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Territories in dispute in the Legal Amazon: Conservation, Fragmentation, and Drivers of Biodiversity Loss in Mato Grosso

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Resumo
O artigo discute a perda de biodiversidade na Amazônia Legal, com ênfase no estado de Mato Grosso, analisando como processos ecológicos e dinâmicas territoriais se articulam na produção de vulnerabilidades socioambientais. O problema de pesquisa centra-se em compreender de que maneira os “motores de perda” — diretos e indiretos — se expressam em um território marcado pela expansão agropecuária, conflitos fundiários e fragilidades institucionais de governança ambiental. O objetivo do estudo é examinar como a fragmentação de habitats, a ruptura da conectividade ecológica e hidrológica e a pressão sobre terras indígenas e unidades de conservação convergem para aprofundar a perda da biodiversidade em escala regional. O referencial teórico mobiliza autores da ecologia da paisagem, biologia da conservação e estudos socioambientais, articulando conceitos como biodiversidade, conectividade ecológica, fragmentação e diversidade biocultural. A metodologia integra revisão bibliográfica, análise documental e indicadores oficiais, permitindo uma leitura multiescalar dos processos de degradação. Os resultados apontam que Mato Grosso constitui uma fronteira crítica da perda de biodiversidade, onde desmatamento acelerado, incêndios, expansão das *commodities*, contaminação hídrica e pressões sobre territórios indígenas produzem um sistema integrado de degradação. Evidencia-se que a crise ambiental não decorre apenas de fatores ecológicos, mas de escolhas políticas que subordinam a conservação a modelos produtivos intensivos, comprometedores da conectividade e da resiliência socioecológica regional.

Palavras–chave: Biodiversidade. Conectividade ecológica. Mato Grosso.

Territories in Dispute in the Legal Amazon: Conservation, Fragmentation, and Drivers of Biodiversity Loss in Mato Grosso

Abstract

The article examines biodiversity loss in the Legal Amazon, with emphasis on the state of Mato Grosso, analyzing how ecological processes and territorial dynamics intersect in the production of socio-environmental vulnerabilities. The research problem focuses on understanding how "drivers of loss" — both direct and indirect — manifest in a territory marked by agricultural expansion, land conflicts, and institutional weaknesses in environmental governance. The objective of the study is to assess how habitat fragmentation, the disruption of ecological and hydrological connectivity, and pressures on Indigenous lands and protected areas converge to intensify biodiversity loss at a regional scale. The theoretical framework draws on authors from landscape ecology, conservation biology, and socio-environmental studies, articulating concepts such as biodiversity, ecological connectivity, fragmentation, and biocultural diversity. The methodology integrates bibliographic review, document analysis, and official indicators, enabling a multiscalar interpretation of degradation processes. The findings indicate that Mato Grosso represents a critical frontier of biodiversity loss, where accelerated deforestation, wildfires, commodity expansion, water contamination, and pressures on Indigenous territories form an integrated system of degradation. The study shows that the environmental crisis arises not only from ecological factors, but from political decisions that subordinate conservation to intensive production models, undermining connectivity and regional socioecological resilience.

Keywords: Biodiversity. Ecological connectivity. Mato Grosso.

Territorios em Disputa en la Amazonía Legal: Conservación, Fragmentación y Motores de Pérdida de la Biodiversidad en Mato Grosso

Resumen

El artículo analiza la pérdida de biodiversidad en la Amazonía Legal, con énfasis en el estado de Mato Grosso, examinando cómo los procesos ecológicos y las dinámicas territoriales se articulan en la producción de vulnerabilidades socioambientales. El problema de investigación se centra en comprender de qué manera los "motores de pérdida" —directos e indirectos— se expresan en un territorio marcado por la expansión agropecuaria, los conflictos por la tierra y las debilidades institucionales de la gobernanza ambiental. El objetivo del estudio es evaluar cómo la fragmentación de hábitats, la ruptura de la conectividad ecológica e hidrológica y la presión sobre tierras indígenas y áreas protegidas convergen para profundizar la pérdida de biodiversidad a escala regional. El marco teórico moviliza autores de la ecología del paisaje, la biología de la conservación y los estudios socioambientales, articulando conceptos como biodiversidad, conectividad ecológica, fragmentación y diversidad biocultural. La metodología integra revisión bibliográfica, análisis documental e indicadores oficiales, permitiendo una lectura multiescalar de los procesos de degradación. Los resultados señalan que Mato Grosso constituye una frontera crítica de pérdida de biodiversidad, donde la deforestación acelerada, los incendios, la expansión de las *commodities*, la contaminación hídrica y las presiones sobre territorios indígenas producen un sistema integrado de degradación. El estudio evidencia que la crisis ambiental no resulta únicamente de factores ecológicos, sino de decisiones políticas que subordinan la conservación a modelos de producción intensiva, comprometiendo la conectividad y la resiliencia socioecológica regional.

Palabras clave: Biodiversidad. Conectividad ecológica. Mato Grosso.

1 Introduction

Global biodiversity loss is one of the most pressing challenges of the twenty-first century, resulting from anthropogenic processes that transform complex ecosystems into homogeneous landscapes oriented toward commodity production. According to IPBES (2020), land-use change, intensive resource exploitation, pollution, climate change, and invasive species constitute a global system of degradation that combines ecological pressures with political choices.

In Brazil, these processes acquire particular significance in the Amazon, a territory historically shaped by land disputes, socio-environmental conflicts, and tensions among different knowledge systems. The Legal Amazon, of which Mato Grosso constitutes a strategic portion, has become simultaneously a frontier of agricultural expansion and a space of resistance for Indigenous peoples and traditional communities. In this region, conserving biodiversity also means confronting territorial inequalities and power asymmetries that structure frontier expansion.

The Amazonian socioecological crisis should also be understood as a consequence of the failure to fulfill the international commitments established under the 2030 Agenda. The degradation observed in Mato Grosso affects targets related to SDG 15 (Life on Land), particularly biodiversity protection and ecosystem restoration; SDG 13 (Climate Action), through emissions associated with land-use change; and SDG 6 (Clean Water and Sanitation), through impacts on hydrological connectivity. Integrating ecological analysis with the Sustainable Development Goals (SDGs) makes it possible to assess not only habitat loss but also its consequences for water security, ecosystem services, and territorial rights—dimensions that are essential for public policies aligned with sustainable development (United Nations, 2025; MapBiomas, 2025).

Ecological connectivity emerges, in this context, as a key analytical framework for understanding the relationship between fragmentation, land use, and socioecological processes. The literature has emphasized that measuring protected areas alone is insufficient; rather, the spatial configuration of landscapes, their permeability, and the genetic and hydrological flows circulating through them determine the persistence of life (Fahrig, 2003; Haddad et al., 2015). In the Amazon, these processes are intertwined with land conflicts, the criminalization of local leaders, and pressures on Indigenous territories, demonstrating that connectivity and fragmentation are also political issues.

The gap between international commitments, such as the Sustainable Development Goals (SDGs) of the 2030 Agenda, and concrete territorial practices reveals important limitations in environmental governance. The expansion of monoculture plantations, large-scale infrastructure projects, and illegal activities contrasts sharply with sustainability discourses and reinforces mechanisms that generate socio-environmental inequalities. In Amazonian territories, this contradiction is particularly evident: areas essential for conservation remain under intense pressure, revealing that ecological processes cannot be dissociated from social dynamics and territorial disputes.

