ORBITAS
A Climate Advisers Initiative

Brazil's Cattle Sector Amidst Climate Transitions

CLIMATE ADVISERS

ORBITAS
A Climate Advisers Initiative

About ORBITAS

This report was produced by Orbitas, a Climate Advisers initiative. Orbitas strives to be a leading source of reliable and actionable analysis on climate transition risks in the agricultural, forest and land economy. Climate Advisers, a B Corporation, works to strengthen climate action in the United States and around the world through research, analysis, public policy advocacy and communications strategies. We develop and promote sensible, high-impact initiatives that improve lives, enhance international security and strengthen communities.

> Further information is available at **climateadvisers.org** and **orbitas.finance**.

REPORT

Acknowledgements

Authors

ORBITAS AUTHORS:

Niamh McCarthy, Orbitas Director and Director of Climate Related Risk at Climate Advisers. Available at mccarthy@climateadvisers.org

Dr. Cathy Wu, Orbitas Senior Economist and Senior Associate at Climate Advisers. Available at wu@climateadvisers.org

Alec Estabrook, Orbitas Researcher and Associate at Climate Advisers. Available at estabrook@climateadvisers.org

Dr. Alexandre Köberle, Orbitas Senior Fellow

Dr. Michael Obersteiner, Orbitas Senior Fellow and Director of the Environmental Change Institute, University of Oxford.

Mark Kenber, Orbitas Senior Fellow

COLLABORATING AUTHORS:

David Chen

Dr. Jan Philipp Dietrich

Dr. Angelo Gurgel, Research Scientist at the MIT Joint Program on the Science and Policy of Global Change.

Dr. Gabriel Hofmann, Department of Geography, Universidade Federal do Rio Grande do Sul.

Dr. Florian Humpenöder

Dr. Nikolay Khabarov, Research Scholar at the Exploratory Modeling of Human-Natural Systems Research Group, Advancing Systems Analysis, International Institute for Applied Systems Analysis.

Professor Dr. Alexander Popp

Dr. Miodrag Stevanovic

Dr. Yiorgos Vittis, Research Scholar, Exploratory Modeling of Human-Natural Systems Research Group, Advancing Systems Analysis, International Institute for Applied Systems Analysis.

PROJECT MANAGEMENT, DESIGN AND COMMUNICATION:

Aishwarya Jadhav, Climate Related Risk Intern at Climate Advisers.

Natasha Ferrari, Senior Director of Communications, Climate Advisers.

Emma McMahon, Orbitas Project Manager and Senior Associate at Climate Advisers.

Kyle Saukas, Deputy Director of Communications, Climate Advisers.

Apply Brasil, a strategy and engagement consultancy providing valuable contributions to understanding and engaging with the Brazilian agribusiness, finance and regulatory communities as part of this analysis.

MG Strategy and Design, a strategy, branding, content, design and development agency.

Photos from iStock by Getty Images (istockphoto.com)

> This report was produced with financial support from the Children's Investment Fund Foundation (CIFF) and facilitation by Nature Finance.

ORBITAS
A Climate Advisers Initiative

Brazil's Cattle Sector Amidst Climate Transitions

Table of Contents

Orbitas
April 2024

ORBITAS
A Climate Advisers Initiative

Executive Summary

The future of the Brazilian cattle sector is set to look very different from the past. By 2050, government, consumer and private sector responses to climate change, which we term 'climate transitions,' could drive a 25 percent drop in domestic beef production and a significant decline in domestic beef consumption. However, cattle sector companies that invest in new environmental technologies, adopt sustainability-oriented land management practices and diversify their revenue could benefit substantially from climate transitions and capitalize on the higher prices offered by sustainably focused export markets. Cattle producers that transition to more sustainable cattle production, for example, could improve their financial resilience and performance, with a projected 88 percent increase in capital investment and at least an 18 percent increase in yields.

Brazil's cattle sector is undergoing profound changes driven by numerous climate-related transitions, including (i) stronger domestic climate goals and policies, (ii) climate-focused international regulations and trade restraints, (iii) climate technology-driven innovation and competition and (iv) new emerging market dynamics relating to climate change. These forces shaping the Brazilian cattle sector represent responses to the physical impacts of climate change (such as extreme weather and changes in precipitation patterns) that are already acutely felt by Brazilian producers today and are rapidly accelerating. The interplay of these forces has the potential to transform Brazilian cattle production and to initiate a race for production efficiency and sustainable management practices.

Even under a transition pathway aligned with limiting global warming to 2°C above pre-industrialized levels, the Brazilian cattle sector faces enormous risks.[a] Changing consumer preferences and rising prices would decrease demand for ruminant meat by 38 percent domestically and 5 percent globally by 2050, driving a shift toward export markets that are increasingly prioritizing deforestation-free policies.[b] Meanwhile, competition for land would rise significantly, driven by policies that target deforestation, markets that reward land owners for conserving or restoring natural habitats and demand for agricultural inputs for alternative proteins, decreasing pasture land by 37 percent and raising land prices and production costs.

These changes would culminate in a 25 percent drop in production by 2050, as noted above. If cattle producers do not increase production efficiency through new technologies and sustainable management practices or diversify revenue streams, they could face losses of over USD 155 per hectare by 2050. **Climate transition impacts are most material for the least-efficient producers**, those with the lowest level of technology adoption and furthest from critical supply chain infrastructure, including slaughterhouses and extensive road networks.

These producers risk financial losses as early as 2030 if they do not adapt to climate transitions. Producers in northern Brazil, whose current profitability is approximately one-twelfth that of their southern counterparts, are particularly vulnerable. Even so, the probability of financial loss from economic shocks common under climate transitions could surpass 80 percent across a large proportion of the Brazilian cattle sector by 2050, making the entire sector vulnerable.

Risk mitigation will require significant and proactive collaboration among producers, investors, policymakers and mid- and downstream value chain stakeholders. **Investments made today to enhance the efficiency of production without expanding land usage will be the key differentiator for market competitiveness in 2050.** To remain profitable, most cattle producers will need to sustainably intensify production without converting forests into rangelands. Investments in soil restoration, the adoption of new technologies, improved management practices and diversified revenue streams will play a pivotal role in maintaining Brazil's current dominance in the global cattle sector and enabling producers to lean into climate transition opportunities.

Stakeholders across the Brazilian cattle

Even under a transition pathway aligned with limiting global warming to 2°C above pre-industrialized levels, the Brazilian cattle sector faces enormous risks.

[a] The Forecast Policy Scenario, aligned with the Principles for Responsible Investment's Inevitable Policy Response Forecast Policy scenario, represents a modest, highly plausible and impactful reference scenario that clearly illustrates the scale of potential impacts that climate transitions will have on the Brazilian cattle sector. This scenario is aligned with the actions needed to limit warming to 2°C above pre-industrialized levels. Market leaders, however, should prepare for the ambitious climate transitions expected in a world that acts to restrict warming to 1.5°C above pre-industrial levels.

[b] Note that total livestock demand would increase by 19 percent globally over the same period, despite downward pressure in ruminant meat demand.

To remain profitable, most cattle producers will need to sustainably intensify production without converting forests into rangelands.

sector can capitalize on a range of emerging opportunities under climate transitions. A projected 88 percent increase in agricultural investment would drive the average yield per hectare for cattle farmers up by 18 percent between 2020 and 2050, allowing producers to increase output on existing land rather than relying on costly expansion-based growth models. Rising efficiency would contribute to an 8 percent increase in pasture use intensity over the same period. Meanwhile, a 19 percent rise in prices for deforestation-free and low-emission beef by 2050 would allow producers to access higher prices for sustainably focused export markets as exports increase by 9 percent over the same period.

The ability of Brazilian producers to access these opportunities will depend on capital providers and the Brazilian government continuing and expanding investments that help producers meet sustainable production targets and diversify revenue. **A promising area of investment includes regenerative soil restoration practices that could transform farm profitability.** Per hectare yield of severely degraded pastures could increase by up to 310 percent across all farms, raising profitability by over USD 375 per hectare for farms currently experiencing losses. These profitability improvements would put some of the least profitable farms on par with some of the best-performing operations today.

In addition to pasture restoration and improved pasture management practices, producers have access to a range of sustainable yield-enhancing and diversification opportunities, including increased fertilizer efficiency, advanced monitoring, integrated crop-livestock-forest systems and other practices recommended by EMBRAPA (The Brazilian Agricultural Research Corporation). These investments can be used to mitigate the financial risks related to climate transitions and often provide co-benefits by increasing resilience to negative climate-related physical risks that are costing Brazilian cattle farmers billions of dollars in productivity today.

Nevertheless, the expected considerable drop in total production will likely trigger a market shakeout in which cattle farmers who cannot adapt to climate transitions and compete in the new world may need to consider other (non-cattle) activities to remain economically viable. Producing plant-based inputs for the growing alternative protein market, other types of livestock production and receiving payments for conservation may present opportunities for a sustainable and profitable future for these producers. Revenue streams from sugars used in manufactured meat or plant proteins in

MARKET LEADERS WILL CONSIDER A RANGE OF FUTURE TRANSITION PATHWAYS TO NAVIGATE CLIMATE TRANSITIONS

Understanding the impact of multiple future transition pathways, ranging from actions needed to limit global average temperature increases to 1.5° C to over 3° C above pre-industrialized levels, will provide stakeholders with the decision-useful information needed to prepare for the myriad of financial risks and opportunities on the horizon. The most ambitious, innovation-centric, 1.5° C-aligned transition pathway projects the most significant risks for the Brazilian cattle sector by 2050. On the one hand, this transition pathway would lead to a 38 percent and 5 percent decrease in Brazilian and global ruminant meat demand respectively, a 24 percent drop in Brazilian cattle production and a 75 percent decline in pastureland availability by 2050. On the other hand, an expected 133 percent surge in agricultural capital investment in sustainable innovation could drive 198 percent growth in Brazilian cattle yields, a 14 percent expansion of exports, a 71 percent increase in pasture use intensity and a 68 percent rise in beef prices between 2020 and 2050. Producers, supply chain companies and investors that proactively prepare for the full range of projected climate transition pathways will be best positioned to withstand them and even benefit financially.

The full range of projected outcomes across climate transition pathways is outlined below:

Economic Impact	**2.0°C Pathways by 2050** Change from 2020 to 2050	**1.5°C Pathways by 2050** Change from 2020 to 2050
Ruminant meat producer price	+19% to +29%	+68% to +74%
Yield	+18% to +30%	+161% to +198%
Production	-25% to -24%	-38% to -24%
Domestic ruminant meat demand	-38%	-52% to -38%
Global ruminant meat demand	-5%	-22% to -5%
Global livestock demand	+19%	-4% to +19%
Brazil ruminant meat export	+9% to +13%	-1% to +14%
Global ruminant meat trade	+9% to +13%	-1% to +14%
Pastures and rangelands area	-42% to -37%	-76% to -75%
Pasture use intensity	+8% to +9%	+31% to +71%
Agricultural capital investment	+88% to +94%	+96% to +133%

Investors can protect their investments by leading efforts to better understand the potential impacts of climate transitions on the Brazilian cattle sector.

plant-based meats may offer protection from increasing financial risk among low-efficiency beef producers. Producers can also transition to different types of livestock production, given that overall livestock demand is projected to increase 19 percent globally by 2050, despite expected declines in the domestic consumption of ruminant meat.

Diversification opportunities are similarly expanding for landowners to earn sustainable revenue through native species conservation or reforestation. Brazil's newly emerging regulated market for carbon credits and the growing voluntary carbon market provide opportunities to measure and account for the storage or removal of carbon dioxide from the atmosphere and to receive payments. Increased penalties on climate pollution through higher GHG prices will lead to more lucrative opportunities for investors and landowners to reduce the emission intensity of production and participate in carbon markets.

Radical levels of collaboration will be needed to secure economic resilience for Brazil's cattle sector by 2050, as action to limit global warming intensifies climate transition risks for the sector. Investors can protect their investments by leading efforts to better understand the potential impacts of climate transitions on the Brazilian cattle sector and by calling upon others across the cattle sector value chain and the government to support solutions that would enhance the sector's economic resilience. Brazil's continued dominance in the global cattle sector and its ability to mitigate financial risks depend on the ability of key stakeholders to prepare for inevitable climate transitions in the sector. As Brazil navigates the complex landscape of climate transitions, this report serves as a valuable guide for stakeholders seeking to make informed decisions in the face of evolving challenges and opportunities.

