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ENVIRONMENTAL FRAGILITY OF LAND SYSTEMS IN A HYDROGRAPHIC BASIN LOCATED IN THE SOUTH REGION OF THE STATE OF BAHIA, BRAZIL

Gabriel Paternostro Lisboa
Universidade Federal do Sul da Bahia – UFSB
Programa de Pós-Graduação em Biossistemas
eng.gabrielpaternostro@gmail.com

Maurício Santana Moreau
Universidade Estadual de Santa Cruz – UESC
Departamento de Ciências Agrárias e Ambientais
mmoreau@uesc.br

Ronaldo Lima Gomes
Universidade Estadual de Santa Cruz – UESC
Departamento de Ciências Agrárias e Ambientais
rlgomes@uesc.br

Gerson dos Santos Lisboa
Universidade Federal de Goiás – UFG
Faculdade de Ciências e Tecnologia
gerson.lisboa@gmail.com

Vinícius de Amorim Silva
Universidade Federal do Sul da Bahia – UFSB
Centro de Formação em Tecno-Ciências e Inovação
vinicius.amorim@cja.ufsb.edu.br

Robson da Silva Magalhães
Universidade Federal do Sul da Bahia – UFSB
Centro de Formação em Tecno-Ciências e Inovação
robson.magalhaes@gfe.ufsb.edu.br

Luciano Cavalcante de Jesus França
Universidade Federal de Lavras – UFL
Programa de Pós-Graduação em Engenharia Florestal
lucianocjfranca@gmail.com

Alex Mota dos Santos
Universidade Federal do Sul da Bahia – UFSB
Centro de Formação em Tecno-Ciências e Inovação
alexmota@ufsb.edu.br

Haighlanda Calil Haddad
Universidade Federal do Sul da Bahia – UFSB
Programa de Pós-Graduação em Engenharia Ambiental Urbana
haighlandach@gmail.com

ABSTRACT

The drainage system of a hydrographic basin is formed by integrated functional systems, which provide ideal conditions for studies aimed at conserving and preserving ecosystems. Given the need to protect remnants of native vegetation in the Atlantic Forest, this study identified the terrain systems of Una River Basin (BHRU), Bahia, through the technical application of terrain assessment and multi-criteria methodological approach. In addition, the identified systems were evaluated for their levels of potential and emerging frailty. The results showed that the BHRU is subdivided into 8 (eight) terrain systems. Considering the relationship between the natural dynamics of the environment and the pressures exerted by anthropogenic activities, it was found that alluvial and coastal systems have areas with high degree of emerging fragility (8.20% of the BHRU). This high degree of emerging fragility is due to its natural characteristics, allied to the increase of anthropized environments that contrast the Buerarema and pre-coast systems, which have more excellent environmental protection due to extensive vegetation cover on their slopes. The study's methodology was shown to be adequate for the identification and characterization of terrain systems in the BHRU and can be replicated in other ecoregions in the country.

Keywords: Geographic Information System. Fragmentation. Atlantic forest. Multicriteria Analysis.

FRAGILIDADE AMBIENTAL DOS SISTEMAS DE TERRENO DE UMA BACIA HIDROGRÁFICA LOCALIZADA NA REGIÃO SUL DO ESTADO DA BAHIA, BRASIL

RESUMO

O sistema de drenagem de uma bacia hidrográfica é formado por sistemas funcionais integrados, que proporcionam condições ideais para estudos voltados à conservação e preservação de ecossistemas. Diante da necessidade de resguardar remanescentes de vegetação nativa na mata atlântica, o objetivo deste estudo foi identificar os sistemas de terreno da Bacia hidrográfica do Rio Una (BHRU), Bahia, por meio da aplicação técnica de avaliação do terreno e abordagem metodológica multicritério. Os sistemas identificados foram avaliados quanto aos seus níveis de fragilidade potencial e emergente. Os resultados demonstraram que a BHRU está subdividida em 8 (oito) sistemas de terreno. Levando-se em conta a relação existente entre a dinâmica natural do ambiente e as pressões exercidas pelas atividades antropogênicas, constatou-se que os sistemas aluvionares e litorâneos possuem áreas com alto grau de fragilidade emergente (8,20% da BHRU) em decorrência das suas características naturais, aliado ao aumento de ambientes antropizados, contrapondo-se os sistemas Buerarema e pré-litorâneo, que possuem maior proteção ambiental devido à presença de extensa cobertura vegetal em suas encostas. A metodologia do estudo apresentou-se como adequada para a identificação e caracterização dos sistemas de terreno na BHRU e pode ser replicada para outras ecorregiões do país.

Palavras-chave: Sistema de Informações Geográficas. Fragmentação. Floresta Atlântica. Análise multicritérios.

INTRODUCTION

Environmental systems comprise elements (relief, soil, vegetation, climate, among others) that interrelate in dynamic balance. When there is harmful interference in these systems, their responses are given according to their natural characteristics. Environmental assessments can be obtained by mapping potential and emergent environmental fragility, which indicates the susceptibility of natural spaces to the occurrence of natural or induced degradation processes (ROSS, 2012; FRANÇA et al. 2020; ANJINHO et al. 2021).

According to Ratcliffe (1971), the emerging fragility is closely related to the level of natural susceptibility of an environmental system in face of anthropic interference. Thus, any alteration can partially or entirely compromise the entire biodiversity of this environmental system. Therefore, potential fragility is defined as the natural susceptibility of an environment due to biophysical characteristics of the landscape (FRANÇA et al. 2019).

As a result, physical-territorial planning becomes increasingly urgent, considering not only the potential of space but mainly its fragility against any human intervention (DONHA et al., 2006). Obtaining this type of information is essential for monitoring and enforcing environmental systems and contributes to the definition of areas requiring more outstanding care (MANFRÉ et al., 2012; FRANÇA et al., 2020). Spörl e Ross (2004) state that obtaining information about the potential and emerging weaknesses of environments helps managers in decision-making, providing essential parameters for public management.

Knowing that hydrographic basins are priority territorial units for carrying out surveys of emerging fragility, and given its integrating character, this study advocates analysis of the landscape dynamics through a more particularized natural division, also known as landform. According to Petan et al. (2010), landform corresponds to the terrain features composed of a set of natural attributes related by the same genetic processes and, therefore, enables to predict the potentialities and limitations of the physical environment.

The study area proposed for analysis comprises the different forms of relief already diagnosed in the Hydrographic Basin of Una River (URHB). The area is in the southern state of Bahia, standing out as one of the region’s natural systems since it has extensive vegetation of Cabruca (Atlantic Forest thinned by cocoa plantation), preserved remnants of the Atlantic Forest, sandbanks, and mangroves.

It should be emphasized that URHB, until the end of the 1980s, had its economy focused on cocoa crop, predominated by the Cabruca system, a sustainable production technique that conserves tree species from the Atlantic Forest, adding value and ecosystem service for fauna and flora locations (SAMBUICHI et al., 2012; SOLLBERG et al., 2014).

Despite this, the regional economy related to cocoa production has entered a crisis over the decades, mainly due to the spread of witches' broom fungus (*Crinipellis perniciosa*), climatic fluctuations, and low market prices. Consequently, the region has also gone through other crises, adopting less sustainable production practices without considering the emerging fragility and the importance of the local environment (ROCHA, 2008). This subject matter is reflected in the multiple impacts caused on natural resources, especially those resulting from deforestation and the expansion of pasture areas (MARTINS, 2007).

This study evidences the assumption that the absence of efficient planning and a land-use plan in the cocoa region of Bahia, mainly observed as of the 1980s, makes the dynamics of natural resources vulnerable in most of Una River Basin. Thus, to understand the physical and morphodynamic attributes of hydrographic basins, detailed geoenvironmental studies become essential, as these studies are guiding and theoretical-scientific references that enable the implementation of projects on principles of sustainability. Thus, this work aims to identify URHB's land systems through the technical application of land assessment proposed by Lollo (1995, Unpublished data), characterizing each system identified in terms of its potential and emerging fragility levels, according to the method of Ross (1994).

