ANTHROPOGENIC PRESSURES AND ENVIRONMENTAL CONDITION IN THE AMAZONIAN COASTAL ZONE: THE VILLAGE OF SÃO JOSÉ DO GURUPI (VISEU, PARÁ, BRAZIL)

Cézar Di Paula Da Silva Pinheiro[1]

ABSTRACT: Amazonian fluvio-estuarine coastal zones are highly dynamic environments in which natural processes interact with human activities, creating significant challenges for environmental management. This study evaluated anthropogenic pressures and their effects on the environmental integrity of the coastal zone of the Village of São José do Gurupi (Viseu, Pará, Brazil). *In situ* field surveys were conducted, and Environmental Impact Assessment (EIA) was integrated with the DPSIR framework (Driving Forces–Pressures–State–Impacts–Responses) through an interaction matrix between anthropogenic actions and environmental factors. The results indicate that intensive seasonal use, boat traffic, and traffic along the riverbank are associated with geomorphological instability, degradation of riparian vegetation, and changes in the characteristics of the sandy bank. The localized placement of gravel, associated with wooden containment structures, was associated with a local configuration characterized by greater material retention, although the degraded condition of the structures limited their apparent protective function. The integrated application of EIA and the DPSIR framework enabled the systematic organization of relationships among driving forces, pressures, environmental state, potential impacts, and management responses. The results highlight the importance of integrated public policies that combine territorial planning, environmental management, and community participation to regulate the use of riverbanks and conserve the physical and ecological processes that support Amazonian fluvio-estuarine coastal systems.

Keywords: DPSIR; environmental impact assessment; riparian vegetation; integrated coastal management.

PRESSÕES ANTRÓPICAS E CONDIÇÃO AMBIENTAL NA ZONA COSTEIRA AMAZÔNICA: A VILA DE SÃO JOSÉ DO GURUPI (VISEU, PARÁ, BRASIL)

RESUMO: As zonas costeiras flúvio-estuarinas amazônicas são ambientes altamente dinâmicos, onde processos naturais interagem com as atividades humanas, criando desafios significativos para a gestão ambiental. Este estudo avaliou as pressões antrópicas e seus efeitos sobre a integridade ambiental da zona costeira da Vila de São José do Gurupi (Viseu, Pará, Brasil). Foram realizados levantamentos de campo *in situ*, e a Avaliação de Impacto Ambiental (AIA) foi integrada ao modelo DPSIR (Forças Motrizes–Pressões–Estado–Impactos–Respostas) por meio de uma matriz de interação entre ações antrópicas e fatores ambientais. Os resultados indicam que o uso sazonal intensivo, a circulação de embarcações e o tráfego ao longo da margem do rio estão associados à instabilidade geomorfológica, à degradação da vegetação ripária e às alterações nas características da faixa arenosa. A aplicação localizada de cascalho, associada a estruturas de contenção em madeira, esteve associada a uma configuração local de maior retenção do material, embora a condição degradada das estruturas limitasse sua função protetiva aparente. A aplicação integrada da AIA e do modelo DPSIR permitiu organizar de forma sistemática as relações entre forças motrizes, pressões, estado ambiental, impactos potenciais e respostas de gestão. Os resultados reforçam a importância de políticas públicas integradas que articulem o planejamento territorial, a gestão ambiental e a participação da comunidade para regular o uso das margens dos rios e conservar os processos físicos e ecológicos que sustentam os sistemas costeiros flúvio-estuarinos amazônicos.

Palavras-chave: DPSIR; avaliação de impacto ambiental; vegetação ripária; gestão costeira integrada.

[1]Doutorando em Ciências Ambientais. Universidade do Estado do Pará (UEPA). cezarpinheiroo18@gmail.com.

INTRODUCTION

Amazonian fluvial–estuarine coastal zones are highly complex environments where natural processes, including erosion, sediment deposition, and hydrological dynamics, interact with riparian vegetation and aquatic ecosystems. These interactions provide essential ecosystem services while supporting local socioeconomic activities, particularly artisanal fishing and recreation (FERREIRA, 2013; GUO et al., 2015). However, human occupation of riverbanks, often intensified during seasonal periods, can compromise geomorphological stability, riparian vegetation integrity, and overall environmental quality (WOODROFFE, 2002; LIGHTBODY et al., 2019; LIU et al., 2023).

