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URBAN GEOMORPHOLOGY AND ENVIRONMENTAL PROBLEMS IN POTI RIVER PLAIN IN CRATEÚS, NORTHEAST BRAZIL

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Abstract

This paper deals with the Urban Geomorphology of the Poti River in Crateus, at Ceara State, Northeast Brazil. The objective is to carry out a geographical analysis of the aspects that make up this study section. The methodology is based on geosystemic analysis, and the techniques involve bibliographic and cartographic research and analysis-description in the field. The main results found were that the Poti River and the City developed under a very peculiar geological-geomorphological stratum, which contributed to define the current natural and social landscape features present in the fluvial plain. The use and occupation analysis showed that the river course is considerably contaminated and degraded. Soil sealing, water pollution, silting, the presence of sub-anormal agglomerations are some situations that indicate unappropriated use and occupation. It is intended with this geographic-geomorphological research, to support the recovery and conservation of this water resource in the context of the city. It is the first research made in this municipality about its urban problems, and we expect it to be taken into consideration by the local government. It is also an improvement in terms of analysis of the urban environment in countryside Northeast Brazil.

Keywords: Environmental impacts, Urban Rivers, Urban development

INTRODUCTION

Urban geomorphology is a relatively new scientific field that examines the interactions between urban development and geomorphological processes. The discipline offerts a serie of possibilities about these two subjects and is growing in production all over the world in the last decades. The key concepts and methods of Urban Geomorphology display a great number of topics and techniques, which can be presented in the following terms:

Urban areas are significantly shaped by human activities, which act as geomorphic agents. These activities include construction, excavation, and landscaping, leading to the creation of anthropogenic landforms and deposits. A method to assess these anthropogeic landforms and deposits is the Geomorphological Mapping. This involves detailed mapping of landforms and processes in urban areas and helps in understanding the historical evolution of urban landscapes and geo-hazards. Effectively, Urban Geomorphology plays a crucial role in assessing and mitigating geo-hazards such as landslides, floods, and erosion. This is essential for urban planning and sustainable development (Pica et al, 2024). It also aims to raise awareness about the impact of urbanization on natural landscapes, what is known as "Urban Geoheritage": This concept focuses on the preservation and education about significant geomorphological features within urban environments (Del Monte et al., 2016).

Taking into account these situations, it can be postulated that Urban Geomorphology can be used for Urban Planning, as geomorphological insights are used to guide urban development, ensuring that new constructions are safe and sustainable. It also can be a tool for disaster management, considering that understanding geomorphological processes helps in predicting and managing natural disasters in urban areas. It is at the same time a key to environmental conservation, and efforts are made to preserve significant geomorphological features and promote urban geoheritage from research made in Urban Geomorphology.

Urban Geomorphology is a dynamic and interdisciplinary field that continues to evolve with advancements in technology and a growing emphasis on sustainability. It provides essential insights for creating resilient and sustainable urban environments. Recent Advances in this field deal with integration of technology, specially with the use of GIS (Geographic Information Systems), remote sensing, and 3D modeling, what has revolutionized Urban Geomorphology. These technologies allow for more precise mapping and analysis of urban landscapes. There is at the same time a growing emphasis on integrating geomorphological knowledge into urban planning to promote sustainability. This includes designing cities that are resilient to natural hazards and minimizing the environmental impact of urbanization, linking sustainability and Urban Planning.

It is worth to mention the crescent number of case studies. Recent studies have focused on various cities worldwide, providing insights into the unique geomorphological challenges and solutions in different urban contexts. That is the aim of the present paper, which focuses on the analysis of the Poti River in the municipality of Crateús, located in the west of the state of Ceará, in Northeast Brazil. The work follows a socioenvironmental and geomorphological perspective, closely linked to the use and occupation of the riverbed, as well as the characterization of the geoenvironmental and urban aspects present in the defined spatial area. It is considered here that research into urban geomorphology provides support for territorial planning interventions in areas close to water bodies.

