

# Ultraintensive livestock farming: an integrative review of technical, financial, environmental, and social-institutional indicators in Latin America

## Ganadería ultraintensiva: revisión integrativa de indicadores técnicos, financieros, ambientales y social-institucionales en América Latina

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## ABSTRACT

Bovine livestock farming in Latin America faces the challenge of increasing productivity and competitiveness without worsening environmental impacts or conflicts over land use. In this context, ultraintensive systems with strategic supplementation emerge as an alternative; however, regional evidence remains scattered, heterogeneous, and based on metrics that are not always comparable, which limits evidence-based technical and policy decisions. This article comparatively evaluates the technical, financial, environmental, and social-institutional viability of ultraintensive livestock systems with strategic supplementation against traditional extensive models in Brazil, Argentina, Uruguay, Paraguay, and Colombia. An integrative review was conducted following the methodology proposed by Whitemore and Knafl (2005) and PRISMA 2020. Scopus, Web of Science, SciELO, and Redalyc were consulted, supplemented by grey literature (FAO, IICA, CEPAL, INAC, INTA, EMBRAPA). A total of 240 records were identified, and 50 documents were included (32 articles, 10 technical reports, 5 theses, and 3 reviews) published between 2000 and 2024 in English, Spanish, and Portuguese. The synthesis indicates that ultraintensive models increase weight gain (20–35%), improve forage efficiency (up to 40%), and reduce GHG emissions per kg of meat (15–25%). Financially, they show better medium-term returns, although the initial investment and access to credit restrict adoption among smallholder producers. At the social-institutional level, training, cultural acceptance, and traceability and certification frameworks condition scaling. Overall, the findings support policies and investments aimed at sustainable intensification, with financing, technical assistance, and territorial governance.

**Keywords:** ultraintensive livestock farming, integrative review, sustainability, strategic supplementation, financial viability.

## RESUMEN

La ganadería bovina en América Latina enfrenta el desafío de incrementar productividad y competitividad sin agravar impactos ambientales ni conflictos por uso del suelo. En este contexto, los sistemas ultraintensivos con suplementación estratégica emergen como alternativa, pero la evidencia regional permanece dispersa, heterogénea y con métricas no siempre comparables, lo que limita decisiones técnicas y políticas basadas en evidencia. Este artículo evalúa comparativamente la viabilidad técnica, financiera, ambiental y social-institucional de sistemas ganaderos ultraintensivos con suplementación estratégica frente a modelos extensivos tradicionales en Brasil, Argentina, Uruguay, Paraguay y Colombia. Se realizó una revisión integrativa siguiendo la metodología propuesta por Whitemore y Knafl (2005) y PRISMA 2020. Se consultaron Scopus, Web of Science, SciELO y Redalyc, complementadas con literatura gris (FAO, IICA, CEPAL, INAC, INTA, EMBRAPA). Se identificaron 240 registros y se incluyeron 50 documentos (32 artículos, 10 informes técnicos, 5 tesis y 3 revisiones) publicados entre 2000 y 2024 en inglés, español y portugués. La síntesis indica que los modelos ultraintensivos aumentan la ganancia de peso (20–35%), mejoran la eficiencia forrajera (hasta 40%) y reducen emisiones de GEI por kg de carne (15–25%). Financieramente, muestran mejores retornos a mediano plazo, aunque la inversión inicial y el acceso a crédito restringen la adopción en pequeños productores. En el plano social-institucional, la capacitación, la aceptación cultural y los marcos de trazabilidad y certificación condicionan el escalamiento. En conjunto, los hallazgos respaldan políticas e inversiones orientadas a intensificación sostenible, con financiamiento, asistencia técnica y gobernanza territorial.

**Palabras clave:** ganadería ultraintensiva, revisión integrativa, sostenibilidad, suplementación estratégica, viabilidad financiera.

