ISSN: 2447-3359

REVISTA DE GEOCIÊNCIAS DO NORDESTE

Northeast Geosciences Journal

v. 8, nº 2 (2022)

https://doi.org/10.21680/2447-3359.2022v8n29219

Compartmentalization of relief units and land use forms in a sector of the eastern escarpment of the Borborema Highlands

Compartimentação das unidades de relevo e formas de uso da terra em um setor da escarpa oriental do Planalto da Borborema

Paulo Lucas Cândido de Farias[1]; Antonio Carlos de Barros Corrêa[2]; Simone Cardoso Ribeiro[3]

[1] Federal University of Pernambuco (UFPE), Department of Geographical Sciences, Recife/PE, Brazil. Email: paulolucas0407@gmail.com
ORCID: https://orcid.org/0000-0001-6729-6780

[2] Federal University of Pernambuco (UFPE), Department of Geographical Sciences, Recife/PE, Brazil. Email: antonio.correa@ufpe.br
ORCID: https://orcid.org/0000-0001-9578-7501

[3] Regional University of Cariri (URCA), Department of Geosciences, Crato/CE, Brazil. Email: simone.ribeiro@urca.br
ORCID: https://orcid.org/0000-0003-1171-9611

Abstract: The present study proposes a subdivision of relief units in a sector of the eastern Brazilian Northeast, based on the geomorphological compartments as a key elements for the structuring of the regional landscapes. The geomorphological mapping proposal in meso-scale of the International Geographical Union (IGU) was used, which allowed an integrated analysis of the landscape encompassing the geoforms, hypsometry, lithostratigraphic data and physical aspects of the drainage network. For the mapping of land use and land cover, the IBGE (Brazilian Institute of Geography and Statistics) class II and III levels were used. The relief units were distributed based on the anchoring on two morphostructures (the Borborema Highlands and their Piedmont). Regarding the model, five relief units were identified, while for the land use categories, five class levels were defined. The results point to a synergic relationship between the morphological units, the predominant types of land use and occupation and the resulting surface morphodynamics.

Keywords: Geomorphological compartmentation; morphosculptural processes; Goiana - Timbaúba Immediate Region.

Resumo: O presente trabalho propõe uma compartimentação das unidades de relevo em um setor do Nordeste oriental brasileiro, com base na compartimentação geomorfológica como elemento chave para a estruturação da paisagem regional. Foi utilizada a proposta de mapeamento geomorfológico da União Geográfica Internacional (UGI) em meso-escala, que possibilitou uma análise integrada da paisagem que perpassa pelas geoformas, hipsometria, dados litoestratigráfico e aspectos físicos da rede de drenagem. Para o mapeamento de uso e cobertura da terra, foram utilizados os níveis de classe II e III do IBGE (Instituto Brasileiro de Geografia e Estatística). As unidades de relevo foram distribuídas a partir da ancoragem sobre duas morfoestruturas (o Planalto da Borborema e o seu Piemonte). No tocante ao modelado, foram identificadas cinco unidades de relevo, enquanto para as categorias de uso da terra, foram definidos cinco níveis de classes. Os resultados apontam uma relação sinérgica entre as unidades morfológicas, os tipos de uso e ocupação da terra predominantes e a morfodinâmica superficial resultante.

Palavras-chave: Compartimentação geomorfológica; processos morfoesculturais; Região Imediata de Goiana – Timbaúba.

Received: 19/06/2022; Accepted: 28/10/2022; Published: 17/11/2022.

1. Introduction

Geomorphological compartmentalization is crucial for analyzing the complexity of the physical landscape, for based on the spatial representation of landforms one can understand the physical attributes that structure a given geographical setting. For the aims of this study, a sector of the territory that integrates the Zona da Mata Norte physiographical region of the State of Pernambuco was analyzed. It encompasses the municipalities of Vicência, Timbaúba e Aliança, which are part of both the Recife Intermediary Region and the Goiana-Timbaúba Immediate Region (IBGE, 2017) (Figure 1). This region exhibits a diversified mosaic of landscapes which, on the one side, reflects the types of land use, and the other, the morphogenetic processes that operate on the continuous reshaping of the relief.

