THE BEEF CATTLE INDUSTRY IN THE BRAZILIAN LEGAL AMAZON FROM THE PERSPECTIVE OF THE SUSTAINABLE DEVELOPMENT GOALS: A SYSTEMATIC REVIEW

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ABSTRACT: The production and trade of agricultural commodities, such as beef, contribute substantially to the economies of many tropical nations, but also generate significant social and environmental damage, including the conversion of native ecosystems, social conflicts, and land appropriation. Considering that Brazil is one of the largest cattle producers in the world, cattle farming in the Amazon represents a significant part of this production. Adhering to sustainable livestock farming is essential for the region's economic, social, and environmental development. Since livestock farming can help achieve the goals established by the Sustainable Development Goals (SDGs), this research aims to conduct a systematic review of cattle farming in the Brazilian Legal Amazon, focusing on SDGs 1, 2, 13, 15, and 17. Approximately 3,170 articles were analyzed, of which only 34 were included in this study because they met the eligibility criteria. The analysis of these articles revealed that 2016 had the highest number of publications, while 2022 had the lowest number. It was observed that none of the articles that met the criteria directly related livestock farming to achieving the Sustainable Development Goals.

KEYWORDS: Livestock; Sustainability; Agriculture; Sustainable Development Goals; Brazilian Legal Amazon; Systematic Review.

INTRODUCTION

Brazilian Legal Amazon includes the entire Amazon biome area, as well as parts of the Cerrado and Pantanal biomes. Nine states make up the region, namely: Acre (22 municipalities), Amapá (16), Amazonas (62), Mato Grosso (141), Pará (144), Rondônia (52), Roraima (15), Tocantins (139), and part of Maranhão (181 municipalities, of which 21 were partially integrated), totaling 772 municipalities. Although Maranhão is the state with the highest number of municipalities, only 79.3% of its territory (or 261,350.785 km²) is integrated into the Legal Amazon coverage area (IBGE, 2019). Brazil is the third-largest cattle producer in the world, behind China and India (USDA, 2023).

In Brazil, beef production systems are characterized by an almost exclusive dependence on pastures due to the low cost and wide availability of land. However, the extensive system has low productivity (Fernandes *et al*, 2022). The production and trade of agricultural commodities, such as beef, contribute substantially to the economies of many tropical nations, but also generate significant social and environmental damages, including the conversion of native ecosystems, social conflicts, and land appropriation (Levy *et al*, 2023).

Although agricultural soil is a natural resource, its renewal is not instantaneous. The essential nutrients for soil fertility, such as nitrogen, phosphorus, and potassium, are constantly recycled through complex biogeochemical cycles. However, inappropriate agricultural and livestock practices can disrupt these cyclical processes, resulting in depleted and infertile soils. In this scenario, restoring soil quality can take centuries, a timeframe incompatible with current human needs. Fortunately, human intervention can also produce positive effects, such as preventing erosion, controlling flooding, and adapting plant species to managed environmental conditions. Therefore, adopting sustainable soil management techniques is essential to ensure the long-term maintenance of soil health and productivity, preventing irreversible damage (Barbieri, 2023)

The 2030 Agenda, also known for its 17 Sustainable Development Goals (SDGs), was established in 2015 when 193 United Nations Member States formalized their commitment to the goals and objectives. These commitments serve as a guide for governments in implementing sustainable public policies (Neto *et al*, 2022). In recent years, the perspectives and challenges of achieving the sustainable development goals have received increasing attention in the context of livestock production.

In line with this effort, the present study aims to systematically review the existing literature to document contributions and methodological gaps related to the beef cattle industry in the Brazilian Legal Amazon from the perspective of the sustainable development goals. Specifically, this review explores, through a systematic review, the authors, journals, keywords, and methodological choices of articles that relate the achievement of the SDGs to agricultural production in the Brazilian Legal Amazon.

RELEVANT SECTIONS

Sustainable development has been debated and addressed at several international meetings. The United Nations Conference on the Human Environment in Stockholm (1972) began this journey, followed by the Brundtland Report (1983) and the Montreal Protocol (1987). The Earth Summit in Rio de Janeiro (1992) distributed Agenda 21. In 1997, the Kyoto Protocol defined targets for reducing greenhouse gas emissions. Rio+10 in Johannesburg (2002) and the Bali Conference (2007) continued the focus on these objectives. The Bangkok Meeting (2008) and the Copenhagen Conference (2009) were important steps towards new international treaties. In 2015, the UN 2030 Agenda proposed 17 Sustainable Development Goals (SDGs). COP 21 in Paris (2015) resulted in the Paris Agreement, with the goal of “zero emissions” by 2050 (Neto et al., 2022; United Nations in Brazil, 2023). The concept of sustainable development, which aims to meet present needs without compromising the future, has been consolidated, connecting livestock farming to the three pillars of sustainability: environmental, social, and economic (Niloofar et al., 2023; FAO, 2018).

Despite recognizing that livestock can contribute to achieving all 17 goals, some stand out cohesively, such as SDG 1: No Poverty, SDG 2: Zero Hunger, SDG 13: Climate Action, SDG 15: Life on Land, and SDG 17: Partnerships for the Goals.

Livestock farming plays an important role in eradicating poverty (SDG 1) and hunger (SDG 2) because, for people considered poor, raising cattle represents not only an income that can be sold in times of crisis, but at the same time, cattle provide animal traction, fertilizers, and food such as milk, meat, and leather (FAO, 2018).

Eradicating hunger and extreme poverty is possible through the implementation of a series of strategies, including social measures and targeted investments. Social protection programs, which include specific nutritional actions, are examples of social initiatives that can be adopted. Additionally, supporting small producers, with a focus on low-income families, can contribute to the development of their economic capital, helping to eradicate poverty and hunger (FAO, 2016).