Urban Geomorphology is a broad line of research and has theoretical and methodological paths for various branches of science, such as Environmental Engineering, Architecture and Urban Planning, Geography (Physical and Human), among others. According to Jorge (2011), urban geomorphology is the branch of studies that focus on actions on forms and processes in artificial urban environments. In an urbanized anthropic world, there is an urgent need to consolidate viable strategies at the various scales of Geography in cities, whose dynamics need urban planning and environmental management interventions (Soares; Claudino-Sales, 2023).

The dynamics present in urban centers, whether in the Global North or, especially, in the Global South, involve environmental, social, political and economic problems, such as pollution, contamination, inadequate solid waste disposal, socioeconomic and structural inequalities, among others that make up the pulsating reality of these environments. These are problems that are characteristic of cities, from small towns to large metropolitan centers, thus requiring interventions by public and private authorities that contribute to qualifying these realities as suitable living spaces, without disrupting the functionality of the urban space (Moraes, 2005).

In this work, we will follow the focus and perceptions linked to geographical science in its physical branch and in the sub-branches of the Socio-environmental and Geomorphological Perspective. The objective of the research is to to carry out a geographical analysis of the aspects that make up this study section. It is intended with this geographic-geomorphological research, to support the recovery and conservation of this water resource in the context of the city. It is the first research made in this municipality about its urban problems, and we expect it to be taken into consideration by the local government. It is also an improvement in terms of analysis of the urban environment in countryside Northeast Brazil.

STUDY AREA

Crateús is 350 km from the state capital of Ceará, the city of Fortaleza. Its location is between the coordinates 5°00’ to 5°30’ south latitude and 40°30’ to 41°00’ west longitude. This city is the hub of the Intermediate Geographical Region of Crateús, located in the western portion of the state of Ceará, and is close to the border with the state of Piauí, in Northeast Brazil (Costa, 2017). Access to the region is predominantly by road. The main highways are BR-020 and BR-226 (Fig. 1). Air access is via the Crateús Regional Airport - SNWS (Dr. Lucio Lima), which is located 4.0 km from the municipal urban area (Costa, 2017; IBGE, 2017; Ceará, 2023).

The Poti River rises in the Serra dos Cariris Novos, in the municipality of Quiterianópolis, in the state of Ceará, and flows into the state of Piauí, into the Parnaíba River, in the municipality of Teresina (state capital). The river basin covers 51,870,751 km², of which 14,171,714 km² represent the upper reaches, located entirely in Ceará. The river is intermittent, with an anastomosed channel and the presence of sediment banks transported and deposited by Cenozoic fluvial erosion. The flow of water in the channel is sinuous. The type of drainage within the basin, analyzed using Google Earth images, is subdendritic (Carneiro, 2022; Soares; Claudino-Sales, 2023).

From a geological-geomorphological point of view, the city of Crateús is characterized by the presence of the Ibiapaba Glint, located to the west of the municipal headquarters. Popularly known as Ibiapaba Highland, it is built on sedimentary rocks belonging to the Parnaíba Basin, of Paleozoic age. At its foot lies the so-called Peripheral Depression, supported by rocks of the Precambrian crystalline basement, where metamorphic rocks dominate (Brandão, 2014; Lima; Silva, 2015; Claudino-Sales, 2002, 2016; Santos; Nascimento; Claudino-Sales et al., 2020; Claudino-Sales; Lima; Diniz, 2020) (Fig. 2).

The urban constituent of the city's headquarters district is conditioned by the crystalline basement of Precambrian age, with a surface marked by the intense action of weathering, erosive and sedimentary agents. The plain shows an accumulation of sandy-clay to sandy-silty sediments (the granulometry of the sediments in the entire plain visited in the urban area was assessed based on the experiences of a knowledge professional geologist in the field). The area studied is entirely associated with the alluvial plain. In the surrounding area, there is planation surface in Precambrian rocks exposing dissection oriented and directed towards the main watercourse.

The Poti River channel drains the Peripheral Depression, flowing towards the glint, where it opens a perceé, becoming a tributary of the Parnaíba River, already in the state of Piauí. On this route, it crosses the urban area of Crateús. Its drainage is of the dendritic type. In Crateús, it is made up of subdentritic subunits. It has a sinuous shape and an irregular pattern throughout the main course, and is characterized as a braided channel, according to criteria defined by Kellerhals, Church and Bray (1976).