Risks and Opportunities in the Brazilian Cattle Sector

Seven main trends drive these findings

Emissions pricing	Greenhouse gas emissions pricing could materially drive up production costs for emission-intensive cattle producers and create opportunities to diversify revenue streams.
Land constraints	Climate action, land conservation measures and competition for land from the bioeconomy could reduce the availability of affordable pasture land.
Yield improvements	As business models reliant on high land use and deforestation become less feasible, cattle farmers can prioritize sustainable productivity investments and process improvements to boost yield on existing land and on degraded pastures.
Accelerating investment	Investment in capital goods, land, advanced technology adoption and improved management practices could increase production efficiency.
Beef price fluctuations	Climate transitions could create producer price increases for deforestation-free and low-emission cattle products globally, presenting opportunities for producers that increase productivity and provide transparency to buyers and financiers.
Dietary shifts	Evolving global dietary trends could threaten demand for beef and other cattle products under climate transitions, as the growth in sustainable-minded consumers increases demand for protein alternatives and low-emission beef.
Growing exports	Export markets are likely to become increasingly important due to Brazil's competitive advantage in beef production, although regulations promoting source of origin disclosure will restrict market access for deforestation-linked beef.

Brazilian Cattle Sector Transition Risks

The reference pathway highlighted here aligns with a 2°C world and showcases the risks of climate transitions already forecasted by the Principles for Responsible Investment.

Pastureland reduces

37%

by 2050 compared to 2020

38%

domestic reduction in Brazilian ruminant meat demand by 2050 compared to 2020

Producers that fail to invest in sustainable management practices all together

Risk financial loss as early as

2030

Average probability of financial loss could surpass

80%

by 2050

due to volatility from economic shocks common under climate transitions

5%

reduction in global ruminant meat demand by 2050 compared to 2020

11%

increase in forest cover by 2050 compared to 2020, decreasing the availability of pasture land and driving up production costs

Low efficiency producers in Northern Brazil could see

12x

less profits than high efficiency southern counterparts

due to access to technology, infrastructure and slaughterhouses

Production of Brazilian ruminant meat drops 25% **by 2050 compared to 2020**

Brazilian Cattle Sector Transition Opportunities

The reference pathway highlighted here aligns with a 2°C world and showcases the opportunities of climate transitions already forecasted by the Principles for Responsible Investment.

310%

increase in per hectare yield through restoring severely degraded pastures

1,356

MMT CO_2e/yr decrease in GHG net emissions from land use change by 2050

8%

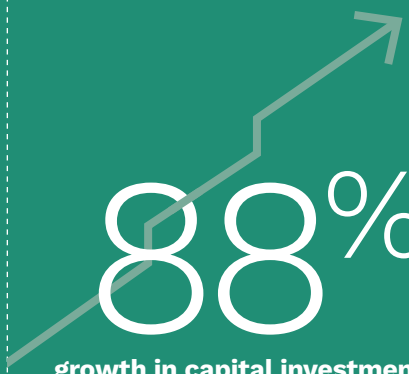
increase in pasture use intensity across Brazil by 2050 compared to 2020

Pasture restoration could raise profitability over USD375 per hectare in 2050 for low productivity cattle farmers

Deforestation-free and low-emission ruminant meat producer prices rise

19%

by 2050 compared to 2020



88%

growth in capital investment in Brazilian agriculture by 2050 compared to 2020

Brazilian beef yield increases

18%

per hectare by 2050 compared to 2020

9%

increase in exports by 2050 compared to 2020

45%

decrease in CH_4 emissions by 2050 compared to 2020, primarily driven by enteric fermentation

Definitions

30x30 initiative: A conservation goal aimed at protecting at least 30 percent of the world's land and oceans by the year 2030. Seeking to address biodiversity loss, habitat destruction and climate change by establishing protected areas, marine reserves and other conservation measures to safeguard ecosystems.

Agriculture, Forestry and Other Land Use (AFOLU): A category used for greenhouse gas (GHG) accounting encompassing a range of land-based practices including agriculture, forestry and land use changes.

Animal Unit (AU): 1 animal unit is defined as a 454 kg (1000 pound) cow, with or without an unweaned calf, with a daily feed requirement of 12 kg (26 pounds).

Arroba: 1 arroba is equal to 15 kg (33 pounds).

Biodiversity Credits: A financial instrument that assigns a measurable value to the conservation or restoration of biodiversity. Entities can purchase these credits to offset their ecological impact. This market-based approach creates a financial incentive for sustainable practices, allowing the trading of credits to strike a balance between economic activities and environmental conservation.

Biodiversity Hotspots: Regions characterized by exceptionally high levels of species diversity and endemism, valuable targets for conservation efforts due to their unique ecosystems.

Cap-and-Trade System: A carbon pricing strategy that sets a limit on total GHG emissions. Entities receive allowances, and those emitting less can sell excess permits to those exceeding their limits. This market-based approach incentivizes emission reductions efficiently and allows flexibility in meeting targets.

Carbon Credits: Carbon credits are tradable permits representing the right to emit one metric ton of carbon dioxide or its equivalent. They are used as a mechanism to reduce GHG emissions by allowing entities to buy and sell credits based on their emission levels, encouraging emission reductions and investments in cleaner technologies.

Carbon Dioxide Equivalent (CO_2e): A standard unit used to express the total impact of various GHGs in terms of the amount of carbon dioxide that would have the same global warming potential. Allows for the comparison of methane, nitrous oxide and carbon dioxide.

Conference of the Parties (COP): The decision-making body of the United Nations Framework Convention on Climate Change (UNFCCC), where member countries meet annually to assess and negotiate international climate policies and agreements.

European Union Deforestation-Regulation (EUDR): An update to existing European Union import restrictions prohibiting the sale of commodities – soy, beef, palm oil, wood, cocoa, coffee and rubber – sourced from regions affected by deforestation or forest degradation.

Inevitable Policy Response (IPR): A climate response scenario developed by the UN PRI that aims to prepare institutional investors for the portfolio risks and opportunities associated with the projected acceleration of policy responses to climate change.

Land Use Change (LUC): The process by which the purpose or function of a piece of land is altered, typically involving a transition from one land use category to another. This can include transformations such as converting natural landscapes (e.g., forests, grasslands) into agricultural fields, urban areas or industrial zones.

Livestock: Agriculture goods derived from domesticated animals. For use in this report, the category includes monogastric meat, ruminant meat, poultry, eggs and dairy.

Loss probability: The probability of costs exceeding farm revenue in a particular year.

MMT: Million metric tons.

MMT DM/yr: Million metric tons of dry matter per year.

Monogastric Meat: Meat produced from specific livestock, including pigs, poultry (chickens, turkeys, ducks) and rabbits.

Nationally Determined Contribution (NDC): Voluntary GHG emission reduction targets submitted under the Paris agreement detailing each country's strategy towards mitigating and adapting to climate impacts.

Non-Timber Forest Products (NTFPs): Items harvested from forests excluding traditional timber, encompassing goods like fruits, nuts, fungi, fibers, charcoal, honey, fish and game among others, from existing forestry or agroforestry systems.

Pricing Greenhouse Gas (GHG) Emissions: A market-based strategy that assigns a cost to carbon emissions utilizing a range of mechanisms (e.g., carbon tax) to encourage entities to reduce their GHG output. This strategy provides a financial incentive for companies to adopt cleaner practices.

Principles for Responsible Investment (PRI): Supported by the United Nations, these principles have been signed by investors with over USD 121 trillion in assets under management. The voluntary principles guide investors to integrate environmental, social and governance factors into their decision-making processes promoting sustainable and responsible investment practices.

Ruminant Meat (RM): Meat produced from specific livestock, including cattle, sheep, goats and deer.

South Atlantic Subtropical Anticyclone: A high-pressure system located over the South Atlantic Ocean, characterized by clockwise circulation of air across the southern hemisphere. It influences weather patterns in the region, including the formation of trade winds and the steering of tropical cyclones.

Task Force on Climate-Related Financial Disclosures (TCFD): A framework that guides companies in the voluntary disclosure of climate-related financial risks and opportunities. It provides a standardized approach for reporting on governance, strategy, risk management and metrics related to climate impact. Disclosure assists investors and financial stakeholders in assessing the climate-related aspects of a company's operations and strategies.

The Paris Climate Agreement: An international treaty adopted in 2015 under the UNFCCC. It seeks to limit global warming to below 2°C through voluntary commitments to emissions reductions.

World Business Council for Sustainable Development (WBCSD): A global organization of 200 leading businesses working to advance sustainable development through environmentally and socially responsible practices.

Introduction

Climate transitions present disruptive financial risks that are already shaping the cattle sector in Brazil in ways that will drive stakeholders to adapt their practices and investments

Opening

The future of the sector will look very different from its past due to its exposure to both the physical impacts of climate change and the risks stemming from the emerging global response to climate change. To maintain or increase profits and ultimately build resilience in an ever-changing world, the Brazilian cattle sector will have to adapt to mitigate risks and lean into emerging transition opportunities both in Brazil and abroad. Producers, meatpackers, downstream companies and financiers who plan for these transitions will be best positioned to withstand them and reap the benefits of emerging opportunities.

The financial materiality of climate transitions depends on the pace of change and the ability of stakeholders to adapt. Business models in the cattle sector traditionally reliant on deforestation and land-use changes for economic expansion will be most vulnerable to financial losses. Conversely, market leaders will proactively assess and mitigate exposure to transition risks while identifying future opportunities.

The following sections integrate climate and economic modeling with spatial analysis and financial stress testing to illuminate climate transition risks and opportunities at the national, subnational, sectoral, firm and asset levels. Four climate transition scenarios, alongside Business as Usual, shed light on the impacts of climate transitions on the Brazilian cattle sector between now and 2050. These reflect the consequences of actions aligned with limiting climate change to 1.5°C and 2°C above pre-industrial levels, while the Business as Usual scenario represents a world with over 3°C of warming.

Even in the least ambitious transition scenario, the Forecast Policy Scenario, climate transitions will materially change the future of the Brazilian cattle sector. This projection is highly plausible and aligned with the Inevitable Policy Response (IPR) scenario developed by the UN-supported Principles of Responsible Investment (PRI). These principles have been signed by investors with over USD 121 trillion in assets under management.

Market leaders can analyze the full range of scenarios to prepare for potential outcomes under climate transitions by mitigating disruptive risks and identifying new opportunities in a changing world. Those who make decisions based on forward-looking modeling will be best positioned to invest in higher and more resilient activities capable of weathering a range of climate transition shocks. Although the pace and scale of climate transitions are yet to be seen, it is clear that they have already created a new operating environment, and their impacts will only intensify over the decades to come.

Those who make decisions based on forward-looking modeling will be best positioned to invest in higher and more resilient activities capable of weathering a range of climate transition shocks.

What Are Climate Transitions?

Climate transitions are driven by government, private sector and civil society responses to climate change. As the physical impacts of the climate crisis intensify, these groups are under mounting pressure to adopt policies and regulations to shift behavior to mitigate the worst impacts of climate change and to achieve political objectives on climate change, such as the Paris Agreement's goal of limiting global warming to 1.5°C. Climate transitions, as defined by the Task Force on Climate-related Financial Disclosures (TCFD), can be divided into four categories: policy and legal, technology, market and reputational. The scale of future risks and opportunities for actors in Brazil's cattle sector depends on how producers proactively assess and manage these transitions.

The Brazilian Cattle Sector Lies at a Crossroads

Market conditions are quickly evolving amidst volatile domestic consumption, increasing exports, accelerating climate risks and heightened pressure to invest in sustainable production practices

Section 1

Brazil is a global powerhouse for the production of cattle. It accounts for 20 percent of global beef exports and is second in the world in stock, boasting 232 million heads of cattle.[1] [2] The sector has grown significantly, with 2022 production 119 percent higher than 30 years ago and exports 26 percent higher year over year.[3] [4] This growth has positioned the Brazilian cattle sector as a major domestic employer with 3.3 million people engaged in production, transportation and sales along the cattle industry supply chain, including 2.5 million farming jobs.[5] [6]

Out of a total of 7.9 million tons of beef produced in 2022, 72 percent was consumed domestically, while 28 percent made its way to international markets.[7] Almost two-thirds of exports went to China.[8] Despite this remarkable growth in exports, the domestic market has experienced volatility driven by dietary shifts, turbulent prices and economic pressure as the average income of Brazilians has declined.[9] [10] [11] A report from Consultoria Agro, a division of Banco Itaú BBA, highlighted that Brazilian beef consumption per capita reached its lowest level since 2004 in 2022.[12] Still, Brazil's large size, diversity of landscapes, favorable climate and extensive cattle ranching infrastructure have positioned the country as a key player in meeting the rising global demand for meat.

Cattle production is a significant contributor to Brazil's agricultural sector, with growing international financing and trade, especially involving the largest meatpackers in Brazil. The Brazilian cattle market is dominated by three meatpacking companies, JBS, Marfrig and Minerva, which collectively control 33 percent of Brazilian production capacity.[13] Although founded in Brazil, each has welcomed substantial investment interests from Europe, the Middle East and the US since 2000. European institutions are responsible for 24 to 32 percent of the financing across the big three, and Brazilian capital totals just 15.5 percent at Marfrig.[14] [15]

If buyers are unable to distinguish between high- and low-risk suppliers, the entire Brazilian cattle sector may experience financial pressure due to the actions of a portion of the producers.

