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Socio-environmental impacts of soil erosion in different management areas in the Brazilian Amazon and sustainable soil conservation practices: a literature review

Socioenvironmental impacts of soil erosion in different management areas in the Brazilian Amazon and sustainable soil conservation practices: a literature review

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ABSTRACT: The Amazon biome, the largest tropical forest in the world, plays a crucial role in global climate balance and biodiversity preservation. However, the advancement of economic activities has aggravated environmental degradation, making it urgent to adopt conservation measures. Deforestation, driven by agricultural expansion, burning and mining, compromises the stability of Amazonian soils and generates significant socio-environmental impacts. This article aims to analyze the effects of soil erosion in different management areas in the Brazilian Amazon and investigate sustainable practices for its conservation, through a qualitative approach based on a literature review. The results demonstrate that soil erosion is not only an environmental concern, but also a social and economic one. Logging, agricultural and mineral exploration must be carefully planned to mitigate negative impacts. Proper soil management and the implementation of conservation practices from the early stages are essential to ensure its preservation and sustainable productivity. In addition, strengthening public policies aimed at monitoring deforestation and the exploitation of natural resources is essential. Effective conservation strategies must involve local communities, promoting awareness and engagement. Efficient environmental monitoring, based on concrete and permanent measures, can ensure the protection of the biome. Only through a collaborative effort will it be possible to preserve the natural wealth of the Amazon and guarantee a sustainable future for future generations.

Keywords: Anthropization. Sustainable management. Erosive process. Environmental quality. Amazonian Soils.

ABSTRACT: The Amazon biome, the world's largest tropical forest, plays a crucial role in global climate balance and biodiversity preservation. However, the expansion of economic activities has exacerbated environmental degradation, making conservation measures urgently necessary. Deforestation, driven by agricultural expansion, wildfires, and mining, compromises the stability of Amazonian soils and leads to significant socio-environmental impacts. This article aims to analyze the effects of soil erosion in different management areas of the Brazilian Amazon and investigate sustainable conservation practices through a qualitative approach based on a literature review. The results show that soil erosion is not only an environmental concern but also a social and economic issue. Logging, agriculture, and mining must be carefully planned to mitigate negative impacts. Proper soil management and the implementation of conservation practices from the earliest stages are essential to ensure preservation and sustainable productivity. Furthermore, strengthening public policies focused on deforestation monitoring and natural resource management is fundamental.
Effective conservation strategies should include the involvement of local communities, fostering awareness and engagement. Efficient environmental oversight, based on concrete and permanent measures, can safeguard the biome. Only through a collaborative effort will it be possible to preserve the Amazon's natural wealth and ensure a sustainable future for the next generations.

Keywords:Anthropization. Sustainable management. Erosive process. Environmental quality. Amazonian soils.

1. INTRODUCTION

The Amazon, recognized worldwide for its immense reserves of drinking water, mineral wealth and tropical biodiversity, has been the target of growing concern due to the impact of human activities on its natural resources. Sustainable land use, in particular, emerges as a central topic of discussion, as its quality and conservation are essential for the maintenance of the region’s ecosystems (Nascimento, 2016).

Considered the largest tropical forest on the planet, the Amazon plays a vital role in climate regulation and in the provision of environmental services essential to sustainability global (IPEA, 2008). However, practices such as the conversion of forests into agricultural areas, mining and burning have been generating successive changes in the natural balance of the soil, modifying their physical, chemical and biological attributes. These phenomena accelerate the degradation of natural resources and negatively impact the quality of life, the economy local and biodiversity (Sales, 2019).

The functional and structural recovery of the Amazon forests, on the other hand, strengthens the soil quality, increases biodiversity and reduces erosion processes (Bertoni, 2014). In Amazon region, deforestation, burning and the conversion of forests into pastures and agricultural areas have been agents of environmental degradation, causing soil instability, erosion and contamination, with direct consequences on the well-being and health of local communities.

Soil management in the Brazilian Amazon, often neglected, has been associated with the unbridled exploitation of natural resources, causing environmental damage significant over the decades (Santos et al., 2014). The expansion of activities agricultural and mining activities without technical criteria have intensified impoverishment and soil erosion, worsening the region's environmental challenges (Silva et al., 2015).

The Brazilian Legal Amazon (ALB), covering vast territories from Amazonas to Maranhão and from Roraima to Mato Grosso, faces substantial impacts resulting from the urbanization and infrastructure. Socioeconomic factors and development policies regional intensify deforestation, particularly in the Deforestation Arc, which comprises areas in the states of Maranhão, Pará, Tocantins, Rondônia, Mato Grosso, Amazonas and Acre (Sales, 2019; Becker, 2010). This change in land use causes structural degradation, accelerating erosion and compromising its productive capacity (Oliveira et al., 2016).

In this context, soil erosion in the Amazon presents impacts severe socio-environmental problems, affecting everything from the fertility of agricultural soil to the conservation of river ecosystems. In areas of agricultural and livestock management, the loss of the surface layer of the soil compromises food production and increases dependence on chemical fertilizers. In areas of logging and mining, the removal of vegetation intensifies the silting of rivers, directly affecting local biodiversity. These processes contribute to climatic and environmental imbalances, making it difficult for people to survive Amazonian communities. Based on these challenges, the following research question arises: *"What are the main socio-environmental impacts of soil erosion in different areas of management in the Brazilian Amazon and how sustainable conservation practices soil can mitigate these effects?"*

Research on the topic of soil management in the Legal Amazon is essential for map the consequences of the inadequate use of natural resources and support the formulation of effective conservation strategies (Nunes et al., 2012). Historically, improper management of these resources has intensified erosion processes, resulting in socioeconomic losses. monkeys and environmental issues for local populations.

