019).

Riparian forests are plant formations adjacent to the banks of rivers, lakes and dams that develop on deep sedimentary soils (Araujo, 2009), ranging from the marginal to the ebb dikes (Ab'Sáber, 1999), formed by evergreen plants such as jaramataia (*Vitex gardneriana* Schauer), joazeiro (*Sarcomphalus joazeiro* (Mart.) Hauenshild), mulungú (*Erythrina velutina* Willd), mutamba (*Guazuma ulmifolia* Lam.), oiticica (*Microdesmia rigida* (Benth.) Sothers & Prance), umarizeiro (Geoffroea spinosa Jacq.) and, mainly, carnauba (*Copernicia prunifera* (Mill.) H.E.Moore) (Moro et al., 2015; Prado, 2003), fundamental for the protection of these areas against erosion processes and siltation (D`Álva, 2004; Ferreira et al., 2019). They are also called riverside forest and riparian vegetation, formations that are currently very uncharacterized floristically and structurally, since they are preferential spaces for agriculture (Claudino-Sales; File; Diniz, 2020; Souza; Rodal, 2010), in addition to its natural landscape disconfiguration as a result of urbanization (Falcão Sobrinho; Costa-Falcão, 2006).

As a geographical study unit, the Acaraú River Basin is one of the main basins in the state of Ceará, with an area of 14,427 km^2 (Claudino-Sales; File; Diniz, 2020) covered by landscapes formed by a diversity of reliefs (Falcão Sobrinho, 2020). Inserted in its geographical context is the sub-basin of the Groaíras River, located between the municipalities of Santa Quitéria, Catunda, Forquilha and Groaíras (Braúna; Souza, 2009; Rodrigues et al., 2020). According to these same authors, this sub-basin involves three geomorphological features: the sertanejo depression, the fluvial plain and the inselbergs. Along the lower course of the Groaíras River, over new and old alluvial deposits (colluvium) of Quaternary age (CPRM, 1998), an extensive riparian forest is formed with the presence of the carnauba palm, also called the mixed dichotyl-palm forest (Figueiredo, 1997) and the carnaubal (Moro et al., 2015), considered a subtype of caatinga (Andrade-Lima, 1981; Sampaio, 1934), one of the least studied plant formations (Souza; Rodal, 2010).

Considering the importance of research in the context of hydrographic basins of the Brazilian semi-arid region, the objective of this study was to characterize the physiography of a stretch of the lower course of the Groaíras River, Ceará, highlighting the physical aspects and their relationship with the riparian forest, as well as the main environmental impacts observed in the area.

2. Metodology

The research, of a qualitative-descriptive nature (Silveira; Córdova, 2009), involves a systemic conception based on Landscape Ecology (Rodriguez, et al., 2017), as it seeks to "understand the dynamics of spatial heterogeneity and the effect of anthropic action as a factor of landscape organization" (Soares-Filho, 1998, p. 1), an integrated approach considered for studies in watersheds (IBGE, 2009; Lima; Silva, 2015). In view of this, a bibliographic survey was carried out based on consultations with scientific articles and technical documents published in national and international journals and on official government websites (CPRM - Mineral Resources Research Company, FUNCEME - Ceará Foundation of Meteorology and Water Resources, IBGE - Brazilian Institute of Geography and Statistics and IPECE - Institute of Research and Economic Strategy of Ceará), with the aim of characterizing the study area based on its physiographic aspects, such as geology, geomorphology, climatology, pedology and vegetation.

Eight field expeditions were carried out between August 2020 and September 2021, including the rainy (January to May) and dry (June to December) periods, where the environmental components present in the area were observed and characterized, especially: soils - analyzed and recorded in the field by a specialist in the area, following the methodology of Santos et al. (2005), as well as consultations with Embrapa (2018), Guerra e Guerra (2008) and IBGE (2007); and vegetation - analyzed through a floristic survey based on the methodologies of Peixoto and Maia (2013) and Rotta, Beltrami and Zonta (2008), in consultation with specialists, and authorship and spelling of the scientific names of the species consulted in Flora do Brasil (2020). The collected botanical material was deposited at the Francisco José de Abreu Matos Herbarium (HUVA), of the Vale do Acaraú State University (UVA). The environmental impacts resulting from the process of land use and occupation were also observed and recorded.

2.1. Study Area

Inserted in the Caatingas Domain, the study area comprises a stretch of approximately 4.32 km^2 of the lower course of the fluvial plain of the Groaíras River, located in the municipality of the same name, Immediate Geographic Region of Ceará, Brazil (Figure 1), comprising the localities of Muriçoca, Floresta and Capim I, on the left bank of the river (West), and the localities of Flamengo, Lagoa das Bestas and Gangorra, on the right bank (East). The choice of this was due to the fact that it presents a remnant of riparian forest with carnauba less affected by anthropic action in relation to the other adjacent areas, despite being an open area (unfenced/unprivate) in its greatest extension.

The municipality of Groaíras is 213 km from the capital of Ceará, has an altitude of 110 m (IPECE, 2017) and is bathed by the Acaraú River (southwest-north) and its tributaries Jacurutu River (south-west) and Groaíras River (southeast-northwest) (COGERH, 2016). The Groaíras River, the main tributary of the Acaraú River (Ceará, 2009; EMBRAPA, 2005), is located at the following geographic coordinates: Latitude: 4º44'19" S and Longitude: 39º40'59" W (east) and Latitude: 3º51'48" S and Longitude: 40º24'13" W (mouth) (Braúna; Souza, 2009).

