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Foreword

Cattle ranching in the Brazilian Amazon has undergone a very significant evolution over the course of four centuries, moving from highly extensive, inefficient processes to more intensive and sustainable ones. This publication, titled *Transformation of Brazilian Amazon cattle ranching: a historical and sustainable perspective* deals with that path, describing the main historical phases and technological progress that have influenced the development of the industry within the Amazon biome.

The article underlines remarkable development regarding scientific and technological advancement, focusing on Embrapa's role in developing grass cultivars and preventive management and recovery strategies for degraded pastures. These innovations contribute to enhanced carbon sequestration and support the transition toward net-zero livestock farming. Economically, they contribute to increased meat and milk production without territorial expansion, generating income for rural producers. From a social perspective, they strengthen food security, as more pastures are rehabilitated to become productive in the Amazon region. Environmentally, these efforts help preserve the biome by curbing deforestation and reducing greenhouse gas emissions.

Aligned with Embrapa's mission to generate knowledge and technologies to achieve the sustainability of Brazilian agriculture, this publication illustrates how applied research can balance agricultural production with the conservation of natural resources. It offers a model for tropical regions worldwide, providing significant benefits to society, the economy, and the environment, while promoting a sustainable and resilient future for the Amazon.

Walkymário de Paulo Lemos
Head of Embrapa Eastern Amazon

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Introduction

Cattle ranching in the Brazilian Amazon has evolved over 4 centuries through distinct phases of productivity and environmental impact. This transformation has shifted from extensive, inefficient systems to more intensive, sustainable practices, driven by ongoing research and technological advancements. This review aims to summarize that evolution, tracing its historical origins while examining its sustainable path forward.

Historical advances

Originating in the 17th century, cattle ranching in the Amazon began with Portuguese colonizers introducing *Bos taurus* cattle through Belém, Pará, marking their first documented arrival in the Amazon valley (Dias-Filho; Lopes, 2020). Over the past 400 years, it has significantly evolved, fueling the expansion and consolidation of livestock farming in the region.

The evolution of cattle ranching in the Amazon over the past 4 centuries can be divided into four distinct phases (Figure 1). From the mid-1600s to the mid-1960s, the first phase featured ultra-extensive, highly inefficient systems. The second phase, spanning from the mid-1960s to the mid-1980s, was marked by the dominance of extensive systems with marginal efficiency.

Since the mid-1980s, Amazonian cattle ranching has entered its third phase, which continues today and is characterized by less extensive, more efficient systems. Alongside this phase, a fourth phase is gradually emerging, driven by increasingly intensive and professional production systems. This new phase emphasizes greater productivity and efficiency, promoting environmental conservation while ensuring food security. This approach is grounded in the rising professionalization of ranching, driven by preventive pasture management practices — the most effective strategy for preventing pasture degradation. This strategy involves managing pastures professionally from their establishment, ensuring adequate soil fertility, adjusting stocking rates, and controlling weeds, and pest insects (Dias-Filho, 2023).