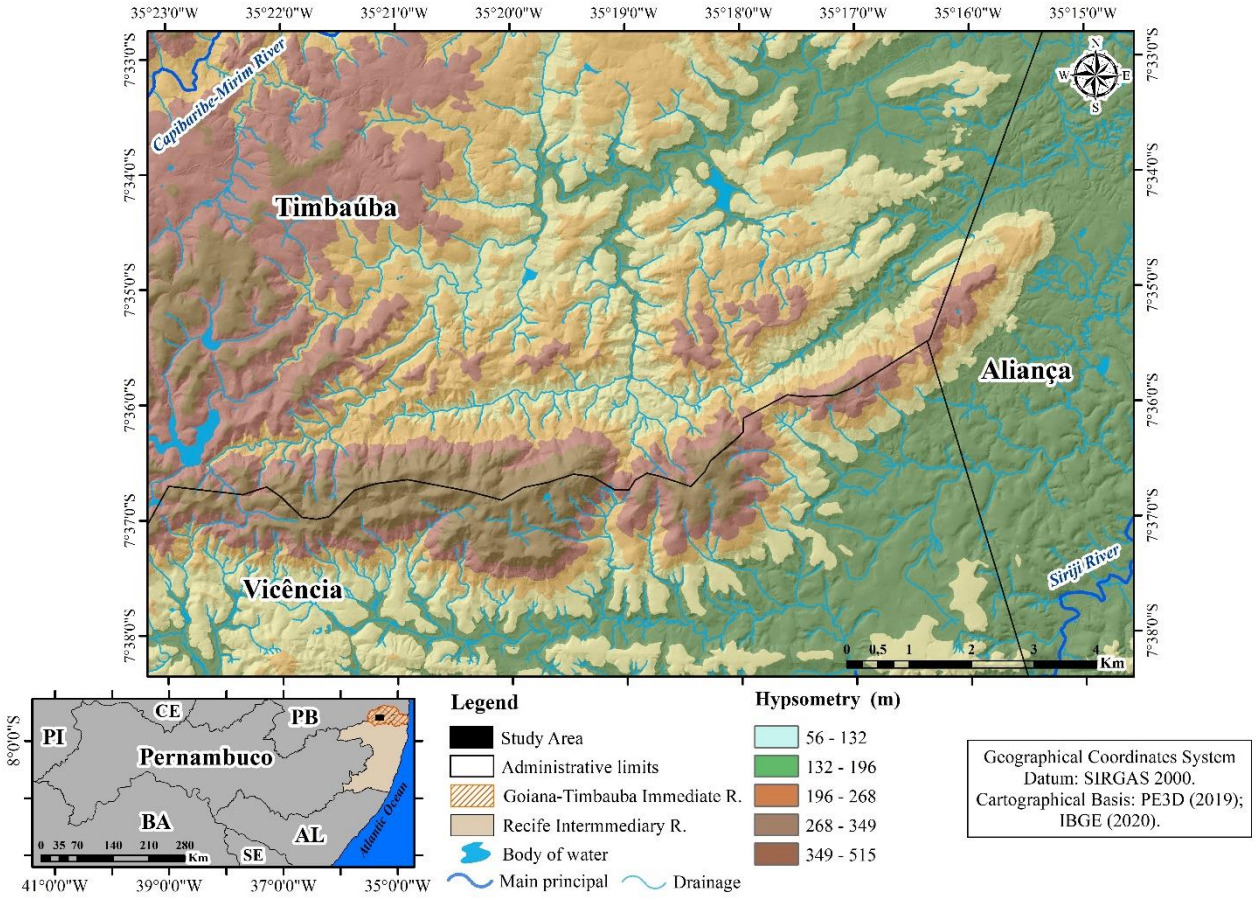


Figure 1 – Localization and hypsometry of the study area within the state of Pernambuco.
Source: The authors (2022).

Morphodynamics can be accelerated as a response to human activities; however, in order to conduct a geomorphological analysis of a given area, it is initially necessary to establish the role of lithological structures in shaping landforms. This reasoning is fundamental in the study of the relief of passive continental margins, where the role of morphostructures and differential erosion on the hierarchization of landforms is more conspicuous (Correa *et al*., 2010).

From the above, geologically, the study area is situated in the eastern sector of Borborema Province (Figure 2), to the north of the Pernambuco Shear Zone (PESZ) and south of Patos Shear Zone (PASZ). Being formed during the Brasiliano Cycle (700-500 Ma), the sector comprises rocks associated with paleo- and meso-Proterozoic metamorphic complexes and Neoproterozoic plutonic intrusions (SILVA, 2012; GONÇALVES, 2018; MONTEIRO E CORRÊA, 2020).

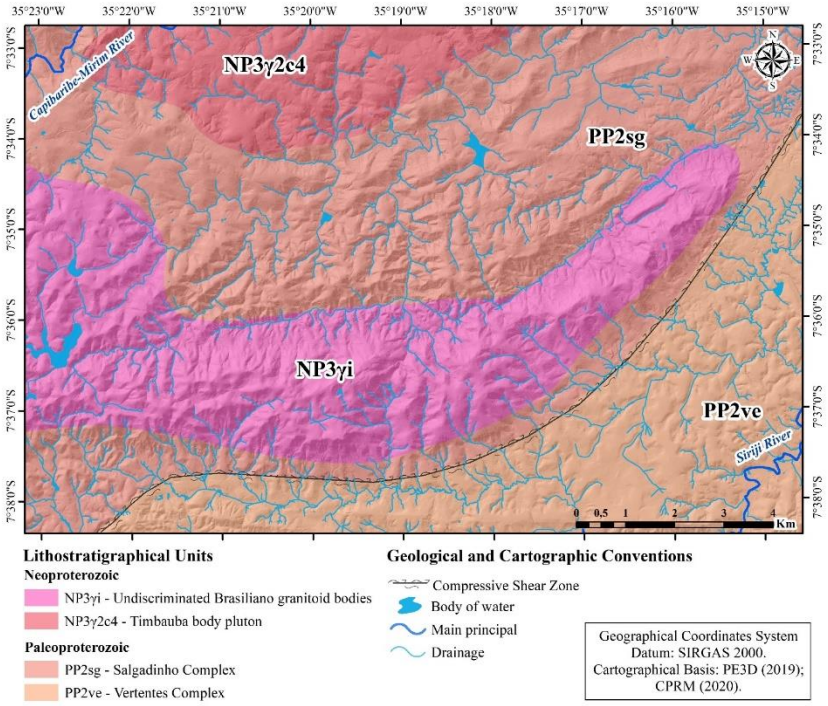


Figure 2 – Geological Map
Source: The authors (2022).