Given this scenario, this research is justified by the need to provide support theoretical and technical for the proposal of sustainable soil management practices, aimed at mitigating adverse environmental impacts and strengthen the conservation of the Amazon. The proper understanding foundation of erosive processes is crucial for the formulation of diagnoses that guide the adoption of best conservation practices, promoting sustainability and balance ecological of the region. This study aims to analyze the socio-environmental impacts of soil erosion in different management areas in the Brazilian Amazon. From this analysis, seeks to identify and propose sustainable conservation strategies, aiming to reduce the effects negative effects of soil degradation and contribute to improving environmental quality and for the sustainable development of local communities.

2. Research methodology and operationalization

The article presents a qualitative methodology for its operationalization, carried out through a bibliographic review research, focused on the impacts socio-environmental aspects of soil erosion in different management areas in the Brazilian Amazon and in sustainable soil conservation practices. According to Sousa *et* al., (2021) and Campos *et* al., (2023), bibliographic research with a qualitative approach allows identifying data from existing research in a given thematic area, helping to identify gaps and solutions.

This research enables a connection between theory and reality, providing subsidies for practical interventions and viable solutions to minimize the problem in question. Furthermore, this methodological approach facilitates the understanding of contexts complex and multifaceted, offering a holistic view of environmental issues and socioeconomic conditions related to soil erosion in the Amazon. This reinforces the importance of continuous literature reviews to maintain the relevance and timeliness of interventions proposals. The research methodology for producing the article followed three main stages, as shown in table 01.

Table 01: Stage, Methodological Description and operationalization of the research

Stage	Methodological description and operationalization of the research
Survey of Materials Bibliographic and Documents (I)	In this stage, data were collected from relevant academic and scientific sources on the socio-environmental impacts of soil erosion in different management areas in the Brazilian Amazon, as well as on sustainable soil conservation practices. The search included scientific articles, publications in newspapers, magazines and periodicals, dissertations, theses, reports, magazine websites and university digital libraries.
Analysis of results and discussion (II)	In this phase, a critical analysis of the collected data was carried out, followed by a comprehensive literature review. The subtitles analyzed included: general characteristics of the Legal Amazon, soil use and management in different Amazonian environments, soil erosion in the Amazon region, influence of soil attributes on erosion, socio-environmental impacts of soil erosion in the Amazon, and sustainable soil conservation practices.
Final considerations (III)	This stage summarizes the main Final Considerations of the research and presents recommendations. Improvements in public policies and environmental management practices were proposed, aiming to minimize soil erosion in the Brazilian Amazon, emphasizing sustainable soil conservation strategies,

Prepared by the authors

The methodology adopted allowed not only an in-depth understanding and analysis of the socio-environmental impacts of soil erosion, but also provided a basis solid basis for the development of mitigation strategies that are scientifically robust and socially equitable. Furthermore, continuous literature review is essential to ensure that the proposed interventions remain relevant and effective in light of new findings and of the emerging challenges in the Amazon region.