The influx of cash over the past 20 years has spurred substantial growth. However, foreign investment also exposes Brazilian companies to international pressure for climate action, in line with public opinion and regulations in investor countries. With a growing share of Brazilian production destined for international markets, Brazilian cattle value chains are increasingly exposed to the changing consumer preferences, regulations and civil society pressures buyers face around the world. The production system, made up of a small number of large agribusinesses, many medium-sized family farms and thousands of smallholder farmers, is highly concentrated and remains opaque, despite ongoing efforts to increase transparency. If buyers are unable to distinguish between high- and low-risk suppliers, the entire Brazilian cattle sector may experience financial pressure due to the actions of a portion of the producers.

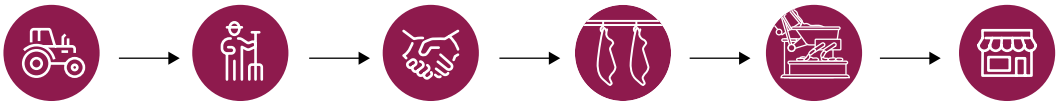
The Brazilian cattle sector has responded to pressure for deforestation-free and low-emission products with significant advances in sustainable production over the last 30 years. In 1990, livestock produced 16.4 tons of meat per ton of carbon-dioxide equivalent (CO_2e), which has since climbed to 51.9 tons of meat per ton of CO_2e in 2020.[16] This enhanced performance can be attributed to a variety of factors, including better soil carbon sequestration through vegetation restoration and a shift to renewable energy sources, such as biodiesel.[17] However, these advancements have consistently been overshadowed by the high emission intensity of beef production.

Brazil's beef sector is one of the world's most emissions intensive, ranking fifth in global CO_2 emissions and second in meth-

FIGURE 1.

BRAZILIAN CATTLE VALUE CHAIN

Brazilian cattle supply chains can be complex and opaque for downstream buyers and financiers



Inputs	Farmers	Traders	Slaughterhouses	Meatpackers	Market
Pasture management: • Land • Seeds and fertilizer • Pesticides and insecticides **Farm operations:** • Electricity • Machinery • Labor • Maintenance • Fuel and lubricants	**194.7M** cattle divided across three stages of production • Breeding farm • Rearing farm • Feedlots	**Auctioneers and brokers** connect independent farmers with corporate meatpackers	**265** registered slaughterhouses **48.5M** head of cattle slaughtered in 2023	Three largest players in the Brazilian processing market: • JBS • Marfrig • Minerva	**28%** of total slaughter exported. Leading market share China (64%), US (7.6%), and Egypt (4.6%) **72%** of total production sent to further processing or domestic supermarkets

Sources: United States Department of Agriculture (USDA), The Food and Agriculture Organization of the United Nations (UN FAO), United States International Trade Commission (ITC), and Chain Reaction Research

Sustainable suppliers... benefit from the resources, financing and market access these practices can bring through increasing transparency along supply chains.

ane emissions in 2021.[18] Cattle production alone accounted for 65 percent of 2021 CO_2e emissions from the Brazilian agricultural sector, 16 percent of Brazil's total CO_2e emissions and 75 percent of Brazil's methane emissions, primarily resulting from enteric fermentation and manure management. [19] [20] [21] [22] Notably, the sector ranks third globally in CO_2e emissions when associated land use change is included. Some estimates suggest that as much as 79 percent of Brazilian food emissions may be associated with beef production when linkages to land-use change are taken into consideration. This would amount to more than 1.4 billion tons of CO_2e.[23] [c] Deforestation and encroachment onto indigenous territories have risked significant reputational concerns across Brazilian supply chains, with estimates projecting 70 percent of deforested Amazon land eventually being used as cattle pasture.[24]

However, the number of producers responsible for rising deforestation is limited, with only 2 percent of agricultural properties in the Amazon and Cerrado responsible for 62 percent of all potentially illegal deforestation, while an estimated 17 percent of beef exports from the region to the European Union may be exposed to illegal deforestation.[25] In states such as Mato Grosso, it is estimated that around 10 percent of producers are responsible for 60 percent of deforestation.[26] Thus, this highlights the potential opportunity for significantly reducing deforestation risk with targeted actions and for enabling sustainable suppliers to benefit from the resources, financing and market access these practices can bring through increasing transparency along supply chains.

Illegal Deforestation Risk Analyzer

Available at:
orbitas.finance/brazil-illegal-deforestation-tool

This interactive tool is designed to understand the scale of illegal deforestation within the Amazônia, Cerrado and Pantanal biomes in Brazil. Users can employ this tool to access information on total deforestation areas, the proportion of illegal deforestation and fines for illegal deforestation in each municipality.

[c] As defined by the United States Environmental Protection Agency (EPA), Carbon dioxide equivalent (CO_2e), represents "the number of metric tons of CO_2 emissions with the same global warming potential as one metric ton of another greenhouse gas." It is used to describe the global warming potential of all greenhouse gasses.

Rapidly Materializing Physical Risks Are Making Climate Transitions Inevitable

Section 2

Materializing physical risks are closely followed by heightened transition risks, as regulators, private sector actors and civil society have no choice but to act

Both human-caused climate change and regional deforestation pose threats to agricultural systems. Physical climate risks are well known to the cattle industry, as the financial implications of extreme weather conditions materialize. For example, in July 2023, 3,000 cattle perished due to hypothermia in the state of Mato Grosso do Sul, resulting in estimated losses of over USD 0.8 million. These deaths affected 90 producers across 18 cities, brought on by a rapid temperature drop from 30°C to 4°C within just nine hours.[27] [28]

Broad shifts in atmospheric conditions critical to agricultural productivity are threatening the availability of water in a region responsible for 35 to 55 percent of cattle production.

Regional land conversion and deforestation have already reduced evapotranspiration from the ground, increasing daytime temperatures and reducing air humidity.[29] [30] [31] Further, global climate change has strengthened the South Atlantic subtropical anticyclone, increased atmospheric pressure over Brazilian tropical regions and transferred humidity to the south of Brazil. Therefore, important agricultural areas in the Brazilian tropical region are expected to be affected by reduced rainfall in the coming years (Figure 2).[32] [33]

Hotter and drier conditions threaten crop and animal health, depress yields and compound the effects of extreme heat and drought events. Across Brazil, worsened droughts, extreme flood events and reduced soil productivity increase the likelihood of financial losses. Studies by Embrapa have shown that reducing GHG emissions, especially methane, and increasing productivity and resilience go hand in hand but require substantial investments.[34] [35] Insistence on current low-efficiency production methods will only expose producers to the intensifying effects of climate change in the region.

Researchers at the Federal University of Minas Gerais (UFMG) provided evidence that changes in climate between 1961 and 2020 affected agricultural productivity. Brazil increased average productivity by 190 percent during this period and could have achieved an additional 20 to 25 percent increase without the effects of climate change.[36] Comparing weather station data between two 30-year intervals, 1961-1990 and 1991-2020, shines a light on the changing conditions the Brazilian cattle industry is already experiencing.

In the north of the country, including the Cerrado, broad shifts in atmospheric conditions critical to agricultural productivity are threatening the availability of water in a region responsible for 35 to 55 percent of cattle production, including the states of Mato Grosso, Mato Grosso do Sul and Goiás. These accelerating changes threaten the financial security of agricultural producers dependent on rainfall for irrigation.

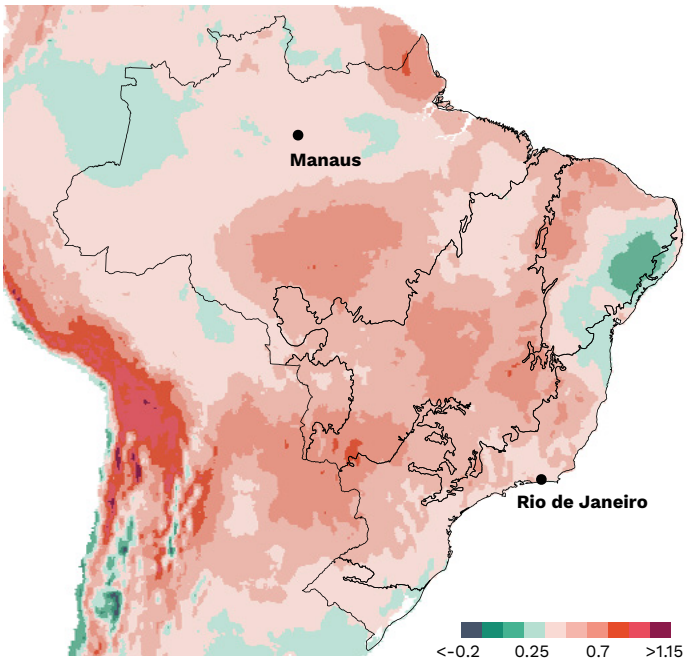
Pastures are the natural food source for 90 percent of Brazil's cattle, and researchers at the University of São Paulo in Ribeirão Preto concluded that water scarcity will directly impact the quality of cattle feed, requiring supplements to achieve the same fattening levels.[37] This could lead to an increase in meat prices and production costs, in addition to a decrease in supply. The direct risks of water insecurity to livestock production could amount to USD 8.92 billion by 2030, according to a study by the National Water Agency.[38] Additionally, this shift may result in higher methane production due to the animals' digestive processes. By contrast, southern Brazil is projected to experience a substantial increase in total rainfall. As moisture shifts from northern Brazil, the prevalence of extreme flood events is projected to rise, threatening financial loss to farmers in the region.[39] [40] [41]

FIGURE 2.

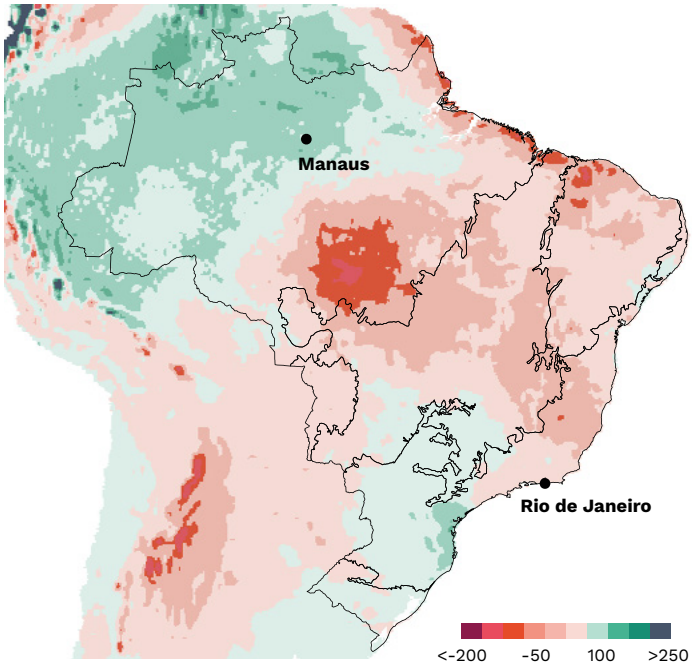
REGIONAL CLIMATE CHANGES BETWEEN THE CLIMATE NORMALS 1991–2020 AND 1961–1990

The physical impacts of climate change are evident across Brazil

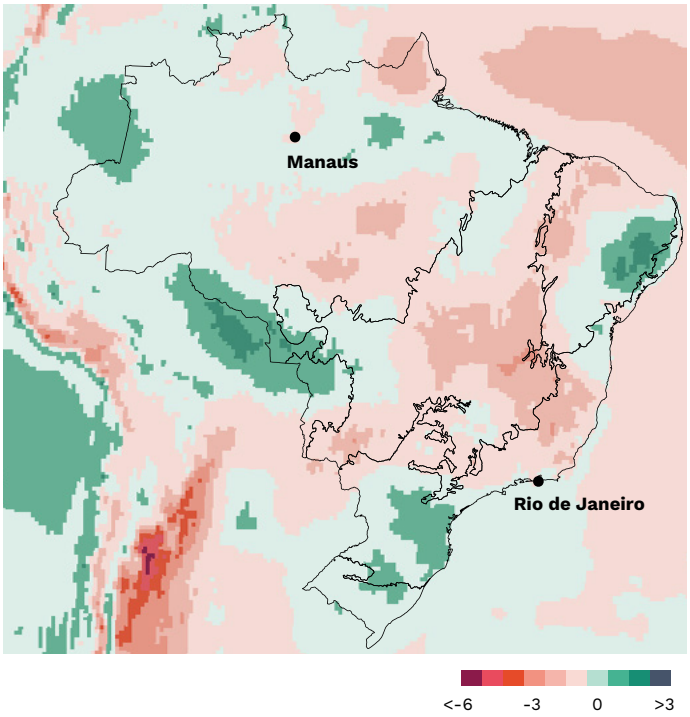
Changes in Mean Temperature (°C)
(Between 1961-1990 and 1991-2020)



