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Environmental governance and traceability: challenges for sustainable livestock farming in the Legal Amazon

Environmental governance and traceability: challenges for sustainable livestock in the legal Amazon

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ABSTRACT

This article analyzes the challenges posed by the implementation of mandatory cattle traceability as an instrument of environmental governance in the Legal Amazon, focusing on promoting sustainable livestock farming. By requiring rigorous control and monitoring of the production chain, traceability emerges as a relevant strategy for combating deforestation and environmental degradation. However, its application in contexts marked by land inequalities, institutional fragility, and a lack of technical support policies can exacerbate socioeconomic vulnerabilities, especially among small and medium-sized producers. The study proposes a critical reflection on the limits and potential of traceability in the Amazonian context, articulating it with principles of socio-environmental justice and participatory governance, aiming to develop more inclusive and sustainable public policies.

Keywords: Legal Amazon; Environmental governance; Sustainable livestock farming; Public policies; Traceability.

ABSTRACT

This article analyzes the challenges posed by the implementation of compulsory cattle traceability as an instrument of environmental governance in the Brazilian Legal Amazon, focusing on the promotion of sustainable livestock farming. Traceability, by requiring strict control and monitoring of the production chain, emerges as a relevant strategy to combat deforestation and environmental degradation. However, its application in contexts marked by land inequalities, institutional fragility, and the absence of technical support policies may exacerbate socioeconomic vulnerabilities, especially among small and medium-sized producers. This study offers a critical reflection on the limits and potentialities of traceability in the Amazonian context, articulating it with principles of socio-environmental justice and participatory governance, aiming at the construction of more inclusive and sustainable public policies.

Keywords: Brazilian Legal Amazon; Environmental governance; Public policies; Sustainable livestock; Traceability.

1 INTRODUCTION

The Legal Amazon is a central space in global conservation dynamics environmental, food security and socioeconomic development, while at the same time constitutes one of the territories most vulnerable to pressures arising from agricultural expansion and climate change (Simas et al., 2024). The cattle production chain plays a ambivalent role in this context: economic engine of the region and, simultaneously, vector of



Year V, v.2 2025 | submission: October 17, 2025 | accepted: October 19, 2025 | published: October 21, 2025

deforestation, environmental degradation and socio-spatial conflicts (Imazon, 2021; Coalizão Brasil, 2023).

The agro-environmental governance of the meat chain in Brazil has undergone profound transformations in recent decades, driven by regulatory, social and market pressures, which culminated in the institutionalization of public and private commitments aimed at eliminating deforestation associated with livestock farming. Through initiatives such as the Conduct Adjustment Agreement (TAC) and the Public Livestock Commitment, established in 2009, a new arrangement of governance, based on the articulation between normative instruments, monitoring technologies and voluntary agreements (Carneiro & David, 2025). These processes configured traceability as a strategic practice and, at the same time, as an arena of controversy, insofar as environmental assessment technologies and metrics actively participate in defining standards socio-environmental issues legitimized in the production chain Carneiro & David, 2025). Traceability, therefore, begins to be conceived as a technical management tool, but also as a constitutive element of contemporary environmental governance, shaping practices, disciplining agents and shaping markets (Mol & Oosterveer, 2015). However, its application compulsory, especially in contexts of institutional fragility and high informality productive, as occurs in the Legal Amazon, poses challenges to the effectiveness of policies environmental, which can generate paradoxical effects by deepening socioeconomic inequalities and promote the exclusion of small and medium-sized producers from the formal marketing chain (Ferguson; Sekula; Szabó, 2020).

In this sense, environmental governance in the Amazon is marked by the tension between the need to promote ecological sustainability, fundamental for global climate balance, and the urgency to ensure the productive inclusion and socio-environmental justice of local communities, strongly dependent on the exploitation of natural resources (Simas et al., 2024). Effective governance in the region requires the strengthening of integrated public policies, capable of articulating command instruments and control with economic incentives, technical assistance and social participation mechanisms (Simas et al., 2024; Carneiro & David, 2025).

Additionally, the recent debate on traceability in the livestock chain has highlighted the emergence of innovative technological solutions, such as the use of blockchain, artificial intelligence and satellite monitoring systems, as alternatives to overcome the limits imposed by precariousness of institutional and infrastructure structures in the Amazon (Ferguson; Sekula; Szabó, 2020). However, such solutions, although promising, face challenges related to data standardization, system interoperability and ensuring the inclusion of small businesses producers, who often lack access to the resources necessary for their implementation (Ferguson; Sekula; Szabó, 2020).