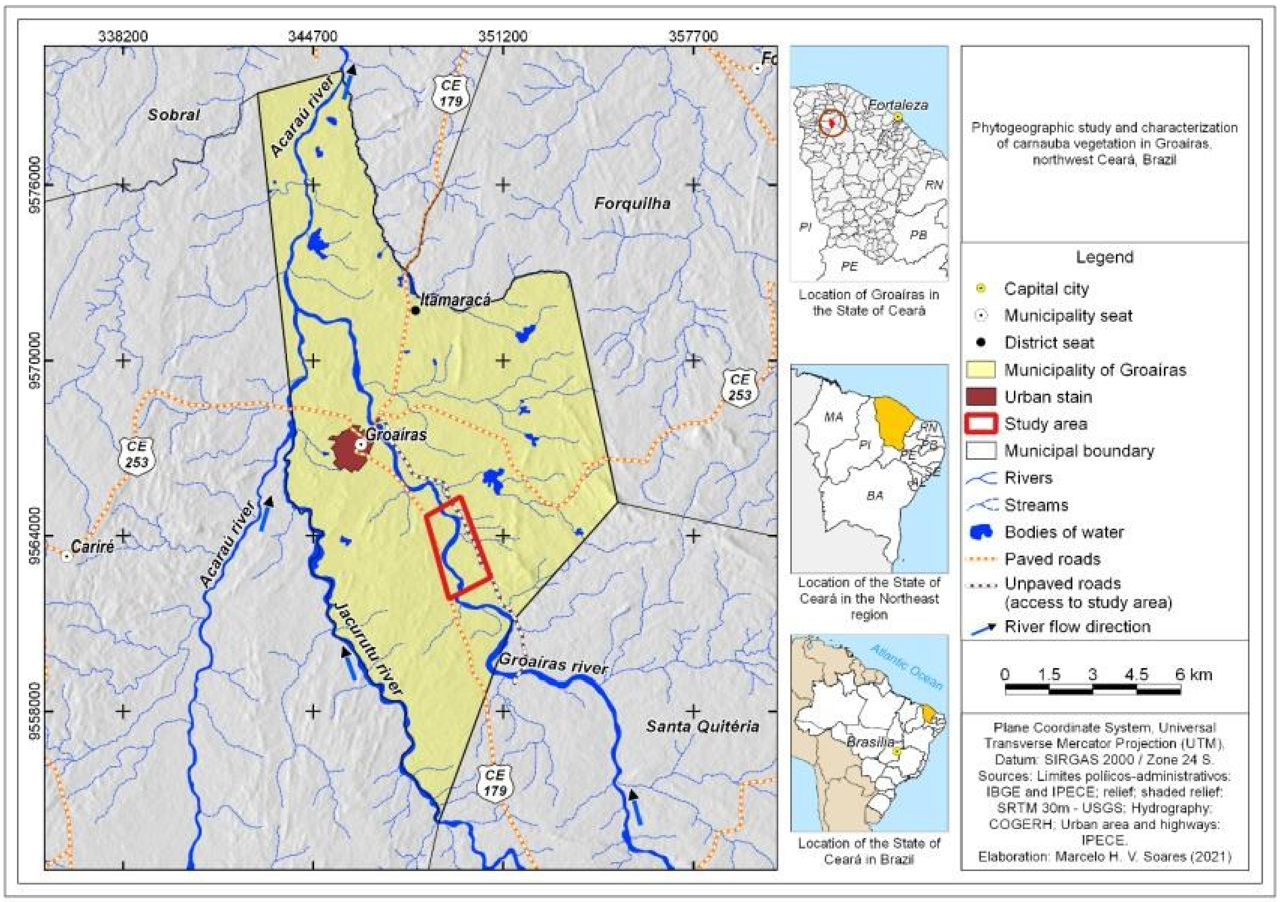

Figure 1 – Location of the study area in the lower course of the Groaíras River, Ceará.
Source: Authors (2025).

2.2. Methods

2.2.1. Preparation of the location map of the area and the cross-sectional geoecological profile

For the elaboration of the location map of the study area, the Geographic Information System (GIS) QGIS 3.10 (QGIS, 2021) was used with georeferenced data in vector and matrix formats, based on the Plane Coordinate System of the Universal Transverse Mercator Projection (UTM), with the horizontal Datum SIRGAS 2000 zone 24 South (EPSG:31984), on the scales of 1:250,000 (South America and Brazilian federative units) (IBGE, 2019), 1:50,000 (municipal limits of Ceará) (IPECE, 2019) and 1:100,000 (hydrographic network and water bodies) (COGERH, 2018). The vector data used were obtained from fieldwork using a GPS receiver device (Garmin e-Trex 20, about 3 meters of accuracy), which allowed the collection of points imported to the QGIS and the delimitation of the study area.

The cross-sectional geoecological profile (Figure 4), established in a NE/SW direction using QGis 2.18 (QGIS, 2021) and Paint (Microsoft, 2019) software, is subdivided into three phytogeographic Features (F): F1 - Riparian forest; F2 - Carnaubal; F3 - Caatinga. The icons representing the vegetation are free to use and were obtained from various specialized websites. The physiographic aspects were based on scientific literature and official websites, including Climate (Monteiro et al., 2011; Muniz et al., 2017), Geology (CPRM, 1998; Pinéo; Palheta, 2021), Geomorphology (Rodrigues et al., 2020) and Pedology (FUNCEME, 2014; IPECE, 2020).

The aerial image (Figure 10) was captured during the dry season (July 22, 2021) using a Mavic Mini Dji drone, flying at an altitude of approximately 300 m, from the reference coordinates 03°56'32.83" S and 40°21'23.97" W.

2.2.2 Climatological analysis

The climatological water balance for the municipality of Groaíras was prepared by compiling data from the Celina 1. 0 program, a temperature estimator for the state of Ceará, developed by Costa (2007) at the Geography Department of the Federal University of Ceará (UFC), which estimates the temperature of a given area using altitude, latitude and longitude data from which the estimated average monthly temperatures for the municipality were obtained; and from the Ceará Meteorology and Water Resources Foundation (FUNCEME, 2022), from which the average monthly rainfall data was obtained for the year 2021.

For the analysis, the average Available Water Capacity (AWC) of 40 mm was adopted, following the methodology of Rolim, Sentelhas and Barbieri (1998). To obtain the results and create the graphs shown in Figures 4, 5, 6, 7 and 8, we used the Excel spreadsheet (Microsoft, 2019) Normal Water Balance ("Rational Climate Classification Worksheet (PCRC)") modified by Silva-Neto (2020).