The Village of São José do Gurupi, located in the estuarine sector of the Gurupi River (Pará, Brazil), is subject to anthropogenic pressures associated with intensive recreational use, recurrent trampling of riverbanks, unregulated deposition of materials, and boat traffic. These pressures highlight the need to better understand the interactions between human activities and natural processes while considering not only their immediate environmental effects but also the adequacy of existing management measures and the limitations of localized mitigation measures (BOND et al., 2025; VIANNA et al., 2020; NOAA, 2023).

Environmental Impact Assessment (EIA), combined with the Driving Forces–Pressures–State–Impacts–Responses (DPSIR) framework, provides a structured approach for analyzing socioeconomic driving forces, environmental pressures, environmental conditions, potential impacts, and institutional responses. The combined application of these tools can support environmental planning and adaptive management in vulnerable coastal environments (EEA, 1999; SÁNCHEZ, 2013; TICKNER et al., 2017). Their application in Amazonian fluvial–estuarine environments can facilitate the identification of anthropogenic pressure patterns, improve the understanding of environmental degradation processes, and support evidence-based environmental management.

Accordingly, this study aims to analyze the anthropogenic pressures affecting the environmental integrity of a selected riverbank section of the coastal zone of the Village of São José do Gurupi (Viseu, Pará, Brazil). Specifically, it integrates Environmental Impact Assessment and the DPSIR framework to examine the relationships between human activities, environmental pressures, and observed environmental conditions, providing scientific evidence to support environmental management in Amazonian fluvial–estuarine systems.

MATERIALS AND METHODS

Characterization of the study area

The Village of São José do Gurupi is located in the coastal zone of the municipality of Viseu, Pará, Brazil, on the banks of the Gurupi River, which is the main physical feature shaping the local landscape. The village has a population of approximately 646 inhabitants (CEMS, 2024). Its settlement developed directly along the estuarine margin, where hydrological and sedimentary processes influence riverbank configuration, bank stability, and the environmental conditions of areas used by the local population. The village occupies approximately 69.2 ha (0.69 km^2) and is located about 340 km west of Belém, the capital of Pará (Figure 1).

The study area comprises an approximately 183 m long section of the Gurupi River bank located in front of the village's urban core. This stretch is used for recreation, bathing, artisanal fishing, small-boat mooring, and subsistence activities, concentrating much of the interaction between the local population and the fluvial–estuarine environment.

