Espaço & Geografia

ENVIRONMENTAL EDUCATION AS A STRATEGY TO MITIGATE RAINFALL-INDUCED EROSION IN MOZAMBIQUE: A CASE STUDY OF THE 21 DE ABRIL NEIGHBORHOOD IN THE MUNICIPALITY OF MASSINGA

EDUCAÇÃO AMBIENTAL COMO ESTRATÉGIA PARA A MITIGAÇÃO DA EROSÃO PLUVIAL EM MOÇAMBIQUE: CASO DE ESTUDO BAIRRO 21 DE ABRIL MUNICÍPIO DA MASSINGA

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ABSTRACT

Ainfall erosion in Bairro 21 de Abril, in the Municipality of Massinga, Rainfall erosion in the 21 de Abril neighborhood, in the Municipality of Massinga, Mozambique, has caused significant environmental impacts, such as the formation of gullies, the removal of vegetation cover, and the deposition of sediments in residential areas, increasing structural risks. This study analyzed the application of Critical Environmental Education (CEE) as a strategy to mitigate these impacts, promoting awareness and community leadership. The research adopted a qualitative approach, based on the principles of Popular, Emancipatory, and Transformative Environmental Education. Semi-structured interviews, participatory educational activities, and measurements of erosive furrows in the territory were conducted. The results showed that 75% of residents were unaware of the technical-scientific concept of rainfall erosion, demonstrating the need for educational actions. After implementing strategies in periodic meetings, such as experimental practices and reflective discussions, 60% of participants developed a better understanding of erosion impacts, preventive measures, and the importance of shared environmental management, reducing the perception that only public institutions are responsible for addressing environmental problems. This result highlights the role of CEE in social and environmental transformation. Additionally, it was found that erosive furrows were deeper in sloped areas and near residences without vegetation cover, confirming the relationship between slope, vegetation removal, and the intensification of the erosion process. It is concluded that CEE is an essential tool to strengthen community resilience and leadership in the face of rainfall erosion, encouraging active public participation in environmental management and contributing to sustainable long-term solutions.

Keywords: Community Protagonism, Education, Erosion, Environmental Management.

RESUMO

A erosão pluvial no Bairro 21 de Abril, no Município de Massinga, Moçambique, tem gerado impactos ambientais significativos, como a formação de ravinas, a remoção da cobertura vegetal e a deposição de sedimentos em áreas residenciais, aumentando os riscos estruturais. Este estudo analisou a aplicação da Educação Ambiental Crítica (EAC) como estratégia para mitigar esses impactos, promovendo a conscientização e o protagonismo comunitário. A pesquisa adotou uma abordagem qualitativa, fundamentada nos princípios da Educação Ambiental Popular, Emancipatória e Transformadora. Foram realizadas entrevistas semiestruturadas, atividades educativas participativas e medições de sulcos erosivos no território. Os resultados evidenciaram que 75% dos moradores desconheciam o conceito técnico-científico de erosão pluvial, demonstrando a necessidade de ações educativas. Após a implementação de estratégias nos encontros periódicos tais como, práticas experimentais e discussões reflexivas, 60% dos participantes passaram a compreender melhor os impactos da erosão, a necessidade de medidas preventivas e a importância da gestão ambiental compartilhada, reduzindo a percepção de que apenas os órgãos públicos são responsáveis pela gestão de problemas ambientais. Esse resultado evidencia o papel da EAC na transformação social e ambiental. Além disso, verificou-se que os sulcos erosivos eram mais profundos em áreas de encosta e próximas a residências sem cobertura vegetal, confirmando a relação entre declividade, remoção da vegetação e intensificação do processo erosivo. Conclui-se que a EAC é uma ferramenta essencial para fortalecer a resiliência e o protagonismo comunitário frente à problemas ambientais ou em particular na erosão pluvial, incentivando a participação ativa da população na gestão ambiental e contribuindo para soluções sustentáveis a longo prazo.

Palavras-Chave: Protagonismo comunitário, Educação, Erosão, Gestão ambiental.

1. INTRODUCTION

Mozambique, located in the Southern Hemisphere between latitudes 10°27' S and 26°52' S and longitudes 30°12' E and 40°51' E, exhibits marked physical-geographical diversity. These characteristics result from long-term geomorphological processes dating back to the Precambrian, shaped by tectonic activity, erosion, and climatic variations, which have progressively structured the country's landscape (MUCHANGOS, 1999). The relief is

characterized by a stepped configuration extending from the inland plateau toward the coastal plain, comprising plains, plateaus, mountains, and depressions, reflecting the continuous interaction between natural erosive agents and environmental conditions over geological time.

Mozambique's intertropical climate, influenced by both continental and maritime factors, contributes to significant climatic variability, with average temperatures ranging from 20°C to 40°C and rainfall distributed throughout the year (MACIE; FREITAS, 2016). The rainy season, generally extending from November to March or April and coinciding with the austral summer, is marked by intense rainfall events, tropical cyclones, and flooding episodes. These events frequently result in population displacement, material losses, and environmental degradation, particularly soil erosion (INSTITUTO NACIONAL DE GESTÃO E REDUÇÃO DO RISCO DE DESASTRES, 2022).

Rainfall-induced erosion, understood as the detachment, transport, and deposition of soil particles by rainfall and surface runoff, is particularly intensified in areas characterized by steep slopes, sandy soils, and unplanned human occupation. This is the case of the 21 de Abril neighborhood, located in the Municipality of Massinga, in the southern region of Mozambique and the eastern portion of Inhambane Province. The municipality is bordered by Vilankulo District to the north, the Indian Ocean to the east, Morrumbene District to the south, and Funhalouro District to the west. According to the Instituto Nacional de Estatística de Moçambique, Massinga covers approximately 7,458 km² and has a population of 228,437 inhabitants, resulting in a population density of 24.7 inhabitants per km² (INE, 2017). The 21 de Abril neighborhood, the focus of this study, is located within this municipality, as shown in Figure 1.