MATERIAL AND METHODS

Study Area

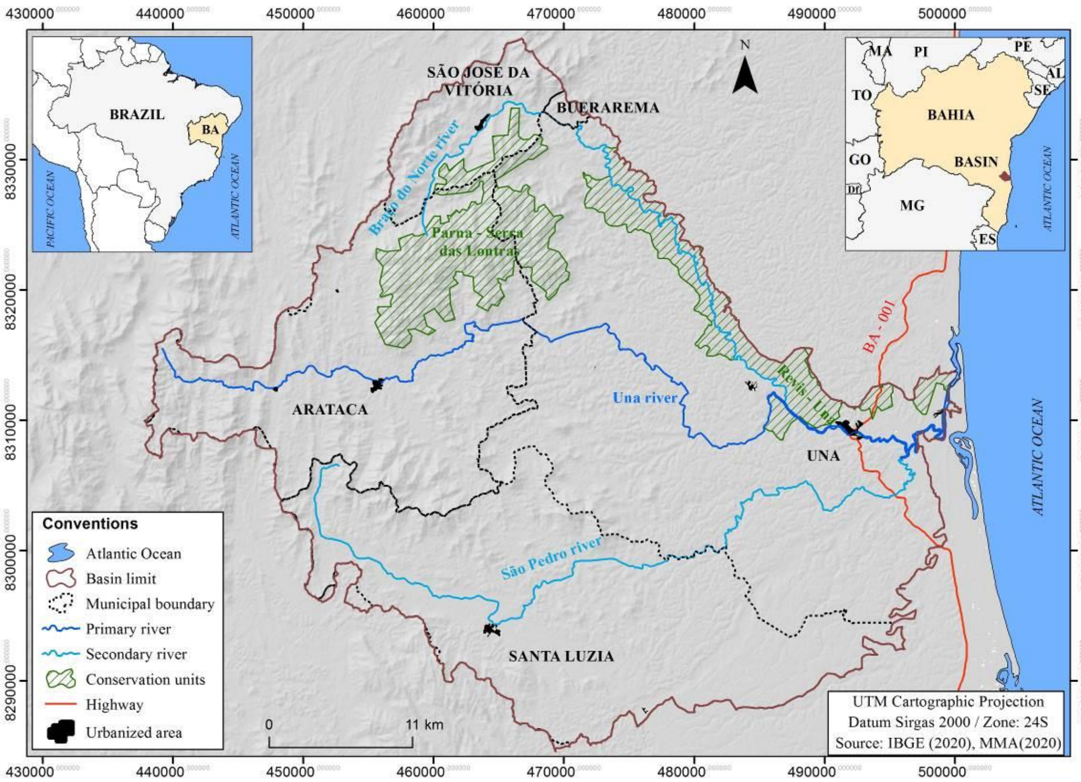
The area under study corresponds to the Southern region of the State of Bahia, specifically in the eastern part of the Cocoa Region (Figure 1). This region has a total area of 1760.30 km², covering the municipalities of Una, Santa Luzia, Arataca, São José da Vitória, Buerarema, Jussari, Camacan and Mascote (Table 1).

Table 1 - Total, the absolute and relative area of municipalities in Una River Hydrographic Basin.

County	The total area of the municipality (km²)	Absolute area of the city (km²)	The relative area of the municipality (%)
Arataca	435.63	427.85	24.31
Buerarema	219.31	5.09	0.29
Camacan	584.42	5.36	0.30
Jussari	328.95	1.46	0.08
Mascote	818.10	0.55	0.03
Santa Luzia	650.05	489.47	27.81
São José da Vitória	127.83	95.22	5.41
Una	1,221.53	735.30	41.77
TOTAL	**4,385.82**	**1,760.30**	**100.00**

Source - Authors (2021).

Figure 1 - Southern Bahia. Location of Una River Hydrographic Basin (Aliança).



Source - Authors (2021).

URHB comprises three Conservation Units, namely: Serra das Lontras National Park (SLNP), Wildlife Refuge (WR), and Una Biological Reserve (UBR). With extensive areas of forest remnants and agroforestry projects within its limits, URHB is a socioecological system of paramount importance for the region.

URHB presents significant anthropic changes in its dynamics and natural landscape, among which the following stand out: suppression of native vegetation, urban expansion, agrosilvipastoral activities, and pollution of water sources. These impacts deserve attention due to the representativeness of URHB for the population of the eight municipalities contained in it, in addition to those in its area of influence.

According to the Köeppen climatological classification system, adapted by Alvares et al. (2013) the prevailing climate in the basin is Humid Tropical Climate or Af type. This climate zone presents monthly rainfall above 60 mm and annual rainfall of 1,500 mm, with the main characteristic being well-spaced rainfall over the years. The period from March to August presents greater precipitation index, while in January and February, which are hotter, the temperature ranges from 24 to 25 °C. It is noteworthy that this unit presents average of the coldest month, above 18°C.

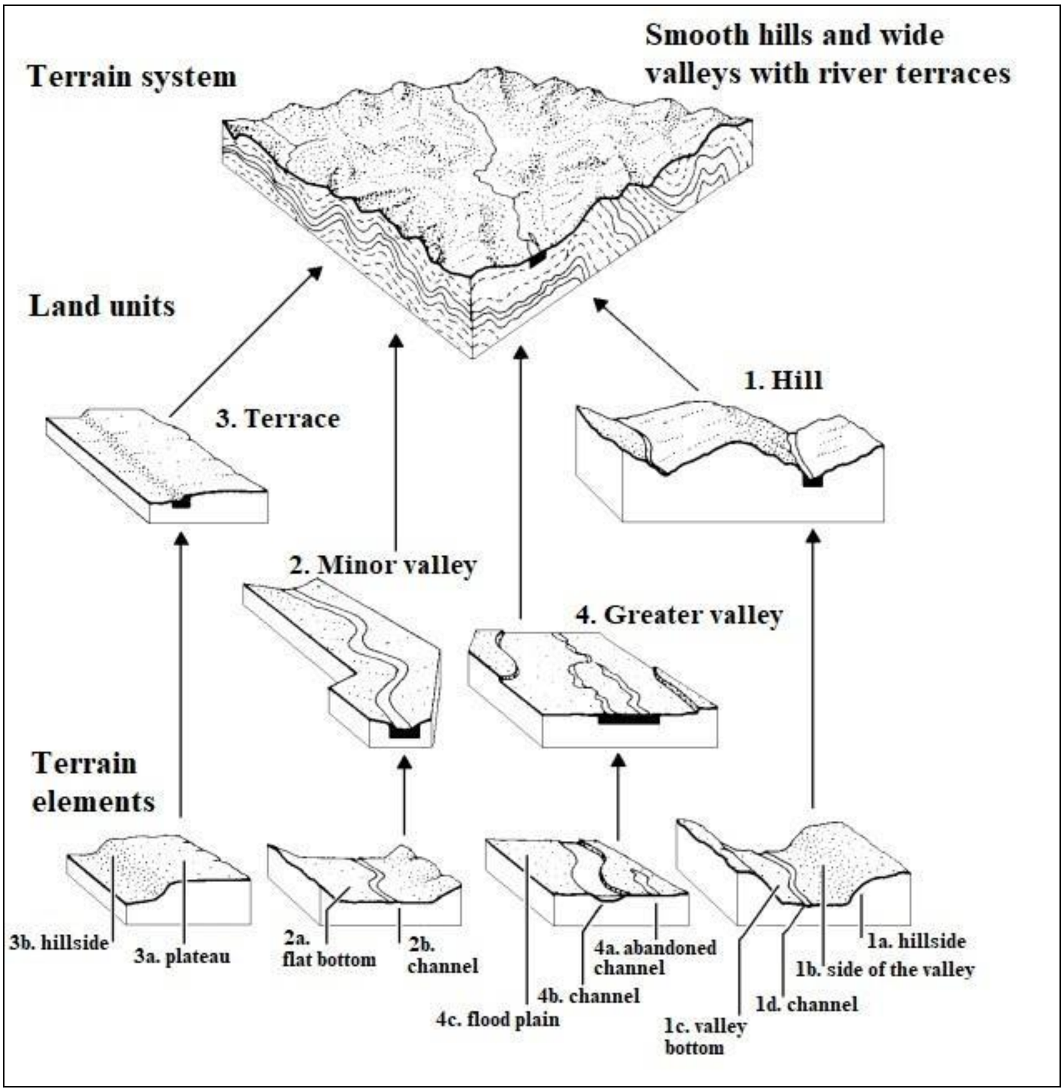
At URHB, small climatic types are also observed, which are Cfa and Cfb. According to Alvares et al. (2013), the first-class corresponds to the Subtropical Climate with hot summer. Its average temperature is ≥ 22°C in the hottest month, and monthly rainfall > 40 mm. At URHB it is found in regions with altitudes ranging from 750 to 900 meters.