3. Results and discussion

3.1. Geology

The geological context of the study area is characterized by crystalline basement rocks of Precambrian age (Claudino-Sales; File; Diniz, 2020), represented by various gneisses and migmatites, limestones, quartzites, schists, as well as plutonic and metaplutonic rocks of predominantly granitic composition under the recent alluvial deposits (Q2a) of Quaternary age, formed by sands, clays, gravels and silts along the channel of the Groaíras river (CPRM, 1998). As observed in the field, some rocky outcrops of granite, gneiss and migmatite of Precambrian age stand out in the riverbed, in Feature 1 (F1), at 92 m above sea level (Figure 2), due to the excavation of alluvial deposits.

Figure 2 – Rock outcrops in the river channel of the lower course of the Groaíras River, Ceará.
Source: Authors (2025).

The CPRM (1998) mentions the existence of two distinct Hydrogeological Domains (DHs): that of crystalline rocks (called fissural aquifer), with the occurrence of groundwater provided by a secondary porosity represented by fractures and cracks, which is understood as random, discontinuous and small reservoirs; and alluvial deposits, bordering the channel of the Groaíras river. As found in the field, the waters of these DHs are the main water resources present in the area, consisting of surface water (fluvial channel), responsible for a large part of the local supply and maintenance of forage crops, and groundwater (Amazon wells (artezanal well/cacimbão), and artesian/tubular wells), in addition to plate cisterns (Figure 3), responsible for water support in the dry season.

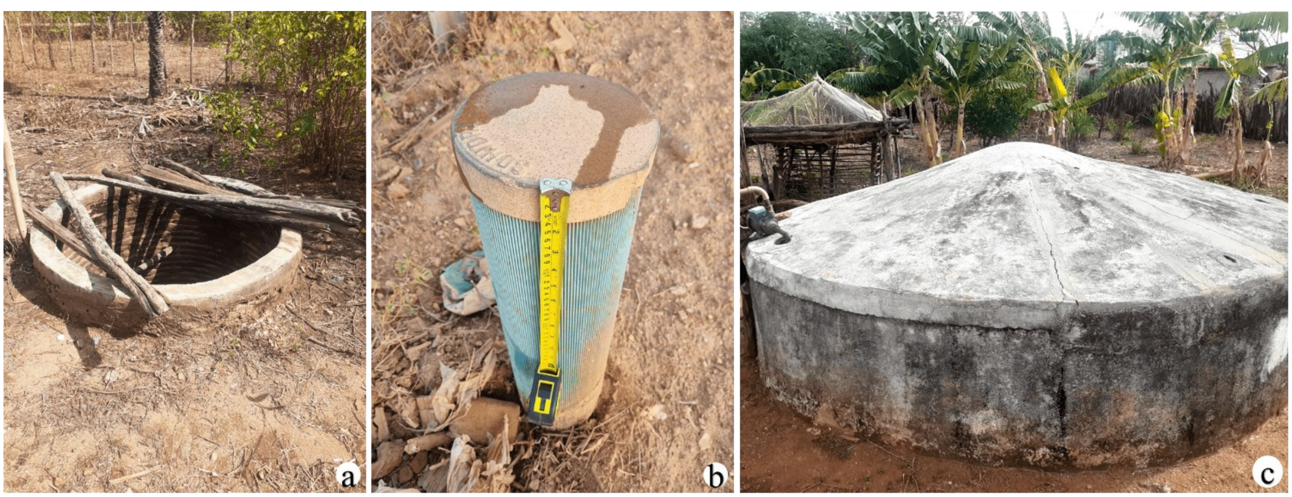

Figure 3 – a - Amazon well; b - tubular well; c – plate cistern, in the lower course of the Groaíras River, Ceará.
Source: Authors (2025).

3.2. Geomorphology

According to IPECE (2017, 2020) and Rodrigues et al. (2020), there are three well-defined geomorphological units for the Groaíras region: the fluvial plain of the Groaíras River, where old alluvial deposits (staggered terraces) and new (larger bed/floodplain) predominate (Figure 4), the planing surfaces and the inselbergs. The area of study is marked by the first two. Claudino-Sales, Lima and Diniz (2020) and Lima and Silva (2015) explained, when dealing with studies related to

BHs, that the formation of these plains is the result of structuring factors resulting from fluvial processes that promoted the longitudinal transport of weathered materials from elevated to lower areas, being considered fundamental for the formation of the landscape in time and space.

The old stepped terraces (exceptional larger bed) (Figure 4, Feature 2: F2), on both banks of the Groaíras River, have altitudes ranging from 98-104 m and, according to CPRM (1998) and IPECE (2020), are made up of Quaternary alluvial deposits. The widths verified in the field in these areas are approximately 180 m (right bank) and 300 m (left bank). The ebb bed (F1), with an altitude of around 89 m, is the local base level. During the dry season (May/December) the surface water is very low, ranging from 0.7 to 1 m deep and 4-6 m wide. In times of great flooding, the riverbed can extend to more than 200 m wide and reach a depth of around 10 m. The water can overlap the floodplains and reach lower areas of the larger exceptional riverbed.

It was found that parts of the river plain between the communities of Lagoa das Bestas and Floresta are relatively well preserved, with the geomorphological features little altered. The marginal dyke, especially on the left bank, is protected by a remnant strip of riparian forest, protecting the soil from erosion and preventing the river channel from silting up.