This article analyzes the mechanisms driving biodiversity loss, with a particular emphasis on ecological connectivity, applying this approach to the case of Mato Grosso—a territory where the Amazon, Cerrado, and Pantanal biomes overlap and where intensive agricultural expansion has produced one of the most critical scenarios of environmental degradation in Brazil. The methodology combines a literature review, documentary analysis, and official data sources (ICMBio, 2018; IPBES, 2020; IBGE, 2022), as well as recent studies on deforestation, forest fragmentation, and pressures on Indigenous lands.

The main contribution of this study is to demonstrate that biodiversity loss results not only from technical shortcomings but also from political choices that subordinate conservation to the interests of the agro-export economy. By situating Mato Grosso within the broader context of contemporary Amazonian territorial disputes, the article seeks to highlight how ecology, politics, and territorial conflicts intersect in the production of socioecological vulnerabilities.

2 Methodology

This study is characterized as a qualitative, exploratory, bibliographic, and documentary research. This approach was adopted based on the understanding that biodiversity loss is a complex phenomenon resulting from the interaction of ecological, economic, political, and territorial processes, whose analysis requires an integrated and contextualized perspective. According to Minayo (2014), qualitative research enables the understanding of socially constructed relationships, processes, and meanings, allowing the interpretation of phenomena that cannot be reduced exclusively to quantitative indicators. Complementarily, Gil (2008) emphasizes that exploratory research seeks to broaden the understanding of a given problem, contributing to the development of more consistent interpretations of the investigated reality.

The study was developed through a systematic literature review focusing on biodiversity, land-use change, ecological connectivity, landscape fragmentation, environmental conservation, territorial governance, and sustainability. The bibliographic review concentrated on scientific articles indexed in the Scopus, Web of Science, SciELO, and CAPES Periodicals databases, as well as books, technical reports, and institutional publications. Priority was given to works published between 2000 and 2025, selected according to criteria of conceptual relevance, academic recognition, and alignment with the research objectives. The descriptors used included biodiversity, ecological connectivity, hydrological connectivity, landscape fragmentation, Legal Amazon, environmental conservation, Indigenous territories, and territorial development. According to Severino (2017), bibliographic research constitutes a fundamental procedure for scientific knowledge production, as it enables the identification, analysis, and interpretation of existing contributions on a given subject, supporting the construction of analytical and critical frameworks.

In addition to the literature review, documentary research was conducted based on national and international official sources related to biodiversity conservation and environmental monitoring. Reports, databases, and institutional documents produced by organizations such as the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), the Convention on Biological Diversity (CBD), the Brazilian Institute of Geography and Statistics (IBGE), the Chico Mendes Institute for Biodiversity Conservation (ICMBio), the National Institute for Space Research (INPE), the Brazilian Foundation for Sustainable Development (FBDS), as well as environmental legislation and documents associated with the 2030 Agenda and the Sustainable Development Goals (SDGs), were consulted. According to Cellard (2008), documentary analysis represents an important methodological strategy for understanding social, environmental, and territorial phenomena, as it provides access to records produced in different institutional and historical contexts.

The spatial focus of the investigation was the state of Mato Grosso, considering its strategic relevance for Brazilian biodiversity conservation and its simultaneous location within the Amazon, Cerrado, and Pantanal biomes. The selection of this state is justified by the intensification of agricultural expansion, conversion of native vegetation cover, habitat fragmentation, and increasing pressure on protected areas observed over recent decades, making it a representative territory for analyzing the drivers of biodiversity loss in the Legal Amazon. From this perspective, the territorial approach adopted is grounded in the understanding that socio-environmental conflicts are produced through the interactions among society, nature, and power, as discussed by Haesbaert (2014), Porto-Gonçalves (2006), and Leff (2001).

The collected data were subjected to interpretative and critical analysis, integrating ecological, territorial, and institutional information. The interpretation of socio-environmental indicators was guided by a socioecological and multiscalar perspective, seeking to identify relationships among deforestation, landscape fragmentation, loss of ecological connectivity, expansion of economic activities, and pressures on Indigenous lands and protected areas. The analysis was structured through the articulation of sustainability frameworks, political ecology, and territorial studies, enabling an understanding of the factors that condition environmental degradation and the limitations of conservation strategies in contexts marked by the expansion of economic frontiers into natural areas.

3 Theoretical Framework

Understanding the contemporary biodiversity crisis requires an integrated perspective on the ecological, spatial, and hydrological processes that sustain life within ecosystems. The literature demonstrates that biodiversity, understood as genetic, species, and ecosystem variability, constitutes the foundation of ecosystem functions and socioecological resilience. Its conservation is not limited to the intrinsic value of life itself but also involves the maintenance of essential ecosystem services, including climate regulation, nutrient cycling, water purification, and soil fertility, whose degradation directly threatens the sustainability of human societies (MEA, 2005; IPBES, 2020).

In the Amazonian context, however, these biophysical processes are intertwined with territorial dynamics, land disputes, and diverse knowledge systems. Biodiversity is not merely a natural attribute but the result of historical interactions among Indigenous peoples, traditional communities, and forest ecosystems. Management practices such as shifting cultivation, controlled use of fire, biodiverse farming systems, artisanal fishing, and agroforestry arrangements have shaped distinctive ways of producing and conserving life. Therefore, understanding the biodiversity crisis also requires recognizing the erosion of biocultural diversity and the loss of livelihoods that sustain ecological cycles throughout the Amazon.

Within this perspective, the concept of ecological connectivity emerges as a central framework in conservation biology and landscape ecology. More than a cartographic attribute, connectivity refers to the capacity of landscapes to maintain flows of organisms, genes, energy, and water among different habitats, thereby supporting fundamental ecological processes. The distinction between structural and functional connectivity enables the understanding of both the physical configuration of landscapes and the effectiveness of the flows that traverse them, integrating spatial, ecological, and political dimensions of analysis (Taylor et al., 1993; IUCN, 2020).

In the Amazon, however, ecological connectivity depends not only on landscape morphology but also on the territorial integrity of Indigenous peoples and traditional communities, who act as custodians of these ecological flows. Indigenous lands and collectively managed territories maintain higher levels of forest continuity and function as large-scale ecological corridors, despite increasing pressures from land grabbing, illegal mining, and agricultural expansion. Consequently, connectivity is simultaneously an ecological and political issue, as its maintenance is closely linked to the protection of territorial rights and the preservation of livelihoods that sustain landscape integrity.

The erosion of these flows is critically manifested through habitat fragmentation, a phenomenon extensively discussed in ecological literature. Unlike habitat loss alone, fragmentation alters the spatial structure of landscapes by promoting isolation, edge effects, and the collapse of population dynamics. By intensifying demographic, genetic, and environmental vulnerabilities, fragmentation compromises gene flow, species dispersal, and natural regeneration processes, thereby increasing the risk of local and regional extinctions (Fahrig, 2003; Haddad et al., 2015).