The Cfb unit, as mentioned above, represents the Subtropical Climate with temperate summer. In the basin, it is in areas with altitudes above 900 meters. Its main characteristics should be highlighted: well-distributed rainfall, with average annual precipitation ranging from 1,100 to 2,000 mm, absence of a well-defined dry season, and average temperature in the hottest month < 22 °C.

Methodological Analysis

The methodology used for delimitation and characterization of the terrain systems is based on the recognition and analysis of different relief features (Landforms) found in URHB. The identified features are classified by their physical properties, such as topographic shape, drainage pattern, and channel morphology. Figure 2 summarizes the procedures established in the application of the land evaluation technique.

Figure 2 - Schematic representation of the technical application of land evaluation.



Source - Modified from Lollo (1996).

Following the assumptions of Lollo (1995, Unpublished data), and according to what was published in the works of Mauro and Lollo (2004), Silva e Gomes (2010) regarding the interpretation of the systems, two approaches are used for the terrain evaluation. In the first, entitled landscape approach, a set of interpretations of satellite images are used, concomitantly with field visits, to define similar areas. In the second approach, called parametric, tools are used based on parameters representative

Gabriel Paternostro Lisboa
Maurício Santana Moreau
Ronaldo Lima Gomes
Gerson dos Santos Lisboa
Vinícius de Amorim Silva
Robson da Silva Magalhães
Luciano Cavalcante de Jesus França
Alex Mota dos Santos
Haighlanda Calil Haddad

of the shapes, such as declivity, amplitude, and extension of the features. After applying both approaches, a geotechnical characterization of the materials (rocky and unconsolidated) is carried out.

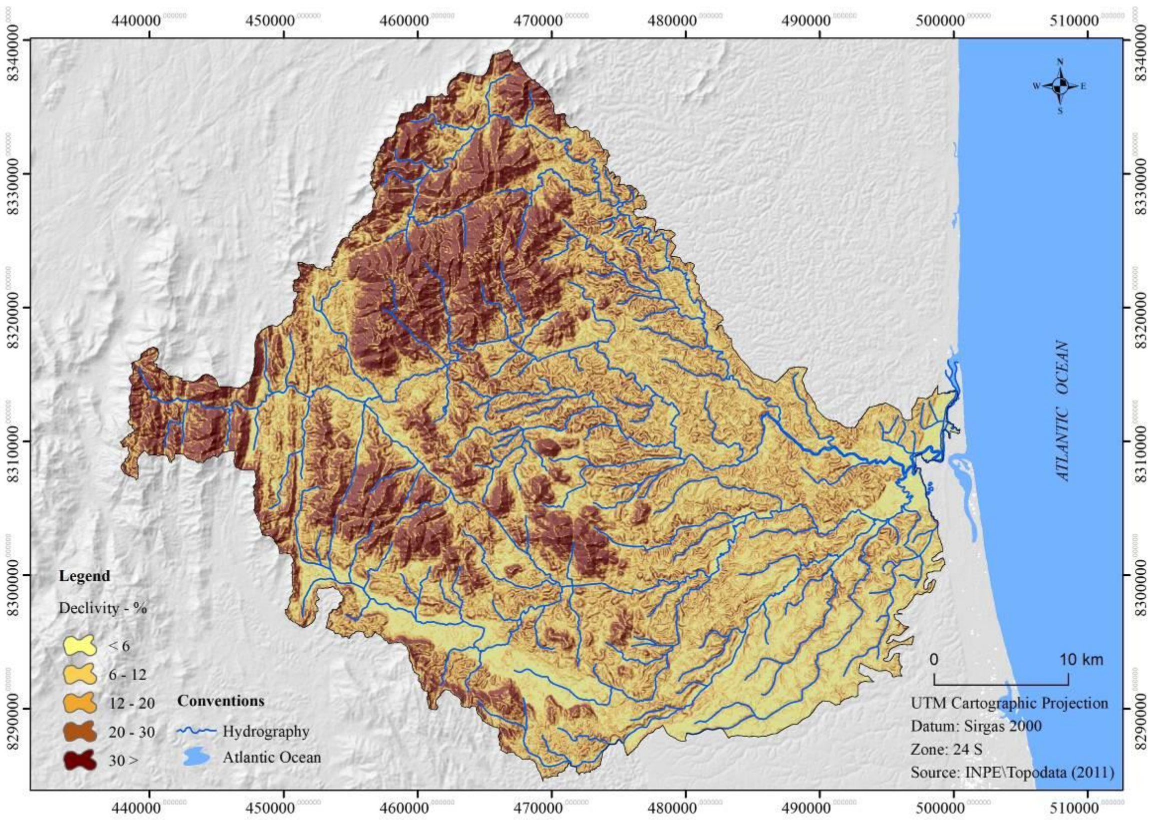
For identification and classification of features, using topographic maps extracted from the Geomorphometric Database of Brazil (Topodata Project) sheets 15S39_ZN and 15S405_ZN, the Digital Elevation Model (DEM) of the terrain is obtained. The charts must be worked in a Geographic Information System (GIS) environment.

Correlated to the classes of hypsometry, declivity, and geological discontinuities observed in the field and highlighted through satellite images (Landsat 8/2015), the DEM results allow greater detail of the study.

The use of QGIS 2.18 software stands out in the digitization and mapping of areas. Due to the scale of work used in the research, the survey of the physical environmental conditions via terrain assessment reaches the hierarchical level of systems, making it possible to search for the intrinsic relationship of each model with the active dynamic processes.

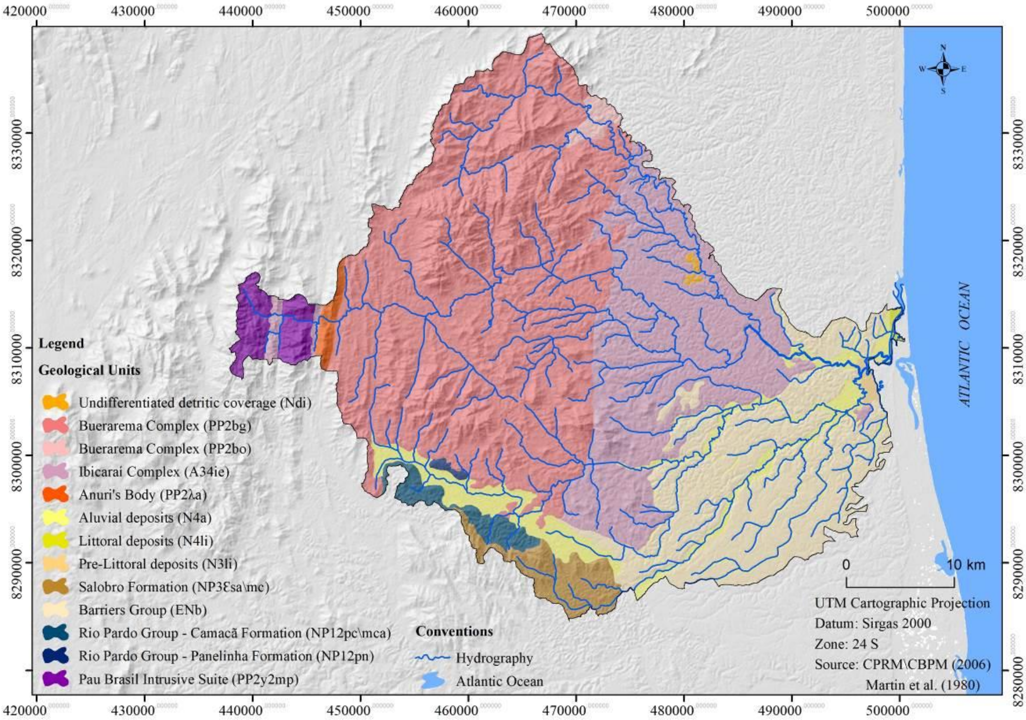
Once URHB's land systems are defined, studies of the potential and emerging fragility of URHB begin. Georeferenced data are organized based on Lisboa et al. (2017) to meet the demand for URHB's physical-environmental attributes necessary to obtain weaknesses. The following Figures (3, 4, 5, and 6) summarize the thematic and geographic elements used.