Year V, v.2 2025 | submission: October 17, 2025 | accepted: October 19, 2025 | published: October 21, 2025

Given this scenario, this article aims to critically analyze the potential and limitations of traceability as an instrument of agro-environmental governance, with a view to promoting of sustainable livestock farming in the Legal Amazon. The premise is that the effectiveness of traceability depends on its articulation with structuring public policies, which promote land regularization, technical assistance and strengthening of participatory governance, forming an integrated approach that is sensitive to the socio-environmental specificities of the region (Froehlich; Stabile, Souza, 2023; Simas et al., 2024).

2 THEORETICAL FRAMEWORK

Environmental governance constitutes one of the central axes of the debate on public policies aimed at sustainability, especially in territories marked by socioeconomic vulnerabilities and environmental issues, such as the Legal Amazon. According to Lemos and Agrawal (2006), this concept relates the capacity of multiple actors, State, private sector and civil society, to coordinate practices use of natural resources in contexts of decentralization and growing institutional complexity.

In the Amazon, such dynamics are crossed by agricultural expansion, by the concentration land ownership and pressure from global markets, creating a space of tension between economic development and environmental conservation (Simas et al., 2024).

In the specific case of the beef chain, Carneiro and David (2025) demonstrate that the notion of agro-environmental governance is particularly relevant to understanding institutional arrangements that emerged in Brazil from 2009 onwards, with the establishment of the Conduct Adjustment Terms (TACs) and the Public Livestock Commitment (CPP). These initiatives inaugurated a model hybrid, in which state regulations, voluntary agreements and technological instruments began to compose a field of disputes over the legitimacy of livestock production practices. In this arrangement, traceability becomes more than a management tool: it is a device sociotechnical that models markets, disciplines agents and redefines socio-environmental quality standards (Callon et al., 2002; Mol; Oosterveer, 2015).

Mandatory traceability has been consolidated as a **strategic instrument to combat to deforestation**, by linking the marketing of beef to compliance with requirements environmental. According to **Armelin et al. (2023)**, given the growing international demand for products free from deforestation, it is essential to strengthen national monitoring systems that integrate health and socio-environmental variables. In this same direction, the **Brazil Coalition (2023)** shows that the implementation of traceability mechanisms still faces obstacles resulting from the fragmentation of information systems, the lack of interoperability technological and the difficulty of tracking indirect suppliers.



Year V, v.2 2025 | submission: October 17, 2025 | accepted: October 19, 2025 | published: October 21, 2025

In this scenario, the literature indicates that the Brazilian Cattle Identification and Certification System and Buffaloes (SISBOV), created in 2002, primarily met the health requirements of international markets, but revealed limitations in dealing with environmental variables. From the 2009 TACs, a parallel model of traceability and monitoring aimed at the market emerges internal, based on agreements between the Federal Public Ministry and meatpacking plants operating in the Amazon (Coalizão Brasil, 2023). This institutional duality generated a fragmented system, with results heterogeneous in terms of effectiveness and territorial coverage.

In addition to institutional initiatives, technological solutions have been highlighted as an alternative for overcome structural weaknesses. Ferguson, Sekula and Szabó (2020), when analyzing innovations in blockchain, artificial intelligence and satellite systems, highlight that these technologies make it possible real-time tracking of the production chain, increasing transparency and reducing risks reputational and financial. However, they warn that the adoption of these mechanisms may accentuate inequalities, since small and medium-sized producers often lack capital, training and infrastructure to meet the requirements of these systems.

The debate on traceability, therefore, cannot be dissociated from the dimensions of justice socio-environmental. Barreto (2021), when examining the dynamics of extractive livestock farming in the Amazon, shows that low productivity is associated with predatory expansion into new frontiers, perpetuating a cycle of environmental degradation and low socioeconomic development. The implementation of traceability policies, without coordination with land regularization, credit accessible and technical assistance, tends to reinforce processes of productive exclusion, marginalizing family farmers and small livestock farmers.

Another relevant aspect concerns the role of national public policies. The Policy Proposal National Mandatory Individual Traceability Report, prepared by the Brazilian Livestock Board Sustainable in 2023, indicates that the consolidation of an effective system depends on coordination between government, private sector and civil society, with a clear definition of roles and responsibilities (Table Brazilian Sustainable Livestock Association, 2023). In this model, each animal must be monitored throughout throughout their lives, integrating land, health, and environmental data. The proposal also highlights the need for a transition phase, in order to enable the inclusion of producers from different shipping.

The reality observed in different Amazonian territories confirms the persistence of these challenges. Vieira et al. (2006), when analyzing the southeastern mesoregion of Pará, found that adherence to bovine traceability was still incipient, compromised by the precariousness of the infrastructure and the high implementation costs, although the potential for increasing the value of the product was recognized and expansion of markets. More than fifteen years later, such problems remain evident, especially in relation to the restricted coverage of SISBOV and the fragmentation of state policies.