With little thermal amplitude and an average annual temperature of ca. 24°C, the predominant climatic type in the region, according to Köppen (1936), is the humid tropical (As'), warm and wet with concentrated rainfall between March and August (SILVA, 2012), which commands the current intensity of erosive processes in the area. In the long term, the Cenozoic denudational history, due to differential erosion, has topographically accentuated the most resistant sectors of the relief and favored the lowering of others, with elevations ranging from 56 to 515 meters asl., thus resulting in a local relief of 459 meters (Figure 1).

From the interplay of regional structures, derived from the action of a compressive deformational regime during the Neogene, with the climatic dynamics, a consequent drainage pattern has emerged, adapted to the uplift of the eastern escarpment of the Borborema Highlands and conditioned by its structural framework. The recurrence of denudational episodes on predominantly granitic lithologies has led to the development of rocky or thin regolith-mantled summits and hillslopes covered in colluvium deposits associated with erosive/depositional cycles (CORRÊA et al., 2010; FONSÊCA et al., 2020a).

Under this perspective, the present work aims at mapping, at a semi-detail scale, the geomorphological compartments by applying the methodology proposed by the International Geographical Union (IGU) mapping committee as put forward by Demek (1972). First, the resulting morphological units have been classified from the crossing of data regarding morphology, hypsometry, and lithology. Following, land use patterns have been mapped on the same scale according to IBGE (2013) proposal. Finally, landform units were associated with the prevailing morphodynamic processes in different landscape sectors.

2. Methodology

The cartographical bases have been constructed based on the treatment of ortho-imagery and laser profiling of the DTM (Digital Terrain Model) within a GIS environment. The PE3D Project provided images with a spatial resolution of 1-meter, geographical coordinate system, Mercator transversal projection, and Datum SIRGAS 2000 UTM Zone 25 S. Due to the spatial dimension of the study area, and the need to identify homogeneous areas of morphologies and surface processes

occurrence, the cartographic outputs have been produced in a semi-detailed scale equivalent to 1:70’000 (PALMIERI E LARACH, 2017) using ArcGIS 10.3 software.

Following the instructions of the Manual for Detailed Geomorphological Mapping (DEMEK, 1972) and according to applications derived from Corrêa (1997) and LIMA et al. (2015) works, the map of “Relief Units Compartmentalization” was produced. Mapped units have been devised by the crossing and interpretation of lithostratigraphic (CPRM, 2020) and hypsometric data, and the assessment of topographic transects, with 15 to 20 meters contour line intervals. Afterward, results regarding geomorphic units and surface processes were validated by fieldwork.

The guidelines of the Technical Handbook for Land Use Mapping of IBGE (2013) were applied for the elaboration of the Land cover and Land use map. For this purpose, Class Levels II and III were adopted. In addition, due to deforestation and absence of use, fallow areas have been added to the Secondary vegetation class.

The Global Mapper 21.0 software was used to create the topographical transects, which later were edited in Windows’ Paint 3D. A 30% transparency level was applied to all maps’ shapefiles, with the overlapping of the shaded relief, thus, evidencing drainage lines and morphologies in the face of the surface dynamics visible in the landscape.

3. Results and discussion

A final map at a 1:70’000 scale was created based on overlapping the parameters used in the geomorphological compartmentalization, mainly the data of the PE3D project. Initially, the morphostructures were defined according to the lithostratigraphical typologies, highlighting the areas between the recognized shear zones, like the Pernambuco Lineament to the south and the Patos Lineament to the north, as well as the subordinated Proterozoic metamorphic complexes (SILVA, 2012; FONSÊCA, 2018).

Throughout the Cenozoic, tectonic processes, denudation, and differential erosion, commanded by the eastbound drainage network under humid tropical conditions (MONTEIRO E CORRÊA, 2020), promoted the general altimetric unevenness of the study area. The primary evidence of those processes is the regional bulge of the Borborema Highlands, their dissected eastern escarpment, and the piedmont. The set of geomorphic units in a semi-detailed scale identified in the area and their respective description are presented below (Figure 3).