These processes are compounded by the dimension of hydrological connectivity, which is essential for continental aquatic ecosystems. Defined as the longitudinal, lateral, and vertical continuity of water, nutrient, and organism flows, hydrological connectivity ensures the ecological integrity of rivers, floodplains, and wetlands (Ward et al., 2002). The disruption of this connectivity, frequently caused by dams, river channel modification, and wetland conversion, compromises biogeochemical cycles and fish reproduction, affecting food webs and traditional livelihoods (Castello & Macedo, 2015; Grill et al., 2019).

In the Amazon and Pantanal regions, the loss of hydrological connectivity is not only an ecological problem but also a social one, as it directly affects riverine populations, artisanal fishers, and communities whose livelihoods depend on seasonal water cycles. Changes in hydrological regimes impact cultural practices, food security, and the continuity of socioecological systems that have sustained life in fluvial territories for centuries.

Accordingly, the theoretical framework underpinning this study is structured around four interdependent pillars—biodiversity, ecological connectivity, habitat fragmentation, and hydrological connectivity—which together provide a comprehensive understanding of the ecological and socio-environmental processes shaping contemporary landscapes. This integrated perspective offers the analytical basis for examining the drivers of biodiversity loss and their manifestations in specific territorial contexts, such as the case of Mato Grosso discussed in the following sections.

By integrating ecological dimensions with territorial dynamics and local knowledge systems, it becomes possible to understand the Amazon as a contested space between competing visions of the future: one associated with the expansion of economic frontiers and another rooted in the continuity of community-based practices, the plurality of knowledge systems, and the defense of the forest as a living territory.

3.1 Biodiversity and Ecosystem Functions

Biodiversity constitutes the foundation of natural systems and human societies, encompassing genetic, species, and ecosystem variability. According to the Convention on Biological Diversity (CBD), biodiversity is defined as the variability among living organisms from all sources, including, inter alia, terrestrial, marine, and aquatic ecosystems and the ecological complexes of which they are part (Brazil, 2000). This multidimensional conception extends the notion of diversity beyond species inventories, incorporating habitat heterogeneity and the complexity of ecological interactions.

Conceptually, the maintenance of biological diversity and spatial connectivity supports ecosystem services that are reflected in specific targets of the 2030 Agenda, including the restoration of terrestrial ecosystems (Target 15.1), the reduction of pressures on habitats (Target 15.5), and the integration of ecosystem services into planning and decision-making processes (Target 15.9). The theoretical literature on socioecological resilience (SDSN, 2025) provides a framework for linking connectivity and fragmentation metrics to Sustainable Development Goal (SDG) indicators, making it possible to translate ecological outcomes into tools for monitoring public policies.

The importance of biodiversity lies not only in the intrinsic value of life itself but also in the ecosystem services it sustains. As emphasized by Costanza et al. (1998)

and the Millennium Ecosystem Assessment (MEA, 2005), biological diversity underpins essential functions such as nutrient cycling, climate regulation, pollination, water purification, and soil fertility maintenance. These services constitute the invisible infrastructure that supports human well-being and ensures the stability of productive, agricultural, and urban systems. Consequently, biodiversity loss directly affects quality of life, economic development, and environmental security.

However, biodiversity is highly vulnerable to anthropogenic pressures. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2020) estimates that approximately one million species are threatened with extinction due to factors such as land-use change, pollution, invasive alien species, overexploitation, and climate change. The decline in biological diversity weakens the adaptive capacity of ecosystems to respond to environmental disturbances, increasing the likelihood of ecological collapse.

The literature further demonstrates that biodiversity is closely linked to socioecological resilience. According to Folke et al. (2004), systems characterized by greater diversity exhibit a higher capacity to absorb shocks, reorganize, and maintain essential functions. This occurs because functional redundancy—the presence of multiple species performing similar ecological roles—provides an ecological "safety net" capable of buffering disturbances. In contrast, simplified and homogeneous ecosystems, often resulting from intensive agricultural practices or unplanned urbanization, become more vulnerable to extreme events such as prolonged droughts, wildfires, and floods.

Socioecological resilience also depends on the interaction between biological diversity and cultural diversity. Traditional knowledge systems, Indigenous practices, and community-based forms of natural resource management represent historical strategies for adapting to environmental variability. In this regard, Toledo and Barrera-Bassols (2008) advance the concept of *biocultural diversity*, emphasizing that biodiversity conservation cannot be separated from the protection of the peoples and cultures that have historically maintained it. This perspective reinforces the understanding that biodiversity loss is not solely an ecological issue but also a social, political, and ethical one.

From this perspective, biodiversity plays a structuring role in maintaining ecosystem functions and socioecological resilience. Its erosion compromises both ecological balance and the sustainability of human societies, requiring integrated conservation strategies that articulate scientific knowledge, public policies, and local knowledge systems.

3.2 Ecological Connectivity

The concept of ecological connectivity has emerged as one of the most relevant analytical frameworks in landscape ecology and conservation biology, serving as a direct counterpoint to the effects of habitat fragmentation and habitat loss. Broadly defined, connectivity refers to the capacity of a landscape to maintain vital ecological flows—including organisms, genes, energy, water, and matter—

across space and time, thereby ensuring biodiversity persistence and socioecological resilience. According to Taylor et al. (1993), connectivity represents a key attribute of landscape structure and function, linking distinct spatial and temporal scales.

Structural connectivity refers to the way landscape elements are spatially arranged, forming a network of habitat patches, corridors, and matrix components (Forman & Godron, 1986). It is therefore a cartographic and morphological category that can be quantified through metrics such as patch size and isolation, corridor density, and edge proportion. Patches correspond to relatively homogeneous habitat areas whose minimum viable size is directly associated with the maintenance of reproductive populations. Corridors function as pathways for faunal movement and plant dispersal, reducing genetic isolation and facilitating seasonal migrations. The matrix, in turn, represents the dominant landscape element, whose permeability largely determines the intensity of ecological flows. Homogeneous matrices, such as intensive monocultures or densely urbanized areas, tend to act as barriers, whereas agroecological or forested mosaics function as permeable filters (Antongiovanni & Metzger, 2005). In this sense, structural connectivity provides a static perspective related to landscape morphology and its potential capacity to maintain ecological linkages; however, its effectiveness can only be fully understood when integrated with the functional dimension of connectivity.

Functional connectivity extends beyond spatial description by incorporating effective ecological dynamics—that is, the actual capacity of organisms, genes, and material flows to move across the landscape. Different species respond differently to the same spatial configuration: for a seed-dispersing bird, an agricultural matrix may be permeable, whereas for a small mammal it may constitute an insurmountable barrier (With, Gardner, & Turner, 1997). This dimension is particularly evident in the maintenance of genetic variability, as population isolation reduces gene flow, increases inbreeding, and compromises long-term demographic viability (Frankham, Ballou, & Briscoe, 2010). Functional connectivity is also reflected in processes of colonization, migration, and seasonal movement, which depend on the existence of effective dispersal routes and may result in ecological traps when organisms are attracted to hostile environments. In aquatic systems, functional connectivity encompasses longitudinal, lateral, and vertical dimensions, whose disruption through dams, channelization, or river modification alters nutrient cycling and destabilizes trophic networks (Ward et al., 2002). This perspective demonstrates that functional connectivity is fundamentally relational and process-oriented, depending both on species ecology and on the permeability of different land-use systems.