The width of the river channel within the city is a maximum of 40 m. In the urban area, where the river bifurcates into two segments (Fig. 3~~ and 4~~), the channel is sometimes strangled, with an even smaller width, due to the occupation by houses along the valley. Figure 4 shows the river valley between the Cidade Nova, Patriarcas and Cajás neighborhoods. Figure 5A-C shows the river between the Ipase, Centro, São José and Ponte Preta neighborhoods.

According to Ab'Saber (2003) and Oliveira (2020), the research area is part of the semiarid "Caatinga" (xeroyphites) domain, with rainfall volumes of no more than 800 mm per year. Corroborating this data, Brasil (2022), IBGE (2020) and Ceará (2017) indicate that the climate is Tropical Hot Semiarid and Tropical Hot Semiarid. The temperature ranges from 26° to 28° between January and April.

At the macro scale (1:5,000,000), according to the Brazilian Soil Classification System (SiBCS, 2006), the following soil types are predominantly identified: SXe (Distrophic Haplic Planosols), PVAe (Eutrophic Red-Yellow Argisols) and TCO (Chromic-Orthic Luvisols) (Embrapa, 2023).

The floristic composition of the study area is fundamentally part of the Caatingas Domain. The variation is between evergreen and deciduous or semi-deciduous species of small to medium size. There are some particular species with exuberant sizes, for example: the Oiticica (Licania rigida), the Tamboril (Enterolobium contortisiliquum) and Cajá (Spondias mombin) (Ab'Saber, 1974; Fernandes and Queiroz, 2018).