Climate change and its connection to livestock: Climate change affects livestock in various ways, both directly and indirectly. One example is the increase in CO2 concentrations in the atmosphere and variations in temperature and precipitation, which affects both small and large producers, leading to a loss of productivity. However, the most affected are those with less capital. If there is good management of natural resources, such as improved water management and utilization, better grazing management, and increased animal mobility, despite animals contributing to the increase in greenhouse gases, with good agricultural management, they can be allies in reducing greenhouse gases (FAO, 2018).

Protect, restore, and promote sustainable development and life on land: Livestock can have either a positive or negative impact depending on its production intensity. Livestock not only exerts pressure through the conversion of natural areas into pastureland but also impacts the quality and quantity of water. Improving management practices using technology can contribute to the restoration of pastures, carbon sequestration in soils, and reduced deforestation (FAO, 2018).

According to Larrea et al. (2021), cattle ranching plays a significant role in deforestation in the Amazon. The transformation of forests into pastures results in the loss of biodiversity, changes in the hydrological cycle and substantial releases of greenhouse gases. This process releases large amounts of carbon stored in biomass and soil, contributing to global climate change. According to Maeda et al. (2021), “the expansion of commodity agriculture, including cattle ranching, exacerbates the climate impacts of Amazon deforestation”, evidencing how the conversion of forests to pastures negatively impacts biodiversity, precipitation patterns, and greenhouse gas emissions.

The Amazon rainforest has been disappearing rapidly in recent years to enable the expansion of agriculture and livestock, presenting high risks of irreversible changes to its biodiversity and ecosystems (Bogoni *et al*, 2023). Especially in recent years, there has been a significant increase in annual deforestation rates across the Legal Amazon. The deforested area in Brazil grew by 22.3% in 2022, according to the Annual Deforestation Report (MAPBIOMAS, 2023b). These changes occurred largely in response to the growing global market demand for animal and plant protein (Foley *et al*, 2011).

According to Mapbiomas (2023), agriculture and livestock experienced approximately 50% growth over 38 years, expanding from 187.3 million hectares to 282 .5 million hectares. Of this total, 58% correspond to pastures, which recorded an increase of over 60% between 1985 (103 million hectares) and 2022 (164.3 million hectares).

The conversion of native areas to pastureland remained at high levels during these 38 years of observed data. Although there was a decline from 2008 to 2012, conversion increased again from 2013. Between 1985 and 2022, the five states with the largest deforested areas for conversion to pasture were Pará (18.5 million hectares), Mato Grosso (15.5 million hectares), Rondônia (7.4 million hectares), Maranhão (5.4 million hectares), and Tocantins (4.5 million hectares).

METHODOLOGY

According to Prisma (2020), to ensure that a systematic review adds value to users, authors must prepare a transparent, complete, and accurate report of why the review was conducted, what was done, and what they found. The methodology for a systematic review, as described by Koutsos *et al*, (2019), can be organized as follows:

Step 1) Defining the scope of the research: In this step, the scope of the research is defined. This includes identifying the topic of interest and defining the systematic review protocol; in this study, the protocol chosen was the Key Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (2020).

Step 2) Planning: Planning involves defining the database to be used for the research (in this case, Scincedirect) and delimiting and defining keywords for the search. The keywords used were combined as follows: (i) livestock * brazilian amazon *Sustainability; (ii) livestock * brazilian amazon * sustainable development goals; (iii) livestock * brazilian amazon * poverty; (iv) livestock * brazilian amazon * zero hunger and sustainable agriculture; (v) livestock * brazilian amazon * climate action (vi) livestock * brazilian amazon * life on Earth (vii) livestock * brazilian amazon * partnership and means of implementation.

Step 3) Identification/Search: The search was conducted in the Science Direct database, using the keywords defined in the planning stage. The articles were selected and entered into a table called “database”, where they were counted and evaluated. The search was conducted in October, November, and December 2023. In total, 3,170 articles were included in the database.

Step 4) Screening: The studies identified in the search stage were screened based on the inclusion and exclusion criteria defined in the scoping stage. Only scientific and systematic review articles published in English up to 2023, which address livestock farming in the Brazilian Legal Amazon and are linked to SDGs 1, 2, 13, 15 and 17, were included. Chapters of books, books and articles published in scientific events were excluded. After excluding duplicate articles, 1,463 articles remained. After reading the title and abstracts, 73 articles were selected, with 1,390 articles that did not meet the inclusion criteria being excluded.

Step 5) Eligibility/Evaluation: The studies that passed the screening were evaluated in detail to determine their eligibility for inclusion in the systematic review. Of the 73 previously selected articles, it was not possible to retrieve 1 document and was not included, so of the 72 eligible articles, only 34 specifically addressed livestock farming in the Brazilian Legal Amazon.

Step 6) Presentation/Interpretation: Finally, the results of the systematic review were presented and interpreted. This allowed for discussion of the findings, identification of gaps in the existing literature, and suggestions for future research. The framework applied in this work is presented in Figure 1. This framework ensures that the systematic review is rigorous, replicable, and relevant to the academic community.