Recent literature emphasizes that ecological connectivity should be understood not only as a biophysical issue but also as a socioecological and political category. According to the International Union for Conservation of Nature (IUCN, 2020), conserving connectivity requires consideration of institutional contexts, anthropogenic pressures, and territorial conflicts, since ecological corridors and landscape mosaics frequently extend across agricultural lands, urban areas, and Indigenous territories. In this sense, connectivity is simultaneously a scientific and governance challenge, requiring the redesign of landscapes in ways that reconcile conservation, production, and socio-environmental justice.

Thus, structural connectivity provides the cartographic potential for linking habitat fragments, whereas functional connectivity expresses the ecological reality of these flows. The integration of both dimensions enables a deeper understanding of how fragmented landscapes can be redesigned to sustain biodiversity and ecosystem functions while simultaneously revealing the constraints imposed by economic and territorial models based on habitat homogenization and isolation. Ecological connectivity therefore constitutes both an interpretative and normative framework for conservation across multiple scales and is indispensable for addressing biodiversity crises in the Anthropocene.

3.3 Habitat Fragmentation

Habitat fragmentation is one of the most extensively debated processes in landscape ecology and conservation biology due to its central role in explaining global biodiversity decline. As argued by Fahrig (2003), habitat loss refers to the absolute reduction in the area of natural cover available to species, whereas fragmentation corresponds to the transformation of a continuous habitat into smaller, more isolated, and spatially separated patches, thereby altering the spatial relationships that sustain ecological flows.

This distinction is important because habitat loss and habitat fragmentation produce different ecological effects. Habitat loss directly reduces the availability of resources and living space for species, whereas fragmentation modifies the spatial structure of landscapes, influencing connectivity, population dynamics, and ecosystem stability. Consequently, habitat loss may occur without fragmentation, as in the case of a uniform reduction of habitat area, while fragmentation may occur without substantial habitat loss when the same proportion of habitat is subdivided into smaller patches, increasing isolation among them.

One of the most significant phenomena associated with fragmentation is the so-called edge effect. As habitat patches become smaller, the proportion of peripheral areas relative to core habitat increases. Within these edge zones, environmental conditions such as light availability, temperature, humidity, and wind exposure are altered, creating microclimatic conditions that favor opportunistic species while disadvantaging habitat specialists (Didham & Ewers, 2012). In addition, edge environments intensify processes such as biological invasions, predation pressure, and human disturbance, thereby increasing ecological vulnerability.

Fragmentation also affects population dynamics. Metapopulation theory, originally proposed by Levins (1969), conceptualizes populations as systems of subpopulations distributed across different habitat fragments and interconnected through dispersal processes. Within this framework, species persistence depends on the balance between local extinctions and recolonization events. When connectivity is disrupted, recolonization rates decline and the probability of local extinctions increases, potentially leading to regional population collapse.

These dynamics are further compounded by stochastic vulnerabilities. Demographic vulnerabilities arise from random fluctuations in birth and mortality rates within small populations; environmental vulnerabilities result from climatic disturbances or extreme events that disproportionately affect isolated fragments; and genetic vulnerabilities emerge from population isolation, which increases inbreeding and reduces the genetic variability required for adaptation (Frankham, Ballou, & Briscoe, 2010). Together, these factors demonstrate that small and fragmented populations are particularly vulnerable, even when apparently suitable habitat remains available.

According to Haddad et al. (2015), fragmentation directly compromises the ecological flows that sustain biodiversity. The isolation of habitat patches reduces gene flow, promoting genetic drift and the erosion of intraspecific diversity. The movement of organisms—including migration, seed dispersal, and pollination—becomes increasingly restricted, limiting reproductive processes and natural regeneration. Furthermore, hydrological and energy flows are disrupted when riparian corridors are degraded, impairing nutrient cycling and altering trophic interactions. The loss of these flows compromises not only population viability but also the functional integrity of landscapes, thereby increasing the risk of local and regional extinctions.

Habitat fragmentation should therefore be understood as a multidimensional process that extends beyond the simple reduction of habitat area. Its effects combine spatial, demographic, genetic, and functional alterations that undermine ecosystem resilience and expose species to increasing risks of extinction. In landscapes subjected to intense anthropogenic pressures, such as the Amazon, Cerrado, and Pantanal biomes, fragmentation constitutes a critical driver of socioecological vulnerability, requiring conservation policies that integrate structural and functional connectivity with territorial governance.

3.4 Hydrological Connectivity

In continental aquatic ecosystems, connectivity is a fundamental attribute for maintaining ecological integrity, as it expresses the spatial and temporal continuity of water, organism, sediment, and nutrient flows that sustain life in riverine and wetland environments. Unlike connectivity in terrestrial ecosystems, which is primarily defined by the spatial arrangement of habitat patches, corridors, and matrices, hydrological connectivity is inherently multidimensional, integrating longitudinal, lateral, and vertical relationships that ensure the dynamic functioning of aquatic systems (Ward et al., 2002).

The longitudinal dimension refers to continuity along the upstream–downstream axis, ensuring that water, organisms, and organic matter can move freely throughout river networks. This dimension is particularly important for long-distance migratory fish species, such as the dourado (*Salminus brasiliensis*), which depend on river integrity to complete their reproductive cycles. When this flow is interrupted by dams and other barriers, longitudinal connectivity is disrupted, preventing migration, reducing genetic variability within populations, and compromising the resilience of aquatic ecosystems (Dagosta et al., 2024).

Lateral connectivity, in turn, refers to the exchange processes between river channels and their adjacent floodplains. This interaction ensures nutrient renewal, the formation of temporary habitats, and the reproduction of both aquatic and terrestrial species in seasonally flooded environments. In the Pantanal, for example, periodic flooding expands the availability of feeding and breeding areas, transforming floodplains into highly productive natural nurseries. The loss of wetlands, the construction of levees, and the unplanned occupation of riverbanks drastically reduce this connectivity, impoverishing biodiversity and increasing socioecological vulnerability (Junk et al., 2012).

The vertical dimension complements this framework by describing the interactions between surface waters and groundwater systems, including exchanges with aquifers and the atmosphere. Vertical connectivity contributes to the thermal and chemical regulation of aquatic environments, influencing processes such as oxygenation, pollutant dilution, and groundwater recharge. The degradation of this dimension, often associated with groundwater depletion, urban surface sealing, or sedimentation of water bodies, compromises water quality and reduces the resilience of aquatic systems to extreme climatic events.

The disruption of these three dimensions of hydrological connectivity represents one of the most significant contemporary environmental threats. Studies indicate that more than 60% of the world's large rivers are fragmented by dams (Grill et al., 2019), a condition that compromises not only fish migration cycles but also broader ecological processes, including sediment transport, floodplain fertilization, and the maintenance of artisanal fisheries. In Brazil, this scenario is particularly concerning, as the expansion of hydropower infrastructure in the Amazon and the intensification of agricultural activities across the Cerrado and Pantanal floodplains have accelerated the erosion of hydrological connectivity (Castello & Macedo, 2015). Furthermore, the loss of wetlands—which function as climate regulators and important carbon sinks—intensifies the risk of socioecological collapse under conditions of global climate change.