## INTRODUCTION

Bovine livestock farming is one of the economic, social, and cultural pillars of Latin America, contributing significantly to the agricultural gross domestic product, rural employment, and meat exports (FAO, 2018; Instituto Brasileiro de Geografia e Estatística (IBGE), 2024). However, it faces the challenge of increasing productivity to meet growing global food demand, while simultaneously responding to environmental and social pressures arising from climate change, natural resource degradation, and international market requirements regarding sustainability (Garnett et al., 2013; Thornton, Nelson, Mayberry, and Herrero, 2022). The transformation of the livestock sector is key to achieving the Sustainable Development Goals (SDGs) (FAO, 2018). A critical aspect is heat stress, which affects production, particularly in confined systems (Frigeri et al., 2023). The demand for sustainable production is not limited to technical efficiency, but extends to compliance with high animal welfare standards (Rius, 2015), climate change mitigation, and responsible management of natural resources. Therefore, the viability of these ultraintensive systems in the Latin American context must be evaluated holistically. However, regional evidence remains scattered, heterogeneous, and based on metrics that are not always comparable, which limits evidence-based technical and policy decisions. This article aims to comparatively evaluate the technical, financial, environmental, and social-institutional viability of ultraintensive beef cattle systems in Latin America through an integrative review, synthesizing key indicators to inform decision-makers.

In this context, and aligned with the regional bioeconomy framework that promotes the transformation of raw materials into higher-value and more sustainable products (Rodríguez, Mondaini, and Hirschfeld, 2019), and forming part of a global policy agenda (OECD, 2009), traditional extensive systems—characterized by low stocking density and limited supplementation—show significant constraints in productive efficiency, climate resilience, and integration into global value chains (Reinosso Ortíz and Soto Silva, 2006). In response to these limitations, ultraintensive livestock models with strategic supplementation have emerged, combining high-density rotational grazing, nutrition adjusted to forage seasonality, and, in some cases, precision technologies (Berckmans, 2017; Jiang, Tang, Cui, and Deng, 2023). These systems have demonstrated potential to increase daily weight gain, reduce fattening periods, and optimize land and water use, contributing to a lower environmental footprint per kilogram of meat produced (Mottet et al., 2017; Morais et al., 2023).

Beyond the technical dimension, livestock intensification raises important economic and social questions. On one hand, it requires substantial investments in infrastructure and training, which may constitute a barrier to entry for smallholder producers (Pereira et al., 2024). On the other hand, it offers opportunities to access differentiated markets that value attributes such as traceability and environmental certification, as demonstrated by Uruguay's experience with carbon-neutral beef (Instituto Nacional de Carnes (INAC), 2024a). At the same time, cultural resistance and financing limitations in countries such as

Paraguay and Colombia highlight that intensification is not solely a technological process, but also a social and institutional one (OPSAA-IICA, 2024).

The search for a solution to the trade-off between productivity and sustainability has led the region to adopt Sustainable Intensification (SI) models. Bungenstab (2012), describing the Crop-Livestock-Forestry Integration (CLFI) system in Brazil, emphasizes that the key to SI lies not only in increasing production, but in maximizing resource-use efficiency (soil, water, inputs) and in productive diversification to mitigate risks and reduce the environmental footprint per unit of product. This integrated approach underpins the long-term viability of the ultraintensive systems under review.

Several recent studies and reviews agree that sustainable intensification, when properly designed and managed, can contribute to reconciling productivity and environmental performance through improvements in resource conversion efficiency and reductions in emissions per unit of product (Pereira et al., 2024; Pesenti Rossi, Dalla Costa, Barbieri, Minero, and Canali, 2024). In Latin America, available empirical evidence reports weight gain increases of 20–35%, forage efficiency improvements of up to 40%, and GHG emission reductions per kg of meat of 15–25% in ultraintensive systems with strategic supplementation, with results conditioned by the productive context and the technological package implemented (Sales et al., 2011; Cortiana Tambara, Härter, Silveira Rabelo, and Kozloski, 2021; Mottet et al., 2017; Gerber et al., 2013). However, the regional literature remains fragmented: numerous studies present technical or environmental indicators in isolation, with methodologies and metrics that are not always comparable, and with gaps in financial assessment (initial investment, access to credit, and returns) and in the analysis of institutional frameworks that condition adoption and scaling (Pereira et al., 2024; FAO, 2025; OPSAA-IICA, 2024). This heterogeneity, combined with national differences in policies, traceability, and certification (e.g., Uruguay) or in structural constraints (e.g., Paraguay and Colombia), generates divergent trajectories and limits evidence-based technical decision-making and public policy design (OPSAA-IICA, 2024; FAO, 2025). Within this framework, a comparative integrative review that simultaneously addresses technical, financial, and environmental dimensions in the Latin American context is warranted.