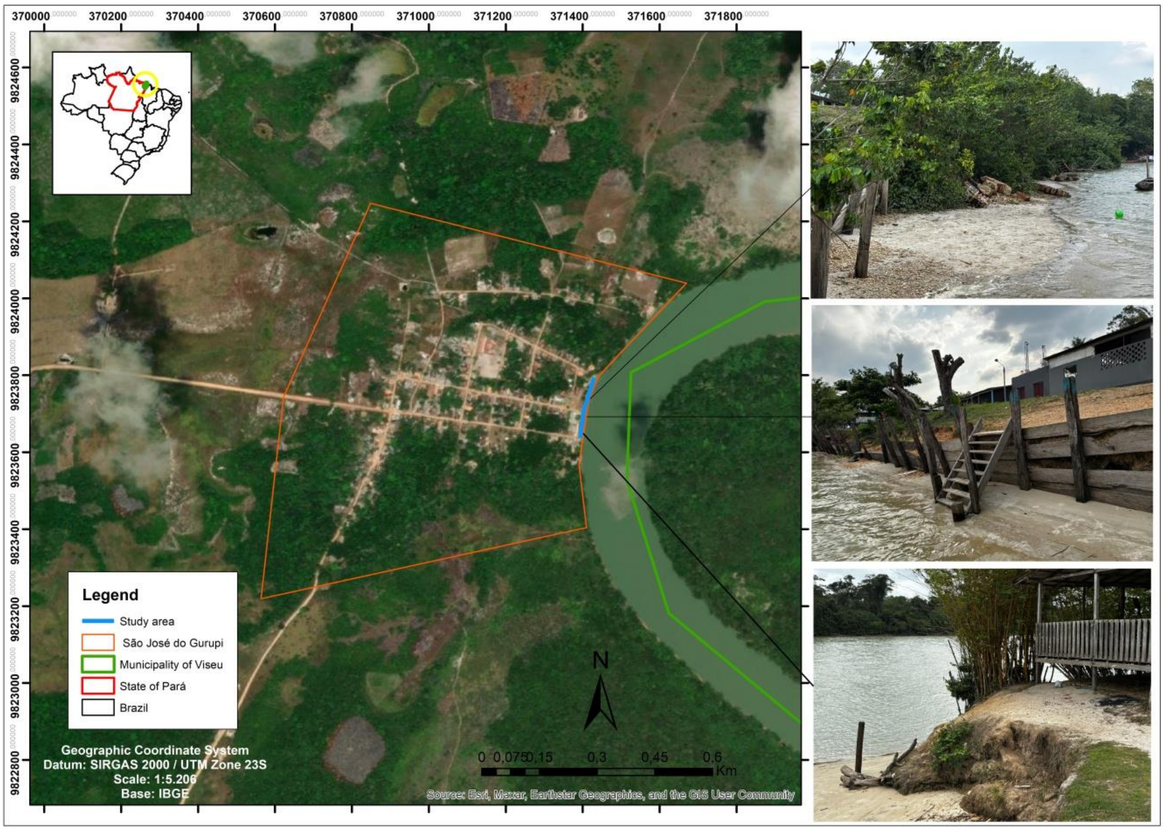

Figure 1 – Location of the Village of São José do Gurupi, municipality of Viseu, Pará, Brazil. Source: Author (2026).

The Gurupi River is approximately 719 km long, with about 70% of its basin located in the state of Maranhão, while its main left-bank tributaries drain the state of Pará (MARTINS; OLIVEIRA, 2011). In the study area, the river occupies its lower estuarine reach, where fluvial discharge interacts with tidal forcing and seasonal variations in freshwater input. Silva et al. (2023) classified the Gurupi as a tide-dominated estuary based on its morphology and mean hydrodynamic conditions, with a macrotidal regime and partially mixed circulation. The authors also documented seasonal differences in tidal propagation, fluvial discharge, suspended sediment concentration, and sediment transport, demonstrating that both tidal and fluvial processes contribute to the dynamics of the estuarine system (SILVA et al., 2023). These processes provide the broader hydrodynamic and sedimentary context for interpreting the riverbank conditions observed in the study area (FERREIRA, 2013; GUO et al., 2015).

Variations in water level and sediment transport contribute to erosion and sediment redistribution, potentially affecting riverbank stability, particularly in urbanized sections (GUO et al., 2015). The studied riverbank exhibits characteristics of sandy environments, including erosional scarps, exposed roots, variability in the riverbank profile, and a narrow sandy substrate along the river margin that is seasonally used for recreation, boat access, and other community activities (FERREIRA, 2013; MARTINS; OLIVEIRA, 2011). Riparian vegetation is predominantly composed of species adapted to unstable substrates and seasonal fluctuations in river water levels.

METHODOLOGY

This study adopted an integrated approach combining Environmental Impact Assessment and the Driving Forces–Pressures–State–Impacts–Responses framework. Field surveys were conducted in situ in December 2025, during the period of intensive seasonal use of the study area. December corresponds to the dry season in the Gurupi basin, characterized by substantially lower river discharge than the rainy season (SILVA *et al*., 2023). Direct observations and photographic records documented environmental conditions along the coastal strip, including human occupation, recreational activities, circulation of residents and visitors, riverbank conditions, riparian vegetation, and the conservation status of access and containment structures.

The study area was delineated in a Geographic Information System (GIS) using the Gurupi River shoreline and the coastal use strip identified from field observations and photographic records. It comprises the riverbank section directly influenced by the urban core of the Village of São José do Gurupi and the human activities occurring along this stretch.

Environmental Impact Assessment was conducted using an interaction matrix between anthropogenic actions and environmental factors, adapted from the procedure proposed by Leopold *et al*. (1971) and following the methodological principles described by Sánchez (2013). The matrix was used to identify, organize, and qualitatively evaluate potential interactions between anthropogenic activities and the physical, biotic, and socio-environmental components of the fluvial–estuarine coastal system.

