

**DIAGNOSIS OF ENVIRONMENTAL IMPACTS IN THE INHAMUM STREAM WATERSHED
IN CAXIAS – MA** <https://doi.org/10.63330/aurumpub.015-009>**José Manoel Morais Silva¹ and Jéssica Cristina Oliveira Frota²****ABSTRACT**

Environmental impacts in watersheds are a global concern, resulting from actions such as deforestation, urbanization, and pollution. These processes compromise water quality and the balance of ecosystems. The environmental impact caused by deforestation in the Inhamum stream basin in Caxias (MA) is evident, especially regarding the degradation of hydrographic systems and native vegetation cover. The destruction of riparian vegetation promotes erosion and river siltation, reducing flow and compromising water quality, alongside urbanization processes. Given this, the general objective of the research is to identify the impacts of deforestation on the banks of the Inhamum stream and its effects on the hydrography in the Caxias-MA region. To this end, the following specific objectives were defined: to characterize the physiographic aspects of the study area; to identify the main consequences of anthropogenic actions within the watershed; and to analyze the effectiveness of public policies and environmental management practices implemented to combat deforestation and preserve water resources. The research has a qualitative nature and a descriptive approach, with data collection through direct observation, photographic records, and the use of geotechnologies such as QGIS software. The results indicate that the loss of vegetation cover has directly affected the basin's hydrological cycle, contributing to erosion, siltation, and reduced water availability. The study aims to contribute technical input for the development of environmental management strategies and the strengthening of public policies aimed at protecting natural resources and promoting the sustainable development of the region.

Keywords: Preservation area; Conservation; Ecosystem; Resource management.

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INTRODUCTION

Water is an essential resource for the maintenance of life and the balance of ecosystems. However, increasing anthropogenic actions, especially deforestation and the disorderly occupation of land, have significantly compromised the quality and availability of this resource in various regions. The municipality of Caxias, located in eastern Maranhão, contains two important rivers—Itapecuru and Parnaíba—as well as a network of streams that, in recent decades, have been impacted by environmental degradation processes, particularly in the Inhamum stream basin.

The removal of vegetation, especially riparian forests, leaves the soil exposed to erosion, contributing to the siltation of watercourses and the loss of biodiversity (Castro; Martinez; Souza, 2013). According to Moreto et al. (2021), monitoring the dynamics of land cover is essential to ensure the maintenance of environmental quality, enabling planning and management actions for natural resources.

The Inhamum stream basin is particularly sensitive to these dynamics due to its proximity to urban areas and the presence of the MA-127 highway, which crosses the Inhamum Environmental Protection Area (APA), facilitating access and disorderly occupation. This dynamic not only leads to ecosystem degradation but also directly threatens the water supply capacity of the basin, which serves part of the population and economic activities of Caxias. Additionally, cultural and traditional practices, such as wood extraction for local festivities (Araújo, 2012), combined with hunting, firewood extraction, and urban expansion, intensify the degradation scenario.

Thus, the research problem arises: What are the main environmental impacts resulting from deforestation in the Inhamum stream basin in Caxias (MA), and how do anthropogenic actions and public policies influence the conservation of the region's water resources? To address this question, the general objective was formulated: to identify the impacts of deforestation on the banks of the Inhamum stream and the effects on hydrography in the Caxias-MA region. To achieve this objective, the following specific goals were outlined: to characterize the physiographic aspects of the study area; to identify the main consequences of anthropogenic actions within the Inhamum stream watershed; and to analyze the effectiveness of public policies and environmental management practices implemented to combat deforestation and preserve water resources in the region.

The research is qualitative in nature and adopts a descriptive approach, with emphasis on direct observation and environmental analysis. According to Gil (2019), this type of approach seeks to understand phenomena from their context. Data collection was conducted through field research in the Inhamum stream basin in Caxias (MA), as highlighted by Cunha and Silva (2001), using observation, notes, and photographic records (Trivinos, 2008). QGIS 3.4 software was used to create the location map, supported by GIS, an essential tool for representing and analyzing spatial dynamics (Câmara et al., 2001). The data were interpreted through descriptive analysis, which, according to Yin (2016), allows for the



identification of patterns and the development of preliminary diagnoses of observed environmental impacts.

Therefore, the research is justified by the urgency of diagnosing these impacts, understanding their causes, and proposing strategies to support public policies aimed at preserving native vegetation and protecting water resources. Furthermore, the proximity of the APA to urban areas and the presence of the MA-127 highway amplify the effects of anthropogenic actions and hinder enforcement, making a technical and analytical perspective on the local reality even more necessary. By diagnosing the main problems and their consequences, the study strengthens the discussion on the preservation of natural resources and sustainable development in Caxias and its surroundings.

LITERATURE REVIEW

DEFORESTATION AND ITS IMPACTS ON WATER RESOURCES AND ECOSYSTEMS

As Fausto et al. (2023) affirm, deforestation and vegetation removal—characterized by tree cutting through machinery—are primarily associated with agricultural activities. Pre-use land clearing often involves burning, a practice that has become routine yet remains highly harmful.