This article aims to comparatively evaluate the technical, financial, environmental, and social-institutional viability of ultraintensive livestock systems with strategic supplementation against traditional extensive models in Brazil, Argentina, Uruguay, Paraguay, and Colombia. These countries were selected for three complementary reasons: (i) productive relevance and diversity of systems within regional livestock farming (ranging from highly technified frameworks to predominantly extensive schemes); (ii) institutional and market heterogeneity, which allows for contrasting regulatory frameworks, monitoring capacities, technology adoption, and access to financing; and (iii) sufficient availability and continuity of evidence (scientific, technical, and institutional literature) to build comparisons

within the same analytical framework. Together, this selection captures contrasting trajectories: Brazil and Argentina concentrate greater scale and adoption, Uruguay provides a case of more advanced traceability and certification development, while Paraguay and Colombia represent transition scenarios with structural constraints that condition scaling. The originality of this review lies in offering an integrative analysis that not only systematizes the available scientific and technical evidence, but also links it to public policies, market trends, and global debates on agri-food sustainability.

## MATERIALS AND METHODS

The research was structured as a comparative review of technical, financial, environmental, and social indicators, aimed at evaluating the viability of ultraintensive livestock systems against traditional extensive models in Latin America. The methodological design was inspired by the proposal of Whitemore and Knafl (2005), adapted to an integrative analysis of indicators, and operationalized following the PRISMA 2020 guidelines, ensuring traceability, transparency, and rigor in document selection.

Publications up to 2024 were considered, as this is the last year with complete and comparable evidence in the consulted sources, in high-impact academic databases including Scopus, Web of Science, SciELO, and Redalyc, supplemented by grey literature from international organizations such as FAO, IICA, CEPAL, EMBRAPA, and INTA. Search descriptors were formulated in English, Spanish, and Portuguese, combining terms related to livestock productivity, strategic supplementation, financial viability, and methane emissions.

The initial screening identified 240 records. After the removal of duplicates and the systematic application of inclusion criteria (indexed articles, reviews, technical reports, and theses) and exclusion criteria (non-peer-reviewed, duplicate, or thematically irrelevant publications outside the Latin American context), the final corpus comprised 50 documents, representing the set of eligible studies to address the research question under the defined protocol. This number was not calculated a priori as a sample size to statistically “represent” the total body of publications; rather, it results from the PRISMA selection process: these are the works that, in addition to being relevant, provide sufficient and comparable information on the technical, financial, environmental, and social dimensions analyzed. Methodological quality was assessed using CASP checklists and PRISMA criteria, classifying the evidence as high, medium, or low robustness, which allowed for the prioritization of confidence in the results and the interpretation of findings considering the heterogeneity of designs and sources. In this regard, the “representativeness” of the synthesis is grounded in the coverage and traceability of the process (academic databases and grey literature, diversity of document types, languages, and the 2000–2024 period), rather than in numerical sampling.

The integration of findings was organized into a comparative indicator matrix structured around four axes: (i) technical

productivity (e.g., weight gain, forage efficiency), (ii) system financial viability (e.g., supplementation costs, initial investment, margin, and return on investment), (iii) environmental impact (e.g., GHG emissions, water and land use), and (iv) social-institutional dimension (e.g., cultural acceptance, training and technical assistance needs, adoption barriers, and institutional/market frameworks such as traceability and certification). This strategy enabled the contrasting of results across countries and productive models within an integrative framework. It should be noted that, given the availability and heterogeneity of the evidence, the financial axis focused on direct monetary indicators reported by the studies; therefore, the term “financial viability” is used rather than “economic viability,” since a comprehensive economic evaluation would additionally incorporate total factor productivity, opportunity costs, employment and territorial effects, and externalities, which are not systematically reported in the reviewed literature. Together, the matrix provides an integrated view of the technical, financial, environmental, and social-institutional performance of livestock intensification in the region.

In summary, this integrative approach not only synthesizes the available scientific evidence, but also provides strategic inputs to guide business and public policy decisions, constituting an original contribution to the debate on sustainability and competitiveness of livestock farming in Latin America.

## RESULTS AND DISCUSSION

The results of the integrative review confirm that ultraintensive livestock systems with strategic supplementation present significant advantages over traditional extensive models in Latin America.