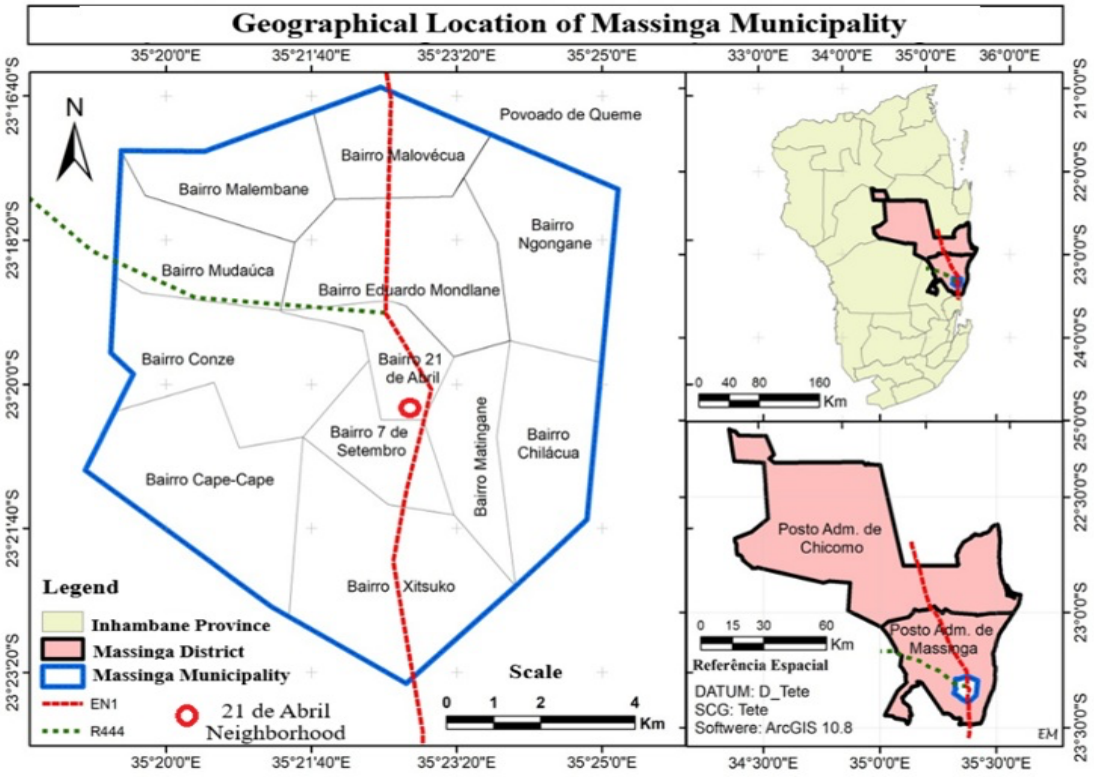


Figure 1. Location of the 21 de Abril neighborhood. Source: Prepared by the authors (2023).

In the study area, the combined effects of recurrent rainfall, terrain slope, and low soil infiltration capacity have contributed to the formation and expansion of gullies, significantly affecting local infrastructure and the population's quality of life. During periods of intense rainfall, solid waste and sediment are transported into residential areas, compromising public health, increasing the risk of housing collapse, and exacerbating environmental vulnerability. These conditions, combined with precarious socioeconomic circumstances and inadequate urban planning, intensify the exposure of local residents to rainfall-induced erosion and related risks.

In this context, Critical Environmental Education (CEE) emerges as a strategic approach that goes beyond awareness-raising by promoting critical reflection on the social, political, and economic drivers of environmental degradation. According to SOBRAL and RIBEIRO (2020), CEE seeks to foster meaningful changes in values, practices, and social relations by strengthening collective engagement in sustainable actions and community-based problem-solving processes. In the case of the 21 de Abril neighborhood, CEE played a central role in fostering critical awareness of erosion-related risks and in enabling residents to engage actively in mitigation strategies through the principles of Popular Environmental Education, Emancipatory Environmental Education, and Transformative Environmental Education. These dimensions contributed to strengthening community autonomy, encouraging soil conservation practices, and enhancing local participation in socio-environmental management.

This study aims to analyze how the application of Critical Environmental Education can promote environmental awareness and encourage the adoption of sustainable practices among residents of the 21 de Abril neighborhood, thereby contributing to social and environmental transformation. To achieve this objective, semi-structured interviews were conducted with local residents, combined with practical and reflective activities carried out within the territory.

This article is structured into five main sections. First, the methodological procedures are presented, detailing the qualitative approach adopted as well as the data collection and analysis techniques employed. Next, the theoretical framework is developed, focusing on rainfall-induced erosion, its impacts, and the contributions of Critical Environmental Education. Subsequently, the research findings are presented and discussed, highlighting the relationship between rainfall dynamics, socio-environmental impacts, and the implementation of educational strategies in the study area. Finally, the concluding remarks synthesize the main findings and discuss their implications for addressing rainfall-induced erosion in contexts of socio-environmental vulnerability.

2. METHODOLOGICAL PROCEDURES

This study was developed using a qualitative research approach, combining direct observation, semi-structured interviews, and the analysis of documents and previous studies related to the topic. Critical Environmental Education (CEE) served as the theoretical and methodological framework guiding both data collection and the educational strategies implemented in the 21 de Abril neighborhood. The study was structured around the four core dimensions

of CEE: Popular Environmental Education, Emancipatory Environmental Education, Transformative Environmental Education, and Environmental Education in the Environmental Management Process.

To implement the CEE approach, an educational process was conducted involving community meetings, practical field-based activities, and participatory assessments focused on improving participants' technical and scientific understanding of rainfall-induced erosion. The educational activities were carried out over a two-week period through periodic and alternating meetings, totaling six sessions of one hour each (six hours in total). The process involved seven families from the neighborhood, representing 53% of the study sample.