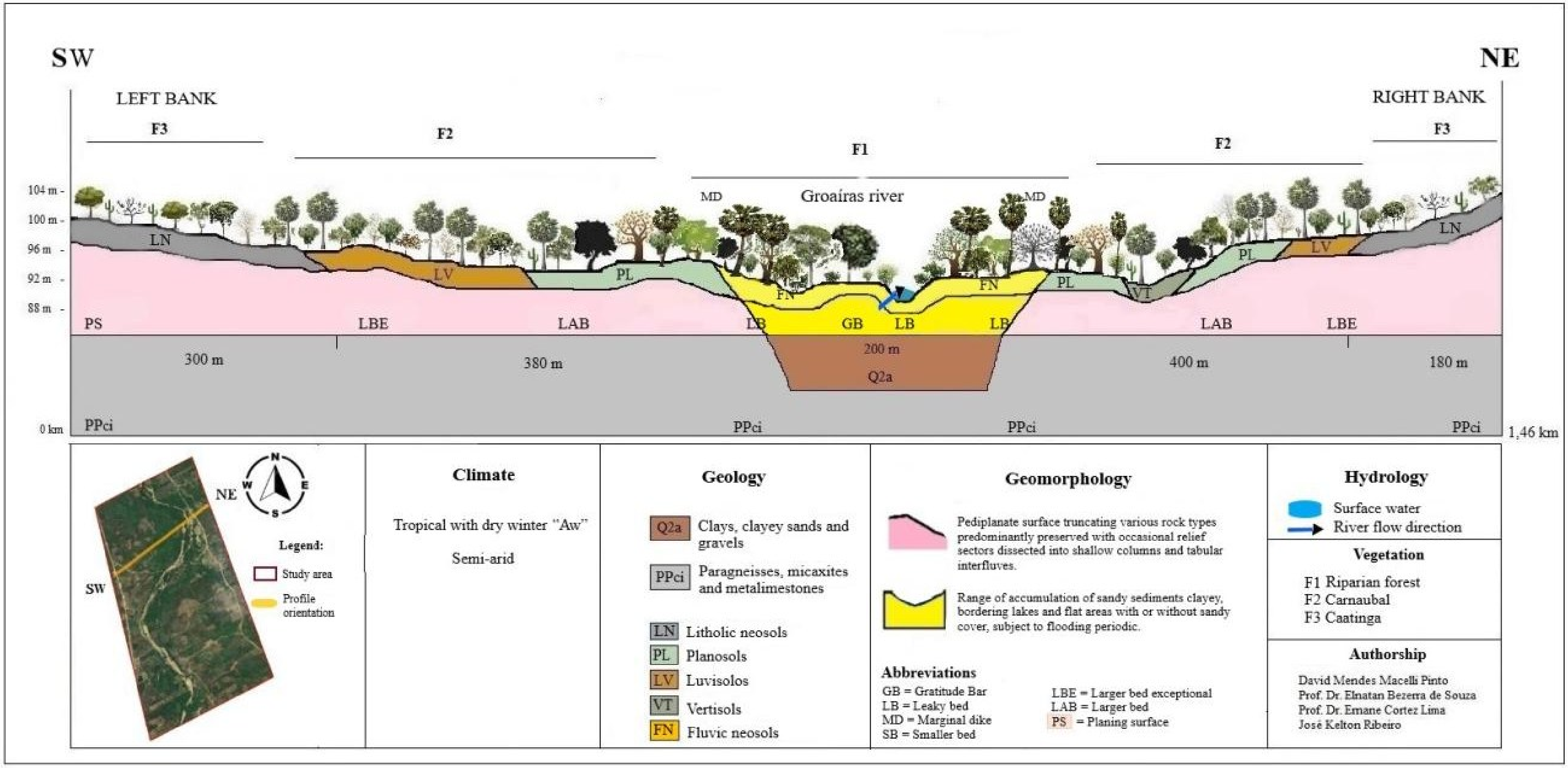

Figure 4 – Cross-sectional geoecological profile of the Carnaubal of the Groaíras river, Ceará.
Source: Authors (2025).

3.3. Climate

According to Muniz et al. (2017) and Peel et al. (2007) the climate of the area is of the Tropical type with Dry Winter "Aw" in the Köppen-Geiger classification (1900), characterized as Savannah climate. In the classification of Thornthwaite and Matter (1955), it is characterized as dry subhumid (C1), semi-arid, with a rainy season between the months of January and April and dry between the months of May and December, with an average annual rainfall of 791.2 mm (Monteiro et al., 2011).

Based on a climatological analysis (Table 1), considering the year 2021 and the average CAD of 40 mm for the area under study, the water deficit (DEF) presented an annual average of 1058 mm, the potential and actual evapotranspiration a monthly average of 143 mm and 54.6 mm and an annual average of 1713 mm and 654.8 mm, respectively. According to the climatological analysis carried out by Monteiro et al. (2011), which adopted the average CAD of 100 mm, a thermal factor of the dry subhumid megathermic type: C1dA'a'[1], with a Moisture Index (UI) lower than 30. Other indices consulted in the literature presented the following annual averages: 39.38%, Aridity Index (AI) (FUNCEME, 2017a); 66%, Soil Moisture Index (maximum water retention capacity in the soil) (FUNCEME, 2017b) and 215.7 W/m^2, Solar Radiation Index (FUNCEME, 2011), with temperature ranging from 26° to 28° C (IPECE, 2017).

Table 1 – Monthly averages of the climatological water balance of the municipality of Groaíras, Ceará. MRA - soil water storage, DEF - water deficit, ETP - potential evapotranspiration, REE - actual evapotranspiration, EXC - water surplus, P - precipitation, P - ETP precipitation - potential evapotranspiration, T - temperature.

Anus: 2021	T	P	ETP	P - ETP	MRA	REE	DEF	EXC
Monthly (average)	26,8	62,2	143	- 79,5	9,95	54,6	88	8,65
Annual (total)	--	758,6	1713	- 954,4	119,4	654,8	1058	103,8

Source: Adapted from Celina 1.0 (Costa, 2007) and FUNCEME (2022).

Also according to this analysis, the data partially confirms what was found by Monteiro et al. (2011), with the rainy season (P > 50 mm/month) between the months of January and May, which had the ten highest monthly rainfall averages for the municipality in question (Figure 5).