On the technical front, evidence indicates that, compared to traditional systems, animal weight gain increases by 20 to 35%, while forage efficiency can improve by up to 40% when supplementation is adjusted to seasonal conditions (Sales et al., 2011; Cortiana Tambara et al., 2021). Strategic supplementation studies have demonstrated direct efficiency improvements in Argentine systems (Instituto Nacional de Tecnología Agropecuaria (INTA), 2025), while seasonality also impacts key zotechnical indicators such as survival and fertility (Pinedo and De Vries, 2017). Foraging behavior in pastures is a key factor influencing consumption efficiency and response to supplementation (Da Silva and Carvalho, 2005). The success of these improvements is grounded in strategic supplementation, an indispensable technology designed to correct nutritional deficiencies in pastures and enable the slaughter of younger animals, meeting market requirements for precocity (Lopes de S. Thiago and Marques da Silva); feeding behavior is positively affected by supplementation during the finishing phase (Xavier et al., 2023). In contrast, extensive systems tend to record lower weight gain and lower forage efficiency, with more variable performance conditioned by seasonality and forage availability, as described by Reinosso Ortíz and Soto Silva (2006).

From a financial perspective, ultraintensive models require initial investments in infrastructure and technical training (Pereira et al., 2024). Nevertheless, they generate superior medium-term returns, particularly in countries with access to differentiated markets. Uruguay stands out as a notable example: mandatory traceability (Sistema Nacional de Información Ganadera – SNIG) (González, Martínez, and Wyszynski, 2016; Ministerio de Ganadería, Agricultura y Pesca (MGAP), 2017) and carbon-neutral beef certification have enabled it to position itself in high-value international niches (INAC, 2024a). This institutional robustness ensures compliance with the most demanding international standards, such as the European EUDR Regulation (INAC, 2024b), sustaining its competitiveness, as supported by foreign trade reports (Uruguay XXI, 2024) and international analyses (Kenneth, 2024). Traditional systems, by contrast, show narrow margins and low global competitiveness (FAO, 2018).

In the environmental dimension, the debate on livestock sustainability centers on reducing the environmental footprint, primarily greenhouse gas (GHG) emissions. The Sustainable Intensification (SI) strategy is consolidating as the primary pathway for achieving mitigation in grazing systems. Dumont, Groot, and Tichit (2018) argue that SI is a fundamental requirement for “greening” ruminant production, as it allows for the reconciliation of productive and environmental objectives by reducing emissions per unit of product. The application of best management practices in livestock, such as intensification, is essential to achieving effective GHG emission reductions at the global level (Andeweg and Reisinger, 2014). This approach forms the conceptual foundation for why ultraintensive systems are considered an environmentally viable alternative in Latin America. In line with this conceptual framework, the empirical evidence from the review confirms that intensification with strategic supplementation in the studied countries reduces greenhouse gas emissions by 15–25% per kilogram of meat, owing to greater productive

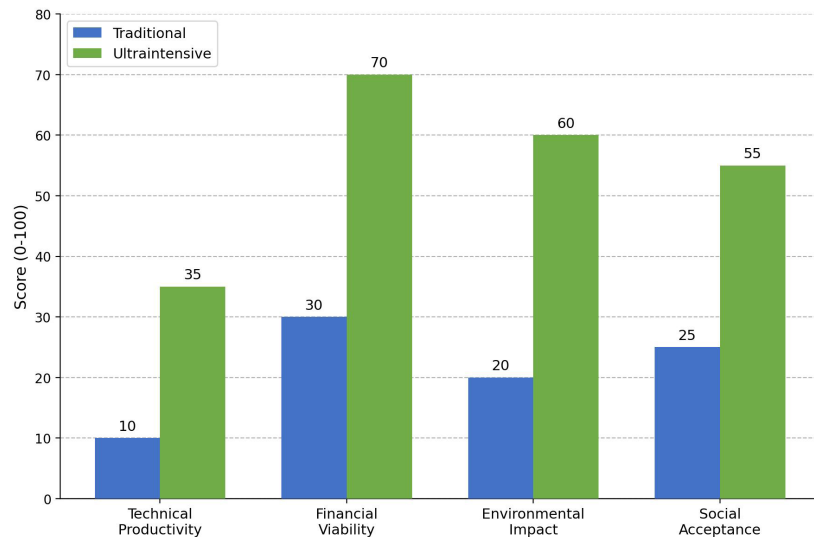
efficiency and a reduction in fattening days (Mottet et al., 2017; Gerber et al., 2013). Furthermore, the incorporation of monitoring and decision-support technologies (PLF), such as precision nutrition (Pomar and Remus, 2023), IoT, and Artificial Intelligence (Issa, Majed, Ameer, and Al-Jawahry, 2024; Aquilani, Confessore, Bozzi, Sirtori, and Pugliese, 2022), can improve productive management and operational efficiency, although their implementation faces barriers related to cost, infrastructure, and adoption (Papakonstantinou et al., 2024; Schillings, Bennett, and Rose, 2021; Werkheiser, 2020). In contrast, extensive systems require up to 50% more land and time to achieve the same production volumes, increasing the environmental footprint per unit of product (Morais et al., 2023). Intensification is viewed as a key strategy for reducing pressure on tropical forests and limiting the expansion of the livestock frontier (Kaimowitz and Angelsen, 2008; Parra-Cortés, Magaña-Magaña, and Piñeiro-Vázquez, 2019).