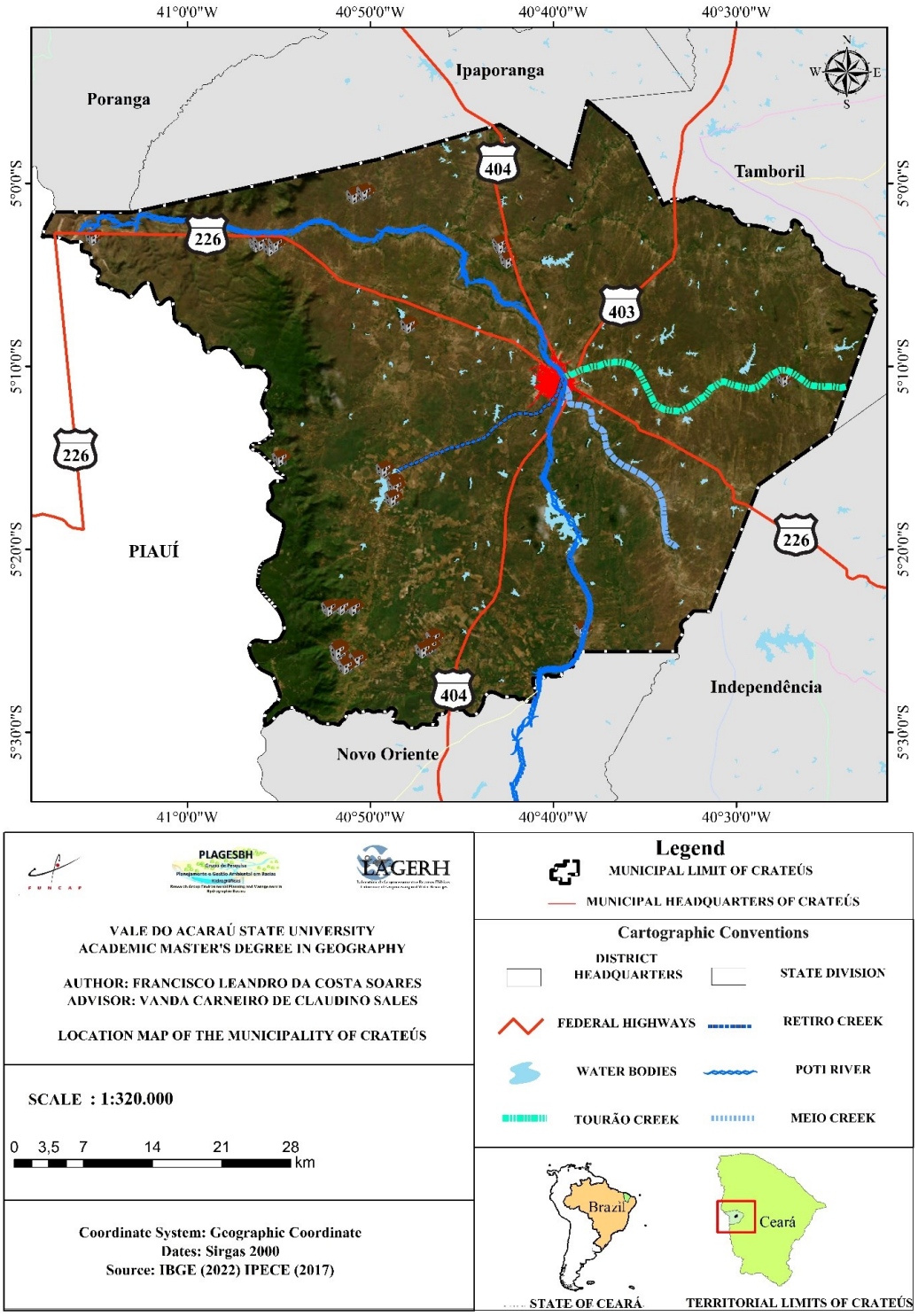

Fig.1 Location map of the research area

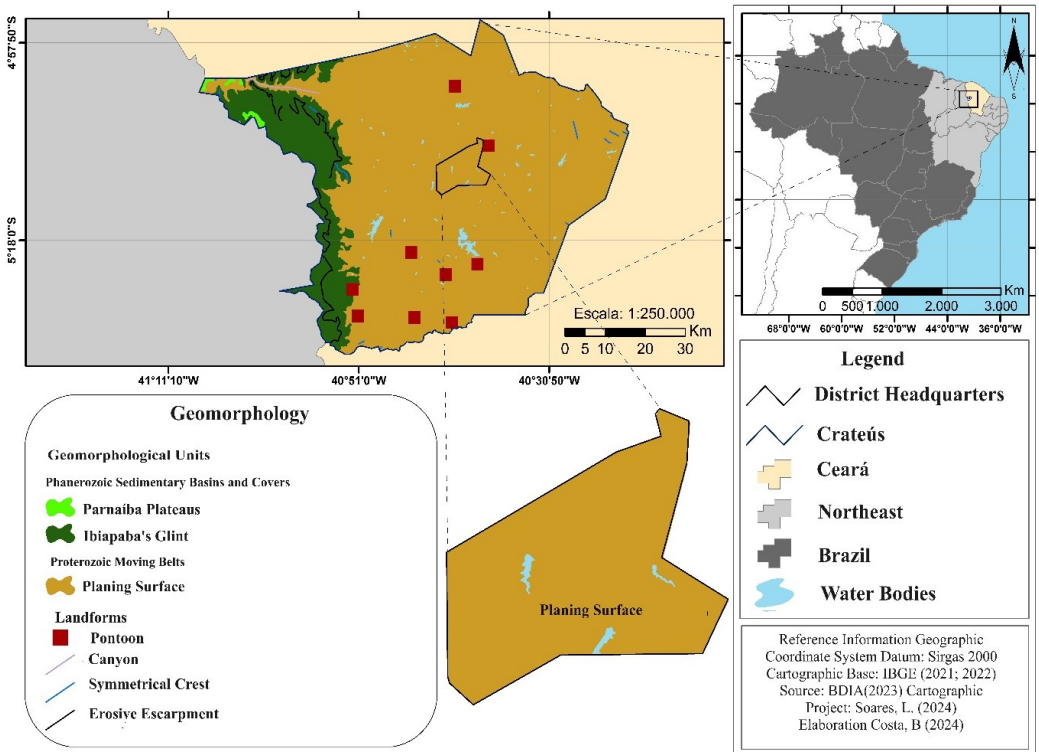

Fig.2 Geomorphology of Crateus City, Brazil

In terms of flora, we observed different types of vegetation occupying the riverbed and/or banks in the urban space. The native species seen were: Oiticica (Licania rígida), Carnaúba (Copernicia prunifera), Cajá (Spondias mombin) and other grass or shrub species. As for the exotic species, there was a monodominance of the Algaroba (Prosopis juliflora) (Corrêa, 1931; Fabricante, 2013).