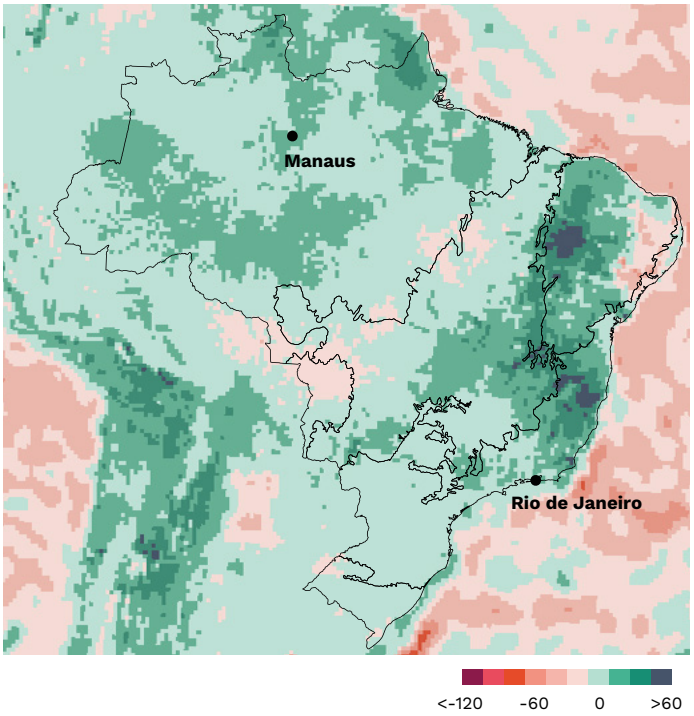
Changes in Rainfall (mm)
(Between 1961-1990 and 1991-2020)



Changes in Relative Humidity (%)
(Between 1961-1990 and 1991-2020)



Changes in Evaporation (mm)
(Between 1961-1990 and 1991-2020)



Source: Authors' modeling. Data: Brazilian National Meteorological Institute (INMET – Instituto Brasileiro de Meteorologia).

Notes: Regional climate changes are detected by ERA5 reanalysis for Brazilian biomes between the climate normals 1991–2020 and 1961–1990. The negative values in the change in evaporation figure represent an increase in evaporation according to the pattern of reanalysis of ERA5. See Appendix 1 for a complete comparison of climate normals between 1991-2020 and 1961-1990 in the Cerrado and Matopiba.

The wide-ranging impacts on livelihoods, food security, natural resources and health brought on by physical climate change risks make accelerating climate transitions inevitable.

Furthermore, the advance of deforestation, particularly in the Amazon, is expected to dramatically alter rainfall patterns across the center-west and southeast Brazil, decreasing rainfall during the dry season and shortening rainy seasons. "Considering a scenario of increasing deforestation in the southern portion of the Amazon biome up to 2050, the new areas opened up for livestock and grain production will generate an additional USD 20 billion of income. However, this same deforestation will result in a loss of USD 186 billion in the already established production in the region," according to the UFMG.[42] The lack of transparency in Brazilian cattle supply chains often results in sweeping characterizations of producers across the sector, but cattle farmers engaging in more sustainable production practices without links to deforestation have a lot to lose financially from deforestation caused by less sustainable competitors.

Finally, labor costs in regions exposed to forest fire smoke may increase due to the risk of worsening respiratory disease, which has emerged due to the rising frequency and intensity of wildfires.[43] These effects are driven by global climate change and compounded by regional land use change, which alters the land–atmosphere interactions crucial to maintaining the historical climate.

As society, the private sector and policymakers become aware of the financial impact of physical changes on Brazil's economy and agricultural producers mobilize to protect the natural resources that create Brazil's competitive advantage, the risk of abrupt climate transitions will rise. The wide-ranging impacts on livelihoods, food security, natural resources and health brought on by physical climate change risks make accelerating climate transitions inevitable. The only unknown is the speed and scale of these transitions. Considering a range of possible climate transitions using forward-looking projections is thus essential to preparing the Brazilian cattle sector for the risks and opportunities that will shape the future.

Section 3

Climate Transitions Are Affecting the Brazilian Cattle Sector Today

Responses to the physical impacts of climate change among policymakers, civil society and private sector actors are accelerating rapidly

Governments, companies, financial institutions, civil society and consumers are all increasingly reckoning with the consequences of a warming climate as the cost and scale of the damage become more widely understood and as the window to mitigate the worst impacts quickly closes. The sooner these groups take action, the more time the Brazilian cattle sector will have to adapt business models to an evolving world. Conversely, waiting to act will create more disruptive transitions in the future, which would compound the financial losses projected as worsening physical impacts are realized. The main impact pathways for climate transitions, as outlined below, are policy and legal, market, reputational and technology.[d]

All of these risks are already materializing on financial statements across Brazilian cattle sector supply chains, but producers, meatpackers, downstream buyers and financiers who proactively adapt can significantly mitigate these risks and benefit from the market opportunities presented by climate transitions.

Climate transition risks are already materializing on financial statements across Brazilian cattle sector supply chains.

Policy and Legal Transitions: Domestic and International Climate Goals and Regulations

Following the election of President Lula da Silva, the new Brazilian administration pledged to update the country's domestic climate goals and committed to removing an additional 400 million metric tons of CO_2e from Brazil's prior standing targets.

Meeting these climate goals would entail substantial emission reductions from the country's agriculture industry. Key low-carbon agriculture policies passed by Brazil are creating transition risks and opportunities, and this trend is expected to accelerate as Brazil takes a more central role on the global climate stage in the run-up to its leadership at the 2024 intergovernmental forum, G20, the 2025 UN Climate Change Conference (COP30) and the 2025 BRICS (Brazil, Russia, India, China, South Africa) Summit, with the group of major emerging economies.

On the international stage, new climate goals and regulations will have a significant impact on the Brazilian agriculture sector. At the 2021 COP26 summit, the largest annual UN climate change conference, over 140 countries pledged to halt and reverse deforestation and land degradation by 2030, which was further formalized by the 2023 UN Climate Change Conference (COP28) agreement.[44] Meanwhile, major export markets, such as the European Union (EU), are already instituting new anti-deforestation regulations.[45]

In 2023, the EU passed a new deforestation regulation that mandates a due diligence statement for all products entering the market to verify that they were not produced on recently deforested or degraded land. The penalties associated with the law are steep and include exclusion from the EU market, confiscation of revenues and large fines. Nearly 80 percent of Brazilian agribusiness exports and 40 percent of the country's total exports to the EU are estimated to fall under the purview of this regulation.[46]

Similar regulations focused on preventing imports of cattle products and other goods tied to illegal deforestation are being enacted in important export markets around the world, while China and Brazil continue talks to end illegal deforestation driven by trade.[47] [48] Failure to satisfy these new requirements could result in significant market access loss

[d] According to the Task Force on Climate-Related Financial Disclosures, widely used by regulators enacting mandatory climate-related financial disclosures

CLIMATE TRANSITIONS AFFECTING BRAZIL'S CATTLE SECTOR

Climate transitions are materializing across every segment of the Brazilian cattle supply chain

Transition risk type Policy and legal | Technology | Market | Reputation

Increased access to satellite monitoring tools allows for stronger enforcement mechanisms and supply chain due diligence practices.

Increased stakeholder awareness about deforestation, nature loss and climate change increases scrutiny of tropical commodity supply chains.

Maturing alternative-meat technologies increase the availability of substitute products.

Consumer preference changes can restrict market access for products with perceived links to deforestation and conversion as information dissemination accelerates.

Retailers, wholesalers, and traders require new environmental standards from their suppliers, creating market access risks for those that do not comply and opportunities for producers with strong policies.

Corporate and consumer demand for sustainable beef grows, creating strong demand for sustainable and transparent supply chains.

Declining demand for carbon-intensive protein sources in some regions may signal a growing trend as climate transitions intensify.

New planting technologies enable higher yields, diversified revenue streams and emission reductions.

Land competition from crops with lower carbon intensity of production and higher efficiency threatens business models centered on low-density expansion.

Government restrictions on deforestation reduce availability of land and increase land prices.

Introduction of greenhouse gas (GHG) taxes or pricing systems can increase production costs and offer new opportunities to earn revenues from nature conservation or restoration.

Importing countries restrict or ban non-certified products or those associated with deforestation, impacting market access.

Shareholders or capital providers divest, raise the cost of capital or engage producers through shareholder engagements or resolutions to address environmental concerns.

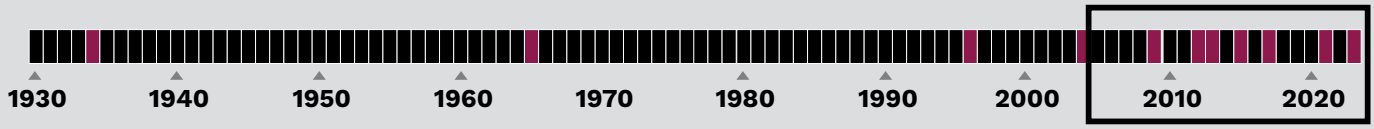
THE EVOLUTION OF CLIMATE-ASSOCIATED AGRICULTURE POLICIES IN BRAZIL

The landscape of climate regulations is quickly evolving as the government responds to accelerating climate impacts

POLICY MILESTONES

1930-2023

See next page for details



1934
Forest Code: Revised in 1965; Updated in 2012. Conserve native vegetation on private property.

1965
The Rural Credit National System (SNCR): In the 2023/2024 crop season, Plano Agrícola e Pecuário (PAP) encouraged sustainable production systems in medium and large farms by decreasing interest rates for recovery of degraded pastures.

1996
National Program for Strengthening Family Agriculture (PRONAF): Increase in resilience of family farmers and mitigate GHG emissions.

2004
National Program on Biodiesel Production and Use (PNPB): Target the production and use of biodiesel and stimulate rural development.

The Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm) and Plan of Action for the Prevention and Control of Deforestation in the Cerrado (PPCerrado): Reduce deforestation rates and achieve zero deforest-ation by 2030. PPCDAm revised and reactivated in 2023; PPCerrado revised in 2016.

In progress

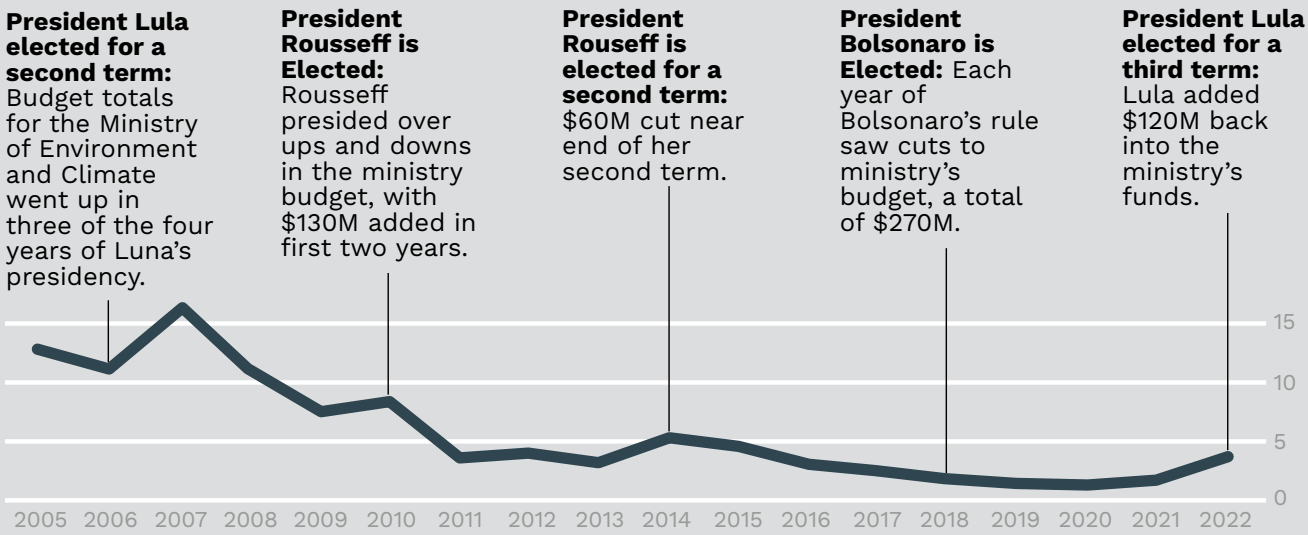
Program to Recover Degraded Pastures: Recover abandoned, degraded and low productivity pastures.

The Brazilian Emissions Trading System (SBCE): Cap-and-trade system that contributes to mitigating emissions and achieving NDC commitments, reducing physical risks

Fuels of the Future Program: Increase the use of sustainable fuels, reduce the average carbon intensity and promote the development of technologies.