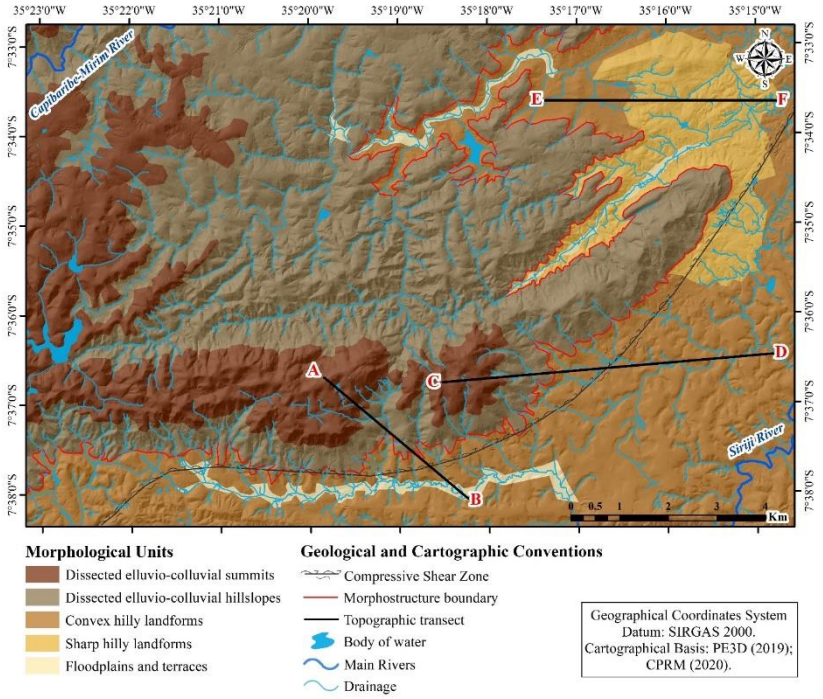


Figure 3 – Compartmentalization of the morphological units and topographical transects.
Source: The authors (2022).

Morphostructural Domain of the Borborema Highlands

Neoproterozoic and Paleoproterozoic basements, primarily through the continental margin flexure, and secondarily the reactivation of the dextral shear zones to the north and south of the area from the Cretaceous onwards. The compression of intermediary blocks between the shear zones led to the differential uplift of the area in comparison to the adjacent sectors (MONTEIRO E CORRÊA, 2020). This domain is subdivided into three units: dissected elluvio-colluvial summits, dissected elluvio-colluvial hillslopes, and floodplains/terraces.

The Dissected elluvio-colluvial summits encompass areas with segments of confined drainage catchments, with the occurrence of the headwaters of the Capibaribe-Mirim and Sirijí rivers, as well as the presence of knickpoints along the stream channels. Demarcating the regional interfluves between E-W oriented watersheds, this unit presents elevated hills with steep escarpments at altitudes ranging from 310 to 515 meters (Figure 4).

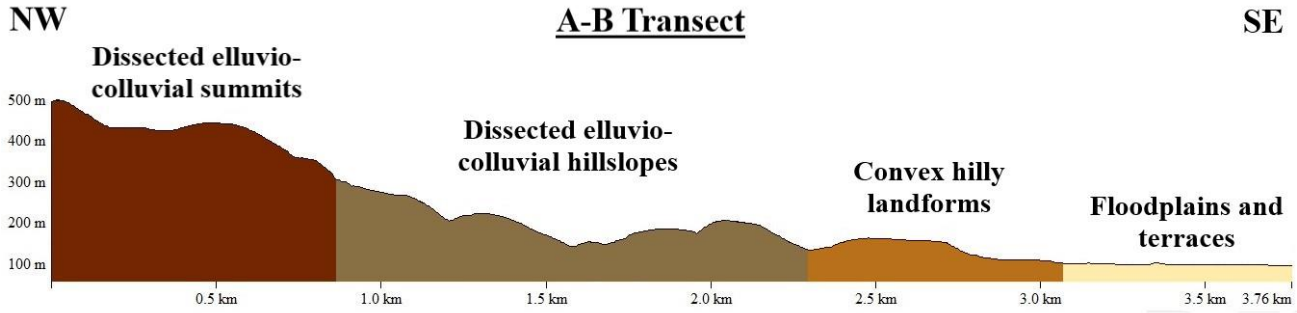


Figure 4 – Topographic transect A-B between the Borborema Highlands and Borborema Piedmonts morphostructural domains.
Source: Farias (2021).

At this unit, the role of differential erosion is noteworthy, as the acidic, more resistant Neoproterozoic granites remain well preserved in the landscape as dissected crystalline residual landforms (Figure 4). Despite presenting the highest summit levels of the area, the steepest morphologies occur along the escarpment, with little evidence of sheet flow or linear erosion associated with the type of land use.

The Dissected elluvio-colluvial hillslopes unit surrounds the dissected elluvio-colluvial summits, thus occupying a sizeable portion of the study area. It is characterized by elevations varying from 160 to 310 meters, with high slope angles (Figures 3 and 4). Regional drainage headwaters are conspicuous at this unit, where perennial and intermittent streams merge from adjacent topographic hollows—the differential erosion lower the valley bottoms on less resistant Paleoproterozoic bedrocks. The unit is directly related to the compressive shear zone with relatively deep weathering mantles, and the occurrence of more intense gullying processes and soil creep.

Floodplains and alluvial terraces, in the far north of the morphostructural unit, constitute areas of alluvial deposits storage, as a result of intense hillslope erosion, with sediment yield peaking from Late Pleistocene to mid-Holocene (FONSÊCA *et al*., 2020b). Slope angles are gentle, and elevations range from 115 to 130 meters (Figures 3 and 4). Floodplains are embedded into mylonites and granitic enclaves of the Timbauba Pluton (FONSÊCA, 2018).

Morphostructural domain of the Borborema Piedmont

The morphostructural domain of the Borborema Piedmont is subdivided according to the lithological characteristics of the underlying bedrock. The morphological aspects of this sector derive from the intense Cenozoic denudation, with low-lying, tectonically stable landforms mantled by deep weathering mantles and surface coverings with stone-lines and unweathered bedrock at greater depths (FONSÊCA et al., 2016; PORTO, 2017; SILVA, 2018).