Figure 3 - URHB declivity.



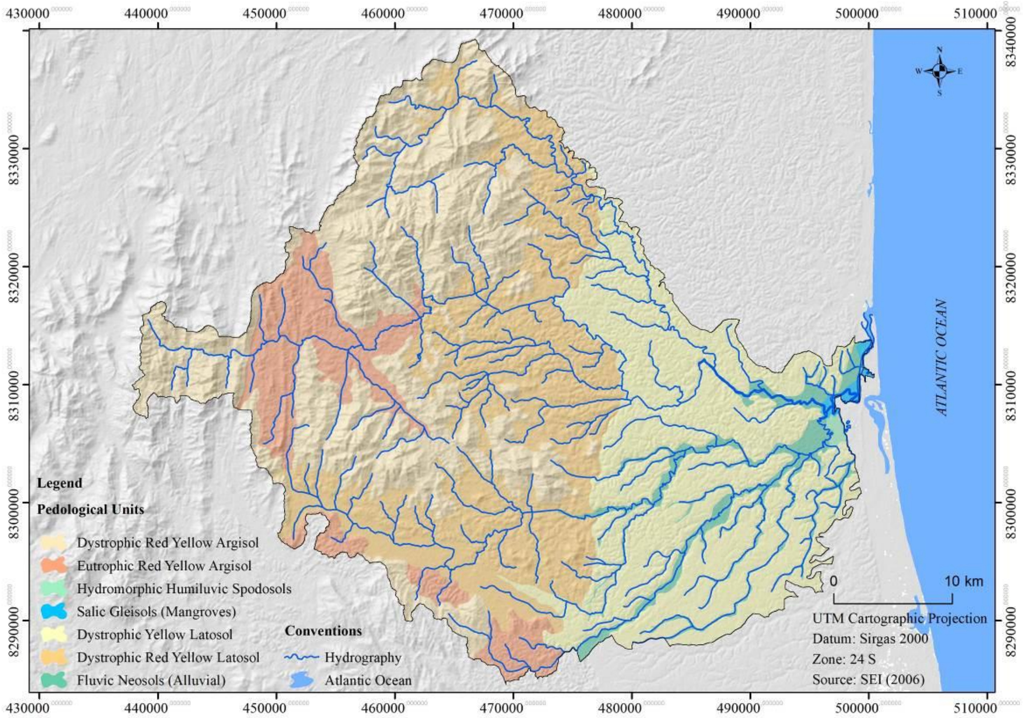
Source - Authors (2021).

Figure 4 - URHB Geological Units.



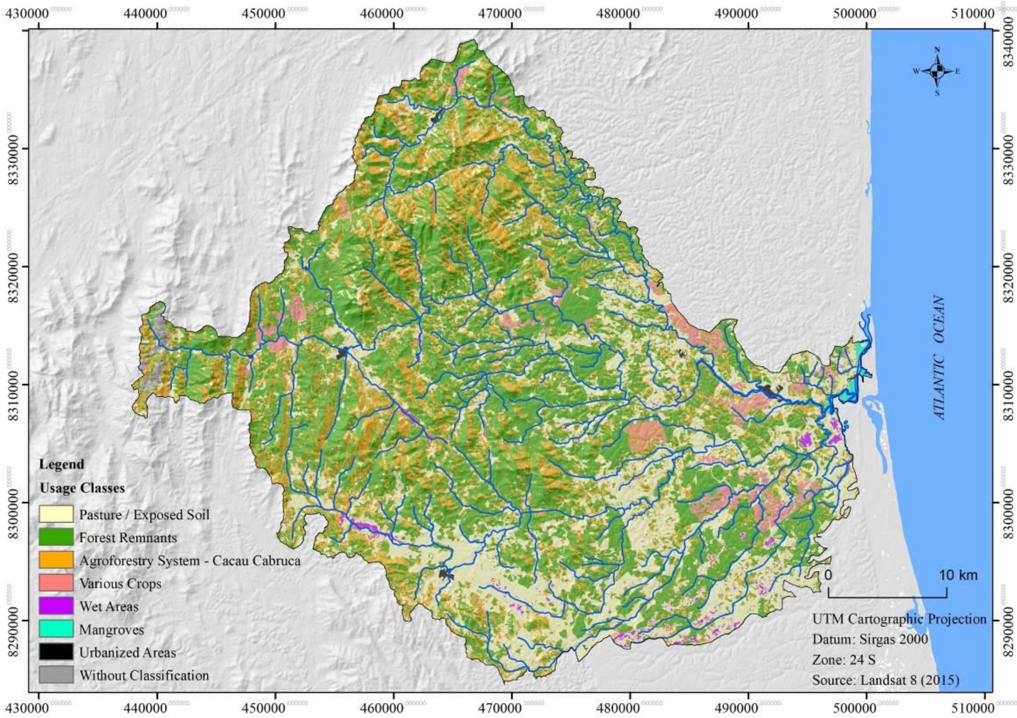
Source - Authors (2021).

Figure 5 - URHB Soil Classes.



Source - Authors (2021).

Figure 6 - Land use and coverage.



Source - Authors (2021).

After settling down the physical-environmental components, the fragility of natural and anthropized environments is based on the research of Ross (1994). According to the author, analyzing the potential fragility of territory requires basic studies of the rocky substrate, soil, slope, and climate. In contrast, analyzing the emerging fragility and considering these natural physical characteristics require information on land use. These elements, treated in an integrated and correlated way, enable a diagnosis of the different hierarchical categories of the land weaknesses.

Therefore, weights are assigned to the classes diagnosed in each thematic map, taking as parameter their environmental susceptibility. The weightings presented in Tables 02 to 05 are based on Ross (1994), Waldburger (2014), and Gomes (2013). For the attribution of weights referring to climate, it is considered that URHB presents constant rain index without defined dry season; in this regard, value of 3.0 is assigned to the weight.

Table 2 - Weights of the different classes of rocky substrate.

Class	Weight
Undifferentiated dentritic coverage (Ndi)	5.0
Buerarema Complex (PP2bg)	2.2
Buerarema Complex (PP2bo)	2.2
Ibicaraí Complex (A34ie)	2.2
Anuri's body (PP2λa)	2.3
Alluvial deposits (N4a)	5.0
Littoral deposits (N4li)	5.0
Pre-Littoral deposits (N3li)	5.0
Salobro Formation (NP3 Ɛ sa\mc)	3.3
Barriers Group (ENb)	4.3
Pardo River Group - Camacã Formation (NP12pc)	3.1
Pardo River Group - Panelinha Formation (NP12pn)	3.2
Pau Brasil Intrusive Suite (PP2y2mp)	2.2

Source - Authors (2021).

Table 3 - Weights of the different soil classes.

Class	Weight
Fluvic Neosols (Alluvial)	4.5
Salic Gleisols (Mangroves)	5.0
Hydromorphic Humiluvic Spodosols	4.5
Dystrophic Red Yellow Argisol	4.0
Eutrophic Red Yellow Argisol	3.0
Dystrophic Yellow Latosol	2.0
Dystrophic Red Yellow Latosol	2.0

Source - Authors (2021).

Table 4 - Weights of the different slope classes.

Class (%)	Weight
< 6	1.0
6 – 12	2.0
12 – 20	3.0
20 – 30	4.0
30 >	5.0

Source - Authors (2021).

Table 5 - Weights of the different classes of land use.

Class	Weight
Pasture / Exposed Soil	5.0
Forest Remnants	1.0
Agroforestry System - Cacau Cabruca	1.0
Various Crops	4.0
Wet Areas	5.0
Mangroves	1.0
Urbanized Areas	5.0

Source - Authors (2021).