Land use along riverbanks and lakes can severely degrade their ecosystems, affecting springs, streams, and creeks they traverse or interact with, leading to rapid siltation and significant loss of local flora and fauna, potentially resulting in their disappearance. According to Bastos (2022), although natural causes exist, deforestation is predominantly driven by human activities such as logging, agricultural expansion, and unregulated urbanization.

There is a profound impact on biodiversity, with native devastation especially in the Cerrado and other Brazilian biomes, causing ecological imbalance. Castilho (2010) argues that this demands the creation of public policies focused on conservation and protection of remaining areas. Gelain (2012) views these issues within a broader framework of destructive practices tied to the globalized economy, which intensify predatory deforestation and sustain deep environmental degradation. Carepa (2010) notes that streams, creeks, and springs may also be classified as lakes and reservoirs, where riparian forests are found. These phytophysiologicals occur in moist or waterlogged soils prone to periodic flooding.

The removal of forests in riparian zones and vegetation suppression in watersheds directly impacts the hydrological cycle, impairing water infiltration and increasing surface runoff and erosion. According to Soares et al. (2019), such actions may alter the microclimate, increase rainfall variability, prolong droughts, and accelerate the manipulation of natural environments.

The lack of effective public policies and environmental oversight exacerbates this situation. Araújo et al. (2009) highlight the absence of controlled management of natural resources, negatively affecting both the quality and quantity of available water. Garcia (2016) emphasizes that unplanned



anthropogenic actions damage drainage systems and ecosystems, also impacting geomorphological stability and intensifying progressive environmental imbalances.

It is imperative to implement sustainable practices such as deforestation monitoring, ecological restoration, and deforestation verification, all of which must be backed by the conservation of Permanent Preservation Areas (APPs). As Carvalho (2012) demonstrates, such interventions are crucial to ensure ecological system resilience and consistently reduce threats that could render natural resources unsustainable.

Another important point is the link between deforestation and climate change. According to Santos (2017), vegetation plays a fundamental role in regulating atmospheric gas balances, particularly in CO₂ sequestration. The removal of vegetation cover contributes to increased atmospheric concentrations of this gas, worsening the effects of global warming. Gil (2020) goes further, stating that the advance of deforestation compromises not only biodiversity but also the health of aquatic ecosystems, deteriorating water quality and availability.

Fausto et al. (2023) emphasize the need for governmental actions, such as those outlined in the National Plan for Controlling Illegal Deforestation and Recovering Native Vegetation, prioritizing bioeconomy, land regularization, and territorial planning as measures to combat deforestation. Research by Rocha and Vianna (2008) and Araújo et al. (2009) reinforces that addressing the impacts of deforestation requires joint action among the State, society, and environmental institutions, with the goal of developing public policies capable of effectively promoting natural resource conservation and environmental sustainability.

PUBLIC POLICIES AND ENVIRONMENTAL MANAGEMENT IN WATER RESOURCE CONSERVATION

Natural resources, such as water, require public policies for environmental management aimed at their preservation and protection. These policies serve functions such as regulating the use of geographic space, controlling human activities that impact the environment, and ensuring the sustainable management of resources. To this end, legal frameworks addressing environmental issues have been established. Coutinho (2007) states that “the environment is increasingly a collective concern [...] scientific knowledge and governmental action are indispensable.” There has been a historical evolution of environmental concerns, from cultural/religious roots to agendas centered on public policies (with presence in constitutional texts).

In Brazil, the National Water Resources Policy was established by Law No. 9,433/1997, which outlines important instruments to optimize water use and management efficiency. These include Water



Resource Plans, classification of water bodies by usage categories, granting or charging for water use, and an information system on water resources (Berlinck, 2003).

According to Araújo et al. (2018), despite the availability of a legal framework, the effectiveness of environmental policies still faces challenges such as deficiencies in enforcement, sanctioning mechanisms, and insufficient investment in regulatory and oversight agencies. These issues necessitate an integrated, multi-level environmental management approach, where all levels of government—federal, state, and municipal—collaborate to implement truly effective solutions. Kersting (2023) argues that central water resource management policy should be decentralized, as this would strengthen environmental governance through integration among various public spheres, considering that water management affects other urban, environmental, and territorial policies.

Paula et al. (2024) add that the administration of natural resources must aim for sustainability by ensuring equitable access to water with minimum quality standards essential for use, as well as for environmental conservation and preservation. Santoro et al. (2021) also emphasize the importance of societal involvement in policy implementation and in monitoring government actions.

However, the implementation of these policies often encounters obstacles such as shortages of human, financial, and institutional resources. As Brandão et al. (2022) warn, political instability and budget cuts affect oversight agencies like IBAMA and ICMBio, making it impossible to properly carry out essential functions and directly impairing their operational capacity. Losekann and Paiva (2024) highlight that, in addition to financial limitations, there are also social challenges and weaknesses in environmental control mechanisms, which compromise the effectiveness of protection efforts.

According to Andreoli (1992), environmental policy reflects the development model adopted by a society. Thus, the more committed this model is to conservation, the more effective the existing public policies will be in promoting environmental preservation. Breaking away from predatory models to move toward more sustainable practices requires not only informed political will but also significant social engagement and the strengthening of necessary legal instruments.