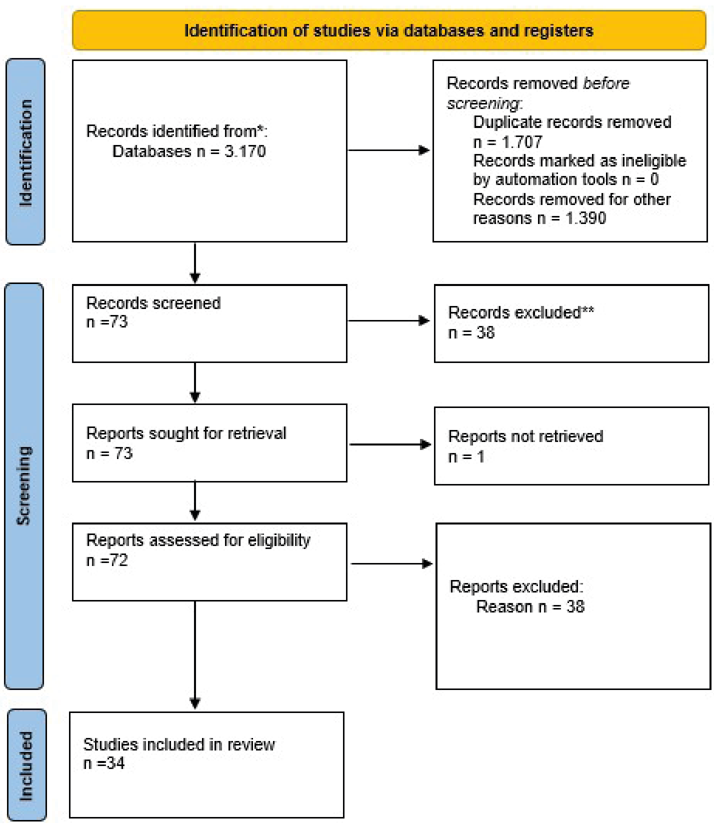


Figure 1- Systematic review framework based on the PRISMA protocol.

Source: Author

RESULTS AND DISCUSSIONS

Figure 2 illustrates the number of articles published annually. In 2016, we recorded the highest number of publications related to livestock farming in the Brazilian Legal Amazon. This significant increase can be attributed to various global agendas, particularly the 2030 Agenda. Established in September 2015, the 2030 Agenda outlines the Sustainable Development Goals (SDGs), which aim to eradicate poverty, achieve zero hunger, promote good health and well-being, provide quality education, ensure gender equality, provide clean water and sanitation, promote affordable and clean energy, achieve decent work and economic growth, foster innovation and infrastructure, reduce inequalities, build sustainable cities and communities, promote responsible consumption and production, take action against climate change, conserve life below water, protect life on land, and promote peace, justice, and strong institutions, along with partnerships to achieve these goals. These objectives are actions designed to protect life on Earth (United Nations in Brazil, 2023).

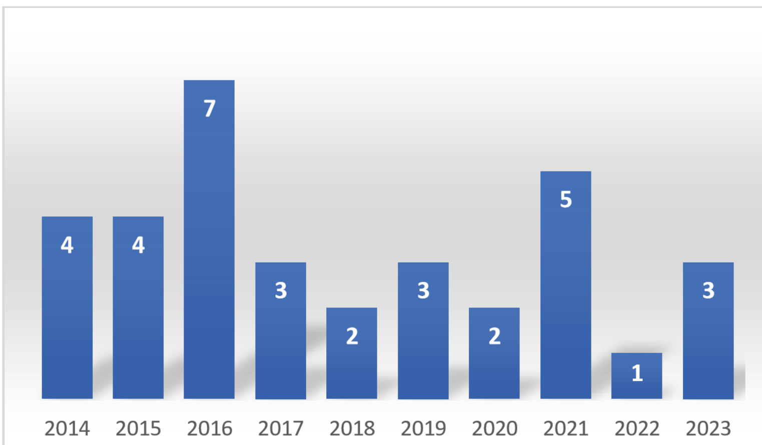


Figure 2- Number of articles published per year

Source: Author

The following table 1 describes the information for each selected article, including Title, Author and Year, Journal, and the SDGs (Sustainable Development Goals) related to each article. For better interpretation, it is important to note that a blank SDG column indicates that the study was not related to that SDG.

Title of th estudy	Authors	Journal	SGD 1	SGD 13	SGD 2	SGD 15	SGD 17
Policy change, land use, and agriculture: The case of soy production and cattle ranching in Brazil, 2001–2012	Gollnow e Lakes (2014)	Applied Geography			SGD 13	SGD 15	SGD 17
Intensification of cattle ranching production systems: socioeconomic and environmental synergies and risks in Brazil	Latawiec *et al.* (2014)	Animal	SGD 1	SGD 2	SGD 13	SGD 15	SGD 17

Market-oriented cattle traceability in the Brazilian Legal Amazon	Ruviaro, Barcellos e Dewes (2014)	Land Use Policy	SGD 1	SGD 2	SGD 13	SGD 13	SGD 17
Poverty dynamics, ecological endowments, and land use among smallholders in the Brazilian Amazon	Guedes *et al.* (2014)	Social Science Research	SGD 1				
Secondary vegetation in central Amazonia: Land-use history effects on aboveground biomass	de Wandelli e Fearnside (2015)	Forest Ecologyand Management	SGD 1	SGD 2	SGD 13	SGD 15	SGD 17
Land use intensity trajectories on Amazonian pastures derived from Landsat time series	Rufin *et al.* (2015)	International Journal of Applied Earth Observation and Geoinformation			SGD 13	SGD 15	
Adoption and development of integrated crop–livestock– forestry systems in Mato Grosso, Brazil	Gil, Siebold e Berger (2015)	Agriculture, Ecosystems & Environment		SGD 2	SGD 13		
Developing a nationally appropriate mitigation measure from the greenhouse gas GHG abatement potential from livestock production in the Brazilian Cerrado	Silva *et al.* (2015)	Agricultural Systems	SGD 1	SGD 2	SGD 13	SGD 15	SGD 17
Relationship between openness to trade and deforestation: Empirical evidence from the Brazilian Amazon	Faria e Almeida (2016)	Ecological Economics				SGD 15	
Land occupations and deforestation in the Brazilian Amazon	Brown *et al.* (2016)	Land Use Policy	SGD 1	SGD 2		SGD 15	
Determinants of crop-livestock integration in Brazil: Evidence from the household and regional levels	Gil, Garrett e Berger (2016)	Land Use Policy					
Aggregate index of social–environmental sustainability to evaluate the social–environmental quality in a watershed in the Southern Amazon	Roboredo, Bergamasco e Bleich (2016)	Ecological Indicators				SGD 15	
Fundamental causes and spatial heterogeneity of deforestation in Legal Amazon	Jusys (2016)	Applied Geography	SGD 1	SGD 2			SGD 17
Economics and environmental performance issues of a typical Amazonian beef farm: a case study	Siqueira e Duru (2016)	Journal of Cleaner Production		SGD 2		SGD 15	
Patterns and processes of pasture to crop conversion in Brazil: Evidence from Mato Grosso State	Cohn *et al.* (2016)	Land Use Policy		SGD 2	SGD 13		
Climate change mitigation through intensified pasture management: Estimating greenhouse gas emissions on cattle farms in the Brazilian Amazon	Bogaerts *et al.* (2017)	Journal of Cleaner Production	SGD 1	SGD 2	SGD 13	SGD 15	SGD 17
Carbon footprint and Life Cycle Costing of beef cattle in the Brazilian midwest	Florindo *et al.* (2017)	Journal of Cleaner Production	SGD 1	SGD 2	SGD 13	SGD 15	SGD 17
Sustainable intensification of Brazilian livestock production through optimized pasture restoration	(Silva *et al*, 2017).	Agricultural Systems	SGD 1	SGD 2	SGD 13	SGD 15	SGD 17
Agricultural innovation and climate change policy in the Brazilian Amazon: Intensification practices and the derived demand for pasture	Harris (2018)	Journal of Environmental Economics and Management	SGD 1	SGD 2	SGD 13	SGD 15	SGD 17