Hydrological connectivity should therefore be understood as a complex and interdependent system in which the loss of continuity in one dimension generates cascading effects across the others, producing consequences for both biodiversity and human populations. Its conservation requires integrated strategies that combine hydrological planning, the maintenance of aquatic corridors, and wetland management, recognizing that the protection of fish diversity and ecosystem services depends on preserving these vital flows across multiple scales. More than a biophysical concept, hydrological connectivity constitutes a normative and political framework that is essential for rethinking the relationships among conservation, water infrastructure, and socio-environmental justice.

4 Drivers of Biodiversity Loss

Understanding the contemporary ecological crisis requires not only the analysis of the effects of habitat reduction and fragmentation but also the identification of the structural factors that drive biodiversity loss across multiple scales. The concept of *drivers of biodiversity loss* refers to the processes that act as underlying forces of environmental transformation. These drivers may be direct, when they immediately affect species and ecosystems, or indirect, when they operate through economic, institutional, and cultural systems (MEA, 2005; ICMBio, 2018; IPBES, 2020; IBGE, 2022).

In the Amazonian context, these drivers are not merely ecological forces but also expressions of territorial disputes, power relations, and competing land-use models. Biodiversity loss therefore results not only from direct impacts on habitats but also from historical processes of colonization, the expansion of economic frontiers, land conflicts, and the systematic marginalization of Indigenous and community-based knowledge systems that have traditionally regulated landscape management.

The IPBES Global Assessment Report (2020) consolidated this perspective by identifying the principal drivers of biodiversity loss at the global scale and emphasizing that these factors do not operate independently. Rather, they interact synergistically, producing cumulative and self-reinforcing effects. Likewise, in Brazil, official institutions such as the Chico Mendes Institute for Biodiversity Conservation (ICMBio, 2018) and the Brazilian Institute of Geography and Statistics (IBGE, 2022) have demonstrated how these global drivers manifest in distinct ways across national biomes, shaped by historical patterns of territorial occupation, social inequalities, and development models based on the intensive exploitation of natural resources.

In the Brazilian Legal Amazon, these drivers assume specific characteristics. Land-use change is associated with the rapid expansion of the agricultural frontier, the illegal appropriation of public lands (*land grabbing*), the expansion of mining activities, and increasing pressures on Indigenous territories and protected areas. These dynamics connect global economic interests with local power structures, intensifying socio-environmental conflicts and violence against leaders and communities who advocate alternative models of land management and coexistence with the forest.

Accordingly, the analysis of biodiversity loss drivers developed in this study is organized into two complementary dimensions. The first, operating at the global scale, examines the structural processes shaping the current pattern of biodiversity erosion worldwide, as identified by IPBES (2020). The second, operating at the national scale, discusses how these drivers materialize within the Brazilian territory based on data from ICMBio (2018) and IBGE (2022), with particular emphasis on the critical situations observed in the Atlantic Forest, Cerrado, and Caatinga biomes, as well as the growing vulnerability of aquatic ecosystems.

This approach seeks to demonstrate that, although the biodiversity crisis is global in nature, it manifests locally through specific dynamics and impacts that require differentiated conservation policies. Understanding these drivers is therefore essential not only for explaining biodiversity decline but also for designing governance strategies capable of addressing the socioecological, territorial, and political dimensions that underlie contemporary environmental change.

4.1 Global Scale

The biodiversity crisis at the planetary scale has been extensively documented by international scientific organizations, particularly by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2020). Its Global Assessment Report provides an unprecedented synthesis of the principal drivers of biodiversity loss, distinguishing between direct and indirect factors that operate synergistically across multiple scales, contributing to an unprecedented erosion of life on Earth.

Among the direct drivers, five are identified as having the greatest impact. The first is land- and sea-use change, including deforestation, agricultural expansion, urbanization, and the conversion of natural ecosystems into homogeneous landscapes. These processes reduce habitat extent and connectivity, intensify fragmentation, and compromise ecosystem functions. The second driver is the direct exploitation of organisms, manifested through overfishing, unsustainable hunting, logging, and wildlife trafficking, all of which place increasing pressure on already vulnerable populations and accelerate the loss of genetic diversity.

The third driver is pollution, which takes multiple forms, including the intensive use of agrochemicals, contamination by heavy metals, nutrient enrichment leading to eutrophication of water bodies, and plastic pollution in marine environments. The fourth driver is climate change, whose impacts on biodiversity are increasingly well documented. These impacts include shifts in precipitation patterns, rising global temperatures, ocean acidification, and the increasing frequency and intensity of extreme events, all of which reshape ecosystems and threaten the survival of sensitive species. Finally, the introduction of invasive alien species constitutes an additional driver of biodiversity erosion, as these organisms alter ecological interactions, compete with native species, spread diseases, and disrupt trophic dynamics when introduced into new environments.

Indirect drivers are equally important and relate to the underlying structures that shape ecological processes. IPBES (2020) identifies global governance systems and prevailing patterns of production and consumption among the most significant. Environmental governance in many contexts has proven insufficient to restrain the economic and political forces driving environmental degradation, whether due to weak regulatory frameworks or the capture of public policies by sectoral interests. At the same time, economic systems oriented toward unlimited growth and intensified international trade promote the expansion of global commodity chains—including soybeans, beef, timber, and mineral resources—which translate into local pressures on ecosystems and communities.

The distinction between direct and indirect drivers is primarily analytical, as in practice they operate through interconnected and mutually reinforcing mechanisms. Land-use change, for example, is driven by global consumption demands and by weaknesses in governance institutions, while climate change amplifies the effects of pollution and habitat fragmentation. Although deforestation in the Brazilian Amazon declined by 18% in June 2025, the state of Mato Grosso experienced a significant increase in environmental degradation, partly associated with wildfire activity. In contrast, the Pantanal recorded a 72% reduction in vegetation suppression alerts, while the Cerrado registered a 20% decline in deforestation alerts (INPE, 2025). The result is a systemic scenario of ecological deterioration in which biodiversity is simultaneously exposed to multiple and interacting threats.

Against this backdrop, IPBES (2020) concludes that biodiversity loss is not merely an ecological phenomenon but also a civilizational challenge rooted in political, economic, and cultural choices. Understanding the drivers of biodiversity loss at the global scale therefore requires recognizing that the current crisis is the product of unequal relationships between society and nature, structured by development models that prioritize capital accumulation over ecological sustainability and socio-environmental justice.

4.2 National Scale (Brazil)

In the Brazilian context, the biodiversity crisis manifests itself in an even more complex manner due to the country's vast territorial extent and the overlap of highly diverse biomes. Through its Ecosystem Accounts, the Brazilian Institute of Geography and Statistics (IBGE, 2022) provides evidence that Brazil continues to lose natural vegetation cover at an alarming rate, particularly in areas affected by agricultural expansion and urban pressure. These findings corroborate analyses conducted by the Chico Mendes Institute for Biodiversity Conservation (ICMBio, 2018), which identified a significant increase in the number of threatened species compared with previous assessments. Together, these studies indicate that although Brazil is recognized as one of the most megadiverse countries in the world, it faces a severe and growing biodiversity crisis.