SUSTAINABLE USE CONSERVATION UNITS AND THEIR CHALLENGES IN ENVIRONMENTAL PROTECTION

Conservation Units (CUs) serve as essential tools for the protection of natural resources and are primarily classified into two distinct groups: full protection and sustainable use. These include Ecological Stations (Esec), Biological Reserves (Rebio), National Parks (Parna), Natural Monuments (Monat), Wildlife Refuges (RVS), and Environmental Protection Areas (APA); as well as National Forests (Frona), Extractive Reserves (Resex), Fauna Reserves (Refau), Sustainable Development Reserves (RDS), and Private Natural Heritage Reserves (RPPN).



Brazil has made significant progress in environmental management following the creation of the National System of Conservation Units (SNUC), regulated by Law No. 9,985 of 2000 and Decree No. 4,340 of 2002. Gartner (2003) provides insights into how SNUC established standardized guidelines that shaped policies for an ecologically sound climate, aiding not only in environmental maintenance but also in incorporating offenders and locations into governance procedures.

The Environmental Protection Area (APA) falls under the sustainable use category, allowing for the coexistence of economic and social activities, provided they align with the conservation of natural resources. Rente (2006) notes that the development of APAs was driven by the need to mitigate environmental impacts caused by nature exploitation and to make such activities more sustainable. According to Brandão et al. (2022), Federal Decree No. 4,340/2002 provides criteria for the development of management plans, the operation of management councils, and the definition of secure rights to natural resources within these units.

However, Bethonico (2009) argues that although APAs represent a significant advancement in integrated environmental management, they are limited by the lack of participatory social monitoring. Literature on conservation units also indicates that the challenges faced are reflections of the current socio-environmental crisis. Oliveira (2023) points out that even in legally designated protected areas, there is intense competition for urban expansion, agriculture, economic extractivism, and other activities that exceed permitted limits and degrade the CUs.

Rosa (2015) emphasizes that these contradictions allow for reflection on the country's historical trajectory, which has been marked by predatory practices and, more recently, by a sustained attempt to build a development model aligned with sustainability. Gartner (2003) reinforces that although the concepts of preservation and conservation have theoretical differences, both aim to ensure the maintenance of ecosystems and environmental services for current and future generations.

In this context, protecting the effectiveness of Conservation Units, especially APAs, requires more than a public and regulatory political framework—it also demands a comprehensive constructive approach focused on improving management instruments, responsible action by environmental authorities, and active engagement and advocacy by society regarding shared environmental commons.

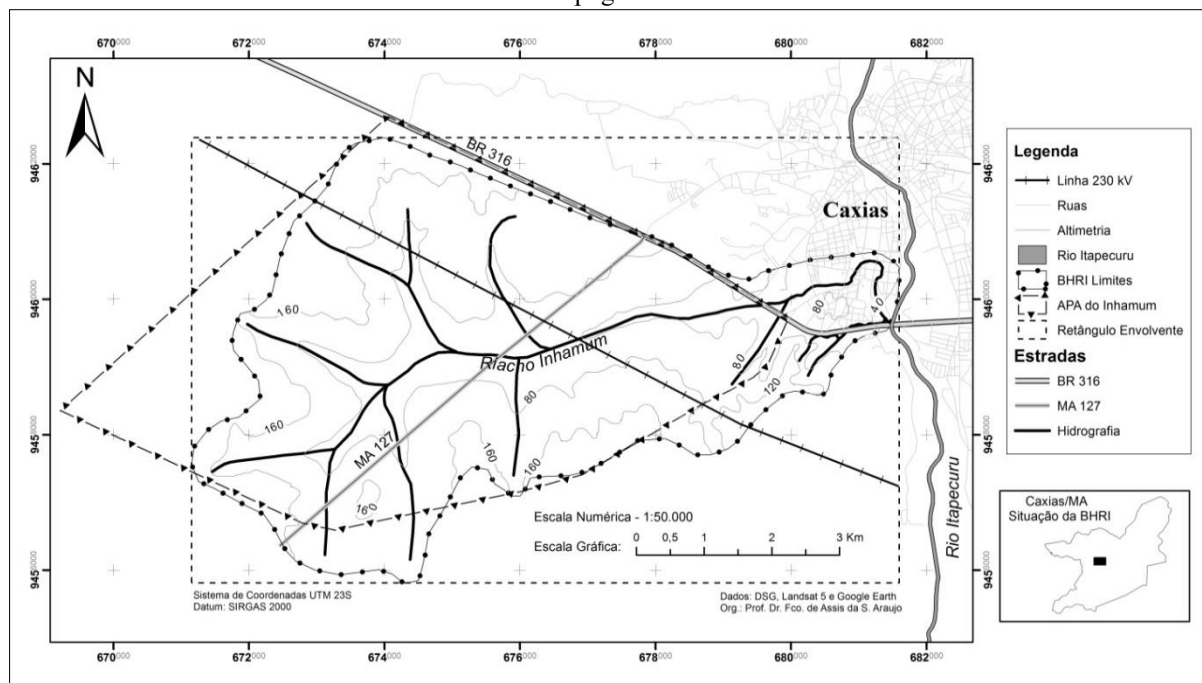
METHODOLOGY

CHARACTERIZATION OF THE STUDY AREA

The Inhamum Stream watershed (Figure 1) encompasses a significant area within the municipality of Caxias, Maranhão. It is located on the right side of the BR-316 highway and is intersected by the MA-127 road. Designated as an Environmental Protection Area (APA) by Law No. 1,464/2001 and

officially established in 2001, the area faces serious challenges due to unregulated urban growth and anthropogenic activities, which have contributed to its environmental degradation.