Mapping pasture management in the Brazilian Amazon from dense Landsat time series	Jakimow *et al.* (2018)	Remote Sensing of Environment	SGD 1	SGD 2	SGD 13	SGD 15	SGD 17
Perceptions of integrated crop-livestock systems for sustainable intensification in the Brazilian Amazon	Cortner *et al.* (2019)	Land Use Policy				SGD 15	
The Expansion of Intensive Beef Farming to the Brazilian Amazon	Vale *et al.* (2019)	Global Environmental Change	SGD 2			SGD 15	
Evaluation of good agricultural practices and sustainability indicators in livestock systems under tropical conditions	Mandarino *et al.* (2019)	Agricultural Systems	SGD 2				
Choosing pasture maps: An assessment of pasture land classification definitions and a case study of Brazil Observation and Geoinformation	Oliveira *et al.* (2020)	International Journal of Applied Earth	SGD 1	SGD 2	SGD 13	SGD 15	
Uncovering the spatial variability of recent deforestation drivers in the Brazilian Cerrado	Trigueiro *et al.* (2020)	Journal of Environmental Management				SGD 15	
Environmental impacts of Brazilian beef cattle production in the Amazon, Cerrado, Pampa, and Pantanal biomes	Dick *et al.* (2021)	Journal of Cleaner Production			SGD 13	SGD 15	SGD 17
Cattle ranchers and deforestation in the Brazilian Amazon:Production, location, and policies	Skidmore *et al.* (2021)	Global Environmental Change				SGD 15	
Environmental policies that shape productivity: Evidence from cattle ranching in the Amazon Moffette *et al.*, 2021	Journal of Environmental Economics SGD SGD and Management	1 2	SGD 1	SGD 2		SGD 15	
Access to information affects the adoption of integrated systems by farmers in Brazil	Perosa *et al.* (2021)	Land Use Policy			SGD 13	SGD 15	
Deforestation drivers in the Brazilian Amazon: assessing new spatial predictors	Santos *et al.* (2021)	Journal of Environmental Management				SGD 15	
Maintaining grass coverage increases methane uptake in Amazonian pastures, with a reduction of methanogenic archaea in the rhizosphere	Souza *et al.* (2022)	Science of The Total Environment		SGD 2		SGD 15	
Deforestation in the Brazilian Amazon could be halved by scaling up the implementation of zero-deforestation cattle commitments	Levy *et al.* (2023)	Global Environmental Change			SGD 13	SGD 15	SGD 17
Deforestation and fires in the Brazilian Amazon from 2001to 2020: Impacts on rainfall variability and land surface temperature	Silva *et al.* (2023)	Journal of Environmental Management				SGD 15	
Açai seed as a fiber source in high-concentrate beef cattle diets and its nutritional effects	Lacerda *et al.* (2023)	Livestock Science		SGD 2			

Table 1- Summary of Selected Articles

Source: Author

Analysis of the last ten years reveals an average of 3.4 articles published per year focusing on the Brazilian Legal Amazon.

Figure 3 illustrates the geographic distribution of the publications included in this study. It is worth noting that publications that cited the Brazilian Legal Amazon, publications that covered the biomes that are part of the Brazilian Legal Amazon, and publications related to the states that are part of the Brazilian Legal Amazon were included. The state of Mato Grosso had the largest number of publications, followed by Rondônia, Amapá, Maranhão, Tocantins, Pará, Acre, Roraima, and Amazônia.