This compartment lies in elevations ranging from 56 to 160 meters, displaying low-lying multi-convex morphologies, floodplains, and terraces. The drainage network displays a dendritic pattern, occasionally controlled by the underlying linear structures, with the presence of well-defined knickpoints along the longitudinal profiles of the major channels

(MONTEIRO E CORRÊA, 2020). The main rivers' channels and their tributaries present straight stretches due to the topographic confinement, as well as meandering stretches along the floodplains sided by levels of fluvial terraces (GIRÃO et al., 2013; FONSÊCA et al., 2016). This domain is subdivided into three units: convex hilly landforms, sharp hilly landforms (forming ridges), floodplains and terraces. The Paleoproterozoic lithologies of the Vertentes Complex predominate, resulting in sharp-summit (ridges) morphologies.

The convex hilly landforms unit occupies a large sector of the Domain, with elevations ranging from 56 to 160 meters above the channel of the Siriji River in the Municipality of Aliança. These are gently rolling convex hills with ample summits interspersed by short pediment ramps (Figure 5). This compartment is characterized by strong chemical weathering and the presence of colluvial deposits at the foot of the hillslopes, and the occurrence of staggered terracettes at the middle and upper slopes where soil creep predominates (FONSÊCA, 2018) and accelerated linear erosion due to land use practices (Figure 5).

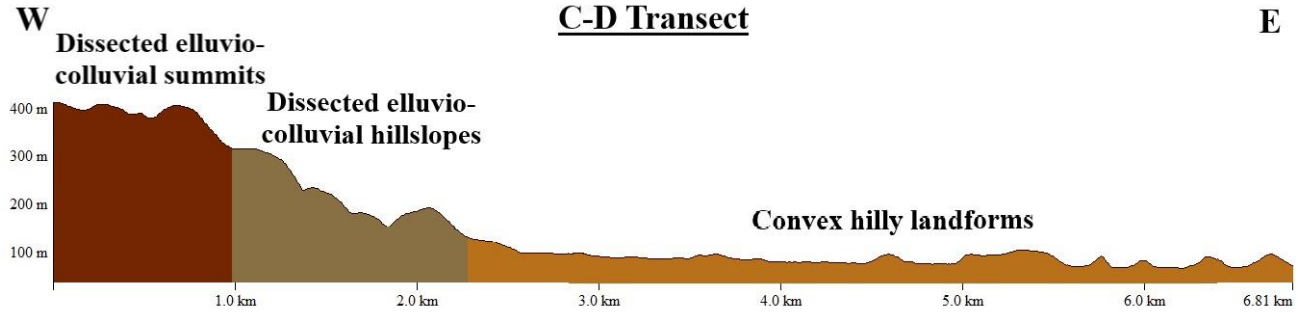
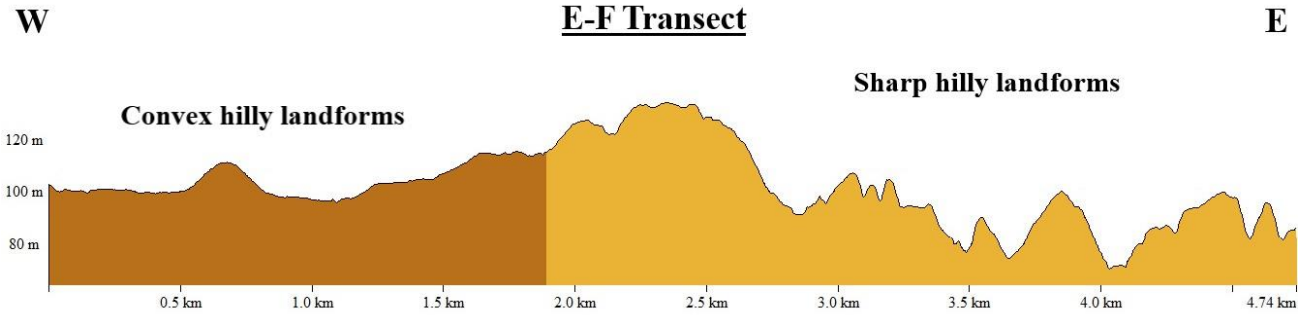


Figure 5 – Topographic transect C-D between the morphostructural domains of the Borborema Highlands and the Borborema Piedmont.
Source: Farias (2021).

The sharp hilly landforms (ridges) unit occur between the municipalities of Aliança and Timbauba following a N-S structural trend. This unit comprises narrow ridge-like hills, with entrenched valleys, in elevations varying from 80 to 170 meters (Figure 6). Due to the excessive dissection and denudation of the landforms, rock outcrops abound at the surface level. Luvisols predominate in the area, with a conspicuous incidence of linear erosion on hillslopes.



Figur6 6 – Topographic transect E-F in the morphostructural domain of the Borborema Piedmont.
Source: Farias (2021).

Floodplains and terraces are mainly concentrated on the Borborema Piedmont morphostructural domain. The fluvial deposition is dominated by siliciclastic sediments derived from the intense dissection of landforms, typical of humid tropical regions (FONSÊCA et al., 2020a). In this unit, materials are eroded directly from hillslopes and first-order channels that cut through the dissected elluvio-colluvial summit surfaces and mostly the dissected elluvio-colluvial hillslopes due to the higher slopes and types of land use. It is noticeable that south of Vicencia Municipality, floodplains follow an E-W trend, accompanying the direction of the compressive shear zone. In contrast, further to the north, they are embedded

within the sharp hilly landforms (ridges) of SW-NE trend. At the same time, in the Municipality of Timbauba, the prevailing orientation is WSW-ENE.