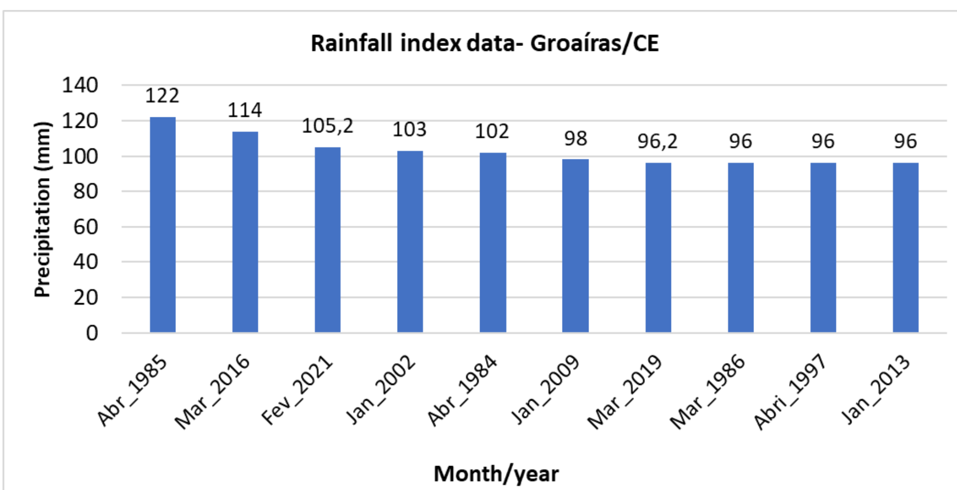

Figure 5 – The 10 highest monthly rainfall averages for the municipality of Groaíras, Ceará – period 1984-2021. Source: Adapted from FUNCEME (2022).

[1] Thermal factor for the municipality of Groaíras: Climatic type as a function of the Humidity Index (C1); Climate subtype as a function of water and aridity indices (d); Climatic Type (A') and Climatic Subtype (a') as a function of TE (Thermal Efficiency): Dry subhumid megathermal with small or no water surplus (Monteiro et al., 2011).

With regard to the estimated temperatures (Figure 6), the mildest temperatures occurred in the months with the highest average rainfall (March and April), while the highest temperatures occurred during the dry season (August to November).

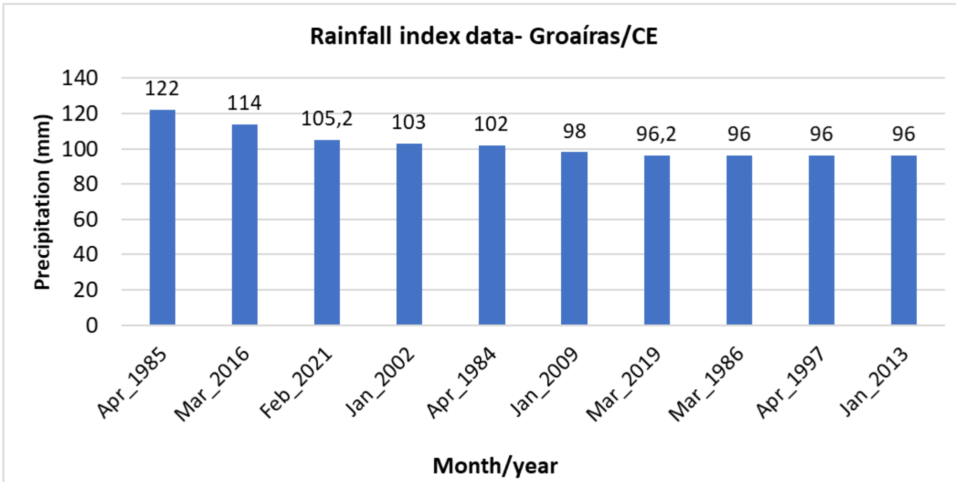

Figure 6 – Estimated average monthly temperatures for the municipality of Groaíras, Ceará.
Source: Adapted from Celina 1.0 (Costa, 2007).

Considering the results of the climatological water balance for the study area, the lowest ETP values (< 150 mm) occurred in the rainy season (EXC) and the highest (≥ 150 mm) in the dry season (DEF). On the other hand, ETR > 50 mm occurred in the months with the highest rainfall, remaining at zero in the dry period.

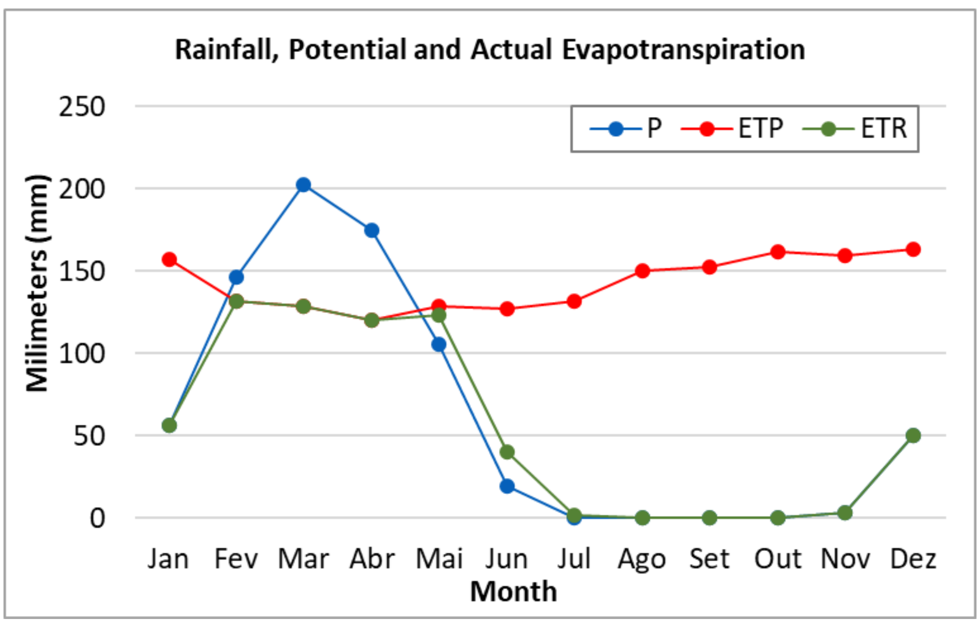

Figure 7 – Climatological water balance for the municipality of Groaíras, Ceará. ETP - potential evapotranspiration, ETR - actual evapotranspiration and P - precipitation.
Source: Adapted from Celina 1.0 (Costa, 2007) and FUNCEME (2022).