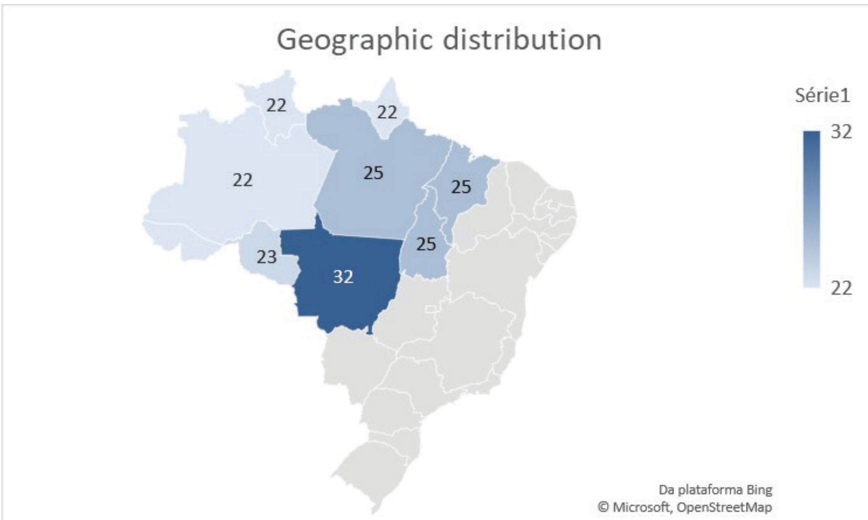
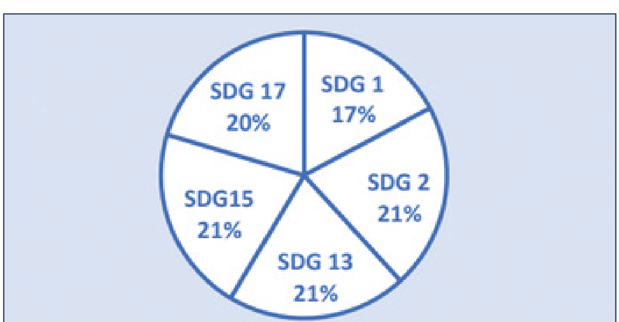


Figure 3 - Geographical coverage of the selected research according to the number of articles that cited that state: Acre (22 articles); Amapá (22 articles); Amazonas (22 articles); Pará (25 articles); Roraima (22 articles); Rondônia (23 articles); Mato Grosso (32 articles); Maranhão (25 articles); Tocantins (25 articles).

Source: Author

The 34 articles included in this study were related to the sustainable development goals, the present study focuses on SDG 1, SDG 2, SDG 13, SDG 15 and SDG 17. They were subdivided into these goals, as can be seen in figure 4. *Figure 4 - Percentage of articles by SDG.*



The analysis of the studies revealed that 17% of them dealt with the eradication of poverty, a central theme of SDG 1. Regarding zero hunger, a goal of SDG 2, 21% of the studies addressed the topic. Regarding climate action (SDG 13), 21% of the works were dedicated to the subject. Life on Earth (SDG 15) was addressed in 21% of the studies, while 20% focused on partnerships and means of implementation, as proposed in SDG 17.

The articles were distributed according to the context in which they were placed. The selected articles were related to more than one SDG. It is important to emphasize that none of the selected articles mentioned the sustainable development goals in their text; they were related according to their central research theme, methodology and the results found. Both studies have a central theme, which is the sustainable development of livestock farming.

SDGs 1:

The Sustainable Development Goal 1 aims to eradicate poverty in all its forms and everywhere, without gender discrimination (United Nations in Brazil, 2023). This topic was mentioned in 17% of the analyzed articles. Guedes *et al*, (2014) focus their research on persistent poverty in rural settlements in the Amazon, presenting empirical evidence on the factors that influence poverty in the region. They advocate for the integration of agricultural production, environmental conservation, and social development in the Amazon to support more effective public policies to combat rural poverty.

Cattle traceability can be crucial for the sustainability of livestock production and access to international markets, contributing to increased livestock production, income, and poverty reduction in the region (Ruviaro, Barcellos, & Dewes, 2014). Although the study by Wandelli and Fearnside (2015) does not directly focus on SDG 1, their data on the recovery of secondary vegetation in abandoned pastures can be useful for the formulation of more effective public policies to combat poverty.

Research shows that sustainable intensification of livestock farming, through measures such as pasture restoration and feed supplementation, can increase productivity and income, as demonstrated by Silva *et a*l, (2015). The article addresses the negative consequences of agrarian reform, which, although aiming to combat poverty, can lead to deforestation and adverse effects on the population. This study opens the door to solutions that promote sustainable and fair agrarian reform (Brown *et al,* 2016).

The study by Jusys (2016) does not focus on poverty eradication, but on the effects and causes of deforestation. Among the identified variables, the relationship between GDP and per capita income stands out, where higher levels of per capita income are associated with lower levels of deforestation in economies with lower GDP.

According to Bogaerts *et al*, (2017), the sustainable intensification of livestock farming can help Brazil increase its production and reduce production costs, being economically viable for producers and contributing to the achievement of sustainable development goals. Increased income generates a better quality of life and poverty reduction.

Pasture recovery can contribute to poverty reduction as it improves the profitability and productivity of livestock activity, in addition to promoting sustainable land use (Silva *et al*, 2017). Identifying cattle production systems that have better financial profitability and are low in carbon emissions is crucial for economic development (Florindo *et al,* 2017).

Increasing agricultural investment and the productivity of the livestock sector can lead to better economic conditions for properties, which helps reduce poverty levels (Moffette *et al*, 2021). Pasture restoration can increase the profitability of livestock on farms, contributing to poverty reduction in rural areas (Silva *et al*, 2017). The intensification of livestock production is an alternative that can improve farm productivity, providing greater profitability for small producers (Harris, 2018). Jakimow *et al*, (2018) highlight that the sustainable intensification of livestock farming is a viable alternative for increasing productivity and income for small producers, which consequently helps combat poverty in the region.

Oliveira *et al*, (2020) highlight in their study that pasture management can increase the productivity of properties.

SDG 2

Sustainable Development Goal 2 aims to end hunger, achieve food security, improve nutrition and promote sustainable agriculture, ensuring that all people have access to sufficient and nutritious food (United Nations in Brazil, 2023). Of the articles analyzed, 21% were related to SDG 2.

Latawiec *et al*, (2014) conducted research on agricultural intensification to achieve global food security. They state that intensification increases yields per unit area, offering a way to increase meat production in Brazil through sustainable practices. Ruviaro, Barcellos and Dewes (2014) highlight the importance of beef traceability to ensure food security and environmental protection.