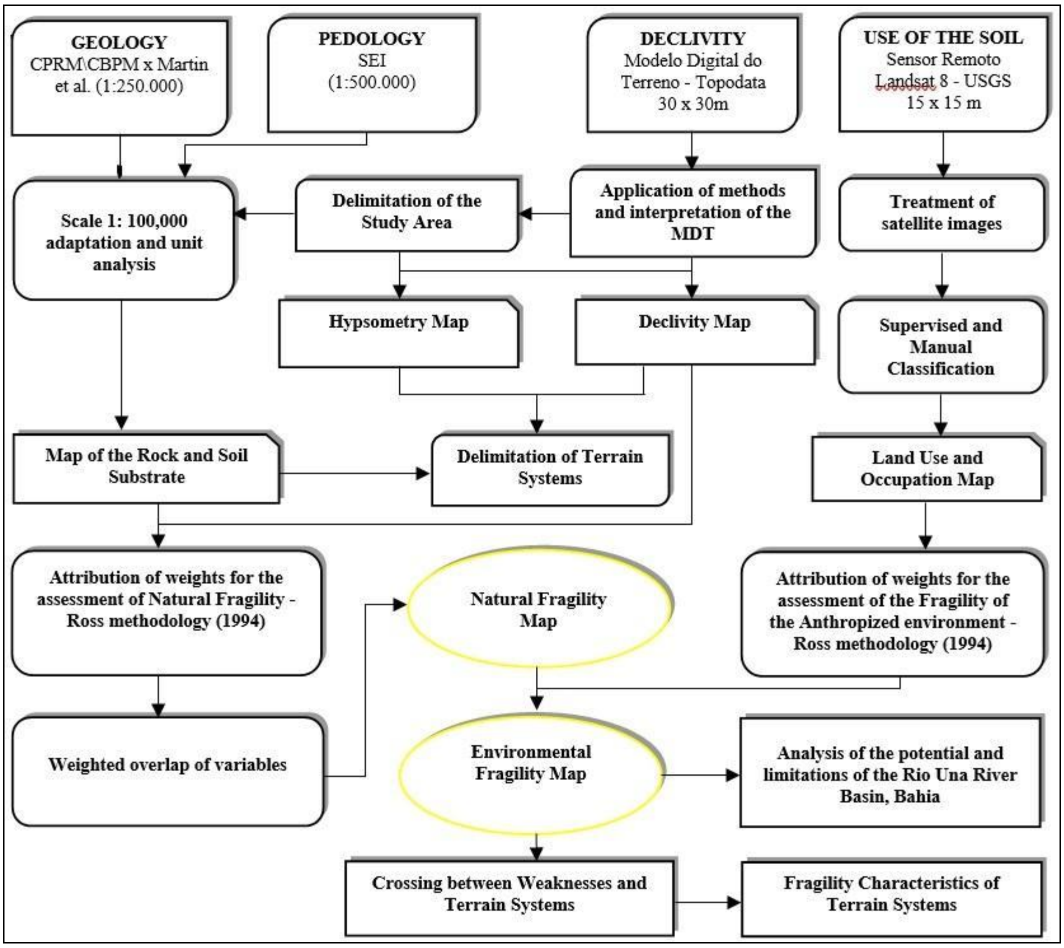
After settling down the assigning of weights, Qgis 2.18 software is used to implement the map algebra technique for integrating data in multicriteria, generating the potential and emerging fragility mappings in a raster format.

The weaknesses belonging to each terrain system are obtained by extracting the weaknesses using a representative mask of each system diagnosed in the URHB. With this, the potential and emerging fragility are sectorized in each mapped terrain system.

All mappings are based on Universal Transverse Mercator (UTM) projection, Datum Sirgas 2000 (Geocentric Reference System for the Americas). Due to the spatialization of the area under study and the existing plan altimetric coverage information, the files obtained are manipulated at a scale of 1:

100,000. In Figure 7, a flowchart of the methodological steps of the study is presented, summarizing the procedures adopted in the research.

Figure 7 - Flowchart with methodological steps of the study.



Source - Authors (2021).

RESULTS AND DISCUSSION

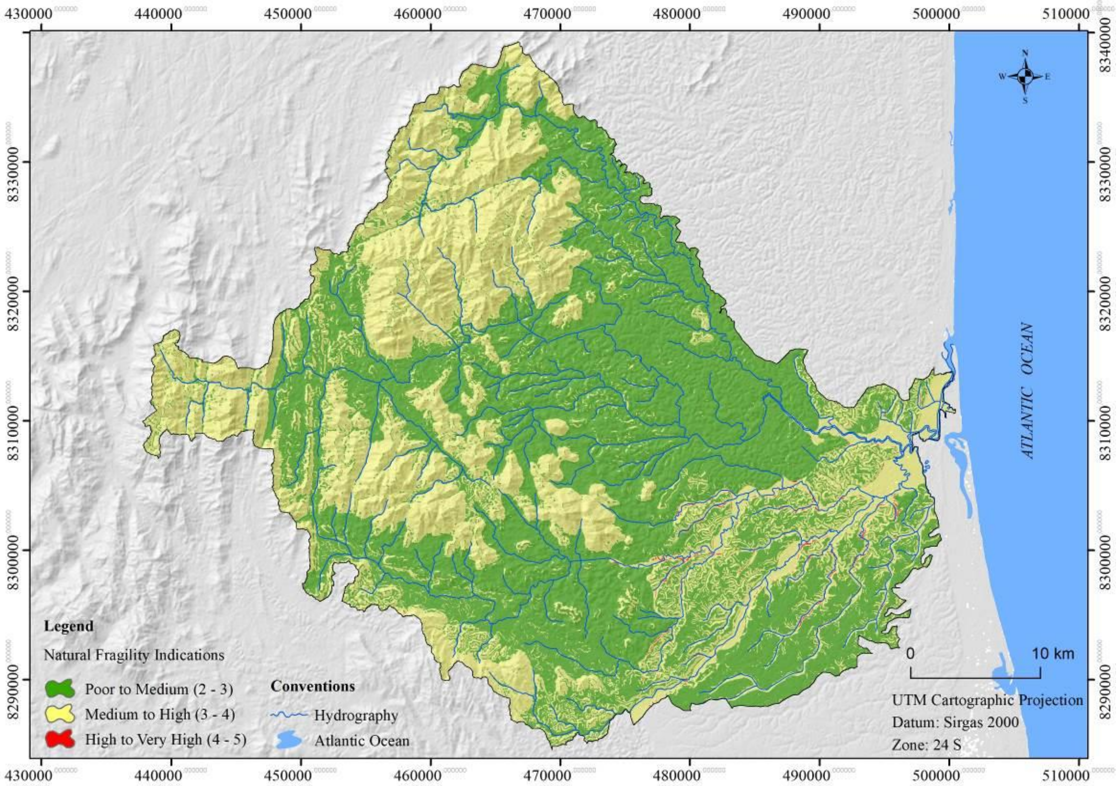
Potential Fragility

In general, the slope is a determining factor in the control of frailty. In URHB, this is visible in the Midwest and Northwest regions, specifically in Serras das Lontras, Lapão, and Onça. Both are in steep areas associated with the Buerarema Complex substrate.

In the case of environments located on the coastal plain and regions of accumulations, the pedological and lithological classes tend to be more determinant due to the predominance of sandy and poorly drained soils supported over unconsolidated Quaternary sediments. This influence is observed in the eastern and southeastern parts of URHB, specifically in river valley bottoms with the greatest contribution.

As shown in the map in Figure 8, URHB has three distinct zones of potential fragility. The one with the greatest spatialization, weak to medium fragility, has an area of 983.61 km², representing 55.88% of the object studied, strongly related to flat to wavy relief sites. This condition of fragility is set by characteristics combined with soils and rocky substrates less susceptible to morphogenetic relief actions.

Figure 8 - Potential fragility map of Una River Hydrographic Basin.



Source - Authors (2021).

Medium to high fragility occupies 43.48% of URHB, distributed in two zones. The first is in the Pre-Littoral Trays and Plateaus, in environments with solid wavy to steep relief (western portion - Figure 8), with slopes above 30%. The second, located in the Coastal Plains and the regions of Fluvial Accumulations (East portion - Figure 8), is associated to sediments with high degree of susceptibility to erosion due to their textural relationship increasing the condition of emerging fragility.

The last category, high to very high fragility, is found in smaller quantity, with 4.77 km² in the valleys of Salobro and São Pedro rivers. What sets up this group are potential small, rugged areas related to low fertility soil and interconnected to more vulnerable substrates.

Emerging Fragility

In order to determine the classes of emerging fragility and consider natural variables in the potential fragility, this analysis includes the anthropic aspects determined by land use and occupation classes, Table 6. Thus, it is characterized by how human activities affect the environment and the consequences resulting from this intervention.