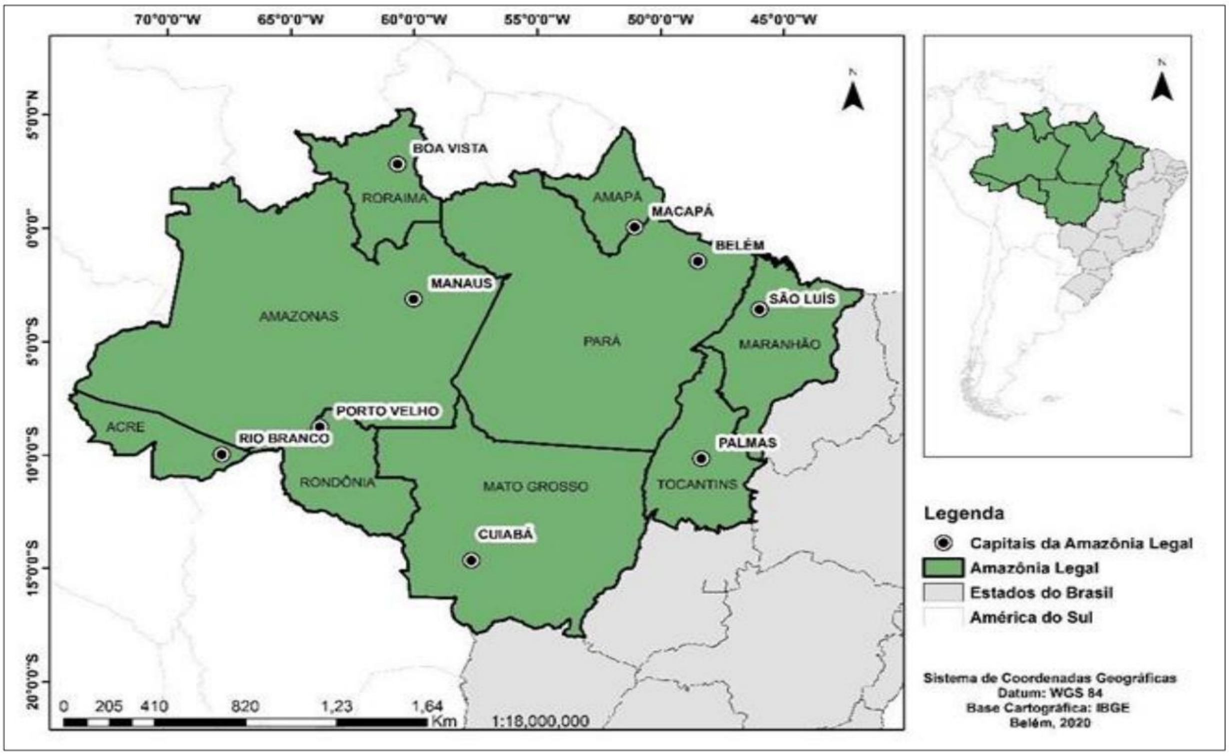
3. RESULTS AND DISCUSSION

3.1. General characteristics of the Legal Amazon

The beginning of the occupation of the Amazon dates back to the mid-16th century (1559), when Dutch, English and French Europeans sailed the rivers of the Amazon and looked for establish settlement and colonization centers (Teixeira et al., 1998; Menezes, 2008). Instituted in 1959, by Law No. 1,806, of 06/01/1953, with the aim of better planning the

social and economic development of the region, the Brazilian Legal Amazon – ALB, also known as the Brazilian Amazon, has a total area of 5 million km² and occupies 59% of the Brazilian territory (IPEA, 2008), covering 772 municipalities in nine states and their respective capitals: Manaus (AM), Rio Branco (AC), Boa Vista (RR), Porto Velho (RO), (IBGE, 2015;
Oliveira et al., 2020), as illustrated in Figure 1.

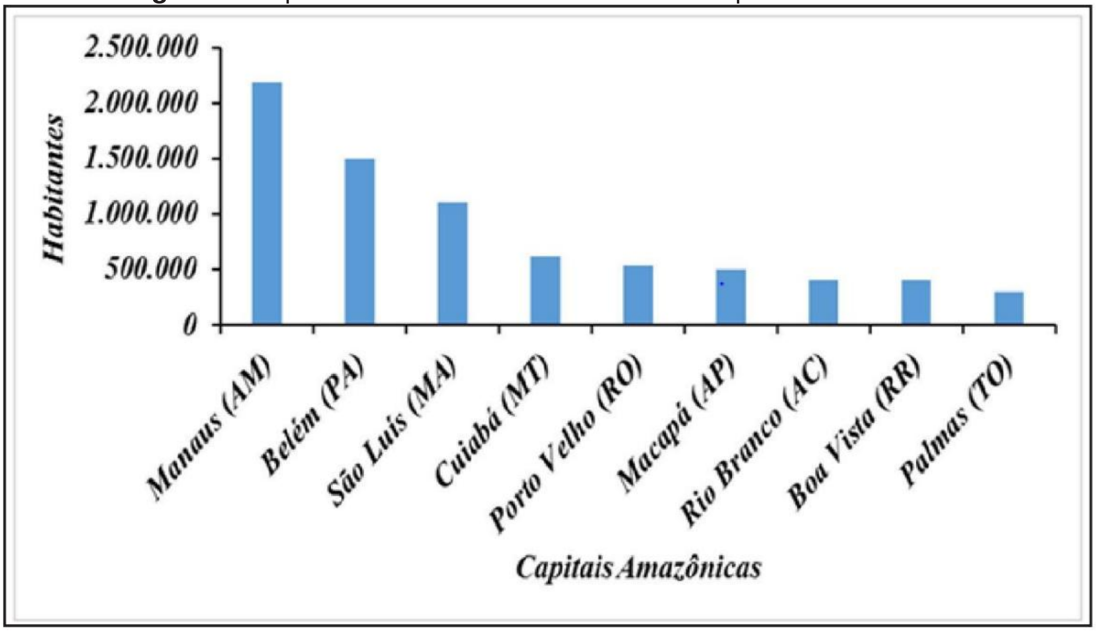
Figure 1. Location map of the Brazilian Legal Amazon



Source: Oliveira et al., (2020)

According to IBGE (2019), the capitals of the Brazilian Amazon have a population ranging from almost 300 thousand to a little over 2 million inhabitants, with the municipalities of Manaus and Belém as the most populous in this region. This concentration population can be explained by geographic and economic factors, such as availability of infrastructure, job opportunities and access to natural resources. Demographic studies indicate that urbanization in areas of the Amazon is strongly influenced by economic corridors and the ability of cities to offer services essential to the population. Thus, the other capitals have a relatively large population low when compared to Manaus and Belém, reflecting regional inequalities in urban development and in the distribution of public investments, as indicated by Figure 1.