The activities included the participation of parents, mothers, and older children, whenever available, totaling 46 individuals. Family size ranged from five to nine members. During the meetings, data collection activities were conducted simultaneously with the practical application of the core principles of CEE, particularly Popular Environmental Education, Emancipatory Environmental Education, and Transformative Environmental Education, which were adopted as the main educational strategies.

In this context, semi-structured interviews were conducted with participants, accompanied by the Free and Informed Consent Form, in accordance with ethical approval granted by the Comitê Nacional de Bioética para a Saúde (Ref.: 581/CNBS/25), ensuring transparency and ethical integrity throughout the research process. The participant selection process followed the snowball sampling technique, whereby initial participants identified other community members with relevant knowledge and experience related to the research topic. This approach enabled the inclusion of key participants, broadening the diversity and scope of the information collected while capturing multiple perspectives and lived experiences.

The final number of participants was determined through the data saturation criterion, which guided the decision on when to conclude the interviews and discussion circles. The selected families had resided in the neighborhood for periods ranging from 5 to 30 years, as shown in Figure 2. This made it possible to better understand both their relationship with the territory and their perceptions of the impacts of rainfall-induced erosion.

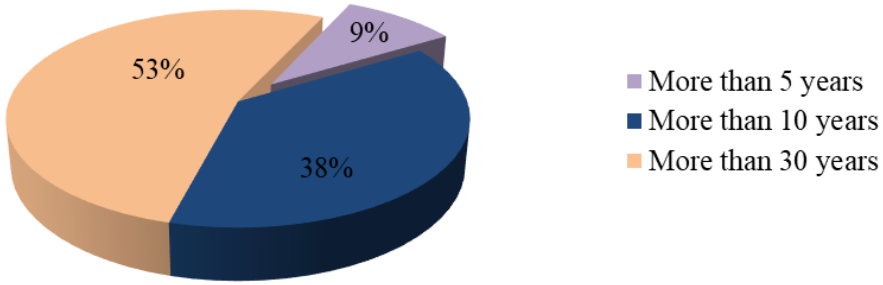


Figure 2. Profile of respondents according to length of residence in the neighborhood.
Source: Prepared by the authors (2023).

3. THEORETICAL FRAMEWORK

3.1. Rainfall-Induced Erosion, Impacts, and Control Efforts

Rainfall-induced erosion is an environmental degradation process caused by the direct action of rainfall on the Earth's surface, resulting in the detachment, transport, and loss of soil particles (HUDSON, 1995; MORGAN, 2005). This phenomenon results from the interaction of both natural and anthropogenic variables and is influenced by rainfall intensity and duration, terrain slope, soil type and land use, as well as the presence or absence of vegetation cover (FAO, 2019). These variables determine different levels of erosive intensity, which may be classified as slight, when soil loss is superficial; moderate, characterized by the formation of rills and gullies; and severe, when deep gullies develop and substantial landscape degradation occurs (FAO, 2019; IPCC, 2021).

In recent years, research has increasingly focused on improving the monitoring and modeling of rainfall-induced erosion through the use of remote sensing, geoprocessing techniques, and empirical models such as the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE). These tools enable the estimation of soil loss rates and the identification of areas at risk (SILVA; OLIVEIRA; CARVALHO, 2020). However, this phenomenon remains particularly recurrent in both rural and urban areas, as evidenced by Brazilian studies supported by institutions such as Empresa Brasileira de Pesquisa Agropecuária and Agência Nacional de Águas e Saneamento Básico. These studies highlight increasing vulnerability, especially in areas of intensive agricultural use and peri-urban zones, where inadequate land management practices intensify erosion processes (EMBRAPA, 2020; ANA, 2018).

The occurrence and intensity of rainfall-induced erosion are also associated with the factors identified by CREPANI et al. (2001, p. 19), namely:

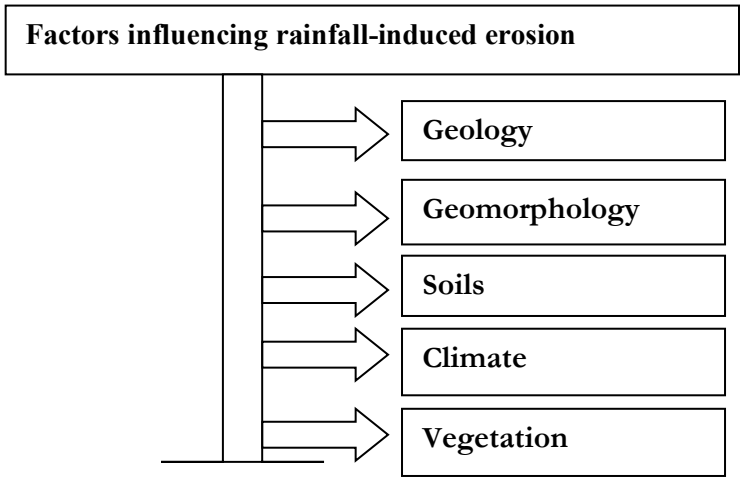


Figure 3. Factors influencing rainfall-induced erosion.

Source: Prepared by the authors based on CREPANI et al. (2001).

According to SANTOS (2015), these elements can be understood as follows:

> geology refers to the study of the Earth's structure and composition, while geomorphology addresses landforms and the surface processes responsible for shaping the terrain. In turn, MENDES (2014) defines soil as the surface material that composes the Earth's crust, formed by the weathering of rocks and the accumulation of organic matter. Vegetation, as conceptualized by SILVA (2004), comprises the set of plant species occupying a given area and plays a fundamental role in protecting the soil against the direct impact of rainfall and surface runoff.

However, gully formation in the neighborhood under study tends to intensify due to geological and geomorphological factors that directly influence this process. The local geological structure is poorly developed, with the uppermost layer consisting of humus, characterized by its dark coloration resulting from a high organic matter content, with a thickness ranging from 5 to 7 cm. The region's topography presents slope declivities associated with a stepped relief, which is directly related to alluvial and sandy-clayey soils in low-altitude zones, as highlighted by Brenchley (2007), who emphasizes the importance of relief in erosion dynamics and sediment transport.