Figure 1- Location of the Municipal Environmental Protection Area and the Inhamum Stream watershed, with some natural and anthropogenic elements.



Source: Org: Prof. Dr. Assis Araújo (2024).

The map illustrates the limits of the Inhamum Stream Watershed (BHRI) and the Municipal Environmental Protection Area (APA do Inhamum), located in the municipality of Caxias, Maranhão. It highlights hydrographic features, altimetry curves, the Itapecuru River, and major roads (BR-316 and MA-127), as well as the 230 kV transmission line. The cartographic base uses the UTM 23S coordinate system with SIRGAS 2000 datum. The inset shows the location of the watershed within the municipality of Caxias.

The Inhamum Stream basin plays a direct role as a water source for Caxias, supplying water to industries, residences, and local agriculture. However, the area has been frequently subjected to illegal invasions and activities such as hunting and wood extraction, which compromise its environmental integrity. The ongoing pressure on this region threatens its ability to maintain biodiversity and the quality of available water resources.

METHODOLOGICAL PROCEDURES

This research is characterized as a qualitative study with a descriptive approach, based on methodological procedures that integrate field research, spatial analysis, and environmental interpretation.



As Gil (2019) states, qualitative research seeks to understand phenomena from the perspective of the subjects and the context in which they are situated.

This approach aligns with environmental and territorial studies, where social and ecological relationships are intertwined. Most scholars focus on field surveys, which, according to Marconi and Lakatos (2017), involve direct observation of phenomena in their natural environment, allowing researchers to collect data through notes, photographic or video records, and situational analysis of the dynamics under study. In the municipality of Caxias (MA), the activities were conducted within the boundaries of the Inhamum Stream sub-watershed, aiming to identify and document the predominant environmental impacts in the area.

Observations were guided by a systematic environmental analysis framework, developed based on criteria proposed by Cunha and Silva (2001). During data collection, the method of direct participant observation was employed, supported by photographic records and field diary notes, in accordance with Trivinos (2008), who recommends such methods for environmental and territorial studies.

For spatial representation of the study area, geotechnologies were utilized, particularly the QGIS 3.4 geoprocessing software, which enabled the creation of a location map based on cartographic data and satellite imagery. As Câmara et al. (2001) point out, Geographic Information Systems (GIS) are essential for visualizing, analyzing, and understanding spatial and environmental dynamics, making them a fundamental tool in watershed research.

Upon completion of field activities, descriptive and interpretative analysis of the collected data was conducted, integrating empirical records with specialized literature. According to Yin (2016), descriptive analysis is effective in identifying patterns and relationships among environmental variables, allowing for the formulation of preliminary diagnoses.