Figure 2. Population estimates for Amazonian capitals in 2019



Source: IBGE (2019), prepared by Oliveira *et al.,* (2020)

These states have ecological structure, economic, political and social conditions similar (Ometto et al. 2016). This delimitation includes not only the Amazon biome, but also areas of Cerrado and Pantanal and extends over approximately 5 million square kilometers, which corresponds to approximately 59% of the national territory (Figure 1). The forest physiognomies originally covered an area of around 4 million square kilometers in the Brazilian Legal Amazon (ALB), which corresponds to approximately 79% of the area. The areas not belonging to forest domains are called, by the methodology of the Deforestation Monitoring Project program in the Legal Amazon by Satellite (PRODES), as "non-forest", which, added to the hydrography, occupy the remaining areas of the ALB (Table 1).

The state of Amazonas concentrates most of the forest vegetation in the ALB, followed by the states of Pará and Mato Grosso. The states of Acre, Amazonas and Pará have more than 90% of their territory formed by forest vegetation. On the other hand, due to the location in transition areas such as the Cerrado savannas, in states such as Tocantins, Maranhão and Mato Grosso, the proportion of areas with forest physiognomy is lower resprentativity (Messias et al. 2021), as shown in Figure 3 and Table 1.

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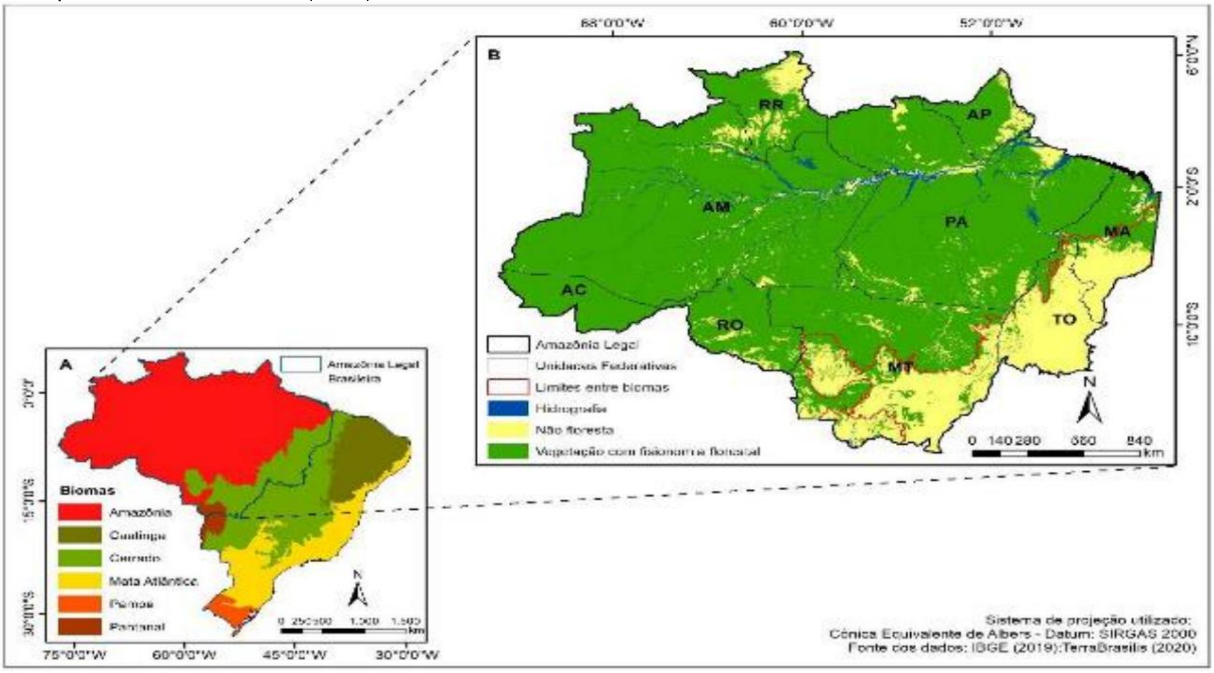
Figure 3. (A) Location map of the ALB in relation to Brazilian biomes; (B) Compartmentalization of (ALB)



Source: Messias et al. (2021).

Table **1.** Non-forest area and hydrography, areas originally constituted by forest physiognomies and proportion of area originally constituted by forest physiognomies in the Federative Units (UF) of the ALB.

State	State area	Non-forest area and hydrography (Km2)	Original area with forest physiognomy (Km2)	Proportion of original area with forest physiognomy (%)
Acre	164,052.52	184.16	163,868.36	99.89
Amapá	142,439.22	29,394.67	113,044.55	79.36
Amazonas	1,559,027.59	99,471.29	1,459,556.30	93.62
Maranhao	262,467.90	118,337.60	144,130.21	54.91
Mato Grosso	902,980.47	381,997.70	520,982.77	57.70
To	1,247,766.29	117,371.59	1,130,394.70	90.59
Rondônia	237.780.46	26,283.51	211,496.95	88.95
Roraima	223,920.94	62,753.73	161,167.21	71.98
Tocantins	277,157.41	237,123.31	40,034.10	14.44
ALB	5,017,592.80	1,072,917.65	3,944,675.15	78.62

Source: Messias et al. (2021)

The Amazon's phytophysiognomies are quite diverse, ranging from savannas to the cerrados, with a predominance of forests in their most varied phytophysiognomies and closely associated with climate and soil (Messias et al. 2021). The Amazon Rainforest is

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characterized by a huge diversity of environments, with more than 600 different types of terrestrial *habitats* and freshwater rivers (MMA/SBF, 2013) that support wildlife diversified.