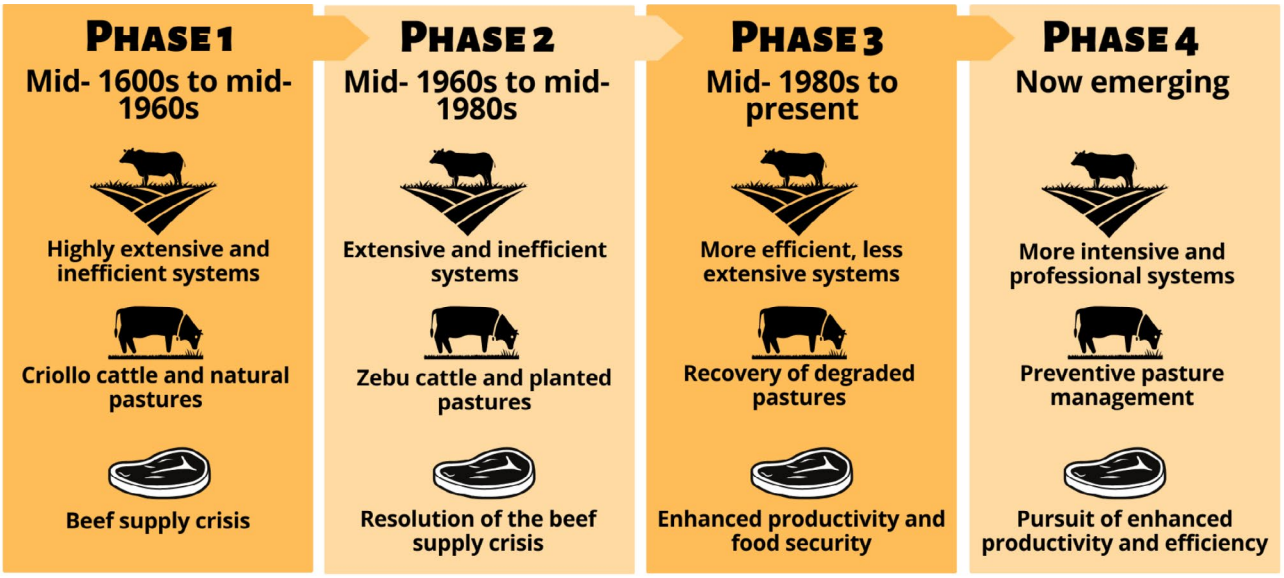

Figure 1. Evolution of cattle ranching in the Brazilian Amazon.
Source: Adapted from Dias-Filho e Lopes (2020).

Transformation of Amazonian cattle ranching

The first phase of cattle ranching in the Brazilian Amazon relied on low-productivity, nutrient-poor natural pastures and criollo cattle, genetically degraded descendants of those *Bos taurus* introduced by Portuguese colonizers. During this period, the transportation infrastructure, heavily dependent on river routes, was inadequate and inefficient for supplying beef to the region's major cities (Dias-Filho; Lopes, 2020).

The inefficient production and transportation systems severely limited the supply of fresh beef in the Amazon region, a crisis that persisted until the mid-1960s and disproportionately impacted the poorer majority of the population (Dias-Filho, 2013; Dias-Filho; Lopes, 2020). During this period of food insecurity, malnutrition among Amazonian residents was deemed "alarming" (Gomes, 1960) with 1960s studies indicating that the issue would persist as long as regional cattle ranching remained "inadequate and inefficient" (Banco da Amazônia, 1967).

Launched in 1966, the federal government's "Amazon Operation" sought to address poverty and neglect in the Amazon, where food insecurity was a major challenge. The program promoted private investment through tax incentives to integrate the region into Brazil's national economy (Banco da Amazônia, 1969).

The incentive policy spurred significant investor migration to the Amazon, with many focusing on extensive beef cattle ranching to secure tax benefits. The construction of the Belém-Brasília highway and other regional roads improved access to new farmland, paving the way for new pastures and herd growth. These highways also enhanced beef distribution and supported genetic improvement of the regional cattle herd through increased imports of zebu breeding stock and cows from the state of Minas Gerais in the Southeastern region of Brazil (Dias-Filho; Lopes, 2020).

The expansion of planted pastures and increased zebu genetics in Amazonian cattle significantly improved beef supply and lowered prices for consumers (Dias-Filho; Lopes, 2020). This transformation marked the start of the second phase of cattle ranching in the region.

In the second phase, an extensive production model, coupled with limited pasture management technologies and a lack of grass varieties suited to the Amazon, resulted in the short productive lifespan of planted pastures. As a result, unable to sustain high productivity, producers often met production goals by abandoning degraded pastures and clearing forested areas for new ones (Dias-Filho, 2014). This extensive production model increased degraded pasture areas and deforestation in the Amazon, reinforcing the perception of regional cattle ranching as unproductive and environmentally damaging (Dias-Filho; Lopes, 2020).

Confronted with extensive, agronomically unstable cattle ranching and limited technological options to enhance efficiency and productivity, the first regional agricultural research initiatives were launched to transform this situation (Dias-Filho, 2014, 2019).

From the mid-1970s, Brazilian Agricultural Research Corporation (Embrapa) research centers in the Amazon intensified studies on the causes of low pasture productivity across various pastoral regions and developed strategies to address this issue (Dias-Filho, 2019). Known as the Propasto Project (Embrapa, 1980), this initiative significantly advanced knowledge, enabling the development and dissemination of technologies for effective pasture management and recovery in the Brazilian Amazon (Serrão et al., 1979; Dias-Filho, 2019).

Beginning in the mid-1980s, the introduction of diverse grass cultivars more than doubled the range of forage plants suitable for Amazonian pasture establishment, complementing ongoing research into improved pasture management and recovery techniques. This increased availability and adoption of technology, along with consistent productivity gains, marked the beginning of Phase 3 in Amazonian cattle ranching (Dias-Filho; Lopes, 2020).