The local geomorphological analysis, according to Oliveira (2018), indicates that erosion on slopes is intensified not only by physical factors but also by anthropogenic actions, such as inadequate land use and vegetation degradation. However, from the perspective of Critical Environmental Education (CEE), the required approach goes beyond the mere dissemination of technical-conservationist knowledge of a moralistic, rationalist, and instrumental nature, which is characteristic of traditional Environmental Education.

In this sense, it is essential to adopt a perspective that establishes a correlation between Freire's conception of education as a practice of freedom (Freire, 1921, p. 15) and the CEE theoretical framework. Freire's idea of education as a practice of freedom is aligned with Popular Environmental Education (PEE), which promotes the construction of environmental knowledge through the valorization of local knowledge and collective experiences. The notion of an act of knowledge is associated with Emancipatory Environmental Education (EEE), oriented toward the development of critical awareness regarding socio-environmental dynamics. Finally, the idea of a critical reading of reality corresponds to Environmental Education within Environmental Management Processes (EEEMP), which adopts a critical stance in the formulation and implementation of public policies and institutional practices.

In line with Rodrigues (2019), who emphasizes the impact of vegetation cover loss on slopes, it can be stated that soil degradation in this area is directly related to the remaining native vegetation, particularly in higher-altitude zones. In this regard, the implementation of CEE-based projects not only encourages the recovery of degraded areas but also strengthens community autonomy in territorial management, promoting ecological restoration practices aligned with local knowledge, as suggested by Lima (2017).

Thus, CEE empowers local actors by problematizing historical processes of environmental degradation and strengthening community autonomy, fostering a critical reading of territorial planning policies and encouraging the construction of sustainable models adapted to local specificities.

Finally, in light of these considerations, how can CEE be implemented, and which conceptual guidelines should inform its implementation?

3.2. Critical Environmental Education and Rainfall Erosion

To answer the question above, this study adopts the critical conception of Environmental Education, understood as an approach that emerged from the need to raise global awareness, through educational processes, regarding concern for the environment and related problems, so that society collectively may develop knowledge, skills, attitudes, motivation, and commitment to collaborate individually and collectively in solving current problems and preventing future ones (SANTOS; SANTOS, 2016 However, this approach has increasingly been replaced, as its guidelines—which emphasize the continuity and interdisciplinarity of Environmental Education—have been reformulated in favor of an Education for Sustainable Development, proposed at Rio-92 by Northern Hemisphere governments, multilateral organizations, and UNESCO itself (LAYRARGUES; LIMA, 2014, p. 32). This shift led Environmental Education to respond to political issues, often aligned with the interests of dominant groups. In a critical analysis of this guideline, Layrargues and Lima (2014, p. 23–24) argue that the social field in which Environmental Education is applied is configured as a space of dispute between dominant and dominated groups:

> […] The dominant groups are those who define the legitimate social capital of the field—the object of dispute among its participants—and, therefore, the rules of the game. They tend toward orthodoxy and develop strategies of conservation; whereas the dominated tend toward heterodoxy and the use of strategies aimed at subverting the established order.

This perspective is essential for understanding the power relations present in the territories studied, where certain groups, holding greater social, economic, or cultural capital, impose norms and practices aimed at maintaining their dominant position. On the other hand, subordinate groups, through heterodox strategies, challenge and often reconfigure these rules, creating alternative forms of resistance and affirmation. This dynamic contributes to understanding socio-environmental conflicts and disputes over resources, directly affecting spatial organization and community relations.

In this context, rainfall erosion emerges as an environmental problem that directly reflects these structural inequalities, since marginalized communities are the most affected by its impacts. CEE proposes the construction of sustainable alternatives through dialogue and social participation, promoting community empowerment to demand public policies capable of minimizing environmental impacts.

Considering these disparities, Environmental Education may be understood simultaneously as a subfield derived from the environmentalist field and as a relatively autonomous field (LAYRARGUES; LIMA, 2014, p. 25). It thus becomes configured as a discipline that is not limited to environmental issues alone. As Lima (2011), Carvalho (2001), and Crespo (1998) point out, when analyzing its relationship with the educational field, its purposes, culture,

knowledge, institutional spaces, and practices, it becomes evident that Environmental Education has its own specific characteristics that grant it a particular ethos, relatively differentiated from the environmentalist field.

Traditional or classical Environmental Education focuses mainly on nature conservation and the control of environmental impacts. It is generally applied in a disciplinary manner, encompassing areas such as biology, geography, and natural sciences. Its approach prioritizes individual actions, such as recycling and resource conservation, based on a more technical and informative model.

This leads Maia et al. (2009, p. 10) to classify Environmental Education as a form of education. In other words, traditional or classical Environmental Education has objectives that do not differ from the educational action of human beings themselves. Following Saviani's concept (2005, p. 13), education aims to "intentionally and directly produce in each individual the humanity historically and collectively produced by humankind." This intentional singularity that humanizes individuals stems from the appropriation of socially produced and historically accumulated knowledge through sciences that enable people to understand their environment. This form of education, from an environmental perspective, is disseminated by dominant groups, who define the legitimate social capital of the field and therefore establish the rules of the game, according to Bourdieu and Loureiro (2001). Maia et al. (2009, p. 10) define this dominant-group approach to education (traditional or classical Environmental Education) as reproductive, characterized by moralistic disciplines that promote environmentally inadequate behavioral changes.

Therefore, this study aligns with CEE, understood as the pedagogical process that thematizes the environment, leading to the appropriation of culture and the productions of humankind, and enabling the confrontation of the societal crisis humanity is experiencing (MAIA, 2011, p. 47). In this context, rainfall erosion emerges as a significant socio-environmental problem, especially in vulnerable communities, where disordered land occupation, deforestation, and lack of infrastructure aggravate its impacts.