According to Salati (1984) and Homma (2014), the Legal Amazon presents the averages monthly data from 48 weather stations spread throughout the Amazon. The Amazon Region It has an equatorial climate, where average temperatures of 24°C predominate in the central area. the 27th [the] C and rainfall in general exceeding 1,700 mm/year, which can reach up to 3,600 mm annually (Abÿsáber, 2003). Relative humidity is above 80% for most of the year. climate is not uniform, as there are regions where there is a well-defined dry season, with low relative humidity (typical of the cerrado), and others that are very humid, where practically there is no dry season. Although the soils are acidic and poor in nutrients, there is evidence of abundance of arable land, as well as other natural resources such as mineral deposits and natural forests that largely remain unexplored (Margulis, 2003).

The Amazon basin covers more than 6 million square kilometers and houses 20% of the planet's fresh water (Abÿsáber, 2003). In addition to being recognized as the area with the greatest biodiversity and reserve of drinking water in the world (IBGE, 2015), plays a crucial role in global climate regulation, influencing precipitation cycles and acting as a carbon sink , essential for atmospheric stability (Fearnside, 2018). However, its preservation faces significant challenges, including deforestation. accelerated, climate change and uncontrolled economic exploitation, factors that compromise the integrity of ecosystems and water availability in the region. Thus, conservation and sustainable management measures are essential for this heritage natural continues to contribute to the environmental balance of the planet.

In addition to its ecological importance, the Amazon is inhabited by several groups traditional ethnic groups, the result of historical processes of colonization and miscegenation (Oliveira et al., 2015). However, despite its rich biodiversity, the region faces infrastructure challenges, including poor roads and limitations on river navigation, the which hinders mobility and local development. Another relevant factor is the fragility of Amazonian soils, naturally poor and dependent on internal nutrient cycling for maintain its lush vegetation. However, deforestation and conversion of forests into

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agricultural areas compromise soil stability, making it vulnerable to erosion and degradation of natural resources (Andon et al., 2014).

Vegetation cover plays an essential role in soil conservation , maintenance of water cycles and preservation of fertility (Brady et al., 2013; Bertoni, 2014). However, the disorderly occupation of the Amazon intensifies environmental impacts, mainly due to human action. Furthermore, Amazonian biodiversity is not only sustains ecological balance, but also provides strategic ecosystem services, such as food security, health and tourism. In this context, the bioeconomy relationship between biodiversity and economy – reinforces the need for sustainable conservation of resources natural resources for balanced economic growth. Therefore, proper soil management is essential for environmental preservation and sustainability of the region.

3.2. Soil use and management in different Amazonian environments

Soil management in the Amazon plays a crucial role in the sustainability of ecosystems, being impacted by natural and anthropogenic factors. In this context, fertility of the Amazon soil is directly linked to the balance between the vegetation cover and the biogeochemical processes that ensure the cycling of essential nutrients contained in the organic matter (Oliveira, 2018; Enck et al., 2020). However, agricultural practices Inadequate practices, such as extensive monoculture and intensive livestock farming, compromise this balance and accelerate environmental degradation. Furthermore, the use of fire to clear areas of pasture, although common, causes irreversible damage, affecting the chemical and physical quality of the soil and promoting the leaching of essential nutrients (Durães et al., 2016). Consequently, the removal of vegetation cover facilitates erosion, exposing the soil to the action climate and reducing its carrying capacity for local biodiversity (Bertoni, 2017). Added to this, the growth of deforestation and the conversion of natural areas into land Agricultural activities destabilize ecosystems and intensify the negative impacts of exploitation of the earth.

Faced with these challenges, sustainable strategies are essential to minimize the damage and promote rational use of the region's natural resources. In this sense, practices how agroforestry systems, crop rotation and reforestation help restore soil fertility, allowing sustainable food production without compromising the environment

environment (Santos et al., 2015). For example, the agroforestry model, which combines species trees with agricultural crops and pasture areas, offers economic benefits and ecological to rural communities, allowing the sustainable development of the Amazon (Daniel, 2000; Menezes, 2017).

In addition, continuous oversight and monitoring of land use are essential to ensure that agricultural and extractive practices do not compromise the conservation of forests and water resources (Oliveira et al., 2015). Furthermore, investments in research and technologies aimed at environmental recovery and preservation are essential for outlining effective strategies to mitigate the impacts of human occupation on region (Frozzi et al., 2018). Therefore, the responsibility for soil preservation in the The Amazon is collective, and its proper management depends on the adoption of public policies and sustainable practices that guarantee its conservation for future generations.

3.2. Soil erosion in the Amazon region

Soil erosion in the Amazon region is a complex phenomenon that involves the de-aggregation, transport and deposition of particles, resulting from the interaction between natural factors and anthropic (Barbosa, 2020). This process is analyzed from several scientific perspectives, being the object of study by professionals from multiple areas of knowledge, such as agronom-mia, geology, geography, civil and environmental engineering (Bertoni, 2014; Oliveira et al., 2018). From a geological and geographical point of view, erosion is not restricted to soil degradation, but also comprises a set of processes responsible for modeling the landscape terrestrial over time (Lepsch, 2002). Although it occurs naturally due to agents erosive factors such as precipitation, winds and river flows, their intensity can be significant-mind magnified by human interference.