Since the mid-1980s, Amazonian cattle ranching has seen a significant productivity surge in stocking rates, decoupling herd growth from the need for new pasture areas (Figure 2).

In 1985, the stocking rate in Brazil's Northern region — which encompasses most of the Brazilian Amazon — held steady at 0.40 heads per hectare, characteristic of the extensive, marginally efficient Phase 2 ranching systems. During this time, herd and pasture expansions were nearly proportional (+140.3% for herd size versus +140.5% for pasture area), fueled by the practice of clearing new forested areas to support more cattle, a method that frequently caused rapid degradation due to inadequate soil and pasture management and reliance on unsuitable forage species.

By 2006, the stocking rate soared to 1.24 heads per hectare, marking a transformative shift driven by improved cattle ranch productivity. This

near-tripling of cattle density coincided with a dramatic herd increase (+681.1%), vastly outpacing pasture area growth (+151.2%) — a relative decline in new expansion exceeding 75% compared to herd growth. In practice, this enabled ranches to sustain significantly more animals on existing pastureland, thanks to technological breakthroughs, including the recovery of degraded pasture areas and the adoption of high-yielding tropical grasses like *Brachiaria brizantha* and *Panicum maximum* cultivars, introduced during the 1980s and 1990s (Latawiec et al., 2014; Dias-Filho, 2019).

This trend continued into 2023, with the stocking rate inching up to 1.33 heads per hectare, accompanied by a +44.2% increase in herd size that outpaced pasture expansion (+34.5%) — a relative decline in expansion intensity exceeding 20%. This shift underscores the growing reuse of cleared areas through degraded pasture recovery, a key trait of Phase 3 ranching in the Brazilian Amazon, and the adoption of preventive pasture management for productive or restored pastures to prevent further degradation, a cornerstone of Phase 4.

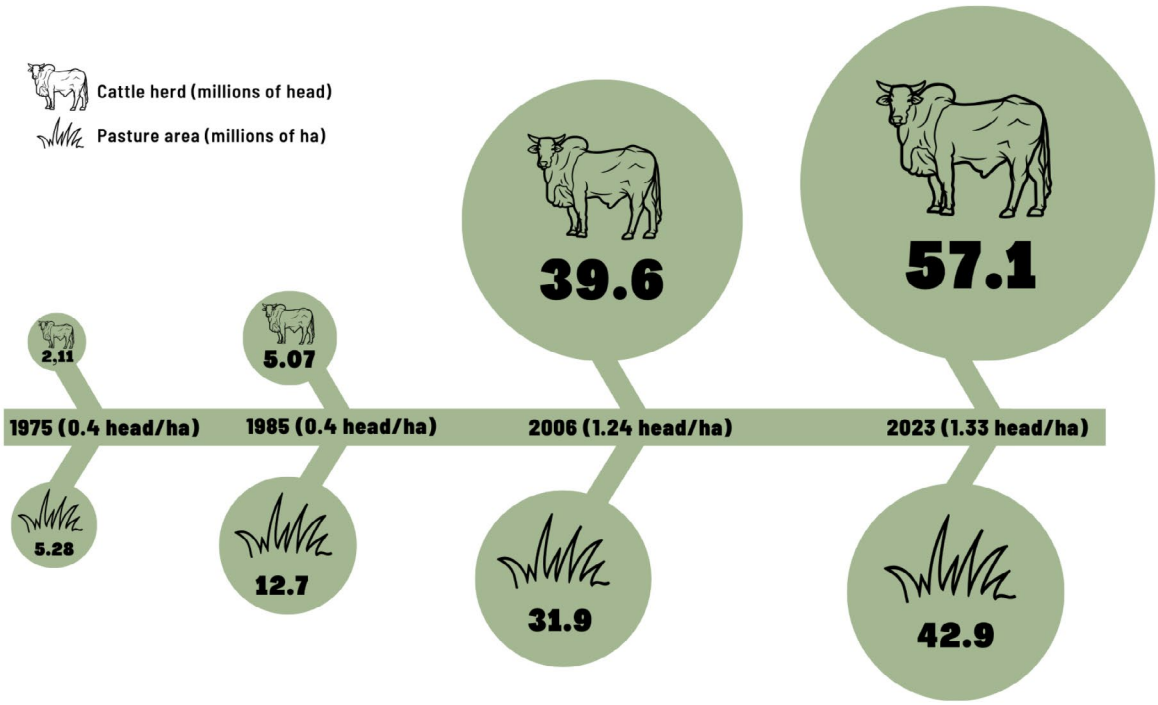

Figure 2. Trends in pasture stocking rates (head per hectare), cattle herd, and pasture area in Brazil's North region, 1975–2023.
Source: Adapted from Atlas [...] (2025) and IBGE (2019).