This study focused on the alluvial-fluvial plains, also known as flood plains. This is an area with high levels of sediment load, relatively flat, under intense weathering and physical-chemical-biological processes, as well as erosion, exposing large rocky outcrops in situ.

Fig.3 Urban route of the Poti River with a total length of 5 km, and the Poti River in the Cidade Nova (Island) neighborhood with a total length of 2.6 km. Source: Google Earth, 2022.

METHODS

The methodology is based on Geosystemic Analysis (Bertrand, 1972, 2009). According to Rodrigues (2004; 2011), Geosystemic Analysis is a theoretical-methodological approach capable of consolidating a set of characteristics and scientific information about a scientific object in a multiple, diverse and interrelated way. The author emphasizes how the methodology has enabled beneficial advances for Physical Geography, and thus for Geomorphology. The multiplicity addressed refers to the possibility of investigating natural aspects (climate, geology, geomorphology, pedology, hydrology, vegetation) and their relationship with social activities, known as anthropic activities, in an organized and systematized way.

From this perspective, four technical stages were carried out to produce the research, based on bibliographical and cartographic research, and analysis and characterization in the field.

The first stage corresponds to the bibliographic survey, the purpose of which was to establish a theoretical basis on the subject to be studied. The research took place mainly on Google Scholar and in geography journals on the subject of "Urban Geomorphology".

The second phase consisted of cartographic and photographic analysis (remote sensing/Google Earth) of the study area between the neighborhoods located near the Poti River. We also searched for photos and maps in city hall archives and engineering projects.

The sum of the first and second stages resulted in the geographic-geomorphological characterization of the urban basin of the Poti River. Much of the characterization was based on mapping carried out by the Geological Survey of Brazil (CPRM). This record is on "Sheet SB.24-V-C-III" (Scale 1:100,000) of 2017 and in the book on the "Geodiversity of the State of Ceará (2014)".

The third phase concerned fieldwork. Thirteen consecutive visits were made to the following neighborhoods: Patriarcas, Cidade Nova (Island) and finally Ponte Preta-São José-Centro. The field reconnaissance took place at different points in the municipal headquarters district, starting at the Barragem do Batalhão and heading towards the Poço Riacho do Meio, the latter already outside the urban area. Figure 5 shows the locations where the field work was carried out.

The fourth phase is the one in which the data acquired during the research was analyzed and characterized, thus producing the scientific material presented here.

RESULTS AND DISCUSSION

The city of Crateús evolved following the dynamics of the river, which was used as a benchmark for land divisions in rural and urban areas. The sudden urbanization of the municipality of Crateús from the 1990s onwards, coupled with the lack of adequate management, planning and land-use planning, has put anthropic pressure on the natural dynamics of the Poti River, altering its physical-chemical-biological behaviour.

Regarding use and occupation, it is worth noting that throughout the process of urbanization of the river plain, the Crateús City Council allowed the installation of a series of homes and commercial buildings. Gradually, what used to be the river's natural domain was occupied by urban facilities, even though it is preserved by law (Law No. 12.651/2012, which creates Permanent Preservation Areas - PPAs). Many buildings, however, have been built spontaneously, and such constructions do not follow adequate standards for a dignified and qualified life. Most of these buildings have rustic, simple structures and engineering styles (Fig. 5A-C), with low added real estate value.

It should also be noted that houses continue to be built near the watercourse with the approval of the town hall, confirming the analysis that the main form of occupation in the valley is housing. However, there are also commercial activities. Besides, in Patriarcas, Cidade Nova and Ponte Preta, São José and Centro neighborhoods, real estate speculation has efficiently pursued its interests, leading to the emergence of buildings with different characteristics. These are regular homes, with high standard styles, sizes and materials, and are not prone to natural disasters (or catastrophes).