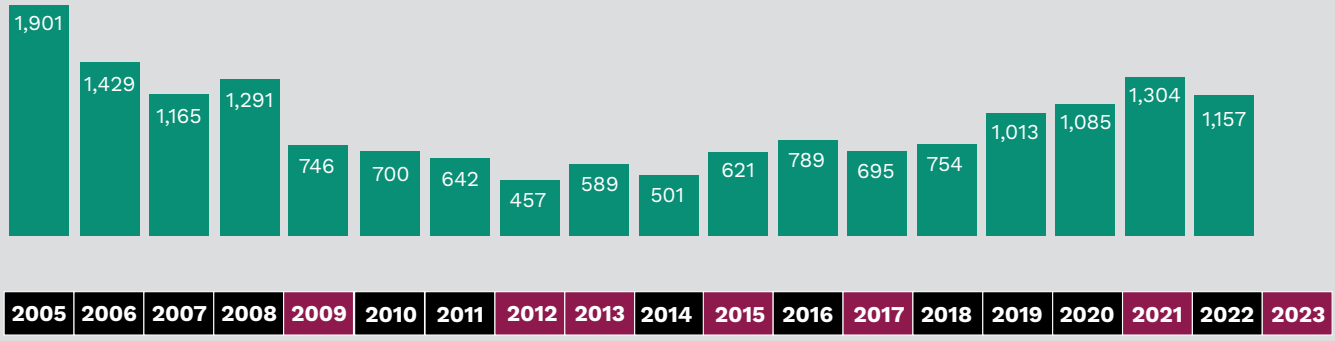
GOVERNMENT SPENDING AND ACTION

Infraction notices issued in the legal Amazon, in thousands



PRIMARY AMAZON FOREST LOSS

In thousands of hectares



2009
The National Policy on Climate Change (PNMC): Approved by the National Congress to achieve emissions reductions. The ABC Plan, PPCDAm and PPCerrado are three of the sectorial plans that form part of the PNMC.

2012
The Sectorial Plan for Adaptation and Low Carbon Emission in Agriculture (ABC Plan): Promote agricultural practices that reduce GHG emissions, increase efficiency and resilience of agricultural systems, and lower pressure on deforestation. New phase ABC+ in 2021.

2013
The National Policy on Agroecology and Organic Production (PLANAPO): Provide incentives to agroecology and organic agriculture through agricultural credits, technical assistance and research and development. Potentially increase resilience and reduce GHG emissions in agriculture by family farmers.

2015
The Nationally Determined Contribution (NDC): The most recent update in 2022 includes a target to reduce GHG emissions by 37% by 2025 and 50% by 2030, relative to 2005 emissions, while achieving climate neutrality by 2050.

2017
National Biofuels Policy (RenovaBio): Reduce emissions in the transportation sector and incentivize biofuel producers to increase the carbon efficiency of operations.

2021
National Policy of Payments for Ecosystem Services (PNPSA): Incentivize a market for eco-system services and create opportunities to recover deforested areas and protect natural vegetation.

2023
Sustainable Finance Policy: Support sustainable finance initiatives, combat greenwashing, enhance transparency and disclosure, foster the development of a suitable taxonomy and promote innovation.

Scientific breakthroughs not only increase the carrying capacity of pasturelands but also contribute to climate resilience and reduced environmental impacts.

for Brazilian agriculture, while transparent supply chains will benefit from more stable demand and potentially higher prices.

Supply chain companies also face mounting legal risks. Various stakeholders have recently begun urging relevant legal and regulatory systems to consider legal theories that regard failure to follow publicly declared sustainability commitments as fraudulent business conduct. For example, a complaint filed with the securities exchange commission (SEC) against a large Brazilian cattle trader accused the company of misleading investors in a sustainability-linked bonds issuance. If these types of complaints lead the relevant authorities to take enforcement actions against deforestation-prone supply chains, the consequences for these companies could be significant.

Furthermore, the EU is currently considering similar legislation in an effort to stem fraudulent claims, requiring the substantiation of voluntary marketing labels. This comes at the heels of a 2020 study by the European Commission, in which officials determined that 53 percent of the 330 EU environmental labels made vague, misleading or unfounded claims, while 40 percent were unsubstantiated.[49]

Technology Transitions: Advances in Science and Technology

Technological advancements present real risks to the Brazilian cattle sector as alternative protein technology increases competition, and satellite imagery improves the effectiveness of enforcement mechanisms to prevent deforestation. However, recent advancements in technology offer unprecedented opportunities for improved productivity and sustainability. Technological advancements also contribute to environmental sustainability by reducing resource waste and mitigating the ecological impact of cattle ranching, creating pivotal tools for shaping the future of the Brazilian cattle industry under climate transitions. Researchers have also made significant strides in developing innovative techniques for optimizing pasture quality and quantity, including improved grass species selection and precision fertilization methods. Furthermore, cutting-edge soil health assessments and sustainable land management practices are helping ranchers restore degraded pastures and maintain healthier grazing ecosystems. These scientific breakthroughs not only increase the carrying capacity of pasturelands but also contribute to climate resilience and reduced environmental impacts, making them a crucial component of sustainable and efficient cattle ranching in Brazil.

Although some producers in Brazil have been able to adapt to and take advantage of these new opportunities, there remains a large segment of producers who could benefit from these opportunities if provided with the regulatory, financial and technical support to implement them. In addition, providing raw materials for alternative protein production, mainly sugars, is an opportunity for some ranchers to diversify their activities.

Market Transitions: Corporate and Investor Climate Efforts

Corporate and investor efforts to meet increasingly ambitious climate goals cannot be overlooked in understanding the future of Brazil's cattle sector. At the 26th global UN climate conference, COP26, 10 of the world's largest companies heavily involved in global commodity production signed a pledge to end deforestation in their supply chains by 2030.[50] Meanwhile, 30 leading financial institutions, with over USD 8.7 trillion in assets under management, collectively committed to eliminate agricultural commodity-driven deforestation from their investment and lending portfolios by 2025.[51] Financiers have also raised significant concerns about protecting investments from reputation risks driven by deforestation. One such incident was in 2020, when a group of investors threatened divestment from Brazil's beef producers, grains traders and even government bonds, citing elevated country-level risk due to unchecked deforestation and a lack of transparency.[52]

Similarly, corporations along deforestation-risk supply chains are under pressure to eliminate deforestation from sourcing while working to improve mechanisms for financing producer resilience in the face of climate transitions. About two-thirds of companies with high deforestation exposure have sourcing policies in place intended to mitigate these exposures, and this number is expected to grow as climate-related financial disclosure requirements are passed around the world and shareholders submit

Negative perceptions by consumers and investors can impact companies' access to international markets and financing.

resolutions in favor of stricter policies and heightened monitoring.[53] Accelerating corporate and investor commitments is preventing market access and financing for suppliers that do not meet these criteria.

Reputational Transitions: Implications for Brand Value and Licence to Operate

Reputational risks are becoming increasingly important to agricultural producers in Brazil due to the growing global awareness of deforestation and environmental sustainability. Significant improvements in satellite monitoring have enabled watchdog agencies, companies and financiers to more effectively monitor for signs of deforestation and degradation to prevent reputational risks, and those without monitoring risk public embarrassment when shortcomings are exposed by NGOs or journalists.

Negative perceptions by consumers and investors can impact companies' access to international markets and financing. Downstream buyers and investors with sustainability commitments and high brand values are particularly likely to respond to reputational risks, especially when they are located in countries or regions with strong climate disclosure requirements. Increasingly, players who fall short of sustainability commitments face allegations of greenwashing and are exposed to reputational risk to brand assets.

STRENGTHS, WEAKNESSES, OPPORTUNITIES AND THREATS FOR THE BRAZILIAN CATTLE SECTOR

The Brazilian cattle sector faces both significant challenges and unprecedented opportunities.

Emerging carbon and biodiversity markets, sustainable intensification strategies and evolving consumer demand offer proactive cattle farmers the opportunity to diversify revenue streams and increase their profitability. Those who fail to respond to the evolving market risk significant challenges, as changing regulations, rising land and carbon prices and potential market access restrictions cloud the future of the Brazilian cattle sector.

Opportunities

- Rising consumer demand for zero deforestation and low-emission beef at higher prices
- High potential to increase revenue through improved land-use efficiencies with low costs through innovative R&D, technical assistance, better management and infrastructure improvements
- Pasture restoration and soil fertility adjustment create higher and more resilient profits
- New opportunities for diversifying revenue streams through carbon and emerging biodiversity markets, along with other nature-based solutions

Threats

- New emission costs from production, processing and transportation with the emergence of GHG prices
- Higher land prices due to deforestation restrictions and competition for land for growing commodity production and carbon market projects
- Declining demand due to lower ruminant meat consumption and alternative proteins, despite growing demand for livestock
- New foreign and domestic policies limiting market access and availability of land for expansion
- New foreign and domestic regulations creating legal risk and affecting the reputational value of supply chain stakeholders

Strengths

- Concentrated midstream and downstream market power to efficiently allocate product processing and sales
- Significant international market share
- Established industry and supporting infrastructure
- Institutional support and promotion of sustainable intensification practices

Weaknesses

- Significant exposure to deforestation and environmental risk
- High transportation costs for farmers located far from slaughterhouses
- High sensitivity of profitability to cattle price changes.
- Volatility in domestic consumption imposing a potential risk to future profitability

Source: Authors' analysis.

A Glimpse Into the Future of the Brazilian Cattle Sector Through Economic Modeling

Section 4

Seven emerging trends stemming from climate transitions are likely to create risks and opportunities for stakeholders across the Brazilian cattle sector

Climate transitions will create winners and losers in the global cattle sector, driven primarily by shifting diets, technological change, improved management practices and reduced land availability. Brazil is in a unique position to seize upon opportunities to ensure that its cattle sector stays competitive among these changes and to support the nation's rural economy for decades to come.

Climate transition scenario analysis is needed to understand who will fare best under climate transitions and how to manage them. By considering different scenarios of the future with alternative levels of climate action, technology adoption and more, stakeholders in Brazil's cattle sector are better able to plan for the future. While it is impossible to know exactly how climate transitions will unfold in the future, utilizing this type of scenario analysis provides an opportunity to understand the range of future impacts and identify where new investments in resilience are most needed.

Companies with high cattle production efficiency, low rent costs, proximity to slaughterhouses, access to capital and diversified revenue from nature-based solutions will survive and thrive on existing land.

Through analyzing the impact of forward-looking projections (see Scenarios Explained box), it is clear that companies with high cattle production efficiency, low rent costs, proximity to slaughterhouses, access to capital and diversified revenue from nature-based solutions will survive and thrive on existing land. On the other hand, producers with higher operational and financial costs will find sustainable land intensification challenging.

Government and investor financing and increased agricultural productivity, particularly through technology and sustainable management practices, will play an important role in either enabling or hampering Brazil's global competitiveness. Sustainability and yield improvements can become the Brazilian cattle industry's source of competitive advantage. Its position as a major global player allows Brazilian cattle producers to set the tone for global standards.

Projecting four versions of the future with modest or ambitious climate action, in addition to a version of the future that follows a Business as Usual trajectory, provides stakeholders with the information necessary to make informed decisions. Market leaders will prepare for the ambitious climate transitions expected in a world that acts to restrict warming to 1.5°C above pre-industrial levels.

Chapter Highlights

The magnitude of the global response to climate change will dictate the impact on the Brazilian cattle sector. Nevertheless, even the modest projections of the IPR-aligned Forecast Policy Scenario anticipate significant changes by 2050, as outlined below:

- Emission intensive cattle producers would experience rising costs and gain opportunities to diversify revenue streams through carbon markets as GHG prices grow.
- Growing forest-conservation strategies would result in 37 percent less pastureland available.
- Producers would experience an 18 percent increase in pasture yield.
- Capital investments in Brazilian agriculture would rise by 88 percent.
- Deforestation-free and low-emission beef products would capture a 19 percent increase in beef prices.
- Rising prices and shifting consumer preferences would reduce Brazilian ruminant meat demand by 38 percent and global demand by 5 percent, although overall livestock demand would increase by 20 percent globally over the same period.
- Despite declines in overall production, Brazil has the opportunity to invest in international trade, with Brazil projected to increase its share of global beef exports by 9 percent.

SCENARIOS EXPLAINED: PROJECTING A RANGE OF FUTURES FOR THE BRAZILIAN CATTLE SECTOR

Each scenario considers both global and corresponding local pathways to achieve global warming temperature targets by 2050.

Business As Usual – Baseline with Warming Target > 3°C[e]

Business as Usual Scenario: The Business as Usual Scenario assumes limited global and local ambitions to address the climate crisis, a continuation of current trends. This would mean that dietary shifts are not adopted, protected areas do not expand and little international ambition in support of climate action is realized. Agriculture, forestry and other land use (AFOLU) GHG emissions are priced at very low levels, while limited deforestation prevention efforts are made. Although this scenario reflects the status quo, the acute physical risks to which the Brazilian cattle sector is exposed will affect production much more than those depicted in the Business as Usual scenario, which covers only transition risks at a decadal scale.[54] Additional risks from extreme weather events, labor productivity effects, pests, diseases and animal heat tolerance will lower yields. The resulting inevitability of climate transitions means that the Business as Usual scenario paints a more optimistic picture of the future than the cattle sector will face. A > 3°C world with extreme temperature, precipitation and humidity impacts would present an existential risk to profitability at Brazilian cattle farms even if transition risks are lower.