Wandelli and Fearnside (2015) provide information on the potential of secondary vegetation to produce food and other non-timber forest products. They point out that this vegetation can provide crucial ecosystem services, such as climate regulation and pollination, contributing to food security and nutrition for rural populations. Gil, Siebold and Berger (2015) mention the adoption of integrated croplivestock systems as a viable alternative to increase food production and promote sustainable agriculture. Silva *et al*, (2015) argue that intensification of livestock farming is essential to meet the growing market demand in the region, emphasizing the importance of animal health and suggesting improvements in diet quality. Brown *et al*, (2016) highlight that deforestation caused by land occupations compromises the availability of fertile land for family farming. They encourage the search for solutions that guarantee access to land for farmers without resorting to deforestation, promoting sustainable activity and food security.

Gil, Garrett and Berger (2016) argue that integrated systems (iCL) can increase agricultural production and restore degraded pastures, contributing to sustainable agriculture. Jusys (2016) highlights that, although his study does not specifically aim to combat hunger, he does point out that livestock farming was one of the main causes of deforestation in 2010, and that the global market is pressuring meatpacking companies to adopt more responsible practices. Siqueira and Duru (2016) emphasize that achieving global food security requires joint efforts to increase production in a sustainable and profitable manner. They point out that livestock farming, as a crucial sector in food production, needs to overcome profitability challenges and ensure long-term sustainability.

Cohn *et al*, (2016) emphasize that the disorderly expansion of pastures can compromise global food security, threatening the availability of land for agricultural production. Bogaerts *et al*, (2017) argue that increased livestock intensification is a viable strategy to increase livestock productivity, which can help Brazil ensure food security and nutrition for its population. Silva et al, (2017) also argue that pasture recovery is a way to intensify beef cattle farming in Brazil, contributing to increased cattle production and, consequently, food security.

Florindo *et al*, (2017) advocate identifying beef cattle production systems that have better financial profitability and are environmentally viable as strategies to reduce environmental impacts and food security. Lacerda *et al*, (2023) evaluate the inclusion of açaí seeds in cattle diets, leading to increased productivity and feed efficiency, thus contributing to food security and the economy.

Levy *et al*, (2023) highlight the production of commodities such as beef, palm oil, soybeans and cocoa for economic production, highlighting that these activities are associated with socio-environmental conflicts, including the conversion of native areas into agricultural land and deforestation, which can cause biodiversity losses and affect global food security due to changes in rainfall patterns and climate change. Moffette *et al*, (2021) state that optimizing land use for food production is an example of how environmental policy can contribute to food security, which is essential to ending hunger. Silva *et al*, (2017) reinforces that sustainable intensification of agriculture aims to increase agricultural productivity in an environmentally responsible way. Restoring degraded pastures can increase beef production more efficiently, contributing to food security and ensuring that land remains productive in the long term, promoting more resilient agriculture.

Harris (2018) highlights the role of livestock intensification in reducing deforestation in the Amazon and increasing productivity, which can contribute to achieving food security.

According to Jakimow *et al*, (2018), livestock intensification can improve pasture management and production efficiency, resulting in an increase in sustainable food production. This contributes to meeting the growing global demand for food.

According to the authors Cortner *et al*, (2019), intensification of integrated crop-livestock systems (ICLS) is a promising strategy to address challenges such as rural poverty, food security, ecosystem degradation, and biodiversity loss.

The research by the authors Mandarino *et al*, (2019) shows that good agricultural practices in beef cattle production systems have shown economic improvements and improvements in the productive weight of the animal, in addition to contributing to the reduction of methane gas, which contributes to achieving food security since it increases productivity in a sustainable way.

Vale *et al*, (2019), highlights in their research that confinement can help increase cattle productivity, contributing to efficient food production, and agricultural intensification can increase food supply.

Effective pasture management on farms is important for sustainable production and greater efficiency, given the challenges that will be faced in the future with a more populated and warmer planet Oliveira *et al*, (2020)

SDG13

Sustainable Development Goal 13 aims to take urgent action to combat climate change and its impacts (United Nations in Brazil, 2023). In this study, we found that 21% of the selected articles were related to SDG 13.

Gollnow and Lakes (2014) highlight that the implementation of the Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAM) resulted in the temporal decoupling between the expansion of livestock farming and deforestation associated with soybeans along the BR-163 highway. This decoupling contributes to the mitigation of climate change. In addition, the authors highlight the relevance of public policies, such as the PPCDAM, in reducing deforestation. Latawiec *et al*, (2014) emphasize that agricultural intensification can reduce pressure on forests, thus reducing greenhouse gas emissions from deforestation. Ruviaro, Barcellos and Dewes (2014) adopt a holistic perspective, arguing that traceability in livestock production and the pursuit of sustainable livestock farming can contribute to reducing deforestation and greenhouse gas emissions. They also highlight the importance of meeting consumer demands with products that have a lower environmental impact.

Wandelli and Fearnside (2015) offer relevant contributions to SDG 13 by providing information on the role of secondary vegetation in mitigating climate change. Their study demonstrates that this vegetation can absorb large amounts of carbon from the atmosphere, contributing to reducing greenhouse gas levels and combating global warming. Rufin *et al*, (2015) emphasize that monitoring the intensification of livestock farming and land use can help identify areas with a greater propensity for deforestation, and that sustainable management can contribute to atmospheric carbon sequestration.

Gil, Siebold and Berger (2015) highlight the importance of implementing Information Systems in the state of Mato Grosso. These systems can increase organic matter in the soil, favoring biomass production and contributing to carbon sequestration, which in turn reduces greenhouse gas emissions, promoting environmental conservation and making livestock farming more sustainable. Silva *et al*, (2015) indicate that pasture restoration is a promising mitigation measure to reduce greenhouse gas emissions, contributing to the achievement of SDG 13. However, the conversion of natural areas into pastures still represents a significant challenge, intensifying climate change and harming terrestrial life (Cohn *et al*, 2016). Bogaerts et al, (2017) demonstrate the potential of sustainable intensification of livestock farming to reduce greenhouse gas emissions, being essential to combat climate change and extreme events. Silva *et al*, (2017) argues that pasture recovery increases carbon sequestration in the soil, reducing carbon emissions generated by livestock production and contributing to combating climate change and global warming.

