

**ENVIRONMENTAL CARTOGRAPHY: SUBSIDY FOR
GEOMORPHOLOGICAL RISK ANALYSIS IN THE PARAUPEBAS RIVER
BASIN (PA)**

Franciney Carvalho da Ponte

Doctor in Geography, Professor at the Faculty of Geography and Cartography - UFPA

fcporte@yahoo.com.br

<https://orcid.org/0000-0002-2200-7057>

Luziane Mesquita da Luz

Doctor in Geography, Professor at the Faculty of Geography and Cartography - UFPA

luzianeluz36@gmail.com

<https://orcid.org/0000-0002-2229-5394>

Débora Cássia Souza dos Santos

Graduate student at the Faculty of Geography and Cartography - UFPA

deborasantos.geo@gmail.com

<https://orcid.org/0000-0002-4222-1149>

Izabele Cristine Correa Pontes

Graduate student at the Faculty of Geography and Cartography - UFPA

correaizabele777@gmail.com

<https://orcid.org/0000-0003-0694-4013>

ABSTRACT

Environmental disasters have occurred more frequently, especially those of origin associated with climatic conditions, generally induced by anthropogenic actions, such as floods and landslides. This work aims to present a proposal for mapping physical-environmental indicators to support the analysis of geomorphological risk in the hydrographic basin of the Parauapebas River (PA). The methodology adopted was based on precepts of the theory of ecodynamics (TRICART, 1977), supporting, in this way, the analysis of variables and criteria adopted in the estimation of the fragility of the natural environment of the environments (ROSS, 1994). Four geomorphological risk classes were identified – very low, low, moderate and high. The hydrographic basin of the Parauapebas River showed a worrying panorama in the face of the geomorphological risk, which may, in this sense, be potentiated by the accelerated and disorderly expansion of human activities.

Keywords: risk analysis; environmental cartography; Parauapebas River

**CARTOGRAFIA AMBIENTAL: SUBSÍDIO A ANÁLISE DE RISCO
GEOMORFOLÓGICO NA BACIA DO RIO PARAUPEBAS (PA)**

RESUMO

Os desastres ambientais têm ocorrido de maneira mais frequente, principalmente, aqueles de origem associada às condições climáticas, geralmente, induzidos pelas ações antropogênicas, como inundações e deslizamentos. Este trabalho tem como objetivo apresentar uma proposta de mapeamento de indicadores físico-ambientais para subsidiar a análise de risco geomorfológico

na bacia hidrográfica do rio Parauapebas (PA). A metodologia adotada fora fundamentada em preceitos da teoria da ecodinâmica (TRICART, 1977), subsidiando, dessa maneira, a análise de variáveis e critérios adotados na estimativa da fragilidade do meio natural dos ambientes (ROSS, 1994). Foram identificados quatro classes de risco geomorfológico – muito baixo, baixo, moderado e alto. A bacia hidrográfica do rio Parauapebas demonstrou um panorama preocupante diante do risco geomorfológico, podendo, nesse sentido, ser potencializado pela expansão acelerada e desordenada das atividades antrópicas.

Palavras-chave: análise de risco; cartografia ambiental; rio Parauapebas

INTRODUCTION

When studying the geomorphological risk factors, it can be understood that risk situations are originated by the sum of several factors, such as geological characteristics, the density of the vegetation cover, the disordered form of occupation, among others. However, the effectiveness in understanding these factors will only occur if the forms inherent to the relief are related in terms of dynamic systems, thus facilitating the understanding of the processes that form its modeling (GREGORY, 1992).

The term geomorphological risk can be defined as the danger of the occurrence of processes of surface dynamics in occupied areas, which shape the landscape and constitute elements of geomorphology (OLIVEIRA, 2004), equating the probability of occurrence, in space and time, of situations of topographic and geomorphological instability on the earth's surface (CUNHA and RAMOS, 2013).

The study area is located within the Carajás Integration Region (RIC), in the state of Pará, more specifically, the hydrographic basin of the Parauapebas River (BHP). The choice of this basin is precisely because it is located in the region with the highest iron ore production in the state of Pará and, therefore, presents possible environmental risks, given the presence of 21 mining dams (ANM, 2021).