RESULTS AND DISCUSSION

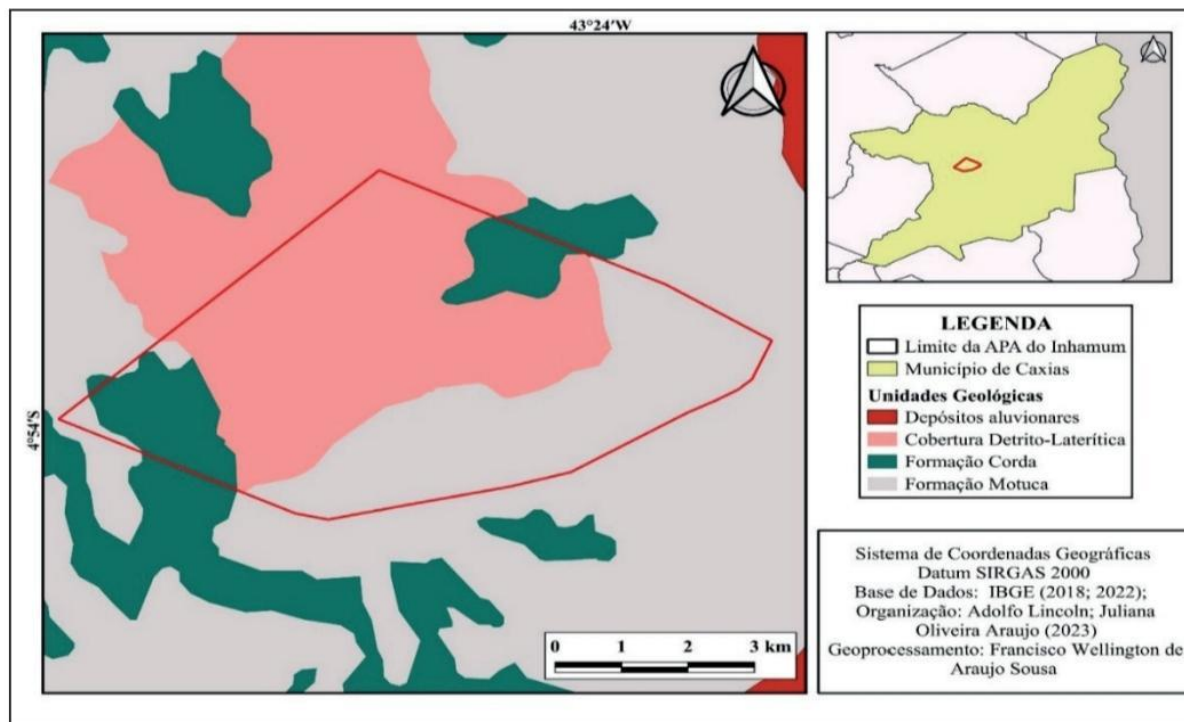
CHARACTERIZATION OF THE PHYSIOGRAPHIC ASPECTS OF THE INHAMUM STREAM BASIN

The Inhamum Environmental Protection Area, located in the municipality of Caxias, Maranhão, possesses physiographic characteristics that include climatic, hydrographic, geomorphological, and geological conditions. The region's climate exhibits relatively regular rainfall distribution, with annual precipitation ranging between 1,600 and 1,800 mm, and consistently high temperatures throughout the year, with an average exceeding 24°C (Araújo, 2012).

The Inhamum watershed is drained by the Inhamum stream, a second-order watercourse with permanent flow, as well as by small tributaries of the Itapecuru River basin, especially near the MA-127 highway. The area is situated within the sedimentary basin of the Meio-Norte region, characterized by

depressions with alluvial soils and quartz sand deposits commonly found along the stream's margins. The Motuca and Corda formations predominate geologically, forming the rocky substrate that influences the local morphology (Figure 2). These features make the landscape vulnerable to erosive processes and siltation (Araújo et al., 2024).

Figure 2 - Geological Base of the Inhamum Environmental Preservation Area (APA), Caxias, Maranhão, Brazil.



Source: Sousa (2023).

The map shows the boundary of the APA do Inhamum (red polygon) superimposed on mapped geological units within the municipality of Caxias. Geological units displayed in the legend comprise: Alluvial deposits, Detrital–Lateritic cover, Corda Formation, and Motuca Formation. The main panel contains a scale bar (0–3 km) and a north arrow; an inset map locates the APA within the municipal boundaries of Caxias. Geographic coordinates and graticule marks are indicated (approx. 43°24'W longitude and 4°45'S latitude). Cartographic datum and coordinate system: SIRGAS 2000 (geographic). Data sources and processing are noted in the map: IBGE (2018; 2022); organized by Adolfo Lincoln and Juliana Oliveira Araújo (2023); geoprocessing by Francisco Wellington de Araújo Sousa.

IDENTIFICATION OF NEGATIVE IMPACTS IN URBAN SECTIONS OF THE INHAMUM STREAM BASIN

From the analysis carried out during the research on deforestation and water resources in Caxias, it was possible to identify some elements that are degrading the space in this region. The results and data

collected through field observation and photographic records, such as the suppression of forest vegetation, the improper disposal of garbage, and the sewage discharged without prior treatment in the vicinity and into the stream bed, are the main agents causing negative environmental impacts that directly affect the region's water resources.

The sections of the Inhamum stream that cut through the urban area of the municipality have been receiving irregular uses, configuring new untreated domestic sewage outlets and accumulation of solid waste, which are often dumped directly into its bed. Such practices significantly contribute to the degradation of water quality and the imbalance of the local environmental system.

Cantinho do Céu, Marinha, Ponte do Babá, Travessa da Glória, Piscina da Ponte, and the bridge at Travessa da União are the main segments impacted by these anthropic actions. Figure 3 highlights a section of the Inhamum stream, popularly known as Cantinho do Céu:

Figure 3 - A: Bridge over the Inhamum stream, in a section known as Cantinho do Céu; B: Preserved riparian forest vegetation.



Source: author (2025).

The section of the Inhamum stream, popularly known as Cantinho do Céu, as shown in Figure 3 above (images A and B), is located within the urban perimeter, where partially preserved riparian forest vegetation is observed. However, anthropic interventions are evident, such as the construction of a bridge over the watercourse and the installation of an electric pole directly in the channel bed.

The irregular discharge of domestic sewage and the significant accumulation of solid waste on the stream's banks are evidenced in Figure 4, constituting a relevant environmental degradation factor, in addition to representing a potential public health risk.

Figure 4 - Section of the Inhamum stream known as Mariinha.. A: Presence of solid waste improperly discarded. B: Construction of houses very close to the stream bed area.



Source: author (2025).