From the perspective of traditional Environmental Education, rainfall erosion is viewed as a technical problem, with solutions focused only on punctual mitigation measures, such as drainage works and sediment control. In contrast, the critical approach makes possible what Freire (1921, p. 15) conceives as education: a practice of freedom, an act of knowledge, and a critical approach to reality. As Maia et al. (2009, p. 10) state:

> Critical Environmental Education does not address environmental issues in an emotional or manipulative way; rather, it approaches environmental problems in a dialogical and critical manner, dialectically overcoming the notion of the environment as a resource by engaging deeply with the complexity of reality in order to understand its essential aspects. (MAIA et al. 2009, p. 10)

CEE breaks with both the conservationist and pragmatic strands that emerged from it and that focus on issues such as urban-industrial waste (LAYRARGUES; LIMA, 2014, p. 28). Unlike these approaches, CEE seeks a deeper reflection on socio-environmental issues, going beyond simple conservation and pedagogical pragmatism. This need is also supported by what Gro Harlem Brundtland states in the preface to the United Nations report Our Common

Future: unless we are able to translate our words into a language that reaches the minds and hearts of people, young and old alike, we will not be able to carry out the broad social changes needed to correct the course of development (GADOTTI, 2009, p. 2).

CEE provides precisely this translation of words into meaningful action by seeking to understand the power relations and structural factors that lead to environmental degradation, particularly soil degradation. It encourages solutions that promote socio-environmental justice and incorporates elements from Popular, Emancipatory, and Transformative Environmental Education, as well as the Environmental Management Process. It is grounded in a critical review of the foundations that sustain human domination and capital accumulation, aiming at the political confrontation of inequalities and socio-environmental injustice (LAYRARGUES; LIMA, 2014, p. 33).

The CEE tetrad supports the understanding that, in the educational experience, learning and change are inseparable (LAYRARGUES; LIMA, 2014, p. 34). In other words, it is not possible to learn without transforming one's way of seeing reality, nor to transform reality without acquiring new knowledge. This interdependence between learning and change reflects the dynamic and continuous character of CEE, which is not limited to the transmission of information, but also aims to promote substantive transformation in the thinking and socio-environmental practices of individuals and communities.

Within this approach, CEE unfolds into four main strands:

- Educação Ambiental Popular (PEE): grounded in Paulo Freire's liberatory pedagogy, it promotes dialogue and community participation in the construction of environmental knowledge, valuing local knowledge and collective experiences (FREIRE, 1921).
- Emancipatory Environmental Education (EEE): focuses on developing critical awareness, enabling individuals to understand power relations and structural constraints shaping environmental problems. Emancipation refers to the process of overcoming domination and dependency structures, enabling autonomous and transformative action, as discussed by Freire (1921).
- Transformative Environmental Education (TEE): seeks both individual and collective structural change, addressing the root causes of socio-environmental problems and promoting sustainable alternatives. Transformation implies a profound change in practices, relations, and socio-environmental structures, guided by critical consciousness (EINSTEIN apud STERLING, 2001).
- Environmental Education within Environmental Management Processes (EEEMP): integrates critical environmental education into public policy formulation and institutional practices, strengthening democratic participation and ensuring socially and ecologically just environmental decision-making (LAYRARGUES; LIMA, 2014).

4. RESULTS AND DISCUSSION

4.1. Precipitation Distribution and Its Influence on Pluvial Erosion

Soil erosion is a complex process influenced by multiple factors, as described by the Universal Soil Loss Equation (USLE). Although this study does not aim at the direct application of the USLE, these factors were considered as fundamental content within the Critical Environmental Education (CEE) process, serving as a basis to promote awareness among local residents regarding the causes of erosion and the importance of adopting sustainable practices derived from a participatory methodology.

However, the Massinga district, where the 21 de Abril neighborhood is located, presents two distinct climatic periods. The first is the wet season, occurring between November and April, concentrating approximately 74% of the annual precipitation, with February being the rainiest month, recording an average monthly rainfall of about 136 mm. The second is the dry season, extending from May to October, with monthly precipitation averages ranging from 30 mm in August to 56 mm in June. In the 21 de Abril neighborhood, the thermo-pluviometric variation is shown in Figure 4.

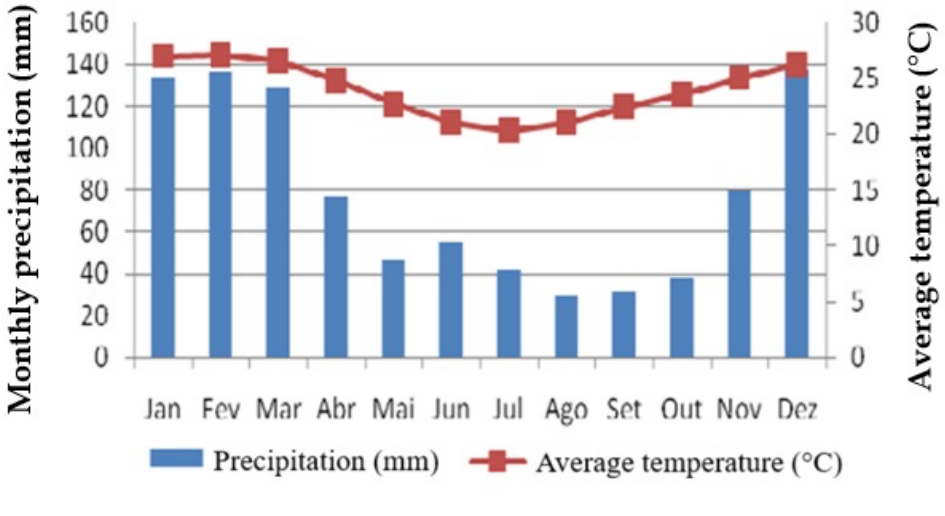


Figure 4. Thermo-pluviometric chart of 2015.
Source: Adapted from the National Institute of Meteorology (2023)

Based on this chart, adapted to the climatic conditions of the district, it is observed that temperature in the 21 de Abril neighborhood remains relatively constant throughout the year, ranging between 20°C and 30°C. During the hot and rainy season, which generally occurs from November to March/April, precipitation ranges between 80 mm and 140 mm, while average temperatures vary between 20°C and 40°C. This period concentrates the months of highest rainfall intensity, favoring the occurrence of pluvial erosion.