In the Brazilian Legal Amazon, these trends assume particularly critical dimensions. The loss of natural vegetation is directly associated with the expansion of the agricultural frontier, the illegal appropriation of public lands (*land grabbing*), mining activities, and increasing pressures on Indigenous territories and protected areas. These processes demonstrate that biodiversity loss in the region is inseparable from territorial disputes, rural violence, and the historical marginalization of traditional knowledge systems that have long guided forest management practices.

Among Brazil’s major biomes, three deserve particular attention because of the severity of their current condition. The Atlantic Forest, the biome subjected to the longest history of intensive occupation, currently retains less than 12% of its original vegetation cover in highly isolated fragments. This situation has resulted in the loss of ecosystem functions and has placed considerable pressure on endemic species, many of which are included in national threatened-species lists. The Cerrado, recognized as the most biodiverse savanna in the world, faces an equally alarming scenario. According to IBGE (2022), more than 50% of its native vegetation has already been converted, primarily for agricultural expansion and commodity production. This reduction in vegetation cover compromises ecological connectivity, weakens hydrological processes, and threatens key species adapted to savanna environments. The Caatinga, in turn, faces distinct pressures. In addition to degradation caused by deforestation and human-induced desertification, this semi-arid biome is highly vulnerable to climate change. Characterized by high levels of endemism, its flora and fauna are increasingly affected by irregular precipitation patterns and the overexploitation of natural resources, making it one of the Brazilian biomes most sensitive to rising global temperatures.

Although discussed in greater detail elsewhere in this study, the Amazon represents a singular case within the national panorama. Biodiversity loss in the region is closely linked to the expansion of illegal activities—including deforestation, logging, gold mining, and large-scale mineral extraction—as well as to the intensification of land conflicts that undermine Indigenous territories and traditional ways of life. Environmental degradation in this biome therefore results from the persistent tension between economic development models and Indigenous and community-based forms of forest management.

At the same time, the growing vulnerability of Brazil's aquatic ecosystems further illustrates the severity of the biodiversity crisis. Rivers, lakes, marshes, palm wetlands (*veredas*), and other wetland ecosystems are increasingly threatened by hydropower development, sedimentation, diffuse pollution associated with intensive agrochemical use, and the expansion of large-scale mining activities. The Brazilian Red List of Fauna documents a growing number of freshwater fish species classified under threat categories, a trend directly associated with the longitudinal fragmentation of river systems and the degradation of riparian habitats (ICMBio, 2018). In both the Pantanal and the Amazon, for example, dam projects threaten migratory routes of fish species that are fundamental to artisanal fisheries and the food security of riverine populations. Hydrological vulnerability therefore affects not only biodiversity but also the ecosystem services that sustain water supply, climate regulation, and traditional livelihoods.

In the Amazon, the disruption of hydrological connectivity also constitutes a territorial and social issue. Large hydropower projects, mining expansion, and river contamination directly affect fish migration routes and threaten the food security of riverine communities and Indigenous peoples who depend on fluvial systems for their social and cultural reproduction.

This panorama demonstrates that biodiversity loss in Brazil is neither homogeneous nor evenly distributed. Rather, it varies across biomes and ecosystems according to distinct historical, ecological, and socioeconomic contexts. Data from ICMBio (2018) and IBGE (2022) reveal that degradation is particularly severe in long-occupied ecosystems such as the Atlantic Forest, in recently expanded agricultural frontiers such as the Cerrado, and in historically vulnerable regions such as the Caatinga, while simultaneously affecting aquatic ecosystems across the country. Taken together, these processes confirm Brazil's insertion within the global biodiversity crisis while also highlighting national particularities that require context-specific public policies capable of integrating conservation, sustainable development, and socio-environmental justice.

The fragmentation patterns observed across Brazilian biomes directly affect SDG Target 15.1, which calls for the conservation, restoration, and sustainable use of terrestrial ecosystems, as well as SDG Targets 13.1 and 13.2, which focus on reducing climate vulnerability and integrating climate change measures into policies and planning. Remaining natural areas function as important carbon sinks and buffers against extreme climatic events (MapBiomas, 2025). However, biodiversity conservation requires measures that extend beyond technical management approaches. It also depends on guaranteeing territorial rights, legal security, and meaningful participation in decision-making processes, principles that are closely aligned with Sustainable Development Goal 16 on peace, justice, and strong institutions.

5 Case Study: Mato Grosso as a Frontier of Biodiversity Loss

The state of Mato Grosso represents one of the most emblematic territories for understanding biodiversity loss in Brazil, not only because of its vast territorial extent but also due to its unique position encompassing three globally significant biomes: the Amazon, the Cerrado, and the Pantanal. This ecotonal condition, located at the intersection of distinct ecological formations, confers exceptional biological richness and ecosystem diversity. At the same time, it increases vulnerability, as environmental degradation in Mato Grosso generates impacts across multiple scales, simultaneously affecting the Amazon rainforest, the world's most biodiverse savanna, and the largest tropical wetland on the planet. Environmental impacts in the state are therefore not confined to a local dimension but reverberate throughout broader ecological networks, disrupting hydrological cycles, species dispersal processes, and trophic dynamics.

According to data consolidated by MapBiomas (2025), Mato Grosso recorded the largest increase in deforestation alerts within the Brazilian Amazon in 2025, with a 141% rise by July of that year, remaining one of the states most affected by forest loss. The Cerrado portion of Mato Grosso was also the most affected in the country. Although deforestation alerts declined by 41.2% compared with 2023 levels, the biome remained the most deforested region in Brazil for the second consecutive year, accounting for more than half of the country’s total vegetation loss (MapBiomas, 2025).

Recent data confirm the intensity of anthropogenic pressures. Between 2015 and 2021, studies based on remote sensing and deep learning techniques identified the loss of approximately 14.8% of the state's total area, corresponding to more than 414,000 km² of clear-cut deforestation. The rate of environmental conversion accelerated considerably during this period, increasing from 6,632 km² in 2016 to 19,818 km² in 2021 (Wagner et al., 2021). This expansion, strongly associated with agricultural frontier growth and commodity production, not only reduces forest cover but also initiates a process of landscape fragmentation that compromises ecological connectivity and profoundly alters the population dynamics of flora and fauna.

Fragmentation intensifies edge effects, reduces core habitat areas, and isolates habitat patches, generating microclimatic changes that favor opportunistic species while increasing the vulnerability of more sensitive organisms. Forest species from the Amazon and savanna species from the Cerrado are simultaneously affected by habitat isolation and the loss of ecological corridors. The disruption of these flows compromises essential ecological processes such as seed dispersal and pollination, both of which are fundamental to natural regeneration. Vulnerability is further intensified by the interaction of demographic, genetic, and environmental factors, increasing the likelihood of local extinctions and reducing the resilience of ecosystems already subjected to intense human pressures (Fahrig, 2003; Metzger, 2016).

The Cerrado presents a particularly distinctive ecological formation characterized by short trees with twisted trunks covered by thick bark, as well as generally large and rigid leaves. Many herbaceous species possess underground structures adapted for water and nutrient storage. However, one of the most persistent threats to this biome is fire, which may originate through natural combustion processes but is predominantly associated with human activities. The increasing frequency and intensity of anthropogenic fires have become a major factor contributing to habitat degradation and biodiversity loss.