This work aims to present a proposal for mapping environmental indicators to support the analysis of geomorphological risk in the hydrographic basin of the Parauapebas River, based on geomorphological, pedological, vegetation cover and land use data.

METHODOLOGY

The analysis of the geomorphological risk was based on precepts of the theory of ecodynamics (TRICART, 1977), which allows the division of the terrain into stable, intergrade (intermediate) and unstable environments, as well as considering variables and criteria adopted by Ross (1994) in estimating the fragility of the natural environment.

PROCEDIMENTOS OPERACIONAIS

First, the thematic data from the Environmental Information Bank (IBGE, 2022) were used, which allowed the preparation of preliminary maps of Geomorphology, Pedology, Vegetation and Land Use.

Subsequently, in order to refine the topic of Geomorphology, the digital elevation model - SRTM (Shuttle Radar Topographic Mission) was adopted, acquired from the Geomorphometric Data base of Brazil (TOPODATA-INPE), with a spatial resolution of 30 m (1 Arc Second). At this stage, the extraction of contour lines was carried out to generate a triangular grid (TIN), the delimitation of the study basin, the production of morphometric data of the terrain (elevation amplitude and slope), allowing the adjustments of the morphosculptural classes and the definition of the morphological units of the relief, equivalent to the 3rd taxon of the Ross classification (1992).

The vegetation cover map was not adjusted, considering its level of detail and information compatible with the purpose of this research. However, land use data were refined from information acquired from IBGE (2015) and Mapbiomas, with regard to urbanized and mining areas, respectively.

After the elaboration of the thematic maps, the crossing was carried out between them, through the map algebra process, which allowed the attribution of weights to sectors/classes of each theme, as well as the definition of values associated with the importance of each thematic map, thus obtaining a weighted average in the risk analysis.

The choice of weights is related to the fragility/susceptibility of each class in relation to the geomorphological risk potential, where values close to 1.0 refer to low potential fragility, around 2.0 moderate fragility and 3.0 high fragility.