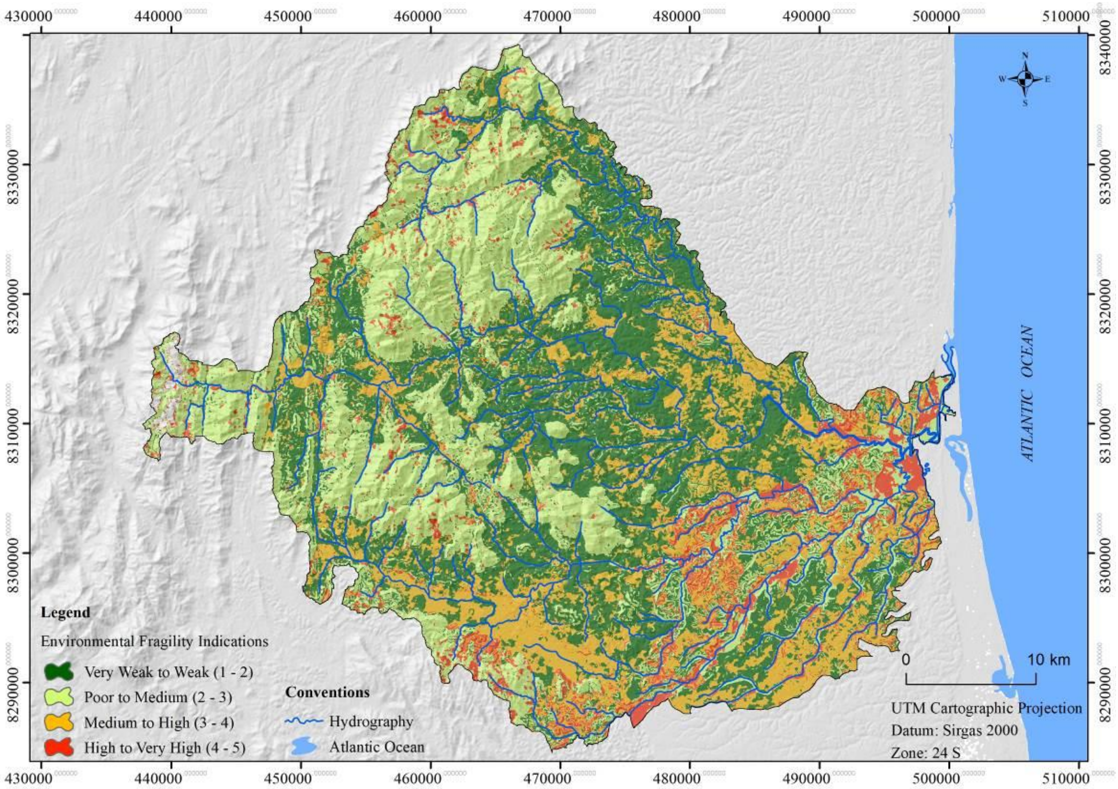
Table 6 - Degrees of protection of classes of land use and occupation.

Classes of Land Use and Occupation	Degree of Protection	Indexes
Pasture / Exposed Soil	Very low	5.0
Forest Remnants	High	1.0
Agroforestry System - Cacau Cabruca	High	1.0
Various Crops	Low	4.0
Wet Areas	Very low	5.0
Mangroves	High	1.0
Urbanized Areas	Very low	5.0

Source - Adapted from Ross (1994).

Based on the concept of Ecodynamic Units (EU), these actions make the environment more stable, as it makes it possible to protect the soil, or unstable, when there are land uses that harm the environment, making it more vulnerable to weathering. In Table 1 and Figure 9, it is possible to observe the fragility indexes of the different classes of occupation found in URHB, based on their degrees of protection.

Figure 9 - URHB emerging fragility map.



Source - Authors (2021).

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Haighlanda Calil Haddad

The new unit characterized as very weak to weak fragility, corresponds to 35.58% of URHB, covering an area of 626.37 km². It is distributed throughout the territory in forest formations interconnected to natural systems (soils, rocky substrates, and slopes) less susceptible to erosive events.

Like the class mentioned, the weak to medium emerging fragility is related to landscapes with vegetation cover; however, these are more fragile due to the degree of dissection of the relief. It is possible to note the presence of these zones in the Central part of URHB and the West and Northwest regions. At its limit, there are heavily moved reliefs.

The medium to high fragility, on the other hand, occupies 371.62 km² and represents 21.11% of the area. It is usually integrated to regions with o natural potential ranging from weak to medium; however, with the introduction of agricultural activities without proper management and the advance of urbanization without proper planning, these are more vulnerable to erosion. It is possible to observe its distribution at two points in URHB. The first is located on tertiary sediments of Barreiras group, while the second is associated with the substrates of the Alluvial Deposits in Rio Pardo Trays.

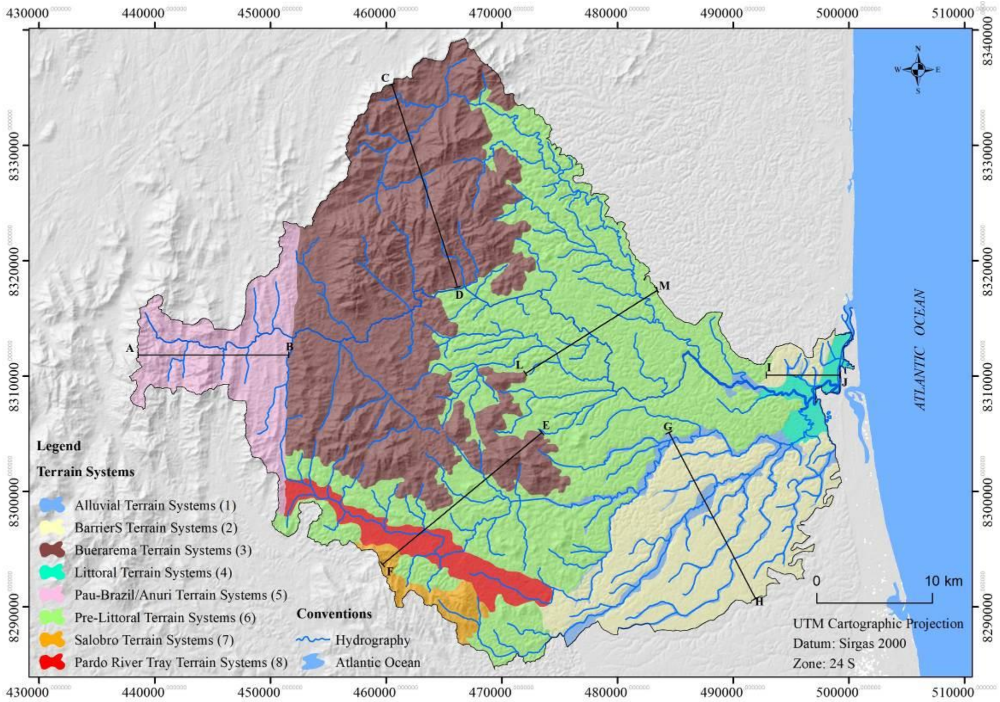
Finally, the upper to very high class is found in greater concentration in the eastern and southern part of URHB, comprising 8.20% of URHB. What sets up this group is the excessive use of land in locations where the dynamic balance of nature favors the transforming processes of the environment (morphogenesis prevails), aggravating the situation of instability of these spaces.

In general, there is strong influence of the vegetation cover in every area, whether formed by forest remnants and/or agroforestry system (cacao cabruca), in the control of the environment's fragility. In places that do not have forest formations, there is greater vulnerability to erosion due to their smaller capacity to absorb rainwater, which contributes to more significant runoff and, in most cases, destabilization of slopes.

Distribution and Characteristics of Terrain Systems

This chapter describes the eight Terrain Systems identified at URHB, after applying the land evaluation technique.For didactic purposes, they received names linked to the different geological and geomorphological forms identified in Figure 10 and Table 7.

Figure 10 - URHB terrain systems and layout of topographic profiles.



Source - Authors (2021).

Table 7 - Distribution of the land systems of the *Una River Hydrographic Basin*.