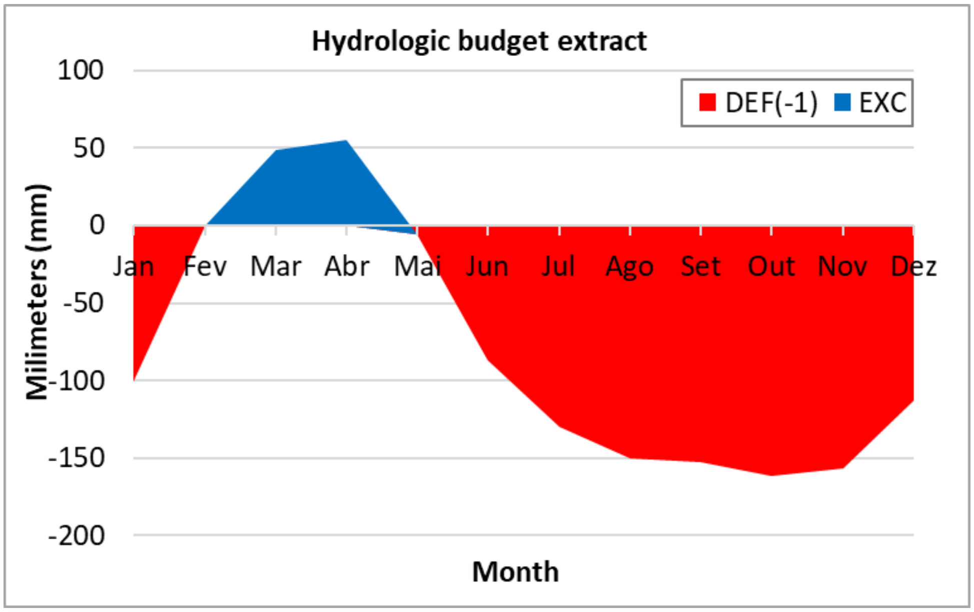

Figure 8 – Extract of the monthly climatological water balance for the municipality of Groaíras, Ceará. DEF(-1) - water deficit and EXC - water surplus.
Source: Adapted from Celina 1.0 (Costa, 2007) and FUNCEME (2022).

Regarding Soil Water Storage (MRA) (Figure 9), the highest values (MRA >10 mm) occurred in the months of February to May, as a result of the higher rainfall averages and mild temperatures occurring in this period of the year.

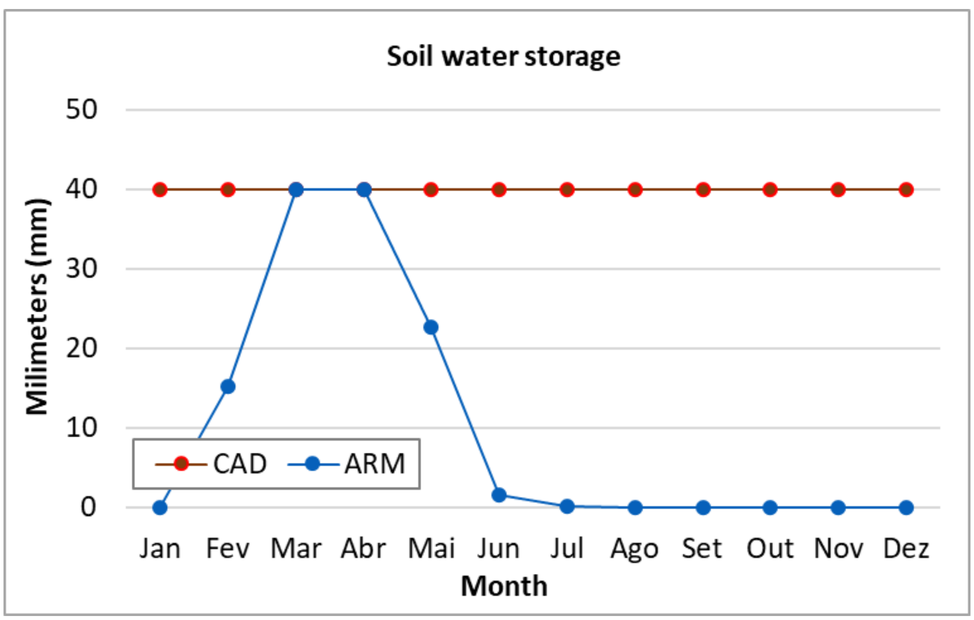

Figure 9 – Monthly average of the MRA - Soil water storage for the municipality of Groaíras, Ceará. CAD - Available Water Capacity.
Source: Adapted from Celina 1.0 (Costa, 2007) and FUNCEME (2022).

3.4. Pedology

The soils identified in the study area are cited considering the geomorphological features from the fluvial channel towards the planing surfaces. On the banks of the fluvial channel (F1) are the fluvic neosols, originated from the Holocene fluvial sediments, ranging from moderately deep to very deep, with variable texture and with generally imperfect drainage.

Table 2 – Geological units, geomorphological features and soils in a stretch of the lower course of the Groaíras River, Ceará.

Geological unit/geomorphological feature	Soil	Figure
Cenozoic sedimentary deposits (alluvium)/ Smaller bed	Quartz sands	
Cenozoic sedimentary deposits (colluvium)/ marginal dike	Planosols	
Cenozoic sedimentary deposits (colluvium)/ Floodplain	Vertisols	
Cenozoic sedimentary deposits/ Várzea: Exceptional Greater Bed	Luvisols	

Mastery of Shields and Ancient Massifs/Planing Surfaces	Litholic Neosols	

Source: Authors (2025).

In the new alluvial deposits (larger bed/varzea), on both banks of the river (F2), at altitudes ranging from 90-98 m, the Natric Planosols predominate, which, according to EMBRAPA (2018, p. 251), have “a plannic horizon and: a) a sodic character [...] below an A or E horizon within 200 cm of the soil surface; or b) a sodic character in one or more horizons within 150 cm of its surface”. According to FUNCEME (2014), Planosols are formed by the process of weathering rocks, consisting of saprolites of gneisses and migmatites from the Undivided Precambrian and Precambrian mica-schists, with a sandy texture on the A horizon and medium or clayey on the Bt, The most frequent coloration varies from dark brown to dark yellowish-brown.

In the lower stretches (Section 2), an accumulation of Hydromorphic Vertisol (colluvium) was observed (Figure 10), characterized by contraction cracks in the dry season and by swamps (small lagoons) in the rainy season.