At the regional level, Brazil and Argentina lead in the adoption of intensification practices and precision technologies; Uruguay stands out for its institutional framework and environmental certifications; while Paraguay and Colombia show limited progress due to structural, financial, and cultural constraints (FAO, 2025; OPSAA-IICA, 2024). Paraguay’s limitations occur despite its status as a significant beef exporter in the region, as reflected in sectoral production and export figures (SENACSA, 2025; Asociación Rural del Paraguay (ARP), 2025), underscoring the dichotomy between volume and institutional sustainability. These findings demonstrate that the viability of intensification depends not only on technical advances, but also on institutional frameworks, accessible financing, and social acceptance (FAO, 2025; OPSAA-IICA, 2024).

**Table 1.** Comparison of main findings between traditional and ultraintensive livestock systems across five Latin American countries.

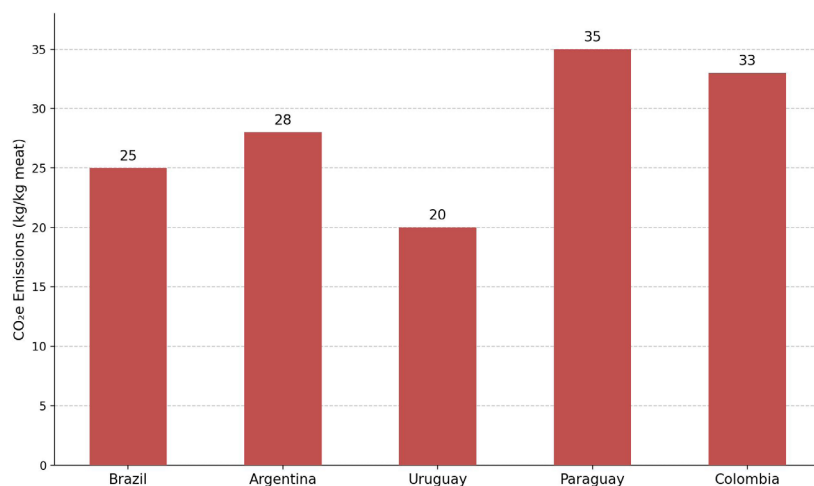
Country	Technical Productivity	Financial Viability	Environmental Impact	Social-Institutional Limitations
<b>Brazil</b>	Weight gain +30%, forage efficiency +40%	High initial investment; competitive return on exports	Reduced emissions per kg of meat ( $\approx -20\%$ )	Need for financing and continuous training
<b>Argentina</b>	25–30% improvements in productivity	Medium-high profitability; strong experimental base (INTA)	Moderate emission reductions; advances in traceability	Variable adoption across regions
<b>Uruguay</b>	Stable productivity with strategic supplementation	Access to premium markets with carbon-neutral beef	Certified carbon footprint reduction	High social acceptance and solid institutional governance
<b>Paraguay</b>	Partial technical gains in pilot projects	Limited access to credit; low-medium return	Still high environmental impact due to low efficiency	Cultural resistance and limited technical training
<b>Colombia</b>	Heterogeneous productivity by region	Low investment in intensification; limited international insertion	Partial emission reduction, without official green certification	Lack of institutionality and green financing

Source: Own elaboration based on FAO (2018), Sales et al. (2011), Cortiana Tambara et al. (2021), Reinosso Ortíz and Soto Silva (2006), Guerra et al. (2016), Euclides, Montagner, Barbosa and Nantes (2014), INAC (2024a), OPSAA-IICA (2024).



Source: Own elaboration based on FAO (2018), Sales et al. (2011), Cortiana Tambara et al. (2021), Reinosso Ortíz and Soto Silva (2006), Guerra et al. (2016), OPSAA-IICA (2024).

**Figure 1.** Comparative performance between livestock models in Latin America. Blue bars represent the traditional system and green bars the ultraintensive system, on a scale of 0–100 points across four evaluated dimensions: technical productivity, financial viability, environmental impact, and social acceptance.