Year V, v.2 2025 | submission: October 17, 2025 | accepted: October 19, 2025 | published: October 21, 2025

Academic production on the topic shows a consensus on the need to understand the traceability as part of a broader environmental governance arrangement, in which technologies, legal norms, market agreements and production practices interact interdependently. The effectiveness of this instrument, especially in the Legal Amazon, requires coordination between command and control, economic incentives, social inclusion and strengthening of participatory governance, linking livestock sustainability to the principles of socio-environmental justice and development integrated territorial.

Furthermore, the debate on environmental governance can be enriched by the notion of governance polycentric, proposed by Ostrom (1990), according to which multiple decision centers interdependent coexist and coordinate at different scales. This concept helps to understand the multiplicity of actors competing to define sustainability standards in livestock farming Brazilian, from government agencies to meatpacking plants, non-governmental organizations and international markets. In this sense, Cashore et al. (2004) emphasize that global supply chains commodities, such as beef, constitute arenas of transnational governance in which norms Private and public regulations overlap, forming hybrid arrangements.

Traceability, therefore, cannot be understood only as a technical mechanism, but as part of a hybrid regulatory regime, in which command and control instruments coexist state-owned companies, market agreements and corporate self-regulation mechanisms (Abbott; Snidal, 2009). This configuration, although it increases the capacity to respond to international pressures, also generates tensions regarding the legitimacy and effectiveness of the instruments adopted.

Another relevant point concerns the alternatives for agroecological transition. Altieri (2012) and Gliessman (2015) argue that traceability systems can be used not only as trade barriers or exclusion mechanisms, but as instruments for inducing practices sustainable production. In this sense, integrating traceability into technical assistance policies, credit and incentives for agroecological innovation can reduce territorial inequalities and strengthen resilience of small producers.

From the perspective of socio-environmental justice, Acselrad (2010) and Zhouri (2018) emphasize that policies environmental factors often reproduce social inequalities by transferring compliance costs for more vulnerable groups. In the case of bovine traceability, this risk manifests itself in the exclusion of family farmers in the formal supply chain, since the technological requirements and administrative processes tend to favor large producers and corporations. Thus, the challenge of environmental governance in Brazil consists of articulating traceability and productive inclusion, ensuring that regulatory progress does not become a mechanism for deepening regional inequalities.



Year V, v.2 2025 | submission: October 17, 2025 | accepted: October 19, 2025 | published: October 21, 2025

Finally, traceability must also be analyzed in its international context. The Regulation European Treaty Against Deforestation (EUDR, 2023) imposes barriers to the import of associated products to deforestation chains, putting additional pressure on Brazil. The response to this scenario demands robust national systems, capable of ensuring transparency and credibility before the international markets. As Armelin et al. (2023) note, aligning Brazilian traceability to global demands is an indispensable condition for maintaining competitiveness, but also requires the construction of internal mechanisms that reconcile environmental protection, social justice and economic development.

3 MATERIAL AND METHOD

This study is based on bibliographic and documentary analysis, carried out from sources institutional, academic and regulatory issues related to environmental governance and traceability cattle in the context of the Legal Amazon. Technical reports, scientific studies and official documents that address the implementation and challenges of mandatory traceability of cattle herd as an instrument of sustainability and environmental control.

Among the main sources analyzed, the reports and publications of the Research Institute stand out Amazon Environmental Institute (IPAM, 2023), Igarapé Institute (Ferguson; Sekula; Szabó, 2020), Coalition Brazil Climate, Forests and Agriculture (2023), Friends of the Earth Brazilian Amazon (Armelin et al., 2023) and Embrapa Amazônia Oriental (Vieira et al., 2006). References were also examined academics discussing agro-environmental governance, bovine traceability and justice socio-environmental (Simas et al., 2024; Carneiro & David, 2025; Acselrad, 2010; Zhouri, 2018). In addition to scientific studies, relevant normative and regulatory instruments were considered to the topic, such as the Proposal for a National Policy on Mandatory Individual Traceability (Table Brazilian Sustainable Livestock Association, 2023) and the European Regulation against Deforestation – EUDR (2023), which directly influence the Brazilian sustainable livestock scenario.

The analysis was developed in a critical and comparative way, seeking to identify convergences and contradictions between literature, public policies and technical reports. The period covered covers the years 2002 to 2025, covering the creation of the Brazilian System of Identification and Certification of Cattle and Buffaloes (SISBOV) to the current proposals for mandatory traceability.