Modest Action with Warming Target < 2°C

Forecast Policy Scenario: The Forecast Policy Scenario (Modest-Forecast Policy) is a component of the Inevitable Policy Response (IPR) scenario by the UN-supported Principles of Responsible Investment (PRI) and projects current policy forecasts through 2050 without substantial deviation from expected commitments. Medium dietary shifts and food waste reductions occur, low-ambition climate policies are introduced and existing land protection policies are expanded across only critically important biodiversity hotspots. AFOLU GHG emission prices are projected to increase. However, values rise abruptly, showing strong regional variance.

Coordinated Policy Scenario: The Coordinated Policy Scenario (Modest-Coordinated Policy) is characterized by slightly more ambitious climate policies which are implemented sooner than in the Modest-Forecast Policy Scenario. Comprehensive pledges for reforestation and reduced deforestation are observed throughout Brazil as effective management of biodiversity hotspots is ensured. Beyond land use policy, modest dietary shifts, food waste reductions and AFOLU emissions prices are also a part of this scenario. However, these changes do not represent substantial societal shifts.

Ambitious Action with Warming Target < 1.5°C

Societal Transformation Scenario: The Societal Transformation Scenario (Ambitious-Societal Transformation) is characterized by strong societal transformation, amplifying actions taken under the Modest scenarios. AFOLU GHG emissions are priced higher and significant dietary shifts take place. This reduces livestock intake and food waste. In addition, protected areas double from the present ~15 percent to 30 percent by 2030, in alignment with the international 30 by 30 initiative. Deforestation is reduced and reforestation is increased.[55] This scenario also assumes medium technological and sustainable management practice change adoption.

Innovation Scenario: The Innovation Scenario (Ambitious-Innovation) deviates from societal transformation, instead favoring innovative solutions to GHG-intensive processes. The most important projected shift is the intensive implementation of yield-enhancing practices, including technology adoption and fertilizer use efficiency. AFOLU GHG pricing rises to the levels observed under a broad societal transformation. This scenario assumes high technology and sustainable management practice adoption, spurred by research and development investments and high innovation diffusion across the sector.

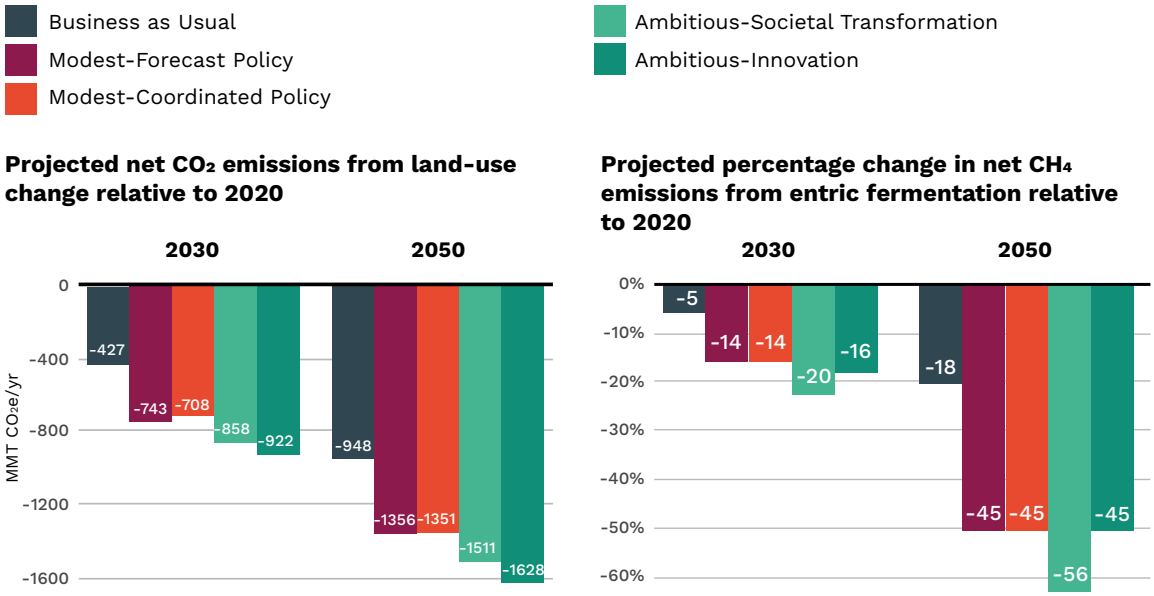
[e] Orbitas is collaborating with World Business Council for Sustainable Development (WBCSD) and Vivid Economics to drive greater alignment around climate transition scenarios assumptions. The scenarios are based on the WBCSD transition scenario tool, which was inspired by Orbitas phase 1 scenarios, with modifications to incorporate recent developments. See here for the earlier WBCSD tool: https://www.wbcsd.org/Programs/Redefining-Value/TCFD/News/WBCSD-releases-new-climate-transition-scenario-tool-for-companies-in-the-Food-Agriculture-and-Forest-Products-sectors

> See **Appendix 2** for more information on scenario assumptions.

FIGURE 3.

PROJECTED EMISSION REDUCTIONS IN BRAZILIAN AGRICULTURE AND LAND USE CHANGE RELATIVE TO 2020

As the world adopts carbon pricing and brazil works to meet international commitments, land use change and agriculture emissions would decline



In absolute values (MMT CO_2e/yr)

	Business as Usual	Modest-Forecast Policy	Modest-Coordinated Policy	Ambitious-Societal Transformation	Ambitious-Innovation
2030	408	366	367	340	360
2050	350	234	237	188	236

Source: Authors' economic modeling (MAgPIE) results.

Methane emission reductions:

Across 2°C and 1.5°C transition scenarios, methane emissions from enteric fermentation would drop between 45 and 56 percent.

However, even modest transition scenarios aligned with 2°C of warming will significantly transform the Brazilian cattle sector. The Forecast Policy scenario, aligned with the PRI's IPR initiative, represents a relatively modest, plausible and impactful reference scenario to clearly see the scale of potential impacts that climate transitions will have on the Brazilian cattle sector. This sheds light on the trends that the Brazilian cattle sector may face as climate transitions become increasingly inevitable. The seven most material trends impacting financial outcomes are outlined below.

Trend 1. Emissions Pricing

GHG emissions pricing could materially drive up production costs for emission intensive cattle producers and create opportunities to diversify revenue streams.

Scenario projections show how different pathways could lead to very different outcomes for the Brazilian agricultural sector as a whole, and especially cattle producers. Emission reductions for cattle producers under climate transitions are expected to be primarily driven by climate policy, ambitious land conservation action, increased productivity and reductions in food waste.

Under the Modest-Forecast Policy scenario, overall net CO_2 emissions from land use change would decrease by 1,356 million metric tons between 2020 and 2050, while methane emissions from enteric fermentation would drop by 45 percent over the same time period. In the more ambitious scenarios that aim to keep temperature rises under 1.5°C, net GHG emissions would experience a more significant drop, with 1,628 million metric tons of CO_2 emission reductions from

land use change each year under the Ambitious-Innovation scenario and a 56 percent decrease in methane emissions from enteric fermentation under the Ambitious-Societal Transformation scenario by 2050 (see Figure 3).

Even under the Business as Usual scenario, Brazil would see a drop in CO_2 emissions from land-use change as a result of reductions in deforestation projected with a full implementation of the Brazilian Forest Code. Merely implementing current policies could transform the Brazilian land use system into a net carbon sink in the short term and establish a broader low-emission potential as a feasible medium-run target for the country.

The lower GHG emissions projected across transition scenarios are the direct result of the higher resource efficiency of Brazilian agriculture, resulting in a significant amount of land currently used for cattle production being spared and creating opportunities for alternative uses of this land.[56] Increasing GHG prices changes the profitability equation for how land is used and makes new revenue streams, such as carbon or biodiversity markets, non-timber forest products and new products from agroforestry, more attractive.

However, emissions pricing would raise production costs for emission intensive cattle producers, thus providing incentives for farmers with low profit margins to consider new business models. The potential to reduce methane emissions from enteric fermentation at scale through existing technological routes is currently nascent, but increasing productivity through better pasture management and improved genetics can already deliver lower methane-intensive beef products.[57]

Pasture land reduction:

Across 2°C and 1.5°C transition scenarios, pasture land would reduce between 37 and 76 percent.

Forest cover increase:

Across 2°C and 1.5°C transition scenarios, forest cover would increase between 11 and 27 percent.

Trend 2. Land Constraints

Climate action, land conservation measures and competition for land from the bioeconomy could reduce the availability of affordable pasture land by up to three-quarters between 2020 and 2050.

Historically, Brazilian cattle industry expansion has largely relied on converting forests and savannas to pastureland. However, this approach to growth is not projected to be feasible under transition scenarios due to the Brazilian government's deforestation commitments and the potential for landowners to earn revenues from forest preservation and restoration projects (see Figure 4). The combination of strict climate policy and high-level land conservation ambitions limits overall land availability for cattle sector expansion. Thus, climate transitions would constrain the industry's geographic expansion, reducing land for grazing to 43 million hectares under the Ambitious-Societal Transformation scenario, 76 percent lower than in the Business as Usual scenario with predicted temperature rises above 3°C.

Under both Modest scenarios, the Brazilian natural vegetation area would increase by 56 to 58 million hectares by 2050, approximately 11 percent, due to additional ambitious pledges for reforestation in support of the Paris Agreement. Under the Modest-Forecast Policy scenario, pastureland for Brazilian cattle production would decrease by 37 percent between 2020 and 2050 with an increase in land-use restrictions, taxes on GHG emissions and policies driving nature restoration. Under the Ambitious scenarios, the higher GHG prices and ambitious land protection efforts would push forest and natural vegetation growth to 27 percent higher than 2020, or 675 million hectares, by 2050. This increase of nearly 144 million hectares represents an area larger than Peru. These changes would contribute to land-based carbon sequestration but also impose economic and legal restrictions on cattle production.

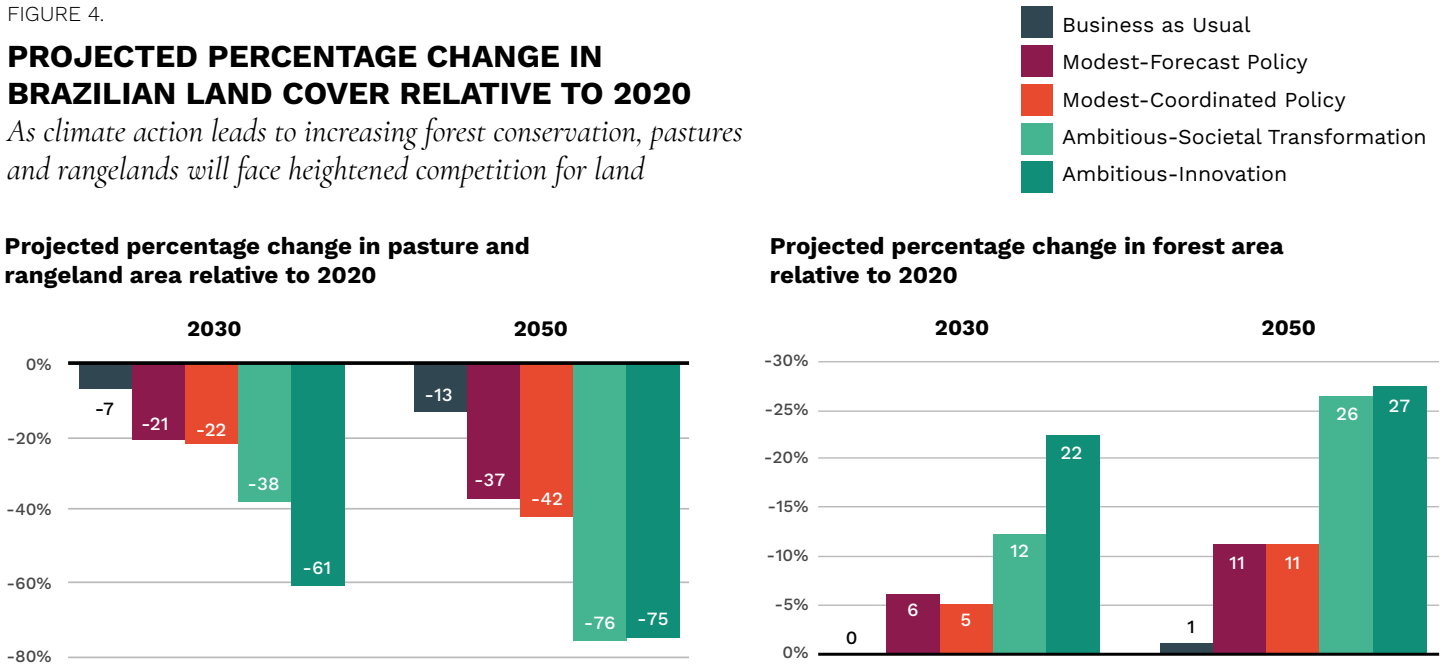
Greenhouse Gas Pricing

These scenarios assume that GHG costs would be relatively minor in the early years but diverge across scenarios over time and increase substantially with greater climate ambition. As climate policies expand in response to worsening physical risks, scenarios project a GHG price increase to USD 87 per ton of CO_2e under the <2°C Modest-Forecast Policy scenario, USD 100 per ton of CO_2e under the <2°C Modest-Coordinated Policy scenario and USD 153 per ton of CO_2e in 2050 under both <1.5°Ambitious scenarios. GHG emission costs for cattle farmers would primarily stem from deforestation and conversion of other carbon-rich ecosystems (CO_2), ruminant enteric fermentation (methane) and fertilizer. However, GHG pricing would also provide opportunities for farmers to diversify revenue streams through carbon and biodiversity markets.