Anthropogenic action, especially through intensive deforestation, expansion disorderly urban environment and inadequate agricultural practices, drastically amplifies the effects erosion in the region (Hassane et al., 2023). Removal of vegetation cover reduces stability soil structure, increasing its susceptibility to water erosion. In addition, excessive use soil fertilization for agricultural activities without conservation techniques compromises its fertility. ality and contributes to the formation of ravines and gullies, significantly altering the local ecosystems.

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Accelerated erosion in the Amazon has direct consequences for biodiversity, hydrological cycle and the quality of natural resources. In addition to anthropogenic factors, the processes Erosive processes are influenced by climatic conditions, such as heavy rains and strong winds, in addition to soil characteristics, such as texture and infiltration capacity. In Brazil, the climate tropical favors erosion due to high rainfall in certain periods.

Thus, erosion can be classified into two major categories: geological, which occurs naturally over time, and anthropogenic, intensified by human action (Souza et al., 2017). There are different types of erosion, such as water erosion (caused by water), wind erosion (caused by wind current) and pluvial current (related to rain) (Lepsch, 2002; Bertoni, 2014). These processes can generate significant environmental and economic impacts, making it difficult to natural soil recovery (Silva et al., 2021). Consequently, conservation strategies tion are essential to minimize their negative effects (Ranhe et al., 2012). Water erosion occurs due to the impact of rain on the soil, causing disintegration and transport of particles, mainly in areas without vegetation cover (Fonseca, 2014; Lima, et al. 2016). According to Magalhães (2001), this phenomenon can manifest itself in a laminar manner, in furrows or even in the formation of gullies, its most advanced stage (Carvalho et al., 2001).

In Brazil, water erosion affects both agricultural and forest areas, compromising soil fertility and agricultural productivity (Telles et al., 2009). In the Amazon, the deforestation for livestock accelerates this process, leading to the degradation of pastures and causing diverse environmental impacts (Soares et al., 2018). Soil erosion varies according to me the physical and chemical characteristics of the terrain, being aggravated by the inadequate use of natural resources. This phenomenon compromises agricultural production and contributes to problems environmental issues, such as the silting of rivers, the increased occurrence of floods and the scarcity of water (Silva et al., 2016; Oliveira, 2018).

In this scenario, sustainable planning and the implementation of practices control are essential to mitigate the impacts of soil erosion, especially in environ- Amazonian environments. In this context, sustainable management strategies and environmental policies effective play an essential role in preserving soils and associated ecosystems. ciados. In addition, measures such as conservation of vegetation cover, adequate management of soil and the use of containment techniques are essential to ensure environmental preservation. thus improving productive conditions and reducing socioeconomic impacts in the region. In this way,

In this way, the integration of these approaches contributes to the sustainability of natural resources.
ral and ecological balance, promoting more responsible and lasting development.
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3.3 Influences of soil attributes and erosion in the Amazonian environment

Soil erosion in the Amazon is a multifactorial phenomenon, influenced by varia- climatic conditions, land use and intrinsic soil characteristics (Stefanoski, *et al* 2013). The heavy rainfall in the region accelerates erosion, especially in deforested areas, where the absence of plant cover leaves the soil more vulnerable to the action of water and wind. Furthermore, fires compact the soil, reducing its water infiltration capacity and increasing surface runoff, which in turn intensifies the loss of fertile soil (Camargo et al., 2008).

The chemical attributes of the Amazonian soil also play a crucial role in its stability. Different agricultural managements affect soil fertility and environmental quality, making it more or less susceptible to erosion. Monitoring human actions and the im- implementation of sustainable practices are essential to mitigate the impacts of degradation of the soil and preserve biodiversity (Costa, *et al.,* 2013). In addition to chemical attributes, physical and biological aspects of the soil directly influence its stability and productivity in agricultural and forestry systems. Factors such as soil structure, density, population volume, ros, acidity and microbial biomass are determinants of soil quality and sustainability. environmental (Frozzi *et al.,* 2018). Thus, adequate management, based on the understanding the use of these properties, favors the conservation of natural resources and prevents degradation of ecosystems.

Soil erosion occurs when these essential attributes are compromised, affecting negatively affecting the fertility and sustainability of production systems. This phenomenon does not become especially worrying in agricultural, forestry and pasture areas, where pra- Inadequate practices accelerate soil degradation, resulting in environmental impacts and significant economic factors (Soares *et al.,* 2018; Hassane, 2021). Therefore, understanding the in- fluency of soil attributes in erosion is fundamental for the development of strategies recovery measures that minimize negative impacts and promote conservation (Silva et al., 2016).

Amazonian soils, naturally poor in nutrients due to weathering and source material, depend on plant cover to maintain their fertility. The litter ra, a surface layer rich in organic matter, supports biodiversity and promotes cycling nutrient extraction through the action of insects, fungi and bacteria (Brito et al., 2020). However, therefore, deforestation compromises this balance, increasing the soil's susceptibility to erosion, raising its temperature due to the oxidation of organic matter and negatively affecting fauna (Sales, 2019). Inadequate management of Amazonian soil, including deforestation, ment, mining, burning and overgrazing, leads to the loss of vegetation cover and inten- sifies erosion processes. Intensive use of soil without planning reduces its fertility and alters its structure, accelerating degradation (Corrêa et al., 2010). Thus, understanding soil attributes and their relationship with sustainable management practices is essential to minimize to reduce losses and ensure the resilience of agricultural systems.