Human activities identified during the field survey were classified as potentially impacting actions, including recreational use and bathing, intensive seasonal use, artisanal fishing, circulation and mooring of small boats, traffic and trampling along the riverbank, solid waste accumulation, gravel placement, and installation of wooden containment structures. These actions were evaluated using an ordinal scale ranging from −3 (strong negative interaction) to +3 (strong positive interaction), following criteria commonly adopted in Environmental Impact Assessment studies (CONAMA, 1986; SÁNCHEZ, 2013). The scale was interpreted as follows: −3 represented a strong negative interaction, −2 a moderate negative interaction, −1 a weak negative interaction, 0 no identified interaction, and +1 to +3 positive interactions of increasing intensity. The scores expressed the direction and relative intensity of the identified interactions and were not intended as quantitative measurements of environmental impact.

The interaction matrix comprised the following environmental factors: riverbank stability, sediment dynamics, riparian vegetation, sandy substrate condition, landscape quality, social use of space, and hydrology. In this study, sediment-related processes refer to potential interactions between anthropogenic activities and sediment-related conditions at the riverbank, rather than to a quantitative assessment of sediment transport or sediment balance. Sandy substrate condition refers specifically to the physical condition of the narrow sandy surface along the riverbank, considering its visible continuity, surface integrity, and apparent alteration associated with natural processes and anthropogenic interventions. These factors were selected based on their relevance to tropical fluvial–estuarine environments and previous studies addressing coastal processes and human occupation (FERREIRA, 2013; GUO *et al*., 2015).

Impact values were assigned qualitatively by the researcher responsible for the assessment, based on direct field observations, photographic records, and specialized literature. Score levels were distinguished primarily according to the perceived intensity of each interaction in relation to the environmental conditions observed in the field. Spatial extent, duration, and reversibility were considered as qualitative contextual criteria and were not independently quantified or converted into numerical sub-scores. The resulting values therefore represent an ordinal qualitative assessment based on researcher judgment rather than quantitative measurements of environmental impact. No differential weighting was applied, and all environmental factors were considered equally important.

The interaction matrix was subsequently interpreted using the DPSIR framework proposed by the European Environment Agency (EEA, 1999). Within this framework, Driving Forces were associated with the socioeconomic and cultural activities responsible for riverbank occupation and use. Pressures corresponded to the anthropogenic actions identified during the field survey and represented in the interaction matrix. State represented the environmental conditions observed in the study area, including riverbank stability, sediment dynamics, riparian vegetation, landscape quality, and sandy substrate conditions. Impacts were inferred from the interactions identified in the EIA matrix, whereas Responses comprised structural interventions, applicable legislation, and environmental management measures observed in the study area.

RESULTS AND DISCUSSION

Field observations indicated that public interventions within the study area were limited and localized, consisting primarily of gravel placement along access roads, streets, and sections of the riverbank. In the marginal zone, the gravel was associated with a wooden containment structure that confined and supported the material. The resulting surface configuration differed from that of the adjacent sandy sections of the riverbank, where the containment structure was absent or discontinuous (BOND *et al*., 2025; NOAA, 2023).

The containment structure consisted of vertical wooden stakes driven into the substrate and horizontal planks forming a frontal barrier that retained the gravel along the riverbank. In this configuration, the wooden elements provided structural support for the deposited material. The combination of gravel and structural elements can function as a riverbank stabilization measure under appropriate local conditions (BOND *et al*., 2025). However, the present study did not include hydrodynamic measurements or sediment transport monitoring and therefore does not allow direct assessment of energy dissipation or changes in sediment transport associated with the structure. The structure was in an advanced state of degradation, with tilted stakes, displaced or missing planks, and collapsed sections that allowed gravel loss through washout, indicating reduced structural integrity and a potentially reduced protective function.

Access stairways associated with the containment structure also exhibited signs of deterioration, including missing steps and unstable supports. In adjacent areas, remnants of former brick and concrete containment structures were observed along the sandy strip, indicating previous attempts at riverbank stabilization.

In the outer sections of the study area, where wooden containment structures were absent and gravel was not confined, field observations revealed greater root exposure, erosional scarps, steeper riverbank sections, and reduced continuity of the sandy surface. These conditions differed from those observed in the central section, where the degraded containment structure remained present. This spatial contrast was considered in the qualitative interpretation of riverbank conditions and supported the identification of the main anthropogenic actions and environmental components included in the EIA interaction matrix (Table 1). However, the observed differences do not establish a causal effect of the containment structure on erosion, as no temporal monitoring or hydrodynamic measurements were conducted.