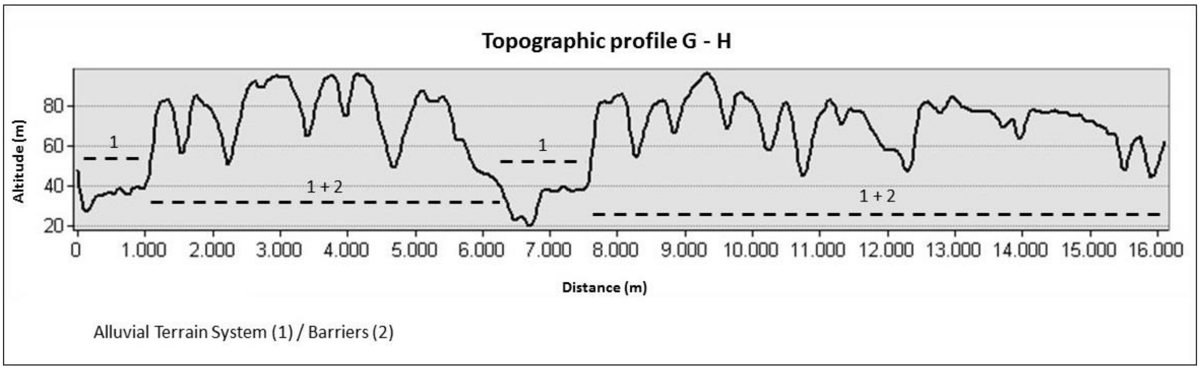
TERRAIN SYSTEMS	**km²**	**%**
Alluvial terrain systems	63.41	3.60
Barriers terrain systems	240.32	13.65
Buerarema terrain systems	566.73	32.19
Littoral terrain systems	24.86	1.41
Pau-brasil/anuri terrain systems	131.09	7.45
Pre-Littoral terrain systems	652.14	37.05
Salobro terrain systems	25.14	1.43
Pardo River Tray terrain systems	56.61	3.22
TOTAL	**1,760.30**	**100**

Source - Authors (2021).

System 1: Alluvial

This first mapped unit covers 63.41 km², corresponding to only 3.60% of the object under study. Nevertheless, it directly relates to URHB river dynamics, associated with flat to smooth undulating reliefs, spatialized in environments with altitudes ranging from 10 to 50 meters, Figure 11.

Figure 11 - Topographic profile of alluvial terrain systems and barriers.



Source - Authors (2021).

Due to the presence of clastic sediments, formed by sands interspersed with layers of clay and gravel, and combined with soils more susceptible to erosion, such as Fluvic Neossols, the potential fragility is medium to high. However, due to the increase in anthropized areas, with diverse crops and pastures, most of them are environmentally fragile.

System 2: Barriers

The System of terrain barriers, reported in the previous Figure, totals an area of 240.32 km², located in the geomorphological domain of Coastal Trays. In this region, there are tertiary sediments made up of immature sandstone with intercalations of clayey and conglomeratic levels of Barreiras group.

Gabriel Paternostro Lisboa
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Haighlanda Calil Haddad

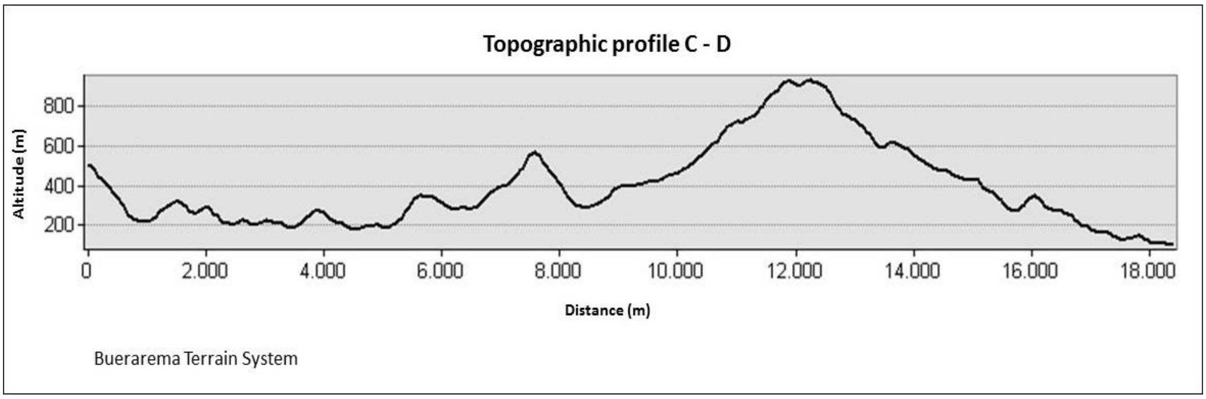
This unit is composed of Yellow Latosols distributed on flat to undulating reliefs, with altitudes varying from 50 to 100 meters, Figure 11. There are pasture areas, various crops, humid areas, and forest remnants, among the occupation and ground cover forms. Its emerging fragility varies from very weak to very high.

System 3: Buerarema

Buerarema System occupies the second most significant area of URHB, with 566.73 km² (32.19%). It is located in the Crystalline Plateaus, specifically in the Geomorphological Domain Mountains and Pre-littoral Massifs.

In its limits, it is possible to notice a predominance of mountain ranges, alveoli, and intramontane depressions, having as main characteristics mountains with altitudes of 100 to 1,009 meters, Figure 12. In addition, another point observed in this terrain system is the wide valleys located in relief wavy planes, with slopes between 0 - 12%.

Figure 12 - Topographic profile of the Buerarema terrain system.



Source - Authors (2021).

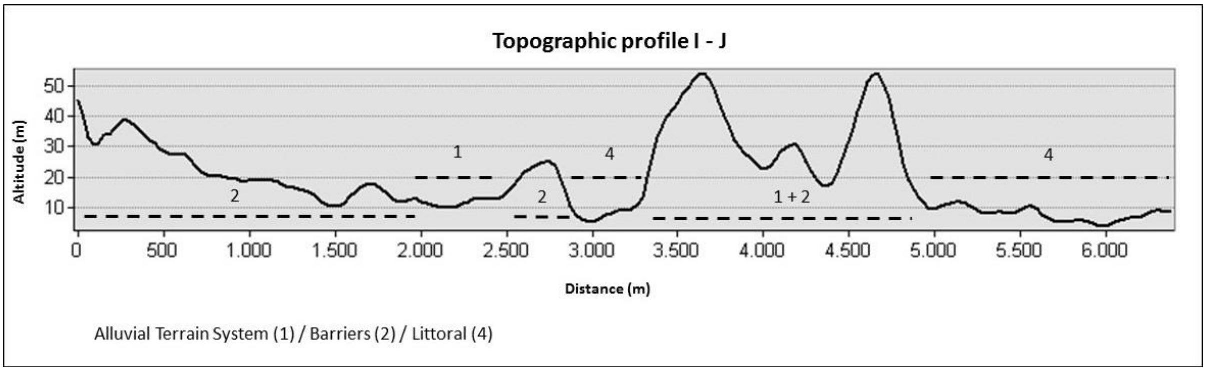
As for the rocky substrates and identified soils, the Buerarema Complex and the argisol stand out, respectively. When associated with high declivity, they tend to increase the levels of potential fragility, as in the case evaluated. However, since it presents large areas with vegetation cover at its limits, the emerging fragility has decreased, becoming weak to average.

System 4: Littoral

This system is distributed over 24.86 km², along the Coastal Plain, specifically in the geomorphological domain of Quaternary Sedimentary Deposits. Since it presents a variety of unconsolidated sediments, such as sands, clays, silts, and gravels, the potential fragility of this system is medium to high.

The types of soils found are humiluvic spodosols, salic gleisols, and fluvial neosols. Both are located in flat reliefs with altitudes varying from 1 - 10 meters (Figure 13). Concerning the use and cover of the soil, humid environments, pastures, cacao trees, and forests are observed. There are also marine accumulation and marine fluvium, with emphasis on the mangroves near Una stone.

Figure 13 - Topographic profile of the alluvial terrain system, barriers, and littoral.