As highlighted by Silva et al. (2011), solid waste improperly discarded in unsuitable locations has a high pollution potential and can favor the emergence of infectious diseases, especially considering the ease with which this improper disposal attracts animals such as rats, mosquitoes, flies, cockroaches, among other types of insects, as well as other biological and chemical agents, such as fungi, bacteria, and protozoa. It is also observed that the riparian forest in this section is significantly reduced, which directly contributes to the siltation process of the stream bed.

Figure 4, image B, illustrates the presence of residential buildings located near the riverbed. This configuration, in addition to intensifying negative environmental impacts on the watercourse, represents a potential housing risk, since in flood situations, residents may be exposed to inundations. Furthermore, unregulated land occupation is observed, which may result in various socio-environmental implications.

In the analyzed section shown in Figure 5, the presence of a structure was observed whose foundation was compromised due to erosion caused by the stream's current. As a result, the structure collapsed, falling into the watercourse and causing a partial obstruction of the channel.

Figure 5 - Section of Ponte do Babá.



Source: author (2025).

Additionally, the absence of riparian vegetation along this segment was noted, which further aggravates the environmental degradation processes in the area. In Figure 6, artificial narrowing of the stream bed is observed, resulting from an attempt to channel the water flow.

Figure 6 Section of Ponte do Babá.



Source: author (2025).

The presence of accumulated bamboo branches is observed, forming a small natural dam, which can retain water and increase the risk of overflows. Thus, unplanned human intervention is evident in this

scenario. Figure 7 shows the construction of a new building very close to the stream bank, as well as the visible discharge of untreated sewage.

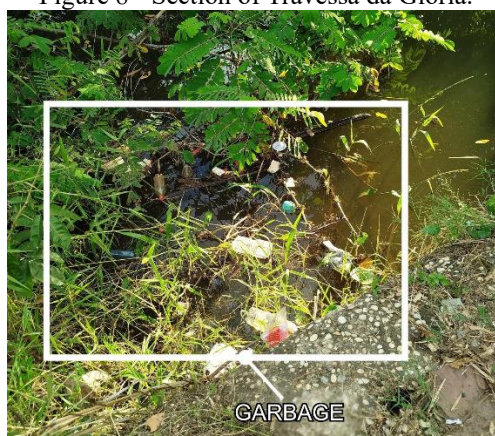
Figure 7 - Section of Travessa da Glória.



Source: author (2025).

It is noted that the irregular urbanization process, by suppressing the remaining riparian forest trees, directly contributes to environmental degradation and the compromise of water quality. The area is used as a space for urban expansion without environmental control, which demonstrates failures in municipal oversight. In several sections of the basin, the presence of solid waste inside the channel is noticeable, especially plastics and organic waste, such as human feces. This indicates a continuous pollution process, which transforms the stream into an open sewer (Figure 8). As a result, water quality is compromised, affecting the aquatic ecosystem and the population that may eventually use this water for consumption or recreation.

Figure 8 - Section of Travessa da Glória.



Source: author (2025).

The lack of environmental education policies and basic sanitation infrastructure is therefore alarming, considering that waste such as plastic bags and cleaning product packaging, discarded directly into the stream by laundry workers, are significant sources of water contamination (Santos et al., 2015).

Residential constructions near the stream bed are also identified as determining factors for its destruction. Given this scenario, the absence of effective preservation actions may lead to the irreversible loss of this water source, essential for supplying a large portion of the local population, as shown in Figure 9.

Figure 9 - Section popularly known as Piscina do Ponte.



Source: author (2025).

The presented section is, among all, the most well-known in the municipality, as it houses a dam called “Piscina do Ponte.” It was possible to identify the presence of solid waste and a large amount of sewage being discharged directly into the stream. It is observed that much of the riparian vegetation in this area has been suppressed, and the banks have been paved with concrete and asphalt, which hinders rainwater infiltration. This impermeabilization increases the runoff force of rainwater, contributing to the transport of waste improperly discarded on public roads, instead of in appropriate containers. In contrast, the section in Figure 10 shows a greater presence of native vegetation, suggesting a less impacted area.

Figure 10 - Section of Travessa da União.



Source: author (2025).

It is noted, however, that the image reveals the cutting of a medium to large tree, evidencing the continuity of human intervention. There are also clear signs of siltation on the stream banks, resulting from sediment transport caused by the lack of vegetation cover. The contrast between the existing vegetation and the negative impacts indicates a transitional stage between conservation and degradation. In this context, Figure 11, which highlights the same section, confirms the signs of human interference and degradation.

Figure 11 - Section of Travessa da União with signs of siltation.



Source: author (2025).

Figure 11 confirms the signs of human interference and degradation presented in the previous figure. The still-resistant vegetation shows that there is potential for ecological recovery, provided that preservation and reforestation actions are implemented. However, the presence of accumulated sedimentary material on the banks alerts to the need for intervention, aiming to contain the advance of siltation and restore the ecological functionality of the stream.

The landscape mismatches caused by degradation in a watershed area or its boundaries, such as valleys, slopes, meanders, or springs, may become irreversible depending on the extent of the devastation, bringing harm not only to nature but also social losses near the basin areas (Rocha and Viana, 2008).