EIA Interaction Matrix

The EIA interaction matrix (Table 1) enabled the identification and qualitative ranking of the potential effects of human activities on the main environmental components of the fluvial–estuarine coastal zone of the Village of São José do Gurupi. The assigned scores reflect the intensity of the interactions observed in the field and the ecological and socio-environmental relevance of the identified pressures.

Table 1 – EIA interaction matrix (actions × environmental factors) applied to the fluvial–estuarine coastal zone of the Village of São José do Gurupi, municipality of Viseu, Pará, Brazil. Source: Author (2026).

Actions / Factors	Riverbank stability	Sediment dynamics	Riparian vegetation	Sandy substrate condition	Landscape quality	Social use of space	Hydrology
Recreational use and bathing	−2	−1	−2	−2	−2	+3	0
Intensive seasonal use	−3	−2	−3	−3	−3	+3	0
Circulation and mooring of small boats	−1	−1	−1	−1	−1	+1	−1
Artisanal fishing	−1	0	0	0	0	+2	0
Gravel placement along the riverbank	+1	−2	−1	−3	−2	−2	0
Traffic and trampling along the riverbank	−2	−1	−3	−2	−2	+1	0
Accumulation of solid waste	−1	−1	−2	−2	−3	−1	0
Wooden containment structures	+2	-1	-1	-1	-1	+1	0
Impact scale: −3 = strong negative impact; −2 = moderate negative impact; −1 = weak negative impact; 0 = no impact; +1 to +3 = positive interactions of increasing intensity.							

The EIA interaction matrix indicates that the most frequent and intense negative interactions are concentrated on riverbank stability, which received high negative scores across most anthropogenic actions. Intensive seasonal use (−3), recreational use and bathing (−2), and traffic and trampling along the riverbank (−2) indicate that occupation of the riverbank coincided spatially with the environmental instability observed along the riverbank. In small sandy estuarine environments, repeated sediment disturbance and substrate compaction can reduce riverbank resistance and promote erosional retreat, particularly in urbanized sectors (LIU *et al*., 2023; NOVAES; LOBO; RANIERI, 2025).

The sediment-related interactions received weak to moderate negative scores (−1 to −2), particularly for trampling, boat circulation, and gravel placement. These scores reflect the potential interaction of the observed activities with sediment-related conditions at the riverbank, as interpreted from field observations and the specialized literature, rather than direct measurements of sediment transport or redistribution. The observed conditions indicate localized alteration of the riverbank substrate, while larger-scale sedimentary processes are governed by interactions between tidal forcing and fluvial discharge, with their relative influence varying seasonally (SILVA *et al*., 2023). Consequently, the observed interactions are interpreted primarily as localized effects on the riverbank rather than as evidence of changes in the broader sedimentary functioning of the estuarine system.

Riparian vegetation emerged as one of the environmental components most sensitive to anthropogenic pressures, with strong negative interactions associated with intensive seasonal use (−3) and traffic and trampling (−3). Although the study area is not characterized by mangrove vegetation, riparian vegetation contributes to riverbank stability through mechanical reinforcement of the soil by roots (KRZEMINSKA *et al*., 2019). Its degradation may reduce this stabilizing function and increase the susceptibility of the riverbank to erosion, particularly where vegetation cover is disturbed by human use (LIGHTBODY *et al*., 2019; MARTINS *et al*., 2021; VOGEL *et al*., 2009; KRZEMINSKA *et al*., 2019).

The sandy substrate condition exhibited a strong negative interaction with gravel placement along the riverbank (−3), as the deposited material directly modifies the predominantly sandy surface of the marginal strip. This score reflects the intensity of the observed alteration in the physical condition and continuity of the sandy surface, rather than a quantitative assessment of grain-size composition. Although gravel may contribute positively to localized riverbank stability (+1), its deposition changes the surface condition of the sandy substrate and may interfere with recreational and bathing areas. Such interventions, when not incorporated into properly designed engineering projects, may generate conflicts of use and environmental degradation in fluvial–estuarine environments (HEMMINGSEN; EIKAAS; MARSDEN, 2019; NOAA, 2023; SIEMES *et al*., 2023).