In the dry or cooler season (May to October), average monthly precipitation decreases significantly, ranging between 25 mm and 41 mm, and average temperatures vary between 20°C and 24°C. Although rainfall is less frequent, precipitation occurs throughout the year, which continuously contributes to the intensification of erosive processes in the region, especially in areas with higher soil vulnerability.

4.2. Impacts of Pluvial Erosion Observed in the 21 de Abril Neighborhood

The CONAMA Resolution of 1986 defines environmental impacts as:

> […] Any alteration of the physical, chemical, and biological properties of the environment, caused by any form of matter or energy resulting from human activities that directly or indirectly affect human health, safety, and well-being; social and economic activities; biota; aesthetic and sanitary environmental conditions; and the quality of environmental resources.

In the present study, in order to identify the impacts caused by pluvial erosion in the 21 de Abril neighborhood, the method of direct observation was adopted. This approach enabled a detailed analysis of local environmental and social conditions, allowing the systematic recording of the main identified impacts. The results obtained through this methodology are presented in Figure 5, highlighting the most relevant consequences of the erosive phenomenon for both the community and the environment.

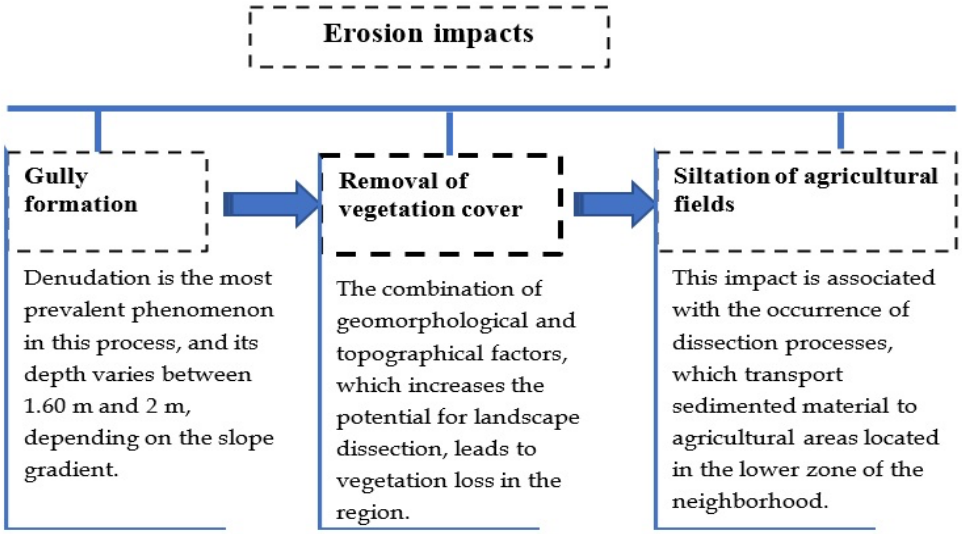


Figure 5. Impacts of erosion in the 21 de Abril neighborhood. Source: Author's elaboration (2023)

The impacts of pluvial erosion in the 21 de Abril neighborhood reveal not only an environmental problem, but also an expression of socio-spatial inequalities, reflected in the lack of adequate infrastructure, occupation of risk-prone areas, and insufficient public investment, which directly affect the local community. The formation of gullies, as illustrated in Figure 6, is intensified by soil compaction due to "intense pedestrian traffic and the use of heavy machinery, directly compromising mobility and residents' safety, and aggravating their social vulnerability" (FERREIRA, 2012).

The inaccessibility of roads reflects a context of exclusion, where the absence of adequate infrastructure limits access to basic services, restricts mobility, and compromises the population's quality of life. Furthermore, the expansion of gullies directly threatens housing structures, exposing residents to risks of collapse and forced displacement. To address the challenges posed by pluvial erosion, it is necessary to overcome a purely technical perspective limited to traditional, conservationist Environmental Education, which often proposes punctual and superficial solutions. The resolution of this problem requires a paradigmatic shift that recognizes the complexity of

territorial and socio-environmental dynamics and involves the community in the processes of diagnosis and planning, in order to translate words into a language accessible to people, young or old alike.

Figure 6. Formation of a gully on the access road of the 21 de Abril neighborhood. Source: Author's elaboration (2023)

The removal of vegetation cover, intensified by geomorphological and topographic factors, significantly accelerates the process of soil dissection, resulting in nutrient loss and degradation of the soil's physical properties. This process compromises local biodiversity, which depends on ecosystem stability, and reduces the soil's capacity to retain water, which is essential for maintaining natural hydrological cycles. "Vegetation degradation, therefore, not only exacerbates erosion processes but also increases environmental vulnerability, making the area more susceptible to landslides and other instability processes" (SOUZA, 2016).

In addition to environmental degradation, this process worsens living conditions in affected areas, as evidenced by sediment deposition in residential zones, increasing structural risks, as shown in Figure 7. The deposition of sediments from higher-altitude areas directly affects local infrastructure, causing damage to housing and forcing the relocation of families.

Figure 7. Sediment deposition in residential areas and subsequent abandonment. Source: Author's elaboration (2023)

These impacts highlight the urgent need to implement integrated mitigation measures, including structural interventions for erosion control through the CEE tetrad. Community awareness is fundamental for the recovery and preservation of the local environment, as supported by authors who emphasize "community participation as a crucial factor for the effectiveness of sustainability programs" (FERREIRA, 2012).