Florindo *et al*, (2017) state that making beef cattle farming more sustainable and with low carbon emissions is an effective way to mitigate climate change. Levy *et al*, (2023) point out that livestock farming is responsible for 70% of all deforestation in the Amazon, making it a major challenge to measure market coverage of zero deforestation commitments (ZDC).

Perosa *et al*, (2021) highlight the importance of Integrated Systems (IS) as fundamental to mitigating greenhouse gases without compromising food production. Dick *et al*, (2021) emphasizes that assessing the environmental impacts of livestock farming requires a comprehensive view, considering the various interconnected factors that influence sustainability and the low environmental impact of pasturebased cattle farming, although this technique has a major impact on land use and greenhouse gas emissions.

Silva *et al*, (2017) conclude that pasture restoration increases soil carbon sequestration and reduces greenhouse gas (GHG) emissions. They mention that optimized pasture management practices have a significantly lower environmental impact (3.59 kg CO2e/kg CWE) compared to traditional practices (9.26 kg CO2e/kg CWE), directly contributing to climate change mitigation.

Harris (2018) states that policies that promote livestock intensification aim to reduce the need for deforestation, contributing to climate change mitigation.

Jakimow *et al*, (2018), shows that livestock farming, and deforestation are the largest generators of greenhouse gases in the Amazon, which is why reducing new pasture areas can help reduce greenhouse gas emissions.

Adequate pasture management can mitigate greenhouse gas emissions and contribute to adaptation to climate change (Oliveira *et al*, 2020).

SDG 15

Sustainable Development Goal 15 aims to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation and halt biodiversity loss (United Nations in Brazil, 2023). Among the studies analyzed, 21% of the articles addressed issues related to SDG 15.

Gollnow and Lakes (2014) highlight in their research the dissociation between livestock farming, soybean expansion and deforestation. By reducing deforestation, PPCDAm helps to preserve forests and natural habitats, contributing to the conservation of soil and water resources. The study also emphasizes the importance of sustainable intensification of agriculture to reduce the need for expansion of agricultural area and, consequently, deforestation.

Latawiec *et al*, (2014) show that the intensification of livestock production can guarantee the conservation of forests and the sustainable use of nature. Traceability, as the object of study by Ruviaro and Barcellos Dewes (2014), emerges as a tool to maintain life on Earth by reducing deforestation and environmental degradation, preserving biodiversity.

Wandelli and Fearnside (2015) emphasize the importance of secondary vegetation for biodiversity, demonstrating that it can provide habitat for several species of plants and animals, in addition to helping to connect forest fragments. Rufin *et al*, (2015) state that the intensification and monitoring of agricultural activities are crucial to assess the impact of human activities on terrestrial life and ecosystem services.

Silva *et al*, (2015) highlights the importance of restoring degraded pastures for the conservation of biodiversity and state that the intensification of livestock farming can be a viable alternative to minimize negative impacts on biodiversity. Faria and

Almeida (2016) note that deforestation is one of the main threats to biodiversity and that understanding how international trade can lead to deforestation is fundamental for environmental preservation.

Brown *et al*, (2016) shows that deforestation results directly from land occupations, affecting biodiversity, and they press for the adoption of deforestation mitigation measures. Roboredo, Bergamasco and Bleich (2016) reveal that 84% of respondents living in the southern Amazon region do not consume water from rivers due to contamination by cattle and capybara feces, highlighting the urgent need for sustainable practices.

Siqueira and Duru (2016) state that livestock farming is an important contributor to greenhouse gas emissions, but when based on pastures, it can contribute to carbon sequestration, promoting sustainable and low-carbon livestock farming.

Bogaerts *et al*, (2017) indicate that livestock intensification can be carried out without converting new areas into pastures and with improved pasture quality, contributing to the preservation of native forests and sustainable soil management. Silva *et al*, (2017) emphasize that the recovery of degraded pastures is essential for the conservation of native forests, ensuring life on Earth and maintaining the quality of life and ecosystem services.

Florindo *et al*, (2017) proposes economically viable agricultural production systems that promote more sustainable livestock farming, avoiding the conversion of new areas into pastures and contributing to the preservation of ecosystems and biodiversity.

Silva *et al*, (2023) analyzes deforestation and fires in the Amazon, showing that between 2007 and 2010, Mato Grosso and Paraná were the most deforested areas, with a significant increase in deforestation between 2016 and 2020.

Levy *et al*,(2023) highlight that deforestation in the Amazon caused by livestock production affects the biome and the global climate, highlighting the importance of private agreements such as the TAC and the G4 agreement to reduce deforestation and promote sustainable livestock farming.

Souza *et al*, (2022) state that livestock farming has been one of the main causes of deforestation in the Amazon since 1970, and that the impacts of methane gas can be partially mitigated through proper pasture management.

Santos *et al*, (2021) conclude that livestock farming in the southern region of the Amazon is the main cause of deforestation due to the extensive practices used.

Perosa *et al*, (2021) highlight that Integrated Systems (IS) are important for the restoration, protection, and sustainable use of properties, in addition to being a lowcost strategy with efficient technical and economic results.

Moffette *et al,* (2021) show that environmental policies can improve agricultural productivity without deforestation, promoting sustainable development that conserves natural resources.

Skidmore *et a*l, (2021) address the threat of deforestation to the Amazon biome and the climate, highlighting the importance of managing forests sustainably to ensure life on Earth.

Dick *et a*l, (2021) state that pasture-based systems have the potential to reduce human and environmental toxicity, promoting the reduction of inputs and the production of quality products.