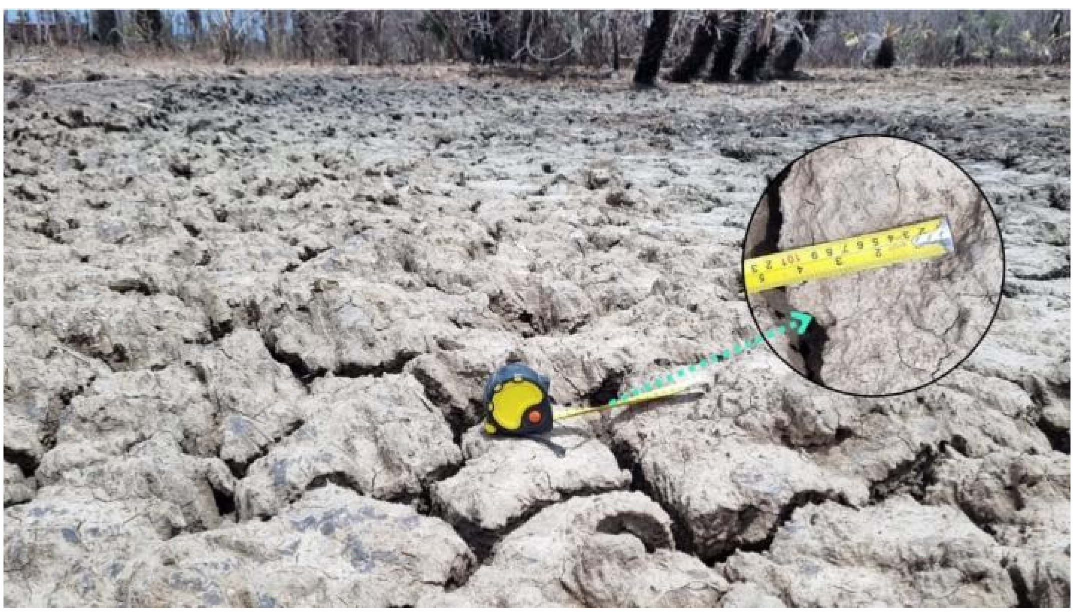

Figure 10 – Water accumulation area (approximately 76 m^2) in the dry season, larger bed (F2), right bank of the lower course of the Groaíras river, Ceará.
Source: Authors (2025).

In the transition zone between the floodplain and the plateau (F2/F3), Luvissolos were identified, whose textural B horizon is followed by the A or E horizon, which are generally shallow and can be stony. Finally, on the plateau surfaces (F3), after the limits of the floodplain, litholic neosols were observed. These soils are shallow, stony or rocky, without a B horizon, with an A horizon followed by a C or R horizon, with an orange to reddish surface color.

3.5. Vegetation

According to IPECE (2017), the types of vegetation present in the area are Open Shrub Caatinga and Dicotyl-Palmaceous Mixed Forest, the latter, designated by Moro et al. (2015) as riparian forest with carnauba or carnaubal (Figure 11). Based on the floristic survey, it was found that the vegetation that accompanies the river channel consists of aquatic and terrestrial species (Pinto et al., 2023). In the ebb bed and water bodies, the water lettuce (*Pistia stratiotes* L.), the mosquito fern (*Azolla filiculoides* Lam.) and the *Ludwigia helminthorrhiza* (Mart.) H.Hara stand out. On the alluvium, in sunnier areas, herbaceous plants grow, such as the mussambê (*Tarenaya spinosa* (Jacq.) Raf.) and parsley (*Ipomoea asarifolia* (Desr.) Bite. & Schult.), and bushes of maritime pine nut (*Jatropha mollissima* (Pohl) Baill.), velame (*Croton heliotropiifolius* Kunth), remela-de-macaco (*Combretum lanceolatum* Pohl ex Eichler) and jaramataia (*Vitex gardneriana* Schauer).

In some stretches of the riverside areas, on the marginal dike and bars of asidement, species characteristic of the riparian forests of the semi-arid region were observed, such as the ingá (*Inga ingoides* (Rich.) Willd.), ingá-bravo (*Lonchocarpus sericeus* (Poir.) Kunth ex DC.), oiticica (*Microdesmia rigida* (Benth.) Sothers & Prance) and pau-branco (*Cordia oncocalyx* Allemão). These species have also been recorded for stretches of riparian forest of the Acaraú and Jaibaras rivers (Lima et al., 2024; Nepomuceno et al., 2023). It is noted that other species appear as the vegetation advances into the floodplain. In addition to the carnauba palm (*Copernicia prunifera*), with a strong ecological preference for saline soils such as planosols (Holanda et al., 2011; IBGE, 2007), some woody species stand out, including the muquém (*Albizia inundata* (Mart.) Barneby & J. W. Grimes), mutamba (*Guazuma ulmifolia* Lam.), joazeiro (*Sarcomphalus joazeiro* (Mart.) Hauenshild), violete (*Dalbergia cearensis* Ducke), black-eared (*Enterolobium timbouva* Mart.), mulungu (*Erythrina velutina* Willd.) and mofumbo (*Combretum leprosum* Mart.) (Pinto et al., 2023).

Figure 11 – a: Aerial view of the riparian forest with carnaúba; b: Interior of carnaubal vegetation; c: Bioinvasion of carnaubal caused by the species Cryptostegia madagascariensis, left bank of the lower course of the Groaíras River, northwest of Ceará.
Source: Authors (2025).

In the transition area of the floodplain with the planing surface (F2/F3), caatinga species gradually occupy the spaces (Figure 12). Among them, stand out the jurema-white (*Piptadenia retusa* (Jacq.) P.G.Ribeiro, Seigler & Ebinger), jurema-preta (*Mimosa tenuiflora* (Willd.) Poir.), jelly (*Croton blanchetianus* Baill.), catingueira (*Cenostigma nordestinum* Gagnon & G.P.Lewis), pear (*Aspidosperma pyrifolium* Mart. & Zucc.) and stick-iron (*Libidibia ferrea* (Mart. ex Tul.) L.P.Queiroz).

Figure 12 – A-f - Vegetation along the lower course of the Groaíras river, Ceará. a - shrubby Caatinga vegetation in the largest exceptional bed; b - carnaubal in the transition between the larger bed and the exceptional larger bed; C-D - Carnaubal in the floodplain (floodplain); and - riparian vegetation on the left marginal dike; f – view of the riparian forest from the ebb bed.
Source: Authors (2025).