In essence, the post-1985 surge in stocking rates highlights how heightened pasture productivity has fueled sustainable intensification, enabling herd sizes to expand substantially while reducing the need for new pasture areas.

Since the mid-1980s, a sustained slowdown in new pasture expansion has indicated heightened pasture productivity and increased reuse of cleared areas through degraded pasture recovery. MapBiomas data for Brazil's Northern region from 2000 to 2023 (Figure 3) reinforces this trend, showing an 11% rise in productive pasture areas and a 32% drop in degraded ones. These patterns underscore significant progress in Amazonian cattle ranching, boosting both productivity and environmental benefits.

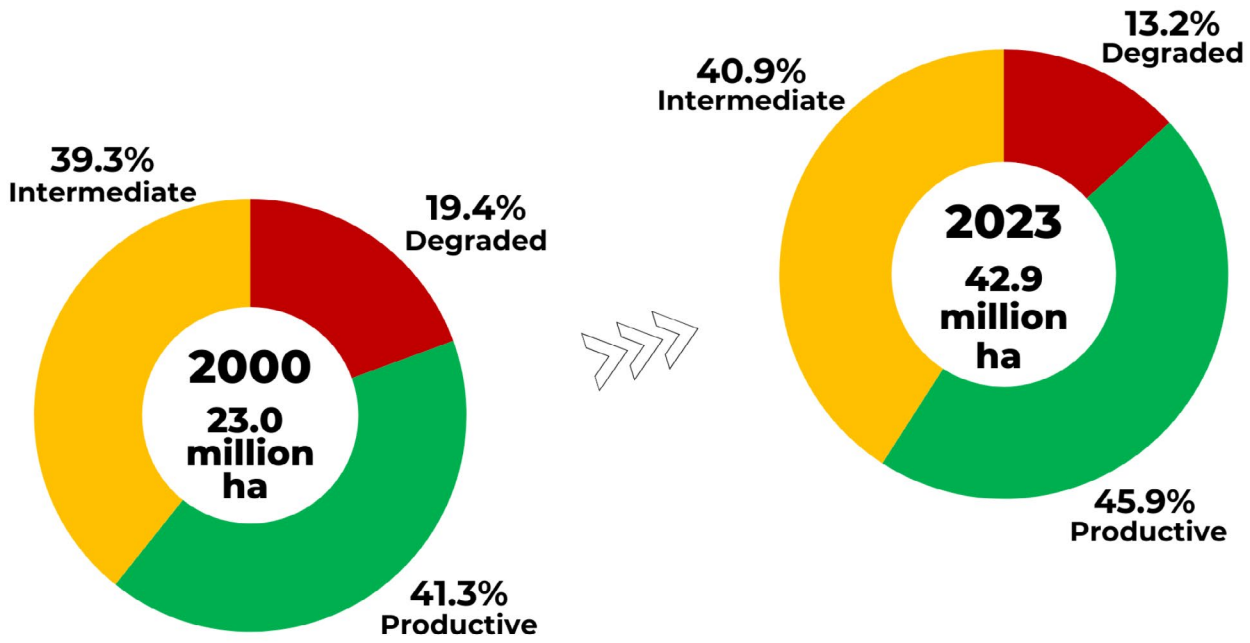

Figure 3. Trends in Brazil's Northern region pasture conditions, 2000–2023. Time series data, derived from remote sensing, should be interpreted with caution due to possible under- or overestimation.
Source: Adapted from Atlas [...] (2025) and Dias-Filho (2023).

Sustainable advances

Over the past four centuries, cattle ranching in the Amazon has undergone significant technological advancements, evolving from an unproductive system (Phase 1) and extensive management (Phase 2) to a more modern, efficient, and technologically advanced model (Phase 3). However, the average efficiency of regional cattle ranching still falls short of its full potential, offering substantial opportunities for technological enhancements to increase productivity (Strassburg et al., 2014). This gap is evident in the continued prevalence of amateurish management practices across many Amazonian pastures, such as using unsuitable grass varieties, applying improper stocking rates, maintaining irregular grazing intervals, and neglecting regular fertilizer or soil amendment applications. These management shortcomings can be overcome by rationally adopting existing technologies tailored to regional cattle ranching (Feltran-Barbieri; Féres, 2021; Cândido et al., 2024; Borges et al., 2025; Hernandez Guzman et al., 2025; Lopes et al., 2025; Moreno-Perez et al., 2025).