Source: Own elaboration based on Gerber et al. (2013), Mottet et al. (2017), Morais et al. (2023).

**Figure 2.** Comparative methane emissions across five countries (2000–2024). Bars show the average emission intensity expressed in kg CO<sub>2</sub>e per kg of meat, considering the national livestock matrix combining traditional and ultraintensive systems in Brazil, Argentina, Uruguay, Paraguay, and Colombia.

Figure 1 offers a visual and comparative synthesis of the performance between traditional and ultraintensive livestock models in Latin America, based on recent literature. The ultraintensive model demonstrates clear superiority across all metrics: it reaches its greatest advantage in financial viability (close to 70 points on a scale of 100) and in environmental impact (around 60 points), reflecting higher returns and better resource-use efficiency per unit of product. Although technical productivity is also markedly superior in the ultraintensive system (35 points versus 10 for the traditional), the social-institutional dimension shows the narrowest gap (55 points versus 25), suggesting that, while the technology is viable, adoption faces significant training and cultural acceptance challenges that require policy and financial attention.

Figure 2 presents the emission intensity associated with methane, expressed in kg CO<sub>2</sub>e per kg of meat, for five Latin American countries over the 2000–2024 period, estimated as the average of their national livestock matrices combining traditional and ultraintensive systems. These estimates, grounded in consolidated literature and reports (Gerber et al., 2013; Mottet et al., 2017; Morais et al., 2023), allow for the comparison of structural differences in productive efficiency across countries. In order to validate the observed patterns, the results were contrasted with current livestock sector emissions reported by national inventories and recent international databases, which report total emissions by category (e.g., methane from enteric fermentation and manure management). This comparison shows that countries with higher absolute

emissions do not necessarily exhibit higher intensities per kilogram of meat, evidencing the role of productivity, fattening cycle duration, and conversion efficiency in the recorded gaps. Likewise, national differences also reflect institutional and market factors such as traceability and environmental certification in Uruguay, which influence technology adoption and the international positioning of the sector. Overall, this verification with current sectoral data strengthens the coherence of the findings and reinforces the need to advance toward well-managed intensification models aligned with climate objectives.

The analyzed results demonstrate that livestock intensification with strategic supplementation constitutes a viable and sustainable alternative to traditional extensive systems. However, its consolidation requires not only technological advances, but also inclusive policies, access to financing, training of rural stakeholders, and robust regulatory frameworks. Under these conditions, the ultraintensive model can contribute to the competitiveness of Latin American livestock farming and align with the Sustainable Development Goals, particularly SDGs 2, 12, and 13.

## CONCLUSIONS

The integrative review confirms that ultraintensive livestock farming with strategic supplementation constitutes a productive and competitive alternative to traditional extensive systems in Latin America. The findings show productivity increases of between 20% and 35%, improvements in forage efficiency of up to 40%, and reductions in greenhouse gas emissions of 15% to 25% per kilogram of meat. These advantages, however, depend on the adequate integration of infrastructure, adjusted supplementation, and precision technologies.

On the financial front, ultraintensive systems generate higher medium- and long-term returns, particularly in countries with access to differentiated markets that reward traceability and environmental certification, as exemplified by Uruguay. However, the high initial investment and restrictions on access to credit remain barriers that limit adoption by smallholder producers, highlighting the urgency of inclusive policies that prevent the concentration of benefits.

From an environmental perspective, ultraintensification presents clear advantages in efficiency and relative emission mitigation. Nevertheless, its sustainability requires robust territorial planning regulatory frameworks that ensure the responsible use of soils and water. Cultural acceptance and technical training emerge as critical conditions for scaling, which explains the differences observed between countries with strong institutional frameworks—such as Brazil, Argentina, and Uruguay—compared to Paraguay and Colombia.

In summary, the transition toward ultraintensive and sustainable livestock farming demands the convergence of technological innovation, training programs, access to financing, and institutional governance. When these factors align, intensification not only increases productivity

and international competitiveness, but also contributes to the achievement of the Sustainable Development Goals, particularly in food security, climate action, and bioeconomy.

The results of this review provide strategic inputs for governments, international organizations, and producers to design policies and investment programs that promote sustainable intensification as a concrete pathway to position Latin America as a global benchmark in efficient, traceable, and climatically responsible meat production.

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## CONFLICT OF INTERESTS

The author declares no conflict of interests.

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