This type of home concentrates people with high socio-economic conditions, both financially and in terms of the structural size of the home. They have a good structure and are inhabited by people with a high level of social and cultural life, when compared to those who live in non-central neighborhoods. The size varies in terms of functionality, with the former having a significant real estate value. In the latter, many of these homes are used as stores, religious spaces, leisure facilities, historical and educational centers, among others. The owners of these homes, who are of high socioeconomic status, collect Urban Property Tax from the municipal tax authorities. In these areas, there are other public and private facilities that increase the economic status of the residents (Mello, 2008; Soares and Silva, 2020) (Fig. 5D-E).

In addition to home occupation and considering contemporary literature on use and occupation in urban centers, cartographic analyses and field visits, it was noted that in the Crateús Urban Basin, there are also activities associated with agriculture.

Agricultural activities are carried out by small and medium-sized farmers, who have historically made use of the plain for agricultural activities. Among the crops grown are Grass (Cybodon dactylon) and Elephant Grass (Cenchrus purpureus), the purpose of which is to provide food for cattle, goats, sheep and poultry (chickens and guinea fowl). The use of the land shows the main caractheristics at this point of view (Fig. 6).

Other products are grown seasonally, mainly between the months of January and May, coinciding with the pre-rainy season and the rainy season. Common crops grown during this period are corn (Zea mays), beans (Phaseolus vulgaris), watermelon (Citrullus lanatus) and pumpkin (Cucurbita moschata), among others. These species vary in type and variety depending on the farmer and the source of their seeds, which can be those saved

over the years, or acquired from the responsible public bodies, such as the National Supply Company (CONAB), Rural Workers' Unions, the Environment Secretariat and others.

This occupation and use of the Poti River valley in Crateús has resulted in numerous environmental impacts, such as contamination and sealing of the soil, water pollution and silting up of the main channel, as can be seen in countless urban river plains in Brazil (Baptista and Cardoso, 2013; Guerra and Cunha, 2010; Guerra and Marçal, 2006; Guerra, 2011; Pinéo and Palheta, 2021).

Other environmental impacts are associated with the removal of riparian forest, reduction of ichthyofauna, birds, mammals, pollution of water wells, impact on artisanal and subsistence fishing and accumulation of solid waste, imposing significant health pressure on residents near these areas, who suffer from gastrointestinal and kidney problems, among others, like other urban river areas in the country (Baptista and Cardoso, 2013; Guerra and Cunha, 2010; Guerra and Marçal, 2006; Guerra, 2011) (Fig. 7).

Other serious environmental problems observed are flooding during the rainy season and high and intense deforestation in the forested area, as well as the concentration of solid waste on public roads adjacent to the river valley, in addition to erosion of the banks of the spring.