The third phase of Amazonian cattle ranching was driven by expanded access to and adoption of advanced technologies. Multiple stakeholders have contributed to transforming regional cattle management. Notably, political and environmental pressures to combat deforestation have been key drivers. Additionally, rising land prices and reduced land availability, driven by the growth of high-tech agriculture on former pasturelands, have significantly influenced this shift, both historically and today (Dias-Filho, 2014; Dias-Filho; Lopes, 2020).

The evolution of Amazonian cattle ranching is driven by a growing number of regional producers who, spurred by initiative, economic pressures, or external demands, are adopting more efficient and professional practices. These producers recognize the need to minimize errors to compete in a global market that increasingly demands high-quality animal protein while prioritizing environmental sustainability. Alongside ongoing efforts to restore degraded pastures, they implement preventive management for productive or recovered pastures to prevent further degradation.

A shift in producer mindset is ushering Amazonian livestock farming into Phase 4. In this phase, professional management practices are gradually replacing amateur approaches, fostering entrepreneurial livestock farming across properties of all sizes.

The Phase 4 of Amazonian livestock farming aligns with Brazil's Paris Agreement goals, including eliminating illegal deforestation, enhancing livestock

productivity, recovering degraded pastures, minimizing greenhouse gas emissions, and restoring forest vegetation (Gianetti; Ferreira Filho, 2024). At the same time, efforts are underway to increase regional meat and milk production capacity on existing pastures (Dias-Filho, 2022).

Pasture recovery boosts production, helping to prevent deforestation and reduce greenhouse gas emissions. For instance, cattle raised on productive pastures reach slaughter weight faster, emitting fewer greenhouse gases per unit of weight produced (Bogaerts et al., 2016; Charmley et al., 2023; Ramirez-Restrepo et al., 2023). This is primarily due to enhanced forage quality and digestibility, which boost liveweight gain and reduce methane (CH4) intensity per kilogram of carcass or liveweight (Cardoso et al., 2022; Kearney et al., 2023; Márton; Szabó, 2023; Smith; Crosson, 2024).

Equally important as reducing emissions, a key focus in livestock farming discussions, is increasing carbon dioxide removals from the atmosphere. These removals, often overlooked in livestock emissions calculations, are critical to achieving net-zero livestock farming, which aims to offset the greenhouse gas impacts of the industry (Fronza et al., 2024; Gianetti; Ferreira Filho, 2024; Correddu et al., 2025; Desta, 2025).

In livestock farming, the primary mechanism for carbon removal in productive, non-degraded pastures is soil carbon sequestration, driven by the efficient photosynthesis of tropical grasses (Tessema et al., 2021; Damian et al., 2023; Santos et al., 2024; Desta, 2025; Tenelli et al., 2025). By sustaining pasture productivity, these systems also prevent the release of carbon stored in the soil from the decomposition of forage plant roots (Oliveira et al., 2022; Damian et al., 2023; Henry et al., 2024; Tenelli et al., 2025).

In Phase 4 of Amazonian livestock farming, cattle ranchers, the primary drivers of this new phase, continue recovering degraded pastures, as seen in Phase 3, while professionalizing operations through preventive management to maintain productive pastures from the outset. These practices are widely recognized for significantly enhancing soil carbon storage and its stabilization within the soil (Tenelli et al., 2025).

The recent focus on professional management and carbon sequestration highlights a promising path forward for Brazilian Amazon cattle ranching, ensuring the industry's resilience while aligning it to meet global food security demands with minimal environmental impact.

Concluding remarks

The recovery of degraded pastures and the professional management of both productive and restored pastures are central to shaping the emerging Phase 4 of Amazonian livestock farming. By harnessing existing technology, this professionalization fosters sustained growth in regional meat production without expanding pasture areas or increasing degradation. Ultimately, Phase 4 strikes a balance between enhanced productivity and environmental preservation, promoting food security while curbing deforestation and the carbon footprint of Amazonian livestock farming.

The gradual transformation of Brazilian Amazon cattle ranching, evolving from its 17th-century origins into a modern, sustainable industry reflects a remarkable journey of adaptation and innovation. With a focus on degraded pasture recovery and preventive pasture management, cattle ranchers are well-equipped to meet global food security demands while minimizing environmental impact, steering the industry toward a net-zero future.

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