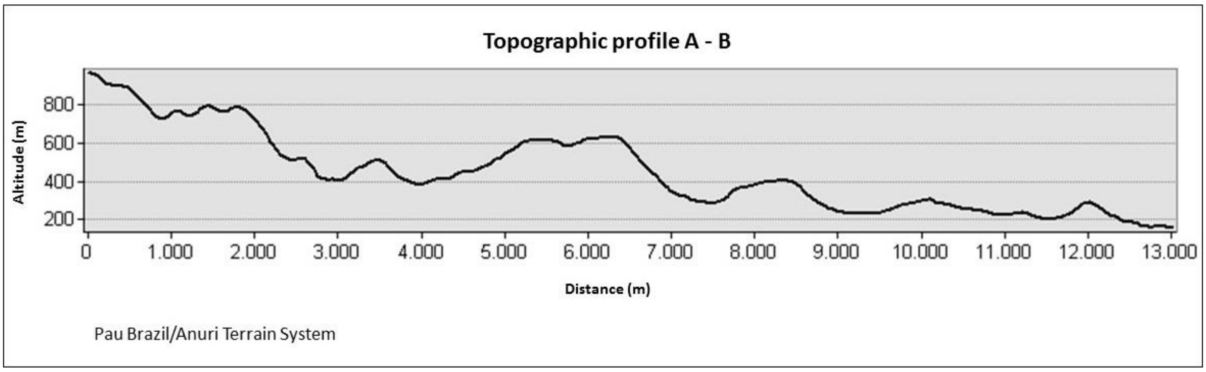


Source - Authors (2021).

System 5: Pau-Brasil/Anuri

This unit is located at the western end of URHB, in an area of 131.09 km². It is composed lithologically by substrates of Pau-Brasil intrusive suite and Anuri's body. The soils most present in this system are made up of Argisols. In general, the relief of this system is presented from the plane, with the presence of long steep valleys, an example of the mountains with North-South oriented axes. In these areas, the amplitude is between 100 to 1,009 meters (Figure 14), with slopes reaching 130%.

Figure 14 - Topographic profile of the Pau-Brasil/Anuri terrain system.



Source - Authors (2021).

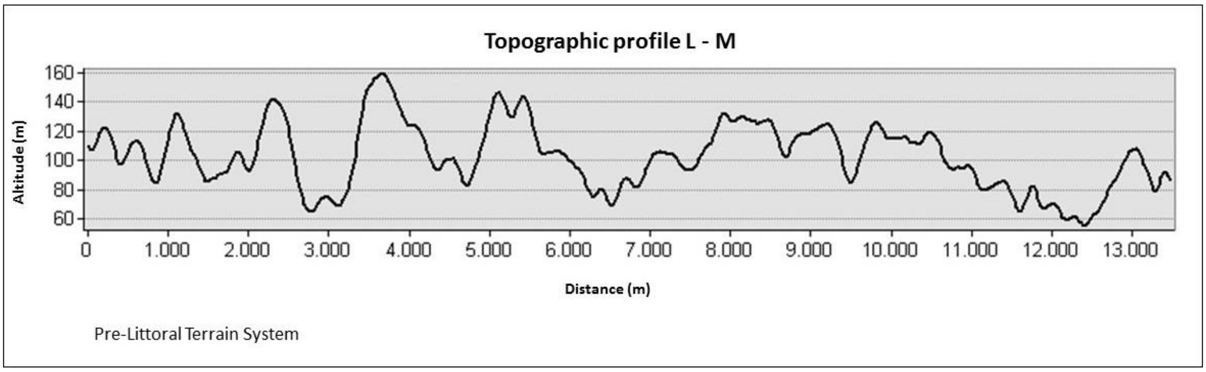
Concerning the present geomorphological domains, a greater area of the Pre-littoral Mountains and Massifs is perceived, with Trays and Plateaus. Among the forms of vegetation found, forest remnants and cacao trees stand out. Therefore, some places are less susceptible to events that transform the environment, with emerging fragility if presented as very weak to average.

System 6: Pre-Littoral

The pre-littoral land system is the largest among those mapped in the URHB, totaling 652.14 km². They are distributed on wavy reliefs, interconnected mostly on the Pre-littoral Trays. Its altitude varies between 50 - 300 meters, Figure 15.

Gabriel Paternostro Lisboa
Maurício Santana Moreau
Ronaldo Lima Gomes
Gerson dos Santos Lisboa
Vinícius de Amorim Silva
Robson da Silva Magalhães
Luciano Cavalcante de Jesus França
Alex Mota dos Santos
Haighlanda Calil Haddad

Figure 15 - Topographic profile of the pre-littoral terrain system.



Source - Authors (2021).

They have mostly low and smooth hills in their domains, comprising small, strongly wavy surfaces with 30% slope, formed by a set of mountains and hills, with marked unevenness.

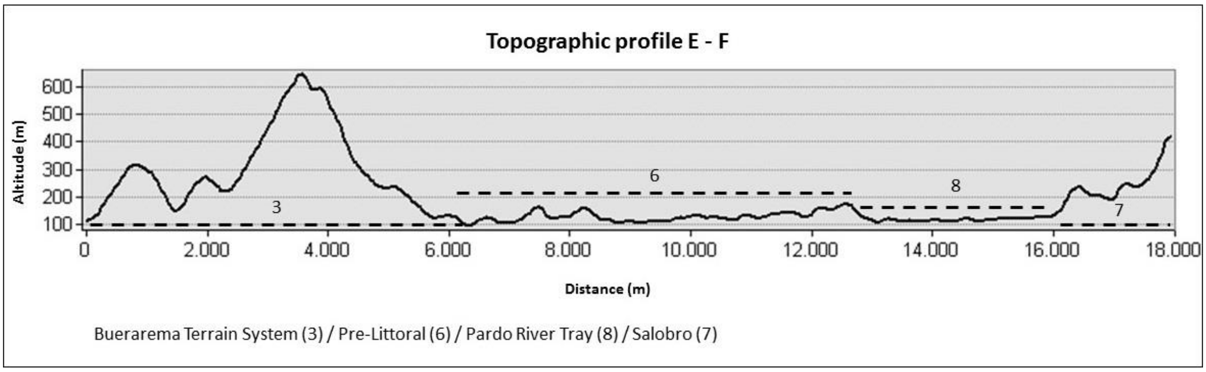
The potential fragility of these systems varies from weak to medium due to the types of soils and substrates found. However, their emerging fragility increases at some points due to excessive land uses.

System 7: Salobro

The Salobro system occupies a small area in the south of URHB with 25.14 km². It overlaps with Buerarema system due to exposed textural relations of the relief. What differentiates this area is its rocky substrate (Salobro Formation), formed by polymitic metaconglomerate, dolomitic metaconglomerate, arcosean metagrauvaca, metarenite, metasiltite and slate.

There is a predominance of mountains in this territory, with altitudes above 150 meters (Figure 16) and slopes above 30%. As for the identified soil, Argisol stands out, largely covered by native forest formations. It is worth mentioning that due to its physical-environmental characteristics that influence its natural dynamic balance, this class presents potential fragility ranging from medium to high.

Figure 16 - Topographic profile of *Buerarema*, pre-littoral, Pardo *river tray* and *Salobro terrain systems*.



Source - Authors (2021).

System 8: Pardo River Tray

Finally, this last characterized system has 56.61 km², corresponding to approximately 3.22% of the mapped area. Furthermore, it is found in a region directly related to the river dynamics, formed essentially by alluvial deposits. Therefore, its geomorphology essentially integrates the domain of Pardo River tray.

There is a flat relief in this area, interconnected to smooth, wavy portions. Its topography varies between 100 to 150 meters, Figure 16, with slopes that do not exceed 6%.

In this region there is an advance of anthropized areas, and due to that, there are more environments vulnerable to the erosive processes of nature. Overlaying the maps in Figures 28 and 29, this system emerging fragility varies from very weak to high.

FINAL CONSIDERATIONS

Given the results presented, it is concluded that the survey of the characterizations of the physical-environmental conditions of URHB plus information from natural and anthropic systems help understand this territory's dynamics.

Regarding the application of the land evaluation technique, the compartmentalization of the URHB area resulted in 8 Systems. This compartmentalization enables the understanding of the attributes that act in the composition of the weaknesses of specific zones. These zones have physical and environmental characteristics. It should also be emphasized that, due to the scale of work adopted, the survey of the environment's physical conditions reaches the hierarchical level of systems.

Another aspect to be considered is the support of geotechnologies. These are of paramount importance and are essential for environmental analysis. Through these tools, it is possible to correlate complex data more quickly and economically.

Finally, the studied attributes enabled the preparation of a detailed digital database, worked in SIG environment. Through this database, it is expected that the research will contribute to the Eastern Watershed Committee (EWC), where the information collected will serve as subsidies for the planning and management of the studied area, with a view to more sustainable economic development, aiming at the conservation/preservation of environmental resources.

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