Soil texture, defined by the proportion of sand, silt and clay, directly influences its physical and biological properties. Porosity, for example, regulates retention and water flow, impacting its structural stability (Menezes et al., 2017). Thus, the assessment tion of these attributes is essential for the implementation of conservation practices that optimize the use of natural resources and avoid environmental degradation (Corrêa et al., 2010). The Soil organic matter (SOM) plays an essential role in maintaining soil fertility and sustainability of agroecosystems. Composed of living and dead microorganisms, residues In both plant and animal forms, MOS undergoes processes of deposition, decomposition and renewal, being directly influenced by the type of vegetation and management adopted (Silva, 2010; Costa et al., 2013).

The decline in organic matter, aggravated by inadequate agricultural practices, compromises affects the aggregation and consistency of the soil, making it more susceptible to erosion and reducing its resistance to penetration. In this sense, the application of organic material is an effective strategy. effective in improving soil fertility and reducing its degradation, promoting sustainability quality of production systems (Oliveira et al., 2016). In addition to directly influencing the structure soil structure, MOS increases its water retention capacity due to the high surface area ficial and electrical charges (Braida et al., 2011). Indirectly, it improves aggregation, consistency

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and structural stability of the soil, ensuring its conservation and sustainable use (Khorramdel et al., 2013).

The deposition of organic matter in Amazonian soils varies according to the type of vegetation. tation, geographical location and climatic conditions, being a determining factor for fertilization. quality and maintenance of forest ecosystems (Brito et al., 2020). However, degradation accelerated soil degradation in the Amazon, intensified by activities such as deforestation and burning results in the oxidation of organic matter and the expansion of erosive processes. In this context, the evaluation of physical and biological soil attributes under different ma- nejo is essential for the formulation of conservation strategies that guarantee sustainability nature of ecosystems and natural resources.

3.4 Socio-environmental impacts of soil erosion

Soil erosion in the Amazon causes significant socio-environmental impacts, affecting the environment and local communities. Soil degradation occurs through the removal of essential nutrients, reducing its fertility and making it difficult for vegetation to regenerate. Riverside communities face risks due to river silting and land loss. ras, compromising homes and livelihoods. The accumulation of sediments alters the flow rivers, creating obstacles to transportation and access to natural resources. In addition, the erosion contributes to the destruction of habitats, affecting local fauna and flora. Climatic events Extreme weather conditions, such as prolonged droughts and heavy rains, accelerate soil degradation, worsening addressing the problem (IPCC, 2023).

The impacts of erosion result from human intervention and population growth disorderly, which lead to deforestation and soil degradation. The loss of vegetation cover This compromises soil quality and reduces biodiversity, affecting ecosystem services. essential functions, such as climate regulation and water retention (Souza, 2018; Sales, 2019; Hassane, 2021). These changes directly impact ecosystems and local populations. piers, which depend on natural resources for their livelihood. Accelerated erosion is aggravated due to inadequate soil use, compromising its fertility and agricultural and forestry productivity. restal. This wear interferes with territorial occupation, water pollution and the balance ecological. Silting of watercourses and desertification are observed, both of which are detrimental to the productive capacity of agricultural and forest lands. In addition, changes in the landscape gem contribute to the extinction of plant and animal species, profoundly impacting the fauna and flora of the region (Campos et al., 2017).

The impacts of erosion can be analyzed in three dimensions: environmental, economic and social. In the environmental aspect, there is a loss of organic matter, reduction in water retention, intensification of silting of rivers and lakes and degradation of terrestrial and aquatic ecosystems. tics (Telles et al., 2009; Bertoni, 2014). In the economic sphere, erosion compromises the pro- agricultural productivity, increases production costs and makes land less suitable for cultivation. vo. In addition, it affects local infrastructure, making travel difficult and increasing expenses. with environmental recovery. Socially, erosion can cause landslides, destruction of infrastructure and rising prices of drinking water. These factors contribute for rural and urban exodus, promoting social disruption and economic imbalances regional (Guerra, 2014). In many cases, communities are forced to modify their habits tos and forms of organization, impacting their traditional cultures (Ferreira et al., 2015).

Faced with these challenges, it becomes essential to adopt sustainable and strategic management practices. environmental conservation strategies to reduce socioeconomic and ecological losses. The public awareness and adequate land use planning are essential to mitigate environmental degradation and ensure the sustainability of Amazonian ecosystems. cos (Silva et al., 2014; Vilhena, 2017). Respect for permanent preservation areas and search for sustainable alternatives plays a crucial role in mitigating the impacts of erosion and promoting sustainable development in the region.

3.5 Sustainable soil conservation practices

Soil conservation in the Amazon involves strategies that minimize soil degradation. physical, chemical and biological, ensuring its long-term sustainability. To this end, they are Three main categories of conservation practices are applied: vegetative, edaphic and me- canic (Pes *et al.,* 2017). Vegetative practices use native vegetation to protect the soil and minimize erosion by covering it with trees, foliage or plant residues, as well as play a crucial role in the recovery of degraded areas. Mechanical practices, in turn, they use artificial structures to reduce the speed of water flow, such as terraces, drainage channels and catchment basins, adapted to the specific characteristics cases in the region.