Morphodynamics: the relation between the morphological units and types of land use

The occupation of the studied territory to develop economic activities related to agriculture and livestock raising started with the suppression of the native vegetation cover. Crops or pastures replaced the pristine vegetation. Animal husbandry was initially destined for family subsistence, but soon the excess production was destined for commercial purposes and the supply of local markets. Such man-induced action upon the natural environment often exposed the soil to erosive agents, which may have triggered landscape degradation processes and the consequent morphodynamic disequilibrium. This scenario was characteristic of phases dominated by eradicating the original vegetation cover for crop growing (GIRÃO E CORRÊA, 2004).

Following the methodology proposed by IBGE (2013) and according to the adopted mapping scale, class levels II and III were applied with a few adjustments to suit the reality of the study area. As a result, five land use classes have been identified, among which one should highlight: banana and sugar-cane crops, pasture, secondary vegetation, and woodland (Figure 7). The "secondary vegetation" category was applied to areas with second-growth open formations containing herbaceous, shrubby, and arboreal vegetation. In the past, those areas have been cleared. Hence it is assumed that through time they might have had different types of use before being abandoned.

By overlapping the geomorphic units identified in Figures 3, 4, 5, and 6 to the land use and land cover typologies (Figure 7), sectors of intense surface morphodynamic processes have been identified, listed in Chart 1. The resumption of surface morphodynamics due to land use may evolve into intensified erosion and mass movement triggering scenarios.

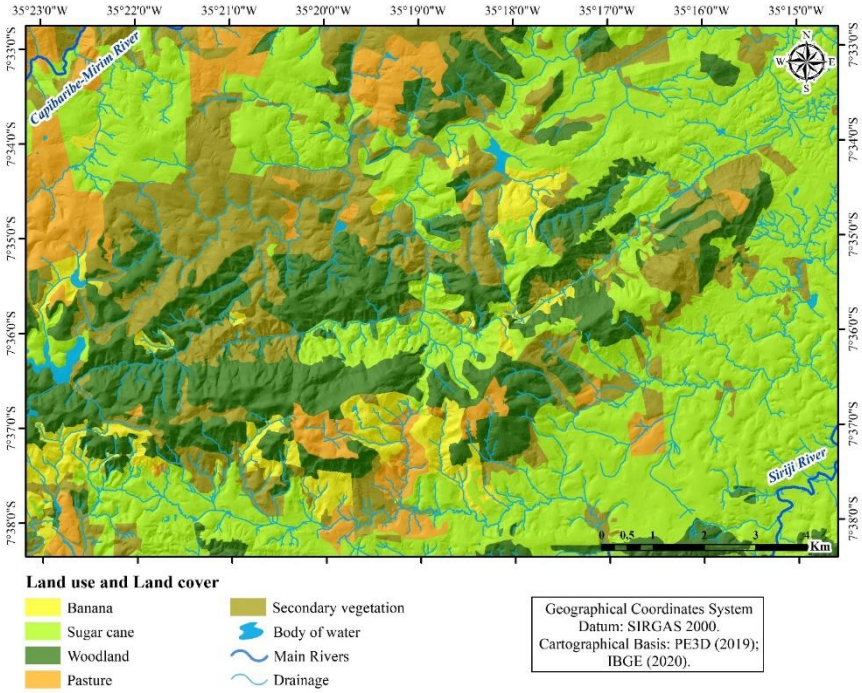


Figure 7 – Land use and land cover map.
Source: The authors (2022).

Being a humid tropical region, land use and occupation processes on colluvial deposits have led to soil erosion and mass movements (GUERRA, 2014a). Concerning the sought equilibrium in the hillslope-channel geomorphological system in humid areas, energy, and matter inputs and outputs, under natural conditions or accelerated by human action, trigger hyper-concentrated flows typical of linear erosion, leading to transport and deposition in local base levels

(CHRISTOFOLETTI, 1999; GRAY, 2013; GUERRA, 2014a). Such chain of events in the studied landscape resulted in the accumulation of contemporary floodplains and the siltation and narrowing of the stream channels.

As observed in the land use map (Figure 6) in croplands and later validated in situ, as organic carbon concentration diminishes in the superficial soil horizons, aggregate instability, and sediment transport increase, ultimately resulting in the erosion of the surface coverings. In the case of agricultural soils, the loss of the upper horizons also leads to a loss in nutrients (SALOMÃO, 2014), which leads to the abandonment of lots.

Chart 1 synthesizes the principal occurrences of surface processes as linked to landforms and land use types in each geomorphic unit. Nonetheless, land use and management forms may attenuate, reverse or accelerate the strength of morphodynamic processes.