4.3. Application of Critical Environmental Education in the Mitigation of Pluvial Erosion Impacts in the 21 de Abril Neighborhood

Based on Critical Environmental Education (CEE) as a methodological approach for mitigating environmental impacts (Figure 5), an educational strategy grounded in PEE, EEE, and TEE was adopted, promoting a critical and participatory form of teaching. The activities aimed to raise awareness and foster community protagonism through practical experimentation and interactive discussions, as follows:

4.3.1. PEE: Collective Construction of Knowledge

During triweekly meetings held over a two-week period, discussions were promoted on the relationship between environmental degradation and social problems. The focus was on how these families understand the concept of pluvial erosion and the lack of access to public policies aimed at sustainable soil management. The objective was to stimulate horizontal dialogue, valuing active participation in the search for effective environmental solutions.

The data collected during the meetings indicate that 53% of participating families have lived in the neighborhood for more than 30 years, 38% for more than 10 years, and 9% for more than 5 years, as shown in Figure 8. This overview demonstrates that most residents have a long-standing relationship with the territory. Within this percentage, regarding respondents' understanding of the technical-scientific concept of pluvial erosion (see Figure 8), 75% initially reported not knowing the concept, which reveals a knowledge gap regarding the natural processes affecting soil in the region.

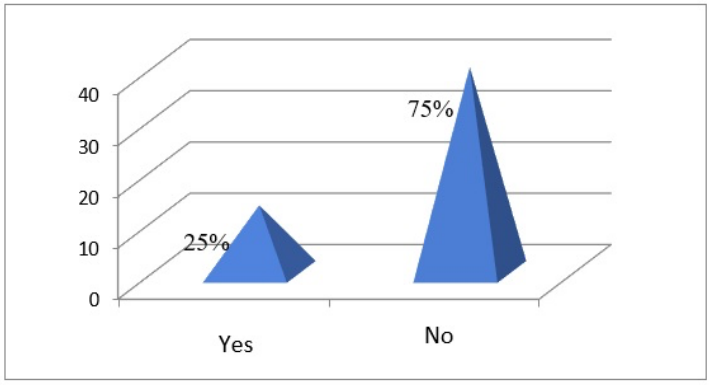


Figure 8. Knowledge of respondents about pluvial erosion.

Source: Author's elaboration (2023)

To mitigate this informational gap, educational activities were carried out within the framework of collective knowledge construction, as shown in Figure 9, initially involving interactive discussions with families.

Figure 9. Dialogue on Environmental Education with Women Community Leaders.

Source: Author's elaboration (2023)

After the implementation of these activities, a second assessment was conducted in the final meeting. A significant improvement in families' understanding of the technical-scientific concept of pluvial erosion was observed, with 60% of participants demonstrating greater awareness of its impacts and recognizing the importance of preventive measures, such as vegetation cover maintenance and the adoption of sustainable agricultural practices.

However, the results also reveal a significant challenge, as 40% of respondents did not show a noticeable change in their understanding or attitude toward the problem. This suggests that barriers such as cultural resistance, limited access to information, and the absence of environmentally rooted practices within the community may hinder knowledge assimilation and the adoption of effective measures.

4.3.1. EEE: Critical Formation and Community Participation

Within the meetings conducted to promote EEE, discussions were guided not only by environmental perspectives but also by social and political dimensions, focusing on questions such as:

- Who is responsible for environmental management in the neighborhood?
- What public policies could be implemented to mitigate erosion impacts?
- How can the community itself act to reverse this situation?

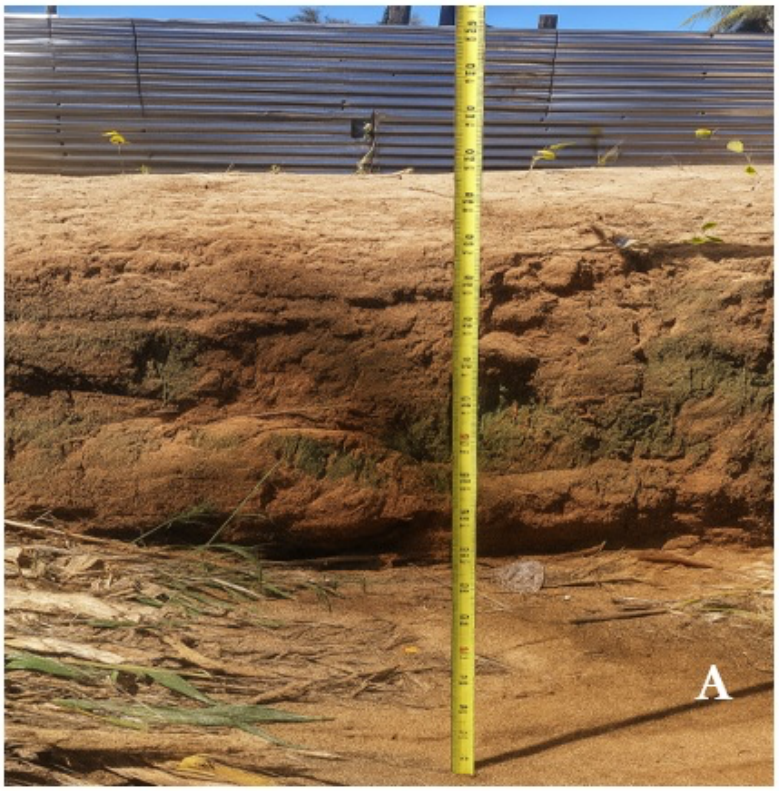
The debates on these issues clearly highlighted the relevance of this research for the community, emphasizing the need for TEE (Experimentation and Collective Action). Participants indicated that environmental management in the neighborhood is the responsibility of public institutions, such as District Governments and the Municipal Secretariat. They also emphasized the need for the construction of an urban drainage system, stressing that political institutions have both the power and responsibility to implement such solutions.