4 RESULTS AND DISCUSSION

The analysis of traceability in Brazilian cattle farming reveals that, despite institutional advances and technological, the implementation of robust systems is still permeated by contradictions, disputes and structural inequalities. This finding arises from the comparison between the literature academic, recent public policy proposals and technical reports that demonstrate the current stage of the sector.

From an institutional point of view, there is an effort to consolidate regulatory instruments.

The **Proposal for a National Policy on Mandatory Individual Traceability** (Brazilian Board of Sustainable Livestock, 2023) marks a turning point by proposing the integration of land data, sanitary and socio-environmental on a single basis, with 100% coverage of the herd destined for slaughter. This initiative, built from broad alignment between government, private sector and civil society, expresses the attempt to transform traceability into a structuring public policy, overcoming the fragmentation of systems such as **SISBOV**, aimed mainly at the foreign market, and controls derived from **meat TACs**, which are concentrated in slaughterhouses in the Amazon. However, as **Armelin et al. (2023) point out**, the effectiveness of traceability in Brazil is hindered in structural challenges. The fragmentation of environmental registries, the lack of interoperability between federal and state systems and the difficulty of tracking indirect suppliers configure persistent bottlenecks. Furthermore, **SISBOV**'s historical experience shows that mechanisms designed to meet international requirements can generate productive exclusion, benefiting only large exporters, while most national producers remain on the sidelines.

Data from the **Brazil Climate, Forests and Agriculture Coalition (2023)** reinforce this diagnosis by indicate that the lack of integration between the Rural Environmental Registry (CAR), Animal Transit Guide (GTA) and land data compromises the credibility of the system. Without a unified platform, traceability loses its ability to measure compliance with socio-environmental criteria, opening space for animals from areas of illegal deforestation to enter the formal chain.

From an economic point of view, the **Friends of the Earth report (Armelin et al., 2023)** shows that traceability cannot be reduced to a trade barrier. On the contrary, it is a requirement of access to strategic markets, especially given the entry into force of the **European Regulation against Deforestation (Eudr, 2023)**. This regulation, by prohibiting the import of products associated with areas deforested after 2020, imposes unprecedented pressure on the meat chain Brazilian. In response, meatpacking companies, as demonstrated by studies by Simas et al. (2024), have expanded the use of remote monitoring technologies, but still face limitations in reach indirect suppliers, who represent the main source of socio-environmental risk.



Year V, v.2 2025 | submission: October 17, 2025 | accepted: October 19, 2025 | published: October 21, 2025

The territorial dimension of the discussion is also central. **Barreto (2021)** argues that the expansion of livestock farming in the Amazon continues to be predominantly extractive, marked by low productivity and extensive use of newly deforested land. The lack of consistent incentives for sustainable intensification perpetuates this model, so that traceability policies, isolated, tend to act only as instruments of command and control. In contrast, local experiences such as the one analyzed by Vieira et al. (2006) in southeastern Pará demonstrate that voluntary adherence to traceability depends on adequate infrastructure, cost reduction and technical-institutional support, elements that are still fragile in many Amazonian regions. In the technological field, Ferguson, Sekula and Szabó (2020) highlight the potential of solutions based on **blockchain, artificial intelligence** and **satellite monitoring** to increase transparency of the production chain. However, the literature also warns of the risk that such innovations reinforce market concentration, since they require high investments in digital infrastructure and training. This connects to the debate on **socio-environmental justice**, as small producers and family farmers may be excluded from the formal supply chain, expanding territorial and social inequalities (Zhour, 2018; Acselrad, 2010). In this sense, a fundamental contradiction emerges: while traceability is defended as an instrument of sustainability and competitive insertion of Brazil in global markets, its implementation can reproduce dynamics of exclusion. As Carneiro and David (2025) point out, Brazilian agro-environmental governance is characterized by disputes between state, private and government actors and civil society, in which different concepts of sustainability are mobilized. Depending on how it is designed and implemented, the traceability system can strengthen arrangements inclusive, based on technical assistance and incentives, or consolidate exclusionary mechanisms that only benefit large exporters.

The results indicate that the future of traceability in Brazil will depend on its ability to constitute a **transversal public policy**, articulating:

1. **Integration of information systems** (CAR, GTA, SISBOV, land data).
2. **Economic incentives** for small and medium-sized producers to avoid exclusions.
3. **Transparency and international credibility**, aligned with the requirements of the EUDR and other regulated markets.
4. **Polycentric governance**, involving the Union, states, municipalities, the private sector and society civil, in order to distribute responsibilities and legitimize the process.