FIGURE 4.

PROJECTED PERCENTAGE CHANGE IN BRAZILIAN LAND COVER RELATIVE TO 2020

As climate action leads to increasing forest conservation, pastures and rangelands will face heightened competition for land



In absolute values (Million ha)

	Business as Usual	Modest-Forecast Policy	Modest-Coordinated Policy	Ambitious-Societal Transformation	Ambitious-Innovation
2030	170	145	143	113	71
2050	159	116	107	43	47

In absolute values (Million ha)

	Business as Usual	Modest-Forecast Policy	Modest-Coordinated Policy	Ambitious-Societal Transformation	Ambitious-Innovation
2030	533	561	559	597	646
2050	536	589	587	667	675

Source: Authors' economic modeling (MAgPIE) results.

Brazilian ruminant meat yield increase:

Across 2°C and 1.5°C transition scenarios, Brazilian ruminant meat yield would increase between 18 and 198 percent.

Trend 3. Yield Improvements

As business models reliant on high land use and deforestation become less feasible, cattle farmers can adapt by prioritizing sustainable productivity investments and process improvements to boost the yield on existing land and on degraded pastures.

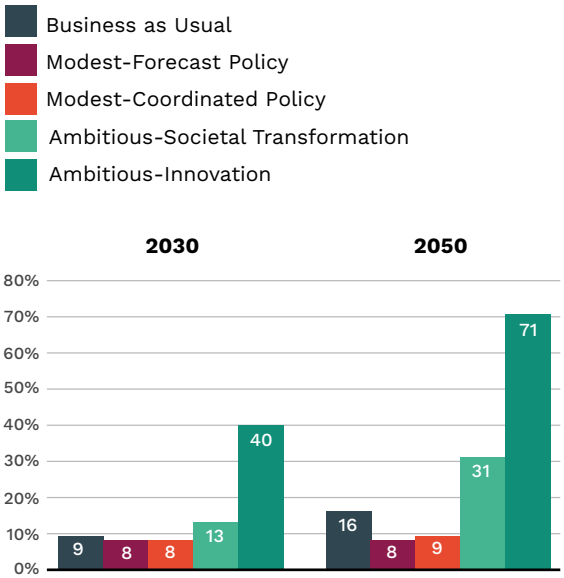
While steep declines in pasture and rangeland areas may seem unrealistic in the short term, the sector has already made significant strides in productivity in recent decades and currently operates well below its potential productivity level. Furthermore, increasing efficiency is an aspiration that is central to Brazil's nationally determined contributions, the country's international commitments to reach Paris Agreement goals.[58] [59] The projected sustainable intensification is driven by technological change, which includes process innovation and machinery technology. Less land would be required for efficient agricultural production, making land available for other uses. Under the Modest-Forecast Policy scenario, land use intensity would increase by 8 percent by 2050 compared to 2020. Over the same time period, under the Ambitious-Innovation scenario with innovative technology and efficient management practices and utilization assumptions, land-use intensity would surge to 71 percent above 2020 levels (Figure 5). The potential for innovation in the livestock sector in Brazil is well documented and could lead to a reduction of several million hectares of pasture area without compromising production while creating space for additional cropland, reforestation and more.[60]

The cattle sector shows strong potential for efficiency improvements that increase yield under the transition scenario with the highest levels of innovation, the Ambitious-Innovation scenario (see Figure 6). Innovation here would mean both technology adoption and improved management practices, such

FIGURE 5.

PROJECTED PERCENTAGE CHANGE IN BRAZILIAN PASTURE USE INTENSITY RELATIVE TO 2020

Ambitious climate transitions are expected to lead to significant increases in pasture use intensity as efficiency improves



In absolute values (Index)

	Business as Usual	Modest-Forecast Policy	Modest-Coordinated Policy	Ambitious-Societal Transformation	Ambitious-Innovation
2030	1.13	1.12	1.13	1.18	1.46
2050	1.21	1.12	1.14	1.37	1.78

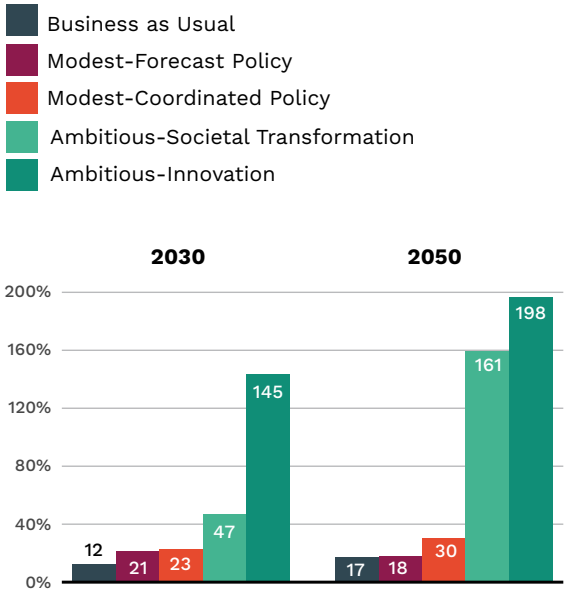
Source: Authors' economic modeling (MAgPIE) results.

Notes: For land use intensity details, see Dietrich et al. (2012).[77]

FIGURE 6.

PROJECTED PERCENTAGE CHANGE IN BRAZILIAN RUMINANT MEAT YIELD RELATIVE TO 2020

Sustainable intensification technologies and practices are projected to substantially increase Brazilian cattle production yields



In absolute values (tDM/ha)

	Business as Usual	Modest-Forecast Policy	Modest-Coordinated Policy	Ambitious-Societal Transformation	Ambitious-Innovation
2030	0.034	0.037	0.038	0.045	0.075
2050	0.036	0.036	0.040	0.080	0.091

Source: Authors' economic modeling (MAgPIE) results.

Notes: Yield projections presented here are calculated based on climate transition scenario assumptions, which are different from productivity improvement through degraded pasture restoration and maintenance, as discussed in Section 6.

Pasture use intensity increase:

Across 2°C and 1.5°C transition scenarios, pasture use intensity would rise between 8% and 71%.

as integrated crop-livestock-forest systems. Assuming low-cost technological changes result in the highest yield growth at the lowest cost for the sector, these changes would enable Brazilian cattle farmers to produce low-cost and low-emission beef and allow the sector to maintain international cost competitiveness and profitability. The low cost of innovation in this scenario would enable Brazil to gain market share and maintain production levels similar to those in both Modest scenarios, despite much stronger environmental constraints and consumer preference changes.

Across scenarios, higher yields would reduce the pressure on land, even if demand and production for beef were to increase. The rise in pasture productivity anticipated is notably beyond the yield improvement rate Brazil has seen in recent years, which continues under the Business as Usual scenario.

Both Modest scenarios already project a significant increase in productivity. Under the Modest-Forecast Policy scenario, producers would increase cattle productivity by 18 percent per hectare. Under the Ambitious scenarios, yield increases would depart sub-

Investing in Technological Innovation

The cost of innovation is an important driver of Brazil's ability to adapt during climate transitions. Under the Ambitious-Innovation scenario, producers would be able to more easily access capital to invest in the technology and sustainable management practices needed to build resilience. The low cost of technological improvement in this scenario means that lower capital expenditure is required to achieve more far-reaching outcomes. The Societal Transformation and Modest scenarios both assume a medium cost of technological improvement, but total investment varies due to differences in demand, production output and availability of land.

stantially from historical trends, especially in the Ambitious-Innovation scenario, which would see a 181 percentage points higher yield compared with the Business as Usual scenario in 2050. Figure 6 shows these results for Brazil's ruminant meat sector, which is dominated by the beef sector.

Furthermore, Brazil would substantially outpace global yields across transition scenarios. Global yields are projected to range from a small decline to a 16 percent increase, while Brazilian yields are projected to increase between 18 and 198 percent. Brazil currently averages 1 animal unit per hectare (AU/ha), well below potential stocking rates.[61] [62] [f] This underscores that Brazil's competitive advantage in cattle production will likely continue to increase as long as the country invests in innovation and the ecosystem services that create this competitive advantage are maintained.

Trend 4. Accelerating Investment

Agricultural capital investment increase:

Across 2°C and 1.5°C transition scenarios, capital investment would increase between 88 and 133 percent.

Investment in capital goods, land, advanced technology adoption and improved management practices could increase production efficiency.

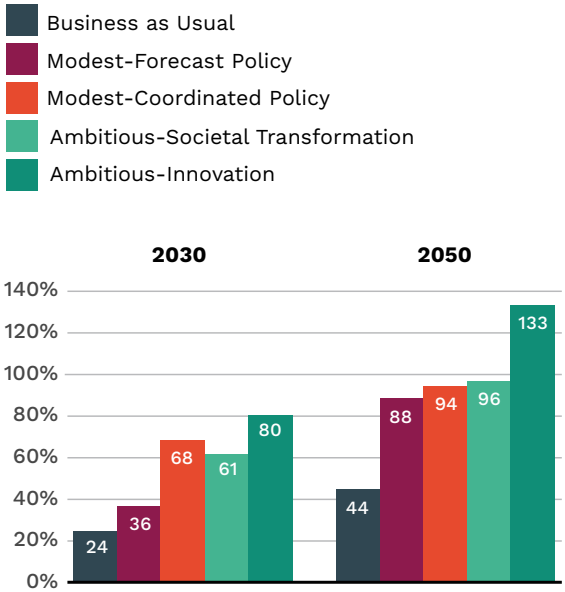
Although climate transitions present considerable risks, they also present opportunities for the Brazilian cattle sector. Across all transition scenarios, investment in capital goods and land, advanced technology adoption and improved management practices would enable increased production efficiency and resilience. It would enhance sustainable land use intensification for both cropland and pasture compared to Business as Usual, therefore increasing producers' ability to cope with the changes foreseen (see Figure 7).

This would mean that less land is required to produce cattle products. Sustainable and transparent producers that do not depend on deforestation for expansion are also likely to be perceived as less risky as a result of

FIGURE 7.

PROJECTED PERCENTAGE CHANGE IN CAPITAL INVESTMENT IN BRAZILIAN AGRICULTURE RELATIVE TO 2020

Significant financing is required to enable projected yield improvements under transition scenarios



In absolute values (Billion USD)

	Business as Usual	Modest-Forecast Policy	Modest-Coordinated Policy	Ambitious-Societal Transformation	Ambitious-Innovation
2030	104	114	141	135	151
2050	120	157	163	164	195

Source: Authors' economic modeling (MAgPIE) results.

Notes: The capital investment presented in the figure represents the aggregated net investment for all agricultural sectors in Brazil. This figure provides an indication of capital investment under climate transition scenarios across agricultural sectors and does not specify the cattle sector.

[f] 1 animal unit is defined as a 454 kg (1000 pound) cow, with or without an unweaned calf, with a daily dry matter forage requirement of 12 kg (26 pounds).

heightened market access and better resilience to climate transition risks, thus increasing access to affordable capital for yield improvements.

However, it is unlikely that these investments will be made or that yield improvement technology will be implemented at the scale projected as long as cheap land enters production through the conversion of native vegetation and land-grabbing practices. This is because it will likely be cheaper to expand production onto native vegetation than to sustainably intensify production at the scale projected until the expansion frontier is closed and zero deforestation becomes a reality.[63] If this Business as Usual scenario materializes, investments would likely center around mitigating the physical impacts of reduced rainfall, lower soil quality and extreme weather.

Trend 5. Beef Price Fluctuations

Ruminant meat producer price increase:

Across 2°C and 1.5°C transition scenarios, producers would see meat prices grow between 19% and 74%.

Climate transitions could create price increases for deforestation-free and low-emission cattle products globally, presenting opportunities for producers that increase cattle farm productivity and provide transparency to buyers and financiers.