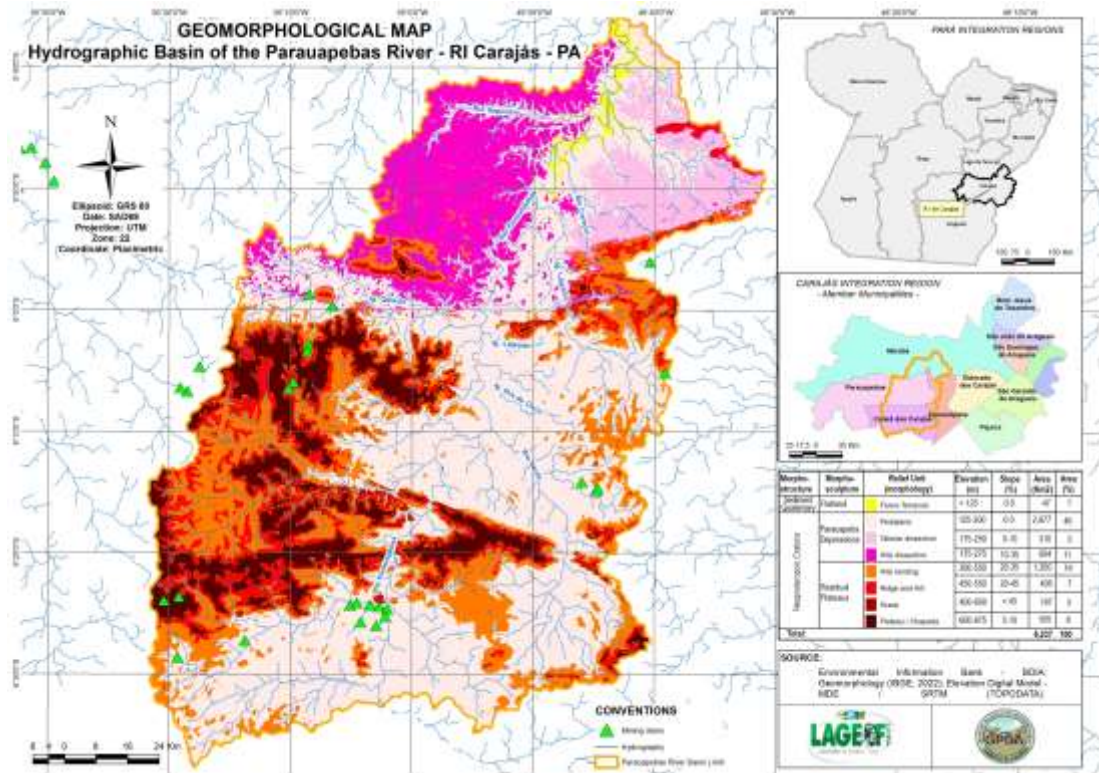
RESULTS AND DISCUSSION

The analysis of the geomorphological map (IBGE, 2022) and the morphometric aspects (TOPODATA/INPE) allowed the identification of a morphostructural class (Neoproterozoic Cratons), three morphosculptural classes (Residual Plateaus, Marginal Depressions/Parauapebas, Plain) and eight modeled/units morphological (Fluvio-Terracial Plain, Pediplano, Tabular Dissection, Hilly Dissection, Hilly Landing, Ridge and Hill, Scarp and Plateaus/Chapadas), both associated with the first three taxonomic levels of Ross (1992), respectively (Figure 01).

The morphostructural class, represented by the Neoproterozoic Cratons, associated with the 1st taxonomic level, functions as a substrate and/or structural shields on which the Depressions and

Residual Plateaus are based. Such structures constitute old and stable formations, dating from the Precambrian, being deeply metamorphosed and constituted, essentially, of crystalline rocks, of igneous formation and of intrusive consolidation, or of sedimentary material folded, razed and metamorphized (PENTEADO, 1983), being predominantly marked by topographic ruptures, in relation to sedimentary formations.

Figure 01 - Geomorphology of the Parauapebas River Watershed, RI Carajás



Source: Environmental Information Bank - BDIA: Geomorphology (IBGE, 2022); MDE / SRTM (TOPODATA / INPE)

Regarding morphosculpture, BHP has three mapping units, associated with the 2nd taxonomic level, which are: Residual Plateaus, Marginal Depressions/Parauapebas and Plain. The Residual Plateaus are part of and represented by a topographic compartmentalization, characterized by the prevalence of erosive processes and by the sculpturing of the relief, through structural control (IBGE, 2009), with altitudes that oscillate between 400 and 900 meters, in general, constituted by crystalline rocks, with ridges, ravine slopes and escarpments (FURTADO and PONTE, 2013). The Marginal Depressions are characterized by their crystalline basement, associated with both the Neoproterozoic Cratons and the Moving Belts. They constitute surfaces flattened by very old erosive cycles, buried by the Paleomesozoic deposits of the great

sedimentary basins, throughout the Tertiary and Quaternary (ROSS, 2013). The Plains are based on sedimentary deposits, dating back to Cenozoic formations, mainly from the Quaternary period, being represented by the most recent and unconsolidated stratigraphic deposits, with elevations ranging from 100 to 200 meters.

In the context of the morphosculptural classes, it was possible to identify eight morphological units of the relief, which are: Fluvio Plain – Terracial (1%); Pediplano (46%); Tabular Dissection (5%); Hilly Dissection (11%); Hilly Landing (19%); Ridge and Hill (7%); Scarps (3%); and, Plateaus/Chapadas (8%).