As previously mentioned, although the study area presents well-preserved sections, it also shows signs of anthropic interventions. Figure 12 exemplifies a well-preserved section of the basin area. The site is known as Sumidouro do Padre, accessible via trails in the conservation unit.

Figure 12 - Sumidouro do Padre.



Source: author (2025).

This environment presents significant environmental integrity, with well-preserved riparian vegetation and high-quality water resources, referring to a spring area, characterized by clear waters and continuous flow, without the presence of anthropic barriers that compromise the natural dynamics of the water. Figure 13, in turn, presents a lagoon formed near the Alambique trail.

Figure 13 - Point near the Alambique trail.



Source: author (2025).

At this point, it is already possible to identify evidence of anthropic intervention, considering that a distillery operated in the vicinity, which in turn demonstrates negative impacts directly on the soil and water resources. Despite this intervention, the riparian forest vegetation remains preserved, with only a few tree trunks that apparently fell naturally over time, but which may possibly be associated with some type of previous negative impact, such as selective cutting, wood extraction, or trail opening. Figure 14 presents a photograph of the margins of Lagoa da Soledade, located closer to the MA-127.

Figure 14 – Area on the margins of Lagoa da Soledade. (A): Apparently preserved riparian forest.(B): Tree cutting representing deforestation.



Source: author (2025).

It is observed that the riparian forest surrounding the lagoon remains in excellent conservation condition, characterized by dense, well-structured vegetation with few signs of direct anthropic intervention. On the other hand, a clear indication of human intervention on the environment is observed (Figure 14B), represented by a recently cut tree trunk. It was also possible to observe, at the beginning of the Lagoa do Padre trail (Figure 15), signs of deforestation directly resulting from human action.

Figure 15 - Signs of deforestation at the beginning of the Lagoa do Padre trail.

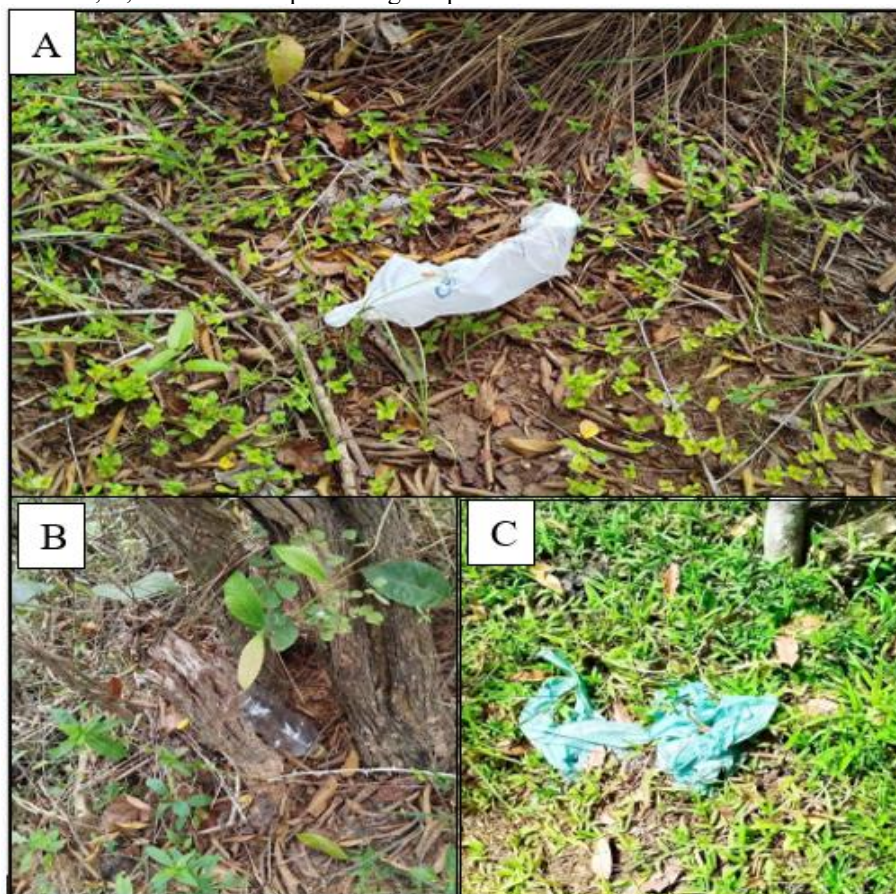


Source: author (2025).

The site presents evident signs of deforestation, characterized by the opening of clearings amid denser vegetation, resulting from anthropic interventions. Such actions represent potential risks to the Environmental Protection Area (APA), compromising ecological balance and the maintenance of ecosystem services.

Continuing the route around the basin area, it was once again possible to perceive the presence of solid waste improperly discarded in the APA (Figure 16).

Figure 16 - A, B, C – Mosaic representing the presence of solid waste in the center of the APA.



Source: author (2025).

This situation constitutes an environmental degradation factor, negatively impacting the local ecosystem, in addition to revealing the fragility of existing monitoring and control mechanisms. This scenario, therefore, proves inconsistent with the assumptions that underpin the current conservation policy of the referred conservation unit.