4.3.2. TEE: Experimentation and Collective Action

TEE was applied from a practical and participatory perspective, in which participants became active agents in the construction of solutions to local environmental problems. To this end, experimental activities were carried out in the territory, including erosion measurements and soil condition observations.

4.3.2.1. Measurement of Erosive Rill Depth

Two strategic points in the neighborhood were selected to measure the depth of erosive rills, considering terrain slope and proximity to inhabited areas. The measurements, carried out using a measuring tape, allowed for the analysis of the impact of vegetation removal and slope inclination on erosion susceptibility, encouraging reflection on mitigation strategies. The results show significant variation in rill depth (Figure 10. A). In less steep areas, the rill reaches 3.6 meters, while in steeper terrains, gravity, low vegetation cover, and soil fragility intensify erosion, resulting in rills of up to 160 meters (Figure 10. B).



This point corresponds to the highest elevation of the neighborhood. The gully shows a significant variation of 3.6 meters in depth, especially in areas with low vegetation cover and those located close to residential buildings.

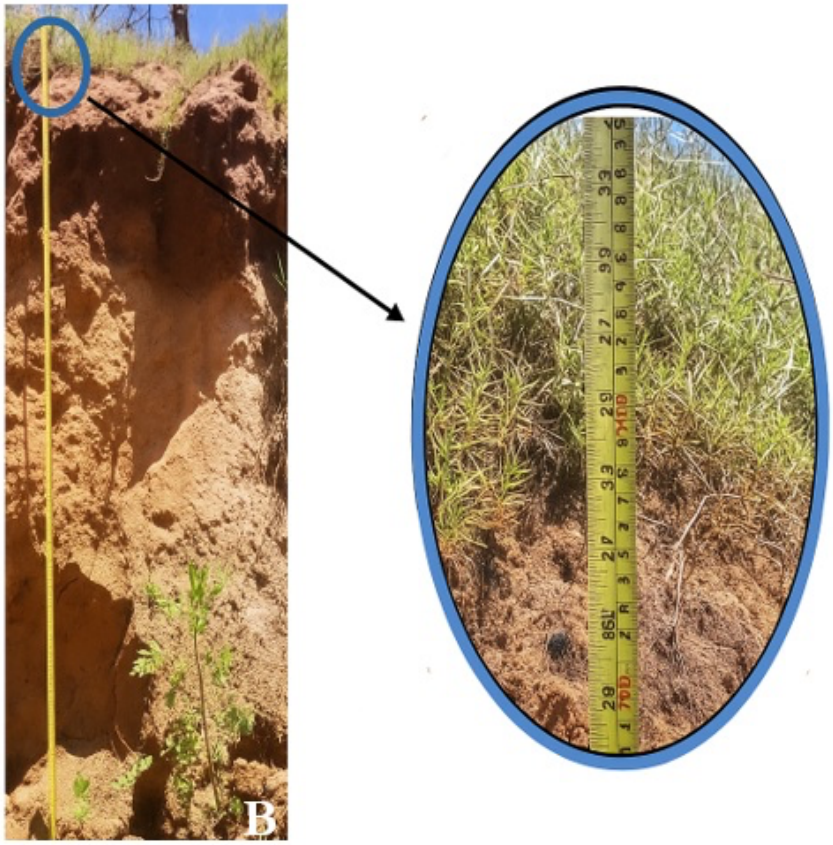


Figure 10. A- B: Measurement of soil erodibility at the slope point

Source: Author's elaboration (2023)

At the end of the experimentation and collective action process, a significant shift was observed in participants' perceptions of environmental management in the neighborhood. Initially, responsibility was attributed exclusively to public authorities; however, during the TEE activities, participants began to recognize the importance of community protagonism in erosion mitigation.

This transformation reflects the process of emancipation as the overcoming of limitations and dependencies imposed by political and social structures (Freire, 1921). The exchange of experiences and engagement with local reality strengthened the perception of collective action for environmental preservation. Proposed solutions included slope vegetation recovery, construction of retaining barriers, implementation of an adequate drainage system, and the use of soil- or sand-filled bags to stabilize vulnerable areas, reducing water impact on exposed soil.

5. FINAL CONSIDERATIONS

The research demonstrated that pluvial erosion in the 21 de Abril neighborhood constitutes a significant environmental problem, characterized by the formation of gullies, removal of vegetation cover, and siltation of agricultural fields. These impacts result largely from the absence of adequate soil management practices, deficient urban planning, and the community's low perception of erosive processes.

In this context, Critical Environmental Education (CEE) was adopted as a key strategy to mitigate the impacts of pluvial erosion, promoting a broader understanding of the problem and encouraging the adoption of sustainable practices. The study demonstrated that, by integrating technical knowledge with a critical analysis of the social, economic, and political factors that exacerbate environmental degradation, CEE strengthens community protagonism and stimulates active participation in the construction of solutions.

The educational actions implemented (including meetings, practical field activities, and participatory assessments) showed significant advances in community awareness. Before the interventions, 75% of residents were unaware of the technical-scientific concept of pluvial erosion. However, at the end of the process, 60% of participants demonstrated a better understanding of erosion impacts and the importance of adopting preventive measures. This progress reflects not only the effectiveness of PEE, EEE, and TEE strategies, but also a shift in residents' perception, who began to no longer see public authorities as the sole responsible actors for environmental management.

The study also showed that 53% of residents have lived in the neighborhood for more than 30 years, 38% for more than 10 years, and 9% for more than 5 years, indicating a strong territorial attachment. This reinforces the need for continuous and participatory educational strategies, valuing local knowledge and encouraging community engagement in erosion mitigation.

CEE in the 21 de Abril neighborhood not only deepened the understanding of erosive processes but also promoted social and environmental transformation, stimulating collective action. To ensure these advances, it is essential to strengthen educational initiatives and promote articulation between the community, researchers, and public policies, ensuring a continuous process of adaptation to environmental challenges.

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Lucas Paulo Ngulube: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Resources, Visualization, Writing – Original Draft, Writing – Review & Editing

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