Chart 1 – Morphological units and surface processes associated to predominant land use

Morphostructural compartment	Morphological Units	Relief Patterns		Predominant land use and land cover	Morphodynamic
		Interfluvial Domain	Fluvial Domain		
Borborema Highlands	Dissected elluvio-colluvial summits	Hilly relief ranging from 310 to 515 meters in elevation with intense differential erosion along its structures	Floodplain, terraces, confined and semi-confined channels	Woodland, secondary vegetation and pastures	Steep to moderate slopes on escarpments favoring sheet-flow on summits and linear erosion on hillslopes associated to types of land use
	Dissected elluvio-colluvial hillslopes	Escarpments and hills ranging from 160 to 310 meters with intense differential erosion along its structures	Floodplain, terraces, confined and semi-confined channels	Woodland, secondary vegetation, pastures, sugar cane fields and banana groves	Steep to moderate slopes favoring linear erosion and mass movements on the mid and lower hillslopes associated to types of land use
	Floodplains and terraces	Finely dissected, topographically confined gently rolling surfaces ranging from 115 to130 meters in elevation	Floodplain and meandering channels	Secondary vegetation, and sugar cane fields	Gentle slope areas prone to flooding and accumulation of clastic sediments associated to land use
Borborema Piedmont	Convex hilly landforms	Finely dissected hills ranging from 56 to 160 meters in elevation	Ample floodplains, terraces, floodplains in local base levels	Sugar-cane fields	Gentle slopes with minor mass movements and linear erosion on the hillslopes associated to land use
	Sharp hilly landforms (ridges)	Moderately dissected hills ranging from 80 to 170 meters in elevation	Ample floodplains, terraces, floodplains in local base levels	Sugar-cane fields	Moderate to gentle slopes with narrow entrenched valleys. Minor mass movements and hillslope linear erosion associate to the pedological cover and land use
	Floodplains and terraces	Finely dissected, topographically confined gently rolling surfaces ranging from 80 to120 meters in elevation	Floodplain and meandering channels	Secondary vegetation, sugar cane fields and pastures	Gentle slope. Mass movements and erosion of mid and lower hillslopes. High flood risk and accumulation of clastic sediments associated to land use

Source: Organized by the authors (2022) from Girão et al. (2013) and Fonsêca et al. (2016).

4. Conclusion

The study has focused on identifying relief units as controlled by the geological structure in the spatial context of the Goiana-Timbauba Immediate Region at a semi-detail scale. The limits of the units have been highlighted by constructing several topographic transects.

The resulting land use and occupation map constitute a subsidy for further studies in areas with similar occupation patterns and a valuable tool for spatial planning and management actions within the realm of physical geography and related areas.

From the crossing of information from several cartographic products and field evidence, as portrayed in Chart 1, it was found that land use and management forms may help attenuate, revert, or accelerate the morphodynamic processes. Due to the steep character of the unit's morphology, such erosive and mass movement processes identified on the dissected elluvio-colluvial hillslopes are enhanced by various types of land use, such as secondary vegetation woodlands, pastures, sugarcane fields, and banana groves. Furthermore, the resumption of accelerated morphodynamics, beyond modifying the

shaping of the landscape – as in narrowing the stream channels – also affects in a positive feedback fashion the geomorphological risks derived from the anthropic actions.

Acknowledgements

To the Foundation for the Support of Science and Technology of the State of Pernambuco (FACEPE), for the Master's degree scholarship during the development of the research.

References

CHRISTOFOLETTI, A. *Modelagem de sistemas ambientais*. São Paulo: Edgard Blucher, 1999. 236 p.

CORRÊA, A. C. B. *Mapeamento geomorfológico de detalhe do Maciço da Serra Verde:* estudo da relação entre a distribuição dos sistemas geoambientais e a compartimentação geomorfológica. (Dissertação de Mestrado) Programa de Pós-Graduação em Geografia/UFPE. 1997.

CORRÊA, A. C. B.; TAVARES, B. A. C.; MONTEIRO, K. A.; CAVALCANTI, L. C. S.; LIRA, D. R. Megageomorfologia e morfoestrutura do Planalto da Borborema. *Revista do Instituto Geológico*, São Paulo, v. 31, n. 1-2, p. 35-52, 2010.

CPRM. Companhia de Pesquisa de Recursos Minerais. *Dados, informações e produtos do serviço geológico do Brasil.* Disponível em: http://geosgb.cprm.gov.br/. Acesso em: 23 jun. 2020.

DEMEK, J. (Ed). *Manual of detailed geomorphological mapping.* Praga: Academia. 1972, 344 p.

FARIAS, P. L. C. *Etnopedogeomorfologia em um setor da escarpa oriental do Planalto da Borborema:* uma proposta taxonômica a partir dos produtores rurais. 2021. 125 f. Dissertação (Mestrado em Geografia) Programa de Pós-Graduação em Geografia, Universidade Federal de Pernambuco, Recife, 2021.

FONSÊCA, D. N.; CORRÊA, A. C. B.; SILVA, A. C. Compartimentação geomorfológica da região metropolitana do Recife (RMR) a partir da análise morfoestrutural. *Geo Uerj*, Rio de Janeiro, n. 29, p. 201-219, 2016.

FONSÊCA, D. N. *Evolução geomorfológica e sedimentação quaternária no setor oriental do Piemonte da Borborema.* 2018. 194 f. Tese (Doutorado em Geografia). Programa de Pós-graduação em Geografia, Universidade Federal de Pernambuco, Recife, 2018.

FONSÊCA, D. N.; CORRÊA, A. C. B.; TAVARES, B. A. C.; LIRA, D. R.; BARROS, A. C. M.; MÜTZENBERG, D. S. Coupling of tectonic factors and precipitation variability as a driver of Late Quaternary aggradation in Northeast Brazil. *Earth Surface Processes And Landforms*, [S.L.], v. 45, n. 14, p. 3525-3539, 4 set. 2020a.