Thus, the discussion shows that bovine traceability is not just a technical mechanism of monitoring, but an instrument of environmental governance that expresses power relations, market disputes and socio-environmental justice challenges. Its effectiveness will depend on the capacity



Year V, v.2 2025 | submission: October 17, 2025 | accepted: October 19, 2025 | published: October 21, 2025
for Brazil to overcome institutional fragmentations and build an inclusive, transparent and aligned with global sustainability demands.

FINAL CONSIDERATIONS

The analysis developed throughout this article reveals that bovine traceability in Brazil constitutes much more than a technical or regulatory control mechanism. It represents an arena strategic environmental and economic governance, in which public interests, pressures market trends and global demands for sustainability. Traceability is, therefore, an instrument regulatory hybrid, capable of articulating technology, politics and territory, but also of reproducing inequalities when dissociated from inclusion and institutional strengthening policies.

The trajectory of Brazilian traceability demonstrates a discontinuous and fragmented evolution. SISBOV, created in 2002, responded to international health requirements, but lacked integration with environmental and land dimensions. Subsequently, the Terms of Adjustment of Conduct (TACs) and the Livestock Public Commitment (2009) introduced a component socio-environmental, inaugurating a new stage of agro-environmental governance. However, coexistence of these systems, added to the multiplicity of registries and databases, such as CAR, GTA and land records, configured a fragmented institutional mosaic, which still compromises the transparency and effectiveness of public policies.

The Proposal for a National Policy on Mandatory Individual Traceability (2023) appears as attempt to overcome these gaps by integrating health, environmental and land variables into a same regulatory framework. This proposal, if effectively implemented, could consolidate the traceability as a structuring public policy. However, its operationalization faces significant challenges: standardization of systems, technological interoperability, integration federative and, above all, the productive inclusion of small and medium-sized livestock farmers, who constitute the link most vulnerable in the production chain.

On the technological front, innovations in blockchain, artificial intelligence and satellite monitoring represent significant advances in the construction of a transparent and traceable livestock industry. These tools, however, are not neutral. Their adoption requires digital infrastructure, technical training and financial investment, conditions that, if not democratized, can increase asymmetries regional and social. Technology, therefore, must be understood not only as a vector of modernization, but as a field of political dispute: an instrument of emancipation when accessible, or exclusionary when monopolized.

Traceability must also be analyzed from the perspective of socio-environmental justice. In regions such as the Legal Amazon, the compulsory implementation of control and certification systems can



Year V, v.2 2025 | submission: October 17, 2025 | accepted: October 19, 2025 | published: October 21, 2025

deepen historical vulnerabilities, displacing small producers and traditional communities

of the formal marketing circuit. Therefore, it is essential to associate traceability with

rural credit policies, technical assistance and agroecological extension, in order to ensure that the

technological advancement is accompanied by productive inclusion and redistribution of opportunities.

In the international context, the entry into force of the European Regulation against Deforestation

(EUDR, 2023) redefines marketing standards and raises the bar for market demands

global. This new situation imposes on Brazil the challenge of developing a traceability system

with global credibility, capable of ensuring the sustainable origin of beef and reinforcing the

image of the country as an agro-environmental powerhouse. The alignment between domestic policies and commitments

international will be decisive for the strategic repositioning of Brazil in the economic scenario

green and to enhance its sustainable production chains.

From the perspective of polycentric governance theory, inspired by Ostrom (1990), the effectiveness of

traceability will depend on the capacity for coordination between multiple actors, State, private sector

and civil society, acting cooperatively and interdependently. This approach requires that the

decision-making power is decentralized, allowing different scales of government and production

participate in the development of sustainability standards and indicators. Thus, traceability

should not be reduced to a command and control mechanism, but understood as an arrangement

dynamic environmental co-management, where social participation and institutional transparency are

conditions of legitimacy.

Individual cattle traceability, when conducted in an inclusive, participatory and

integrated into territorial policies, it can become a transformative milestone for livestock farming

Brazilian. Its potential lies in articulating technology, regulation and socio-environmental justice,

promoting an effective transition to sustainable production models. However, for this

potential is realized, it is necessary to shift traceability from a punitive logic to a logic

inductive, from control to cooperation, from exclusion to inclusion, from obligation to opportunity.

If Brazil is able to build this new paradigm, traceability will no longer be just a

international requirement to become a sovereign instrument of territorial development

sustainable, capable of harmonizing economic competitiveness, environmental protection and social equity,

consolidating the Amazon as a global reference for ecological governance and sustainable innovation.

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Year V, v.2 2025 | submission: October 17, 2025 | accepted: October 19, 2025 | published: October 21, 2025

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