The wooden containment structures exhibited a moderate positive interaction with riverbank stability (+2), reflecting their localized stabilizing function as observed during the field survey. The structure retained portions of the riverbank and was associated with areas where gravel had been placed along the marginal strip. However, field observations also indicated deterioration, including tilted stakes, displaced or missing wooden elements, and partially collapsed sections. These conditions suggest that the protective function of the structure is spatially limited and dependent on its physical integrity. Riverbank protection structures can lose effectiveness under hydraulic forces and inadequate maintenance, with structural stability also influenced by local geomorphological and hydraulic conditions (LENG *et al*., 2023; ZHOU *et al*., 2024). In the present study, hydrodynamic effects and long-term structural performance were not directly measured.

Social use of space received the highest positive scores, highlighting the social, cultural, and economic importance of the riverbank to the local community. This contrast between social benefits and physical impacts reinforces the need for integrated coastal management strategies capable of reconciling public use with the conservation of the geomorphological and ecological processes that sustain the stability of the fluvial–estuarine system (TICKNER *et al*., 2017).

Application of the DPSIR Framework

The DPSIR elements summarized in Table 2 were derived from field observations and the qualitative interactions identified in the Environmental Impact Assessment matrix. The framework was used to organize the observed socioeconomic activities, anthropogenic pressures, environmental conditions, potential impacts, and management responses. The DPSIR classification does not establish causal relationships beyond the evidence provided by the field survey and qualitative assessment.

Table 2 – Summary of DPSIR elements derived from the Environmental Impact Assessment of the coastal zone of São José do Gurupi, municipality of Viseu, Pará, Brazil. Source: Author (2026).

DPSIR Component	Identified Elements	Component Characterization
Driving Forces	Recreational use and bathing; seasonal events; artisanal fishing; social use of the riverbank	Socioeconomic and cultural activities associated with leisure, subsistence, and direct occupation of the fluvial–estuarine riverbank, with seasonal intensification during vacation periods and end-of-year events.
Pressures	Trampling and traffic along the riverbank; circulation and mooring of small boats; solid waste accumulation; gravel placement; trampling of riparian vegetation; implementation of artificial structures	Anthropogenic actions that interact with the physical, biotic, and social components of the riverbank and may contribute to substrate disturbance, vegetation degradation, and modification of local bank conditions.
State	Riverbank sections with and without containment structures; heterogeneous sandy substrate; fragmented riparian vegetation; sectors with exposed roots and erosional features	Environmental conditions observed during the field survey, characterized by spatial differences in riverbank stability, substrate condition, vegetation continuity, and the presence of localized stabilization structures.
Impacts	Potential increase in riverbank instability; reduction of the protective function of riparian vegetation; localized alteration of substrate condition; reduced landscape and recreational quality	Potential environmental and socio-environmental consequences inferred from the EIA interactions and observed conditions. These impacts were not independently quantified or temporally monitored.
Responses	Wooden containment structure associated with gravel placement	Localized riverbank stabilization measure identified in the study area. Its degraded physical condition and the absence of evidence of systematic monitoring indicate limitations in the existing management response.

The identified Driving Forces were associated with recreational use, bathing activities, artisanal fishing, social use of the riverbank, and seasonal events. During the field survey, riverbank use was particularly intensified during the vacation and end-of-year period, when the area receives increased numbers of visitors. In a small coastal area such as the Village of São José do Gurupi, the temporal and spatial concentration of these activities may increase pressure on the system (BORJA *et al*., 2006; EEA, 2018). This interpretation is consistent with DPSIR applications to Amazonian estuarine beaches, where insufficient planning of recreational activities intensified anthropogenic pressures and reduced environmental quality, reinforcing the need for integrated coastal management (SOUSA-FELIX *et al*., 2017).

The identified Pressures comprise trampling and traffic along the sandy riverbank, circulation and mooring of small boats, gravel placement associated with containment structures, solid waste accumulation, and trampling of riparian vegetation. As indicated by the EIA matrix, these activities may interact with riverbank stability, substrate condition, vegetation, and landscape quality. The potential effects of these interactions are discussed in relation to fluvial–estuarine processes reported in the literature (WOODROFFE, 2002; LIU *et al*., 2023; SIEMES *et al*., 2023).