After the on-site analysis in the Inhamum Environmental Protection Area (APA), it was noted that although some sectors maintain a high degree of preservation, characterized by well-preserved riparian vegetation and quality water resources, it is also possible to observe clear signs of anthropic impacts. The presence of old structures such as the distillery tank, traces of deforestation, and improper solid waste disposal demonstrate pressure on the local ecosystem. This scenario highlights the importance of increasing monitoring, control, and environmental awareness actions to ensure the conservation of natural resources and the functionality of the conservation unit.



THE EFFECTIVENESS OF PUBLIC POLICIES AND ENVIRONMENTAL MANAGEMENT PRACTICES IMPLEMENTED TO COMBAT DEFORESTATION AND PRESERVE WATER RESOURCES IN THE REGION

Although there are many laws and guidelines, such as the Master Plan of Caxias (Law No. 1,631/2006) and the National Water Resources Policy, they are not applied with due comprehensiveness. The absence of interregional coordination, the scarcity of resources, and low oversight hinder the implementation of the planned actions. Furthermore, many environmental policies are disjointed, poorly coordinated, or discontinuous, which makes their implementation fragile and undermines their preservation objectives.

Basic sanitation in Caxias is subject to a range of federal, state, and municipal laws, as well as plans, such as the Municipal Basic Sanitation Plan (PMSB). At the federal level, Law No. 11,445/2007, called the National Basic Sanitation Law, provides general guidelines for these services. It requires municipalities to create their own plans, define universalization goals, and methods of social control.

This law was modernized by Law No. 14,026/2020, the New Legal Framework for Sanitation, which strengthens the expansion of access to water and sanitation by 2033. It encourages private sector participation and imposes stricter rules for oversight and regulation. At the state level, the State Basic Sanitation Policy is governed by Law No. 8,923/2009, defining principles such as universal access, environmental and financial sustainability, and integration with Maranhão's Water Resources Plans.

At the municipal level, the PMSB of Caxias was established by Municipal Law No. 2,361/2017, an essential urban planning instrument aimed at the four crucial pillars of sanitation: water supply, effective sanitary sewage, urban drainage, and solid waste treatment.

Recently, Municipal Decree No. 310/2023 instituted a commission tasked with reviewing the PMSB, seeking to align it with new legal demands and local issues. Even with these laws already in force, establishing precise guidelines for sanitation management, the reality in the rural communities of Caxias reveals incomplete oversight, poorly executed actions, and a notable failure to educate the population about the importance of sanitation, delaying progress toward the planned goals.

According to Assis et al. (2012), the environmental issue is complex and involves multiple actors with divergent perspectives. In the debate on the Forest Code, for example, the requirement for Legal Reserves and Permanent Preservation Areas is viewed differently by various groups. While some agricultural sectors consider these restrictions an obstacle to development, others argue that they are essential to ensure the sustainability of natural resources, such as water and soil, for future generations.

The effectiveness of environmental public policies depends on the collaboration and awareness of all social segments. Each sector has an important role to play, and it is essential that governments share decision-making power with the population, including those who have historically been excluded from



this process, without ignoring the legitimate interests of other economic and social sectors (Siqueira, 2008).

The designation of an area as an Environmental Protection Area (APA), within the scope of the National System of Conservation Units (SNUC), implies less stringent protection rules than other conservation units. This flexibility allows for the sustainable use of natural resources, provided that the rules established by SNUC are respected. However, the absence of a management plan developed and implemented by the municipality may violate regulations and encourage inappropriate anthropic activities, leading to biodiversity loss.

The research revealed the urgent need to raise public awareness about the importance of environmental preservation. The local community, often without access to environmental education, contributes involuntarily to degradation, without understanding the effects of their actions. It is essential to invest in educational campaigns, strengthen environmental oversight, and create effective public policies that involve community participation and ensure the protection of the region's water resources. A joint and practical action by public authorities, civil society, and research institutions will be necessary to reverse the current deterioration and ensure the sustainability of the Inhamum stream basin.

CONCLUSION

The analysis of deforestation and water resources associated with the Inhamum Stream in Caxias (MA) demonstrates that the degradation of the area is largely due to the removal of riparian vegetation, the dumping of garbage and sewage into watercourses and bodies of water, and the irregular and intensive occupation of its banks, consequently compromising water quality and posing health risks, especially in the most impacted urban sections.

Despite the fact that the Inhamum APA still has well-preserved sections, such as the Sumidouro do Padre, the presence of selective deforestation processes, garbage, and pressure from the urban area prove distressing in terms of oversight and environmental management in the region. The absence of an effective management plan and the disarticulation of public policies aggravate this situation.

Thus, the loss of riparian vegetation cover harms the local hydrological cycle, with the consequent reduction in water infiltration into the soil, affecting aquifer recharge and increasing vulnerability to floods and droughts. Therefore, vegetation must be preserved to safeguard water supply and the environmental balance of the basin. Finally, the research indicates that more integrated actions involving public authorities, civil society, research institutions, more environmental education, and oversight are needed so that we can collaborate and overcome the current degradation situation.

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