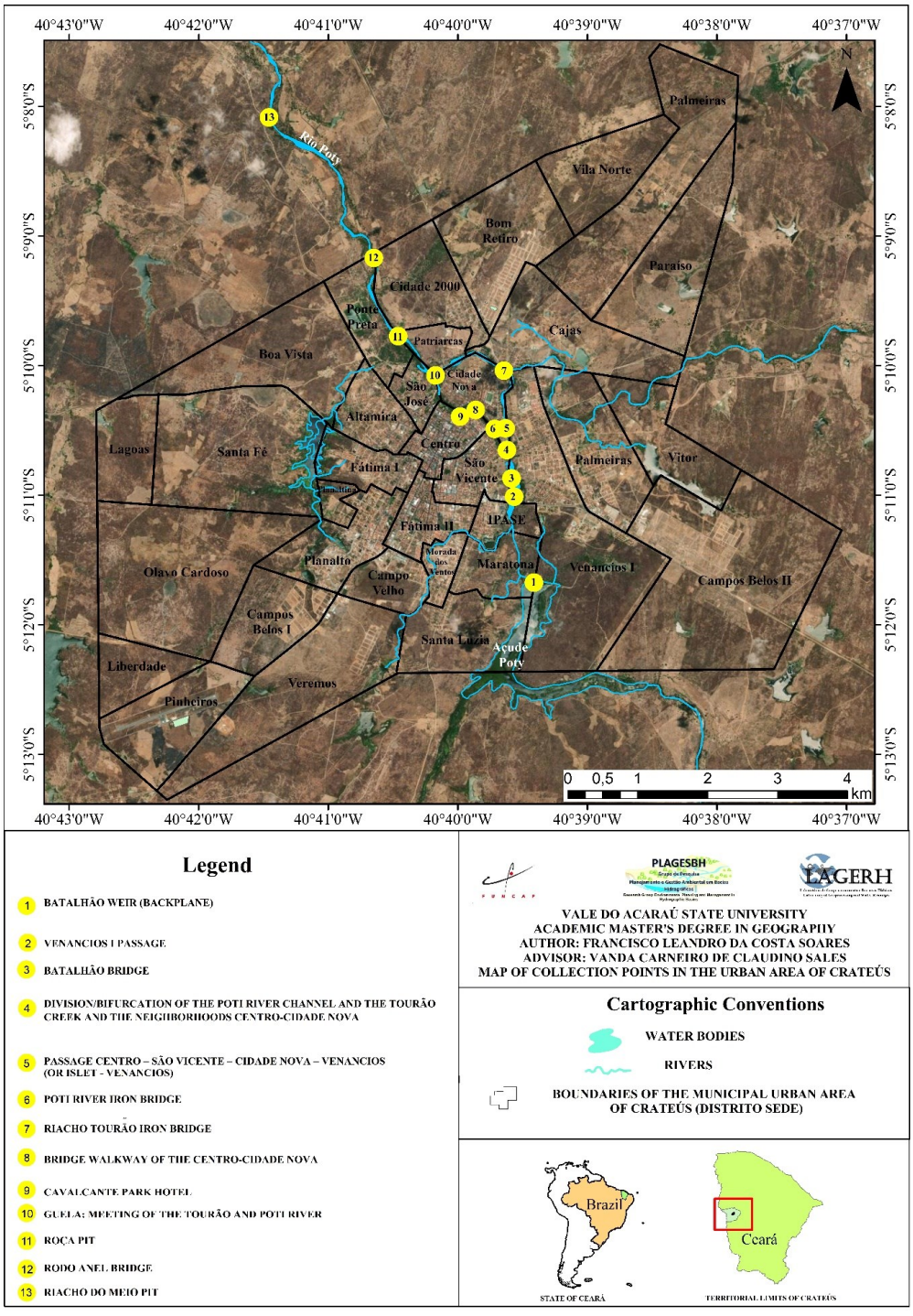

Fig.4 Location of the Points Visited within the Urban Zone of Crateús-CE. Source: Ceará (2017), IBGE (2022)

Fig.5 Irregular occupations on the Poti River plain in the urban area of Crateús (A-B-C), and Houses of a better urban quality in the neighborhood of Sao Jose and Ponte Petra (D-E)