Trigueiro *et al*, (2020) identify the factors that drive deforestation, such as access to rural credit, proximity to roads, precipitation, and terrain slope, and suggest the adoption of specific regional measures to facilitate the recovery and preservation of ecosystems.

Silva *et al*, (2017) conclude that pasture recovery helps prevent deforestation, protecting terrestrial ecosystems and promoting the sustainable use of natural resources, in line with the objectives of protecting, restoring and promoting the sustainable use of terrestrial ecosystems.

Harris (2018) states that livestock farming is the largest contributor to deforestation in the Amazon, which directly threatens biodiversity. The sustainable intensification of agricultural production can be a strategy to reduce pressure on forests and preserve terrestrial life.

Jakimow *et al*, (2018) reveal that improving pasture management practices helps in the conservation and preservation of ecosystems.

According to Cortner *et al*, (2019), The intensification of pasture-based production systems helps to reduce deforestation and greenhouse gas emissions, ICLS have the potential to recover large areas of pastures. This contributes positively to the preservation of life on earth.

Vale *et al,* (2019), The practice of confinement can reduce the need for deforestation for pastures, helping to preserve forest ecosystems and biodiversity in the Amazon.

Sustainable pasture management helps to conserve terrestrial ecosystems, such as the Cerrado and the Amazon, which have great ecological value (Oliveira *et al*, 2020).

SDG 17

The results of this research indicate that 20% of the articles included in the study were related to SDG 17, which aims to strengthen the means of implementation and revitalize the global partnership for sustainable development (United Nations in Brazil, 2023).

Gollnow and Lakes (2014) highlight in their research the importance of collaboration between different sectors of society to achieve sustainable development. The success of PPCDAm is due to the partnership between the government, NGOs, the private sector and local communities. Latawiec *et al*, (2014) highlight the importance of public policies and economic incentives to support the transition to more sustainable beef production systems.

Researchers Ruviaro and Barcellos Dewes (2014) propose traceability as a means of ensuring the sustainability of beef farming in the Brazilian Legal Amazon. This certification guarantees the sustainability of the production chain, meeting market demands and requiring collaboration between different sectors, including producers, industry, government and consumers. Wandelli and Fearnside (2015) highlight the importance of collaboration between different sectors of society, such as universities, NGOs and other partners, to generate technical and scientific knowledge.

Silva *et al*, (2015) highlights the importance of technology transfer to cattle ranchers, allowing the implementation of sustainable intensification practices on their properties. The study by Jusys (2016) takes an economic approach, relating deforestation in the Brazilian Legal Amazon to the per capita income of cattle ranchers, offering a direct view of the economic influence on deforestation.

The results of the research highlight the need for public policies to direct beef production towards a more sustainable future (Silva *et al*, 2017). Florindo *et al*, (2017) introduced an effective and innovative methodology to assess the sustainability and profitability of beef production, which can be reapplied and adapted according to the specific needs of each region, state or country, directly contributing to achieving SDG 17 of the UN 2030 Agenda.

Levy *et al,* (2023) show that deforestation rates are lower in municipalities that actively participate in the G4 market. However, there is still an increase in deforestation throughout the Amazon, reflecting that this policy is not a fully efficient solution. They reinforce that producing and importing countries should play a more active role in the intensification and adoption of zero-deforestation practices.

Dick *et al*, (2021) identifies gaps that show the need for collaboration between different sectors to develop public policies that make livestock farming sustainable. Silva *et al*, (2017) highlights the importance of access to subsidized credit through the Low Carbon Agriculture Program (ABC Program), demonstrating how public policies and financial partnerships can enable the adoption of more sustainable agricultural practices. This highlights the need for collaboration between governments, the financial sector and producers to achieve sustainability goals. Harris (2018) states that the debate on public policies to promote livestock intensification and, consequently, reduce deforestation, requires a comprehensive and collaborative approach. This approach must integrate different sectors and actors, including governments, the private sector and local communities. Monitoring management practices using satellite data, such as those provided by the Landsat and Sentinel-2 missions, not only allows for detailed analysis of livestock intensification, but also fosters collaboration between different institutions and countries (Jakimow *et al*, 2018).

International collaboration and sharing of geospatial data are essential to improve the consistency and quality of land use maps (Oliveira *et al*, 2020).

CONCLUSION

This article presented a systematic review of livestock farming in the Brazilian Legal Amazon and sought to relate the selected articles to the Sustainable Development Goals (SDGs). The analysis revealed that the largest number of articles published was in 2016. The year 2022 recorded the lowest number of publications on livestock farming in the Legal Amazon included in this study. It is observed that the state of Mato Grosso had the largest number of related articles published, and the state that had the lowest number of related articles was Amazonas.

The study connected the included articles to the Sustainable Development Goals. Despite recognizing that livestock farming can contribute to achieving the 17 goals, the research focused on 5 sustainable development goals: SDG 1 - No Poverty, SDG 2 - Zero Hunger, SDG 13 - Climate Action, SDG 15 - Life on Land, and SDG 17 - Partnership for the Goals. The research provided a comprehensive overview of the context of sustainability in beef cattle farming in the Brazilian Legal Amazon. When analyzing articles on the Science Direct website over the last 10 years, a significant gap was identified in the scientific literature: the absence of studies that directly relate livestock farming to achieving the Sustainable Development Goals (SDGs) of the 2030 Agenda.

The studies analyzed predominantly focus on the transformation of traditional livestock farming, characterized by high environmental impact and low profitability, into economically efficient and sustainable livestock farming. However, even though the authors address the search for sustainable livestock farming, there is no explicit connection between this transformation and achieving the sustainable development goals.

The general objective of this research was to establish this connection, demonstrating that livestock farming can indeed contribute to Brazil achieving the SDGs. The analysis performed proves that, with sustainable and efficient practices, livestock farming can play a crucial role in meeting the goals established by the 2030 Agenda.

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