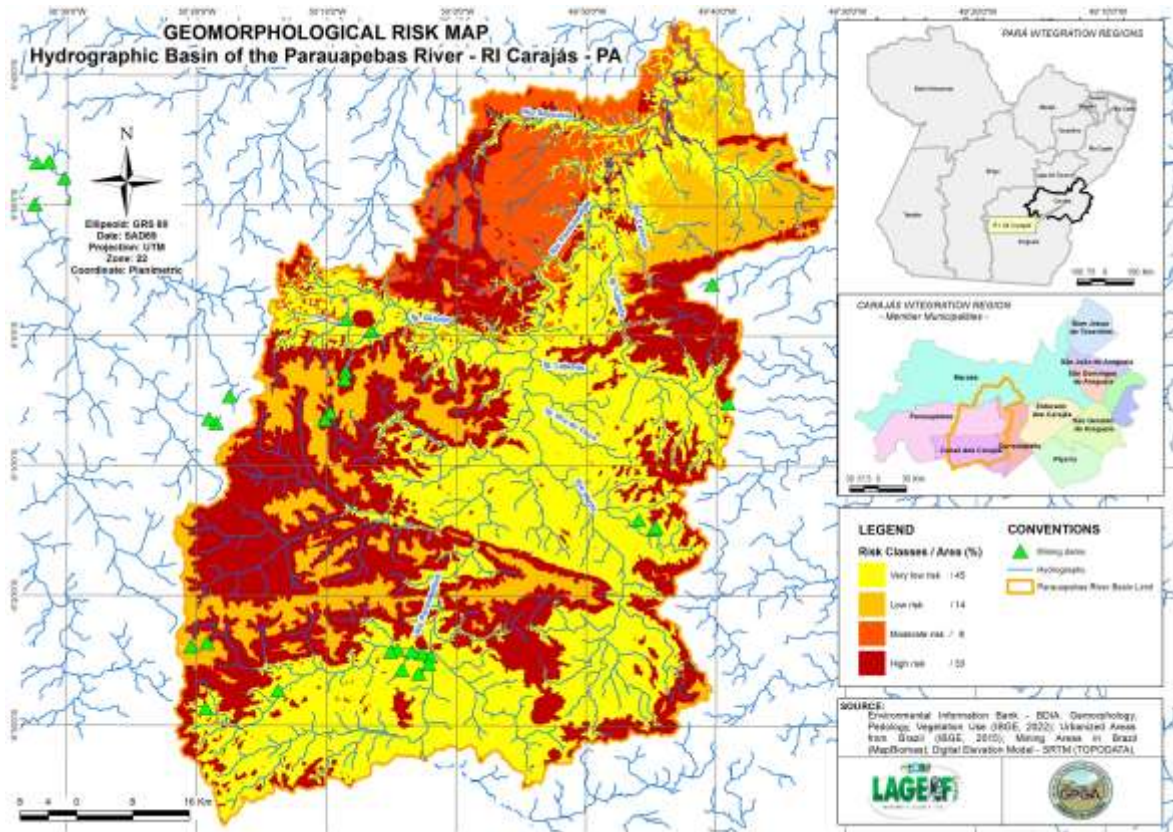
From the individual analysis of thematic parameters in view of the fragility of the environment, it was possible to prepare the geomorphological risk map of the Parauapebas river basin, in the context of the Carajás integration region (Figure 02). Through the geomorphological risk map, four risk classes were identified, which are: very low risk (45%); low risk (14%); moderate risk (8%); and, high risk (33%).

The unit classified as very low risk occupies approximately half of the study area, mainly due to pediplaned depressions. This unit represents predominantly flat to smooth wavy reliefs, associated with low slope and relatively well-developed and stable pedogenetic aspects. Although this class is under predominant use of pastures and this constitutes a technological structure of low transforming threat in face of the geomorphological conditions, the relief stands out in terms of importance in the face of the potential for risk, a fact that culminated in the definition of that unit.

The class considered as low risk corresponds to the areas settled on the reliefs of tabular dissection (northeast portion) and on the reliefs in the form of plateaus/plateaus (central-west portion). Despite the discrepancy in elevation, these areas have similarities in terms of the relatively smooth wavy top and the vegetation cover represented by dense forests, except for those areas under the anthropic typology of pastures (northeast portion), culminating in low pedomorphogenetic instability, in due to the low to moderate slope and, consequently, in the presence of little accentuated erosive processes.

The moderate risk was classified as such due to the predominant occurrence of reliefs with hilly dissection, located in the northwest portion, representing the areas with the lowest occurrence of BHP. These are zones that present slopes that vary from 10 to 30%, conditioning the significant occurrence of erosive processes, mainly, on the steepest slopes, close to the staggered levels (hills and mountains). The phytopedological factors contributed decisively to the definition of this class, through the presence of the Dense Forest and the Red-Yellow Argisol, since they work as mitigating factors against the morphogenetic instability of the terrain.