In the study area, as well as in other watersheds in the northwest of Ceará (Barbosa et al., 2019), it was observed that the native vegetation and flora are heavily impacted by the bioinvasion of the rubber vine, locally called the witch's claw (*Cryptostegia madagascariensis* Bojer), a naturalized African plant that has become an invader of carnauba groves, given its preference for river plain soils (Lima et al.; 2024; Medeiros et al., 2019; Pinto et al., 2023). This exotic species, which is highly aggressive in its competition for light and nutrients, spreads rapidly by wind and water and forms large population clumps characterized by climbing branches that cover a large part of the carnauba canopy, preventing the passage of light, causing individuals to suffocate, strangle and fall (Lima et al., 2024; Sousa et al., 2017). This behavior leads to the death of many native species, especially the carnauba, causing environmental and socioeconomic damage, since this palm is the basis of survival for many riverside communities.

3.6. Socioeconomic activities and environmental impacts

The forms of use and occupation and their interrelations with the environmental components are represented in the study area by the anthropic actions indicated in Table 3.

Civil construction is one of the main responsible for the decharacterization of the natural landscape, since it requires the constant removal of sand from the river channel for landfills and constructions. On the other hand, the potteries, represented locally by three brick manufacturing units, have in recent years caused impacts on the environment of the river plain of the Groaíras River, since the intense and constant removal of clay leaves traces of destruction in the landscape, in addition to the voluminous consumption of firewood from deforestation in the region. It is a fact that these actions generate significant income for the municipality, however, public policies are needed that can contribute to the sustainable use of these raw materials.

Table 3 – Land use and occupation and their environmental impacts in a stretch of the lower course of the Groaíras River, Ceará.

Use and occupancy	Activity and impacts on the landscape	Figure
Material extraction for the construction industry	Sand removal (river channel)	
Ceramic brick factories	Clay removal (exceptional larger bed)	
	Brick making	

Subsistence farming	Deforestation (in adjacent areas) for planting (beans and corn) and selling firewood to bakeries and potteries	 
Extensive livestock farming	Cattle, goat and sheep farming for local meat and milk marketing	 
Plant extractivism	Extraction of carnauba straw for handicrafts, organic fertilizer and wax production for commercialization	 

Source: Authors (2025).

Small subsistence crops for planting corn and beans, locally called “roçados”, are commonly observed in the vicinity of riparian forests and contribute to deforestation and burning of native vegetation, since small farmers are deprived of the information and techniques necessary for sustainable practice (Falcão Sobrinho; Ross, 2008; Farias et al., 2024). The cutting and sale of firewood for bakeries and potteries is a common practice in riverside communities. In addition, the commercialization of wood for the operation of carpentry shops in the municipality, an activity that had been more intense in the past. Practices such as these, over time, exhaust the natural physical elements, in addition to disfiguring the natural landscape (Falcão Sobrinho; Costa-Falcão, 2006).

The extensive breeding of cattle, goats and sheep for the commercialization of meat and milk, without adequate technical care, is another remarkable activity observed in the area. This type of cattle ranching promotes, due to the intense demand for forage, impacts on vegetation, contributing to the loss of biodiversity, and impairs the natural recovery of deforested areas, as observed for other areas of riparian forest in the region (Farias et al., 2024; Lima et al., 2024).

The plant extraction of carnauba wax, which is very common in the municipality, especially in the area studied, is one of the main socio-economic activities of the riverside populations. It is a sustainable practice, as emphasized by the Carnauba Sector Chamber (2009). Carnauba straw is widely used in local handicrafts, works as an organic fertilizer and its wax is a very important product for the state of Ceará. Considering the last ten years (2011-2020), carnauba derivatives (powder, wax, fiber) have generated an average annual income of R$ 560,300.00 for the municipality of Groaíras (IBGE, 2021). On the other hand, it must be taken into account that the improper cutting of native understory plants by extractivist communities during their activities de-characterizes the vegetation, since in this process the plants that are not of interest are removed, leaving space for the straw collectors (comboieiros) to move among the carnauba trees. This can contribute to the proliferation of the exotic species *Cryptostegia madagascariensis*, whose dispersal strategy is highly effective in disturbed areas, especially carnauba forests (Bonilla, 2015; Lima et al., 2024).

4. Final considerations

This study provided a detailed characterization of the physiography and environmental impacts observed in the lower reaches of the Groaíras River, highlighting the importance of riparian forests for maintaining local ecosystems and the challenges associated with preserving these environments in the context of the Brazilian semi-arid region. Based on the results, two well-defined geomorphological units were identified for the study area: the fluvial plain and the plateau surfaces, the former associated with alluvial deposits and the latter with crystalline basement rocks.

Three features were defined, characterized by the type of soil and predominant vegetation. Feature F1 comprises the minor and ebb beds and the pleasant bar, where typical riparian forest species are established on fluvic neosols. Feature F2, under the influence of planosols, luvisols and, in a more localized way, vertisols, includes the flood plain where carnaubal vegetation predominates. In higher sectors and occupying the extremities of the geoecological profile is feature F3, established on plateau surfaces and covered by lithic neosols, where caatinga vegetation is found.

Among the main socioeconomic activities is the vegetable extraction of carnauba wax, which provides employment and income for the local population. However, its productivity is strongly threatened by the bioinvasion of the witch's claw. On the other hand, the demands for inputs for civil construction and potteries exert strong pressure on the natural resources of the river plain, a fact aggravated by the extensive breeding of cattle, goats and sheep.

The data presented highlight the need for public policies that encourage the sustainable use of natural resources and promote actions to recover degraded areas. The conservation of riparian forest is essential, since it protects the soil and biodiversity and ensures the sustainability of local socioeconomic activities.

Thus, this study contributes to the understanding of the interactions between the physical and biological elements of the landscape of the lower course of the Groaíras river, highlighting the importance of an integrated approach in the management of watersheds in the semi-arid region. As future perspectives, it is recommended to monitor changes in vegetation cover and use of water resources. In this way, management strategies can be adopted that combine economic development and environmental preservation.

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