The State was characterized by spatially heterogeneous riverbank conditions, including sections with containment structures, exposed roots, erosional features, fragmented riparian vegetation, and differences in the continuity and physical condition of the sandy substrate. These conditions were directly observed during the field survey and represent the environmental state documented at the time of the study. Previous studies indicate that riparian vegetation contributes to riverbank stability through root reinforcement and hydraulic energy dissipation (OKEKE *et al*., 2022; BIGGS *et al*., 2025; LIGHTBODY *et al*., 2019). In the present study, however, the contribution of vegetation to the observed bank condition was not independently quantified.

The potential Impacts identified through the DPSIR interpretation include increased vulnerability of riverbank stability, reduction of the protective function of riparian vegetation, localized alteration of substrate condition, and reduced landscape and recreational quality. These impacts were inferred from the interactions identified in the EIA matrix and the environmental conditions observed in the field. They should therefore be understood as potential or interpreted consequences rather than quantitatively demonstrated causal effects. Previous studies have shown that human occupation, recreational use, and substrate modification can interact with geomorphological and ecological processes in fluvial–estuarine environments (HAN *et al*., 2025; WOODROFFE, 2002; SIEMES *et al*., 2023; NOVAES; LOBO; RANIERI, 2025).

The identified Response was the localized use of wooden containment structures associated with gravel placement to stabilize sections of the riverbank. The observed condition of these structures indicates that the existing response is limited in spatial extent and affected by physical deterioration. The study did not assess the hydraulic efficiency or long-term performance of the structure. Previous studies indicate that the effectiveness of riverbank stabilization measures depends on local hydraulic, geomorphological, and structural conditions and may require maintenance and monitoring (MAN *et al*., 2022; MAN *et al*., 2024; VIANNA *et al*., 2020). In the study area, the lack of maintenance and absence of integrated planning were interpreted as management gaps rather than as Responses within the DPSIR classification.

The combined application of the EIA interaction matrix and the DPSIR framework provided a structured organization of the information obtained from field observations and the qualitative assessment (EEA, 1999). The DPSIR framework has been applied to coastal social–ecological systems because it facilitates the organization of environmental and socioeconomic components and supports management-oriented assessments (LEWISON *et al*., 2016).

The interpretation of the results should consider the observational and qualitative scope of the assessment. The field survey was conducted during a period of intensive seasonal use and provided a site-specific characterization of anthropogenic pressures and environmental conditions. The EIA matrix was based on ordinal scores assigned from field observations, photographic records, and specialized literature, while the DPSIR framework was used to organize these observations and their potential environmental implications. The absence of temporal monitoring, granulometric characterization, and hydrodynamic measurements limits the assessment of temporal trends and specific physical mechanisms. Within this scope, the results are interpreted as evidence of localized environmental conditions and potential interactions between anthropogenic pressures and the riverbank system, rather than as quantitative estimates of geomorphological change or hydrodynamic processes.

CONCLUSIONS

The integrated application of Environmental Impact Assessment and the DPSIR framework to the fluvial–estuarine coastal zone of the Village of São José do Gurupi provided a structured basis for interpreting anthropogenic pressures affecting the Gurupi Riverbank. The results indicate that recreational use, seasonal occupation, and traffic along the riverbank are associated with riverbank instability, riparian vegetation degradation, and changes in sandy substrate conditions within a system characterized by marked hydrosedimentary dynamics.

The DPSIR framework organized these interactions by distinguishing socioeconomic driving forces, localized anthropogenic pressures, observed environmental conditions, potential impacts, and existing management responses. The findings indicate that the observed environmental conditions reflect interactions between human activities and the natural dynamics of the fluvial–estuarine environment. They also highlight the limitations of isolated mitigation measures and support integrated approaches combining territorial planning, environmental management, and community participation to regulate riverbank use while conserving the physical and ecological processes that sustain the system.

The combined use of EIA and DPSIR provided a systematic framework for organizing the relationships identified between anthropogenic pressures and environmental conditions in the study area. Its application allowed the main pressures, environmental components, potential impacts, and existing management responses to be identified within a common analytical structure, providing a methodological basis for environmental assessments of Amazonian fluvial–estuarine coastal environments with similar socioecological characteristics.

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