While terrestrial environments clearly illustrate the impacts of fragmentation, the aquatic ecosystems of Mato Grosso reveal equally severe pressures. The intensive use of agrochemicals in agricultural regions, particularly around Campo Novo do Parecis and Sapezal, has contaminated surface waters, directly affecting fish populations and posing risks to human communities that depend on these resources (Barizon et al., 2022). Simultaneously, sedimentation associated with deforestation and inadequate land management practices reduces the depth and ecological functionality of rivers and streams. Hydropower projects further fragment river systems longitudinally, disrupting hydrological cycles and blocking migratory routes.

The Pantanal represents perhaps the most critical example of these processes. Recent studies identified twenty-three migratory fish species at risk due to the obstruction of reproductive routes, including the dourado (*Salminus brasiliensis*), pacu (*Piaractus mesopotamicus*), and pintado (*Pseudoplatystoma corruscans*), species that are essential both for biodiversity conservation and for the livelihoods of riverine communities. It is estimated that, if all planned dam projects are implemented, approximately 70% of migratory routes could become inaccessible, placing the biome at risk of ecological and socioeconomic collapse (Ecologia e Ação, 2023).

These pressures are not restricted to agricultural landscapes but increasingly affect territories that have traditionally functioned as biodiversity refuges. Indigenous lands and protected areas, which play a fundamental role in maintaining ecological flows and conserving biodiversity, are under growing threat. A study by OPAN (2024) indicates that more than one million hectares of rural properties overlap Indigenous lands in Mato Grosso, revealing the persistence of land conflicts. The Instituto Socioambiental (ISA, 2024) reported that deforestation within the Zoró Indigenous Territory increased by 88% between 2022 and 2023, demonstrating the advance of land grabbing, illegal mining, and unlawful logging. These processes not only undermine Indigenous ways of life but also weaken environmental governance systems that should function as barriers against environmental degradation.

Pressure on Indigenous territories extends beyond land tenure disputes and produces direct consequences for biodiversity conservation and the social reproduction of Indigenous peoples. Numerous studies demonstrate that Indigenous lands constitute some of the most effectively conserved areas within the Brazilian Legal Amazon, functioning as barriers against deforestation and as strategic spaces for maintaining ecological connectivity. Consequently, the expansion of land grabbing, mining, and illegal resource extraction simultaneously threatens ecosystem integrity and Indigenous territorial rights.

Similarly, riverine communities, extractivist populations, and other traditional groups are directly affected by water contamination, declining fish stocks, and alterations in ecological cycles associated with Amazonian River systems. In this context, biodiversity loss represents not only the reduction of species and habitats but also the erosion of knowledge systems, management practices, and historically established relationships with the territory. The environmental crisis thus assumes the character of a territorial dispute between competing development projects for the Amazon.

The consequences of these processes become particularly visible during large-scale environmental disasters. The 2020 wildfires provide a striking example, having devastated extensive areas of the Pantanal and disproportionately affected apex predators. Estimates indicate that approximately 45% of the Pantanal jaguar (*Panthera onca*) population—around 746 individuals—was directly impacted by the fires, which affected 79% of monitored areas and 62% of protected areas within the biome (Barros et al., 2022). Beyond direct mortality, the fires altered movement patterns and forced animals to migrate toward peripheral areas. This displacement increased the risk of wildlife-vehicle collisions along highways such as BR-163, currently recognized as a major hotspot of wildlife mortality, particularly for large mammals searching for new habitats (Pinto et al., 2022).

The case of Mato Grosso therefore illustrates how multiple drivers of environmental degradation converge within a territory characterized by extraordinary biological richness but also by significant structural vulnerabilities. Accelerated deforestation, habitat fragmentation, contamination of aquatic ecosystems, pressures on Indigenous lands and protected areas, and the impacts of extreme events such as wildfires and wildlife road mortality together form a pattern of systemic biodiversity erosion. Mato Grosso has thus become a critical frontier of biodiversity loss, where the tensions between conservation, agricultural expansion, and environmental governance are manifested with particular intensity. This condition, simultaneously local and global in its implications, encapsulates one of the central dilemmas of contemporary conservation: how to reconcile the protection of biodiversity and ecosystem integrity with development models based on the intensive exploitation of natural resources.

6 Discussion

The analysis of Mato Grosso provides important insights into how global and national trends of biodiversity loss materialize within a territory characterized by the overlap of major biomes and increasing pressure from agricultural expansion. The direct drivers identified by IPBES (2020)—land-use change, intensive exploitation of natural resources, pollution, climate change, and invasive alien species—find concrete and interconnected expression within the state. Deforestation associated with the conversion of land for monoculture production and cattle ranching exemplifies the role of land-use change as a major driver of environmental degradation. At the same time, indirect drivers, including an export-oriented commodity-based economic model, the expansion of transportation and energy infrastructure, and weaknesses in environmental governance, reinforce and accelerate these processes.

In the Amazonian portion of Mato Grosso, however, these environmental drivers also acquire a distinctly territorial and political dimension. The expansion of the agricultural frontier and the illegal appropriation of public lands (*land grabbing*) intensify land conflicts, threaten Indigenous territories, and increase pressure on protected areas, demonstrating that biodiversity loss is deeply embedded in disputes among competing land-use projects, including agricultural, mining, community-based, and Indigenous territorial models. In this region, ecological degradation occurs alongside the erosion of traditional management systems and the weakening of community practices that have historically contributed to forest conservation.

From this perspective, the processes analyzed demonstrate that biodiversity loss in the Brazilian Legal Amazon cannot be understood solely as an ecological phenomenon. It also represents a struggle over territorial control and land use, involving competing development rationalities. While agricultural expansion and the intensive exploitation of natural resources tend to simplify landscapes and reduce ecological connectivity, Indigenous peoples and traditional communities maintain management practices that contribute to ecosystem conservation and the preservation of biocultural diversity. Biodiversity conservation therefore depends not only on ecological protection but also on the recognition of territorial rights and the valuation of historically rooted knowledge systems in the Amazon.

The interaction between direct and indirect drivers further highlights the limitations of analyses focused exclusively on the spatial dimensions of deforestation. As demonstrated by Fahrig (2003) and Haddad et al. (2015), conservation effectiveness cannot be assessed solely by the quantity of remaining habitat but must also consider its spatial configuration and capacity to sustain ecological flows.

An additional factor that must be incorporated into this discussion concerns the role of public institutions and ongoing legislative debates. In particular, proposals to revise Bill No. 337/2022, currently under consideration by the Agriculture Committee of the Brazilian Chamber of Deputies, would modify provisions of Article 3 of the Brazilian Forest Code (Law No. 12.651/2012) concerning the Brazilian Legal Amazon and the definitions of Legal Reserves, Permanent Preservation Areas (APPs), sustainable management, and consolidated rural areas (Brazil, 2012). Such legislative debates have direct implications for territorial governance and may further weaken the protection of areas that are essential for ecological connectivity while simultaneously increasing legal uncertainty for Indigenous territories and protected areas.