FONSÊCA, D. N.; CORRÊA, A. C. B.; LIRA, D. R.; TAVARES, B. A. C. Chemical, physical and mineralogical attributes as markers in the identification of depositional events in the Eastern Northeast of Brazil. *Journal Of South American Earth Sciences*, [S.L.], v. 104, p. 102805, dez. 2020b.

GIRÃO, O.; CORRÊA, A. C. B. A contribuição da geomorfologia para o planejamento da ocupação de novas áreas. *Revista de Geografia (Recife)*, Recife, v. 21, n. 2, p.36-58, dez. 2004.

GIRÃO, O.; CORRÊA, A. C. B.; NÓBREGA, R. S. DUARTE, C. C. O papel do clima nos estudos de prevenção e diagnóstico de risco geomorfológico em bacias hidrográficas na Zona da Mata Sul de Pernambuco. In: GUERRA, A. J. T.; JORGE, M. C. O. *Processos erosivos e recuperação de áreas degradadas*. São Paulo: Oficina de Textos, 2013. p. 126-159.

GONÇALVES, R. B. *Significado geomorfológico dos sedimentos cenozóicos do baixo curso do Rio Capibaribe – PE*. 2018. 137 f. Dissertação (Mestrado em Geografia). Programa de Pós-graduação em Geografia, Universidade Federal de Pernambuco, Recife, 2018.

GRAY, M. *Geodiversity*: valuing and conserving abiotic nature. 2. ed. Chichester: John Wiley & Sons, 2013. 495 p.

GUERRA, A. J. T. Degradação dos solos: conceitos e temas. In: GUERRA, A. J. T.; JORGE, M. do C. O. *Degradação dos solos no Brasil.* Rio de Janeiro: Bertrand Brasil, 2014a. 16-47.

GUERRA, A. J. T. O início do processo erosivo. In: GUERRA, A. J. T.; SILVA, A. S.; BOTELHO, R. G. M. *Erosão e conservação dos solos.* 9. ed. Rio de Janeiro: Bertrand Brasil, 2014b. p. 17-55.

IBGE. Instituto Brasileiro de Geografia e Estatística. *Divisão regional do Brasil em regiões geográficas imediatas e regiões geográficas intermediárias:* 2017. Rio de Janeiro: Coordenação de Geografia - IBGE, 2017. 82 p.

IBGE. Instituto Brasileiro de Geografia e Estatística. *Manual Técnico de Uso da Terra*, 3ª ed, Rio de Janeiro, 2013, 171p.

IBGE. Instituto Brasileiro de Geografia e Estatística. *Portal de mapas do IBGE*. Disponível em: https://portaldemapas.ibge.gov.br/portal.php#homepage. Acesso em: 07 abr. 2022.

KÖPPEN, W. Das Geographische system der climate. In: KÖPPEN, W. & GEIGER, R. *Handbuch der klimatologia*. Berlin: Gerdrulier Borntraeger, v.1, part. C., 1936.

LIMA, F. J.; LIMA, G. G.; CORRÊA, A. C. B.; MARÇAL, M. S. Mapeamento geomorfológico em escala de semi-detalhe e a flexibilização de manuais de mapeamento: breves considerações a partir de um estudo de caso - setor subúmido do planalto sedimentar do Araripe/CE/Brasil. *Ensaios de Geografia*, Niterói - RJ, v. 3, p. 61-78, 2015.

MONTEIRO, K. A.; CORRÊA, A. C. B. Application of morphometric techniques for the delimitation of Borborema Highlands, northeast of Brazil, eastern escarpment from drainage knick-points. *Journal of South American Earth Sciences*, [S.L.], v. 103, p. 102729-102741, 2020.

PALMIERI, F.; LARACH, J. O. I Pedologia e Geomorfologia. In: GUERRA, A. J. T.; CUNHA, S. B. *Geomorfologia e Meio Ambiente*. 13. ed. Rio de Janeiro: Bertrand Brasil, 2017. p. 59-122.

PE3D. Pernambuco Tridimensional. *Mapeamento do território pernambucano*. Disponível em: http://www.pe3d.pe.gov.br/. Acesso em: 07 abr. 2022.

PORTO, C. G. Intemperismo em Regiões Tropicais. In: GUERRA, A. J T.; CUNHA, S. B. *Geomorfologia e Meio Ambiente*. 13. ed. Rio de Janeiro: Bertrand Brasil, 2017. p. 25-58.

SALOMÃO F. X. T. Controle e Prevenção dos Processos Erosivos. In: GUERRA, A.J.T.; SILVA, A.S. & BOTELHO, R.G.M. (orgs.). *Erosão e Conservação dos Solos*: Conceitos, temas e aplicações. Rio de Janeiro: Bertrand Brasil, 2014, p. 229-265.

SILVA, C. S. *Avaliação das condições hidrogeomorfológicas da bacia hidrográfica do Rio Jaboatão*. 2018. 136 f. Dissertação (Mestrado em Geografia). Programa de Pós-graduação em Geografia, Universidade Federal de Pernambuco, Recife, 2018.

SILVA, D. N. F. *Reconstrução da paisagem geomorfológica através da assinatura geoquímica dos eventos deposicionais da bacia do rio Capibaribe-Mirim*. 2012. 167 f. Dissertação (Mestrado) - Curso de Programa de Pós-graduação em Geografia, Universidade Federal de Pernambuco, Recife, 2012.