Soil management also includes edaphic techniques that preserve its structure and fertility. bility, avoiding harmful practices such as burning, which reduce organic matter and vol- latilize essential nutrients, such as nitrogen, compromising soil fertility (Lep- sch, 2002). Furthermore, when carried out frequently, they leave the soil exposed and more vulnerable. susceptible to erosion, making it essential to control or eliminate this procedure. To ensure To ensure satisfactory results in erosion control, several conservation practices must be applied simultaneously, considering environmental and socioeconomic aspects of each Amazon area (Filho et al., 2006).

The choice of these practices must take into account local characteristics, such as intensity and frequency of rainfall, water infiltration into the soil, terrain slope and composition of the vegetation. Thus, the implementation of sustainable management practices contributes significantly captively for the protection of the Amazon soil. Some of the main strategies include the creation of protected areas, such as the Sustainable Landscapes of the Amazon project, which promotes see the integrated management of ecosystems, strengthening conservation units and encouraging the sustainable use of natural resources.

Integrated landscape management, through ecological corridors and supply chains, lor linked to biodiversity, also helps in the preservation of soil and forest. In addition, the use of sustainable agricultural practices, such as agroforestry and the cultivation of native species, reduces environmental impacts, promotes biodiversity and increases resilience to climate change. matics, contributing to carbon sequestration and mitigation of greenhouse gas emissions greenhouse. Extractive reserves allow the sustainable exploitation of natural resources, interconnecting social development and environmental conservation.

Education and awareness, through initiatives of the Sustainable Amazon Foundation, table, strengthen local communities and promote projects that integrate environmental conservation such and quality of life. The recovery of degraded areas restores soil fertility and favors biodiversity, creating balanced natural habitats. Like Amazonian soils are usually poor in nutrients, their conservation must include physical, chemical and biological, in addition to considering the cultural practices of local producers. In this way, the pre-

Soil preservation is essential to maintain ecological balance and ensure a sustainable future. vel to the Amazon.

4. Final Considerations

This research sought to understand the socio-environmental impacts of soil erosion. soil in different management areas in the Brazilian Amazon, as well as identify practices sustainable soil conservation. Soil erosion represents an environmental problem, social and economic, considering the challenges and consequences associated with this phenomenon. In addition to natural factors, aspects such as deforestation, climate change and activities anthropogenic activities including mining, overexploitation of forest areas for timber extraction, deira and opening of pasture areas play a significant role in the degradation of the soil in the Amazon region.

Given this scenario, ensuring the conservation and sustainability of the Amazon biome becomes an urgent need. To this end, it is essential to strengthen monitoring programs monitoring of deforestation, burning, logging, mining and agriculture, in addition to ensuring environmental monitoring in a concrete, active and permanent manner. nent. With the acceleration of deforestation, the biome has been increasingly threatened and de- graded, becoming highly susceptible to erosion. In this sense, soil losses in areas of agricultural crops and pastures are directly influenced by the management system adopted, impacting the structure and functionality of the region's soils.

Therefore, it is crucial that Amazonian soils are monitored continuously and that conservation practices are implemented from the beginning of their use, in order to preserve its productive potential for future generations. To do this, it is necessary to carry out diagnostics environmental issues that allow the identification, characterization and mapping of the areas most vulnerable to erosion in the Amazon. Therefore, it is essential to develop zoning and formulation of public policies that guarantee the preservation of biodiversity, quality environmental land use and the sustainable development of the regional population, both in environmental and socioeconomic terms.

In addition to these measures, complementary studies are essential to obtain more detailed data. detailed information on the problems related to soil erosion in the Amazon. These studies help to prove the possible environmental impacts resulting from inappropriate use of the soil and provide a solid basis for effective conservation strategies. In this context, the implementation of sustainable management practices, such as agroforestry systems and recovery tion of degraded areas, can significantly help in reducing erosion and protecting of water resources.

The adoption of sustainable practices also promotes a series of benefits, such as increasing biodiversity, improving air and soil quality and increasing resilience agricultural development in the face of climate change. The integration of trees and agricultural crops into systems but agroforestry, for example, contributes to carbon sequestration, mitigating emissions. greenhouse gas emissions. At the same time, the recovery of degraded areas allows the restoration of soil fertility, in addition to creating habitats for local fauna, favoring a more balanced and healthy ecosystem.

Additionally, the involvement and awareness of local communities are factors are fundamental to the success of these initiatives, as they ensure that the solutions are adapted adapted to the cultural and socioeconomic realities of the region. Only through an effort collaborative and continuous it will be possible to preserve the natural wealth of the Amazon and ensure a sustainable future for all. Thus, it is concluded that sustainable conservation practices of the soil are essential to minimize the negative impacts of erosion in different areas management in the Brazilian Amazon. The preservation of soil and ecosystems depends on adoption of strategic and integrated measures, reinforcing the importance of environmental planning. ental to guarantee the sustainability of this territory, which is so rich and essential for the ecological balance. global logic.

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