Within this context, proposals for the implementation of ecological corridors and agroecological mosaics represent important strategies for mitigating the effects of habitat fragmentation. However, their effectiveness depends on integration with broader legal and institutional frameworks. Brazil's National System of Protected Areas (Law No. 9.985/2000) establishes categories and guidelines for the creation and management of protected areas, including ecological corridors and conservation mosaics. Nevertheless, implementation remains constrained by the continued expansion of the agricultural frontier (Brazil, 2000). Similarly, the Brazilian Forest Code (Law No. 12.651/2012) establishes requirements for Permanent Preservation Areas (APPs) and Legal Reserves, which could function as strategic components of ecological connectivity. In practice, however, these mechanisms are often inadequately implemented, reduced in scope, or reinterpreted in ways that favor the reduction of protected areas (Brazil, 2012).

In this regard, reports from IBGE (2022), ICMBio (2018), and MapBiomas (2025), together with state-level assessments produced by the Mato Grosso State Secretariat for the Environment (SEMA-MT, 2025), demonstrate the persistence of pressures on biodiversity and the continuing difficulties in reducing deforestation rates and combating illegal activities. The case of Mato Grosso reveals that, despite the existence of a legal framework recognizing the importance of biodiversity conservation, its implementation remains fragmented and marked by contradictions between environmental protection policies and policies that promote agricultural production. Moreover, the overlap of Indigenous territories and protected areas with agricultural, logging, and mining interests demonstrates that environmental degradation extends beyond ecological impacts, affecting territorial rights and traditional livelihoods while further undermining regional socioecological resilience.

The Mato Grosso case therefore demonstrates that biodiversity loss cannot be understood solely through local dynamics but must be situated within a broader socioecological system in which global market demands, national development strategies, and institutional governance failures interact. The situation highlights the limitations of sectoral conservation policies and underscores the need for integrated approaches that consider not only the extent of protected habitats but also their spatial arrangement, connectivity, and capacity to sustain ecological processes within landscapes subjected to intense anthropogenic pressures.

In the Amazonian context, such an integrated approach requires recognizing the central role of Indigenous territories, local knowledge systems, and forms of territorial resistance that contribute to maintaining forest integrity in the face of expanding economic frontiers. Ultimately, biodiversity conservation in Mato Grosso—and in the Brazilian Legal Amazon more broadly—depends on the ability to reconcile ecological connectivity, territorial justice, and sustainable development within a governance framework capable of addressing the interconnected ecological, social, and political dimensions of environmental change.

7 Final Considerations

This study demonstrates that biodiversity loss in Mato Grosso is not merely a localized expression of ecological processes but rather part of a broader global system that links agro-export expansion, institutional weaknesses, and socio-environmental inequalities. The analysis of pressures affecting the Amazon, Cerrado, and Pantanal biomes reveals that Mato Grosso's ecotonal condition, instead of being recognized as an ecological asset of global significance, has increasingly been transformed into an economic resource exploited through deforestation, habitat fragmentation, and wetland conversion. The continued expansion of the agricultural frontier indicates that the primary driver of biodiversity loss is not the absence of technical knowledge or environmental regulations, but rather political choices that subordinate conservation to commodity-based development models.

The contradiction between the existing legal framework and territorial realities reinforces this conclusion. Instruments such as the National System of Protected Areas (Law No. 9.985/2000) and the Brazilian Forest Code (Law No. 12.651/2012) establish guidelines for the protection of native vegetation, the preservation of riparian corridors, and the maintenance of Legal Reserves. However, their implementation remains fragmented, subject to recurrent flexibilization, and frequently reinterpreted in ways that facilitate the reduction of protected areas (Brazil, 2000; Brazil, 2012). In Mato Grosso, the expansion of soybean cultivation, cattle ranching, and logistical infrastructure demonstrates that the effectiveness of environmental legislation is constrained not by the absence of regulatory instruments but by the political influence of dominant economic sectors over their implementation. In the Amazonian portion of the state, this institutional fragility is further reflected in increasing pressures on Indigenous territories, which are frequently affected by land conflicts, invasions, and challenges to the collective rights that contribute to maintaining forest integrity.

Another central finding is that conservation cannot be assessed solely in quantitative terms. As argued by Fahrig (2003) and Haddad et al. (2015), the spatial configuration of landscapes and their functional connectivity are at least as important as the proportion of remaining habitat. In Mato Grosso, forest fragmentation, the low permeability of productive landscapes, and the absence of effective ecological corridors compromise gene flow, species dispersal, and migratory routes of freshwater fish. These findings demonstrate that the mere preservation of forest area is insufficient to ensure long-term biodiversity persistence. The challenge lies in creating spatial and institutional arrangements capable of sustaining ecological processes over time.

The study also demonstrates that the consequences of environmental degradation extend beyond the biological sphere and directly affect human populations. River contamination by agrochemicals, the disruption of migratory fish routes in the Pantanal, wildfires that devastated jaguar populations, and wildlife mortality on highways all illustrate the convergence of environmental and social crises. Indigenous peoples and traditional communities, simultaneously custodians of biodiversity and targets of territorial pressures, face a dual vulnerability: the loss of their territories and the degradation of the ecological conditions that sustain their livelihoods. At the same time, their management practices, knowledge systems, and forms of resistance offer concrete alternatives to the predatory logic of agricultural frontier expansion, reaffirming the importance of biocultural diversity in maintaining forest ecosystems.

This finding reinforces the argument that biodiversity conservation in the Amazon depends not only on technical conservation instruments but also on the strengthening of territorial rights and the recognition of knowledge systems developed by the peoples who have historically inhabited the region.

The case of Mato Grosso ultimately encapsulates a central dilemma of Brazilian environmental policy. On the one hand, international commitments and national legislation formally recognize the importance of biodiversity conservation. On the other hand, prevailing development models continue to normalize environmental degradation as a necessary cost of economic growth. The Mato Grosso frontier reveals the limitations of fragmented and sectoral environmental governance, which often fails to address the structural drivers of biodiversity loss.

Biodiversity loss in Mato Grosso also represents a significant challenge to the achievement of the Sustainable Development Goals established under the 2030 Agenda. Restoring ecological connectivity and protecting traditional territories contribute directly to the achievement of SDGs 6 (Clean Water and Sanitation), 13 (Climate Action), and 15 (Life on Land), while strengthening governance structures and guaranteeing territorial rights (SDG 16) and promoting more sustainable production systems (SDGs 12 and 2) constitute essential preconditions for the effectiveness of conservation strategies. Public policies should therefore incorporate explicit SDG-related targets and indicators, including measures of ecological connectivity and ecosystem services, enabling progress to be assessed not only in ecological terms but also in relation to broader sustainable development objectives.

Addressing these challenges requires more than incremental adjustments. It demands a profound reconfiguration of the relationships among production, conservation, and socio-environmental justice. Such a transformation involves restoring ecological connectivity across multiple scales, promoting more inclusive and less environmentally destructive production systems, strengthening both terrestrial and aquatic ecological corridors, and, above all, recognizing Indigenous peoples and local communities as central actors in biodiversity conservation. Without this structural shift—ethical, political, and territorial in nature—Mato Grosso will continue to function simultaneously as a frontier of economic expansion and a frontier of biodiversity loss, jeopardizing not only ecological integrity but also the future of the Amazon and the peoples who depend upon it.

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