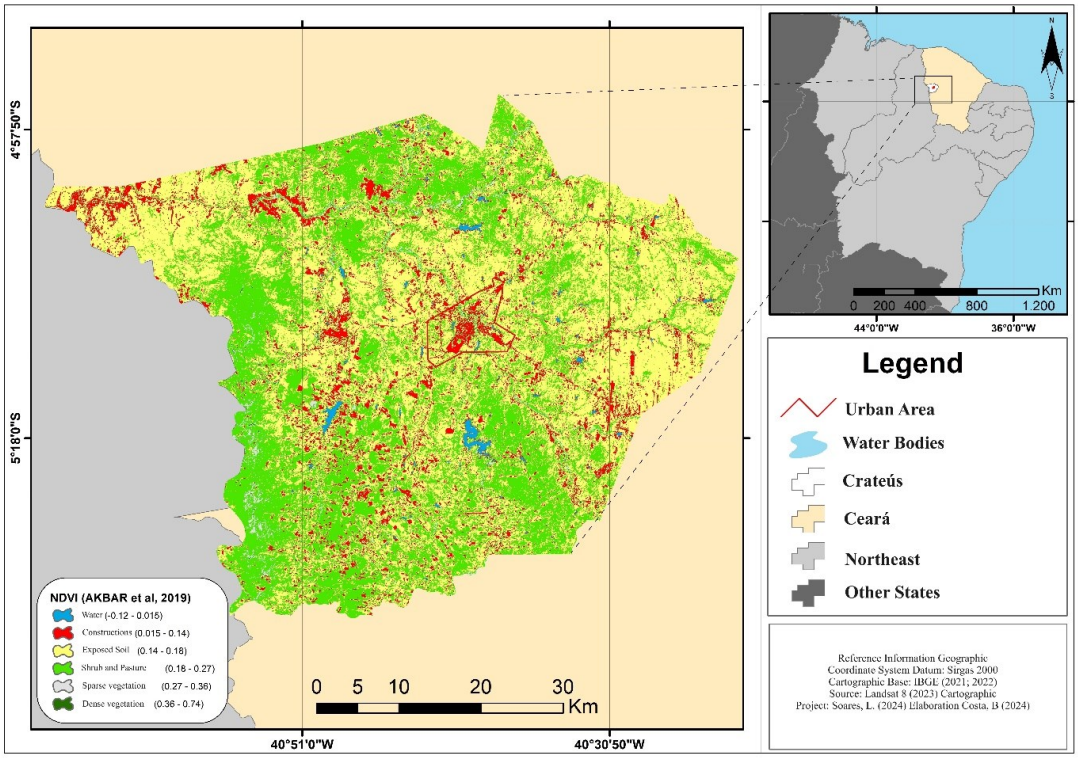

Fig.6 Use of the land in the city of Crateus, in the neighborhood of Poti River plain

Fig.7 Photographic records of the neighborhoods: Cidade Nova, Cidade 2000 and Ilhota.Sectors where the geomorphology indicates occupation, as well as environmental problems. Source: Soares and Claudino-Sales, 2023.

The absence of public authorities in controlling the environmental quality of the water resource can be seen in the historical urban occupation of the riverbed (Almeida and Carvalho, 2009). In fact, there is a lack of basic sanitation and adequate garbage collection, which causes degradation throughout the course of the river in the city of Crateús, which is perpetuated downstream and at the mouth.

The impacts are magnified seasonally during the rainy season, with floods occurring in years of higher rainfall, which creates problems for the poorer riverside population, who are vulnerable because they live in low-quality buildings, installed in a context of disorderly occupation.

CONCLUSIONS

The Poti River and the city of Crateus, in Norhteast Brazil, have developed under a very peculiar geological-geomorphological and social stratum, which has contributed to defining the current natural and social landscape features present on the river plain. Soil sealing, water pollution, siltation, the presence of subnormal settlements and real estate speculation in some sectors indicate improper use and occupation. Residential occupation intensifies the processes of degradation and changes the morphology of the Poti riverbed. Failure to preserve, conserve and care for the river results in processes that are not beneficial to its natural dynamics.

The study showed how necessary it is to adopt practical and strategic measures to try to recover the integrity of the Poti River, which are important and indispensable for building a more promising future in terms of sustainable development. Because rivers are dynamic bodies, precious from a natural point of view, and therefore deserve to be respected.

In addition, there is a need for continued scientific research aimed at implementing more sustainable techniques and technologies, with the purpose of reversing or reducing the impacts mentioned above, as well as controlling actions that are inappropriate for the river and the city. It is clear, however, that caring for water geo-ecosystems is a political, social and environmental action.

The present research has an important scientific value, considering the need to assembly data and environmental information from the hinterland on the countries of South America. Northeastern Brazil is a very good exemple of an area with absence of research on these topics in its countryside. The need of production of data related to these topics are urgent, because it can redirect the process of urbanization and development, allowing to a better way of exploitation of natural resources, was well as inducing a sustainable planning for urban occupation.

This is indeed the first survey produced for the municipality of Crateus, what increases the importance of the research, and should be known by the scientific community and for the public agents responsible for Urban Planning, in order to permit changes on the current process of use of occupation of land, and also to allow other similar research in other parts of the world.

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