Figure 02 - Geomorphological Risk of the Parauapebas River Watershed, RI Carajás



Source: Environmental Information Bank - BDIA: Geomorphology, Pedology, Vegetation Use (IBGE, 2022); Urbanized Areas in Brazil (IBGE, 2015); Mining Areas of Brazil (MapBiomass)

The class considered as high risk constitutes the second highest occurrence in the study area, distributed throughout the BHP, mainly in the peripheral areas, with emphasis on the western portion. This class combines the aspects of greatest potential to instability of the environment, such as heavily dissected residual plateaus, with slopes ranging from 30 to 45% (hills and mountains) and, in some cases, above 45% (scarps), poorly developed soils, with occurrence of rocky outcrops, open ombrophilous forests, vegetation refuge (savannah) and use typologies with high potential threat of stratigraphic transformation (mining).

CONCLUSIONS

The analysis of the geomorphological risk of the hydrographic basin of the Parauapebas River, in the context of the integration region of Carajás (PA), allowed us to draw some conclusions, described below:

1. Environmental cartography has demonstrated its effectiveness due to a greater understanding of conditioning and the dynamics of physical-natural factors, based on the premise of a systemic and holistic approach.
2. The geomorphological risk map constituted the synthesis of a contradictory approach, as it took into account favorable and unfavorable factors about the potential for the occurrence of certain events, as well as allowing the generation of indicators of instability and/or stability of the terrain, with suggestions regarding the fragility facing the occupation of these spaces.
3. The Parauapebas River Basin shows a worrying panorama in view of the geomorphological risk, considering the fact that it has a high potential for the occurrence of disasters, whether natural and/or social. This statement stems from the presence of factors favorable to the outbreak of these events, since almost half of the basin is constituted by moderate to high geomorphological risk.
4. The geomorphological risk of occurrence of natural disasters, such as mass movement, is restricted to areas settled on the highest slopes, such as the slopes of hills, mountains and escarpments, located predominantly in the central- west of the basin.

REFERENCE

Agência Nacional de Mineração. *Sistema Integrado de Gestão de Barragens de Mineração*, 2021.

CUNHA, L., RAMOS, A. Riscos Naturais em Portugal: alguns problemas e perspectivas e tendências no estudo dos riscos geomorfológicos, in: *LOMBARDO, M., FREITAS, M. (Orgs.). Riscos e Vulnerabilidade: teoria e prática no contexto luso-brasileiro*. Cultura acadêmica, São Paulo, pp. 19-43. 2013.

FURTADO, A.; PONTE, F. MAPEAMENTO DE UNIDADES DE RELEVO DO ESTADO DO PARÁ. *Revista GeoAmazônia*, Belém, v. 02, n. 2, p. 56 - 67, jul./dez. 2013.

GREGORY, K. J. *A Natureza da Geografia Física*. (Tradução de Eduardo AlmeidaNavarro). Rio de Janeiro: Bertrand Brasil, 1992.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). *Manual técnico de geomorfologia*. / Coordenação de Recursos Naturais e Estudos Ambientais. 2. ed. Rio de Janeiro, 2009. 182 p.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). *Áreas urbanizadas do Brasil*. 2015.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). *Banco de Dados e Informações Ambientais - BDIA: geomorfologia, pedologia, vegetação e uso*. Acesso em: 15 de maio de 2022.

OLIVEIRA, E. L. de A. Áreas de Risco Geomorfológico na Bacia Hidrográfica do Arroio Cadena, Santa Maria/RS: Zoneamento e Hierarquização. 2004. 141f. *Dissertação* (Mestrado em Geografia) - Universidade Federal do Rio Grande do Sul, Porto Alegre, 2004.

PENTEADO, M. *Fundamentos de Geomorfologia*. 3ª ed. Rio de Janeiro: IBGE, 1983.

ROSS, J. L. S. O registro cartográfico dos fatos Geomórficos e a questão da taxonomia do relevo. *Revista do Departamento de Geografia*, 6, 17-29, 1992.

ROSS, J. Análise empírica da fragilidade dos ambientes naturais e antropizados. *Revista do Departamento de Geografia FFLCH – USP*, São Paulo, n. 8, 1994

ROSS, J. O Relevo Brasileiro nas Macroestruturas Antigas. *Continentes*, ano 2, n. 2, p. 8-27, 2013.

TRICART, J. 1977. *Ecodinâmica*. IBGE, Diretoria Técnica, SUPREN, Rio de Janeiro