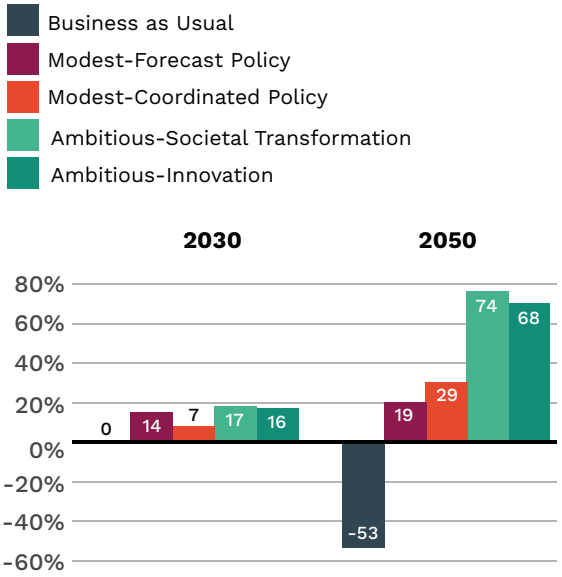
Climate transitions are likely to drive market fragmentation as consumers become more attuned to sustainability concerns, creating both reputational risks and differentiation opportunities for major stakeholders along cattle supply chains. A recent study shows that some consumers may be willing to pay higher prices for sustainable beef, which amounted to an additional 84 percent among respondents.[64] Increasing prices may be accepted more widely under transition scenarios as production prices rise and consumer, government and private sector understandings of climate change and deforestation risk increase (see Figure 8).

Cattle producers would see production price increase by up to 74 percent through 2050 under the Ambitious scenarios. In fact, higher land conservation assumptions in the Ambitious-Societal Transformation scenario would lead to the highest prices, despite lower projected demand. Conversely, cattle product prices would likely decrease under the Business as Usual scenario to about half of 2020 prices as a result of high land availability and affordability. Under this scenario, limited reforestation actions would be undertaken, and Brazilian beef would struggle with access to international markets, such as the European Union. Under the Modest-Forecast Policy scenario, producers would see a 19 percent increase in prices paid for ruminant meat.

FIGURE 8.

PROJECTED PERCENTAGE CHANGE IN BRAZILIAN RUMINANT MEAT PRODUCER PRICE RELATIVE TO 2020

Land conservation projections and deforestation-free production would increase the price of ruminant meat in transition scenarios

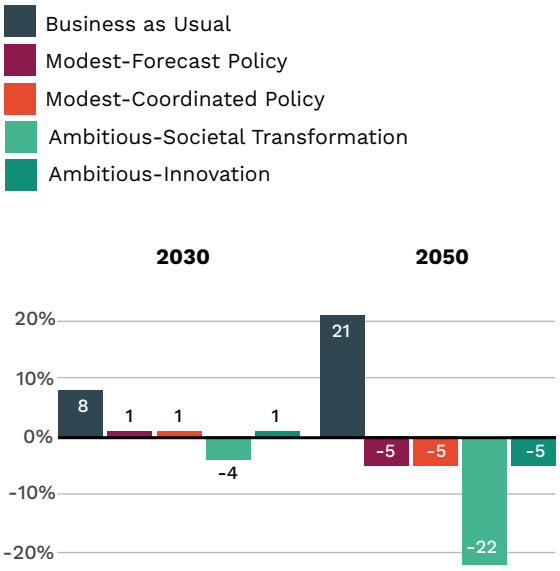


Source: Authors' economic modeling (MAgPIE) results.

FIGURE 9.

PROJECTED PERCENTAGE CHANGE IN GLOBAL RUMINANT MEAT DEMAND RELATIVE TO 2020

Diet shifts projected under climate transitions could decrease global demand for ruminant meat over time



In absolute values (MMT DM/yr)

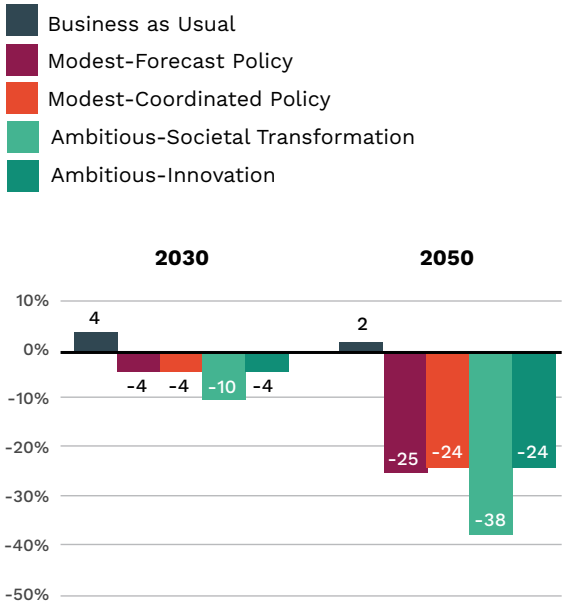
	Business as Usual	Modest-Forecast Policy	Modest-Coordinated Policy	Ambitious-Societal Transformation	Ambitious-Innovation
2030	63	58	58	55	58
2050	70	55	55	45	45

Source: Authors' economic modeling (MAgPIE) results

FIGURE 10.

PROJECTED PERCENTAGE CHANGE IN BRAZILIAN RUMINANT MEAT PRODUCTION RELATIVE TO 2020

Diet shifts and rising production costs are likely to put downward pressure on Brazilian production of ruminant meat



In absolute values (MMT DM/yr)

	Business as Usual	Modest-Forecast Policy	Modest-Coordinated Policy	Ambitious-Societal Transformation	Ambitious-Innovation
2030	5.83	5.39	5.40	5.06	5.37
2050	5.70	4.19	4.25	3.47	4.26

Source: Authors' economic modeling (MAgPIE) results.

Brazilian ruminant meat production decrease:

Across 2°C and 1.5°C transition scenarios, Brazilian ruminant meat production would decline between 24% and 38%.

Trend 6. Dietary Shifts

Despite a projected increase in the global demand for livestock, evolving global dietary trends could threaten the demand for beef and other cattle products under climate transitions, as the growth in sustainable-minded consumers drives the consumption of protein alternatives and low-emission beef.

Lower per capita consumption of ruminant meat, resulting from financial pressures, shifting consumer preferences or potential indirect policy implications, is projected to reduce the overall demand for beef across transition scenarios. Driven by changing consumer preferences and beef price changes, the global demand for ruminant meat is expected to decrease by 5 percent by 2050 under the Modest and Ambitious-Innovation scenarios. Aggressive dietary preference changes under the Ambitious-Societal Transformation scenario would lead to a 22 percent decrease between 2020 and 2050 (see Figure 9).

With Brazil's ambitious dietary shift driven by changing consumer preferences globally, in addition to price increases and rising production costs, the Ambitious-Societal Transformation scenario would lead to a 38 percent reduction in Brazilian ruminant meat production compared to the Business as Usual scenario in 2050. Meanwhile, Brazilian ruminant meat production would drop

Ruminant meat demand decrease:

Across 2°C and 1.5°C transition scenarios, global ruminant meat demand would decline between 5% and 22% while domestic Brazilian ruminant meat demand would reduce between 38% and 52%.

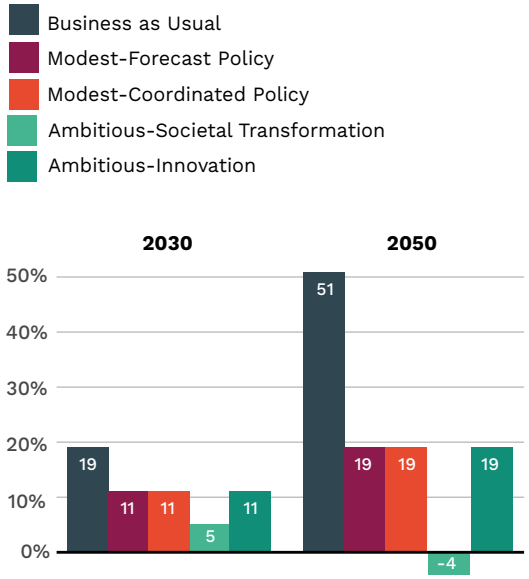
by about a quarter under the Ambitious-Innovation and the Modest-Forecast Policy scenarios when compared to 2020 (see Figure 10).

While global ruminant meat demand will continue to grow under the Business as Usual scenario, driven by rising demand in developing countries and a growing global population, Brazil's beef consumption per capita is already high by global standards at around 35 kg per capita per year.[65] Historically, meat consumption in Brazil has grown in line with GDP growth, but Brazilians have increasingly shifted toward beef alternatives.[66] In the Business as Usual scenario, total demand in the country is projected to remain relatively stable in the short term before it begins to decline slightly toward the mid-century. However, under all four Modest and Ambitious scenarios, Brazilian beef demand will significantly decline by 2050.

FIGURE 11.

PROJECTED PERCENTAGE CHANGE IN GLOBAL LIVESTOCK MEAT DEMAND RELATIVE TO 2020

Despite diet shifts, overall livestock demand is projected to increase substantially with a growing global population



In absolute values (MMT DM/yr)

	Business as Usual	Modest-Forecast Policy	Modest-Coordinated Policy	Ambitious-Societal Transformation	Ambitious-Innovation
2030	374	349	349	331	349
2050	475	374	374	302	374

Source: Authors' economic modeling (MAgPIE) results.

Notes: Livestock products demand refers to an aggregation of eggs, monogastric meat, dairy, poultry and ruminant meat demand.

Understanding the difference between Ruminant meat and Livestock

A subcategory of livestock, ruminant meat comprises animals with multi-chambered stomach systems, including cattle, sheep, goats and deer. Cattle meat makes up the vast majority of ruminant meat produced in Brazil. Livestock as a whole includes a variety of animal-related products, including ruminant meat, monogastric meat, poultry, dairy and eggs. Ruminant meat represented 32 percent of Brazil's total demand for livestock products in 2020, followed closely by demand for poultry at 29 percent. Contrary to ruminant meat, however, demand for livestock is projected to increase domestically by up to 22 percent and up to 51 percent globally by 2050 under the Business as Usual scenario.

Climate Transition Risk Scenario Analyzer

Available at:
orbitas.finance/brazil-cattle-tools

This interactive tool projects the evolution of the Brazilian cattle sector under the climate transition scenarios analyzed here, which are used to assess the performance of representative farms. Users can leverage this tool to access information on:

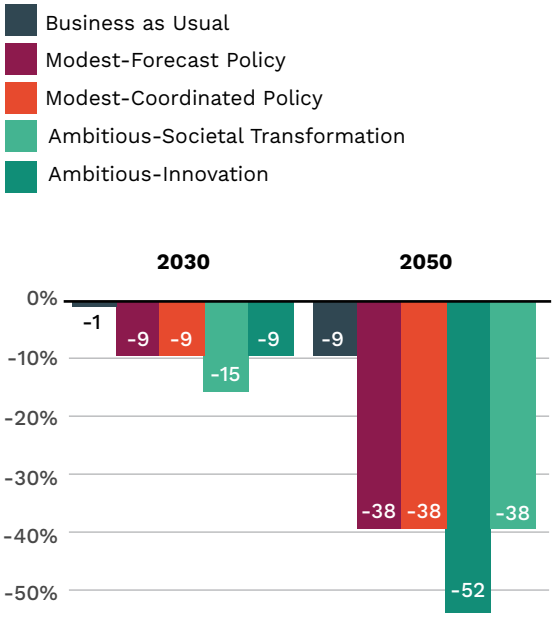
- Demand, export, product prices, production and yield.
- Revenue, costs and profits for representative farms.
- GHG emissions and prices.

Demand would drop by 38 percent under the Modest and Ambitious-Innovation scenarios and by 52 percent under the Ambitious-Societal Transformation scenario, due primarily to shifting diets and increasing prices (Figure 12). Embracing a local deforestation-free and low-emission beef label could counteract slowing demand. This approach would play into the cultural heritage of cattle production in Brazil while also creating a differentiated product that justifies higher prices. In fact, whether a product "protects forests and biodiversity" or not is a top 3 concern for Brazilian consumers when making a purchase.[67]

FIGURE 12.

PROJECTED PERCENTAGE CHANGE IN DOMESTIC BRAZILIAN RUMINANT MEAT DEMAND RELATIVE TO 2020

Diet shifts projected under climate transitions could decrease Brazilian demand for ruminant meat over time



In absolute values (MMT DM/yr)

	Business as Usual	Modest-Forecast Policy	Modest-Coordinated Policy	Ambitious-Societal Transformation	Ambitious-Innovation
2030	4.08	3.72	3.72	3.48	3.72
2050	3.75	2.54	2.54	1.97	2.54

Source: Authors' economic modeling (MAgPIE) results.

Brazilian ruminant meat export fluctuation:

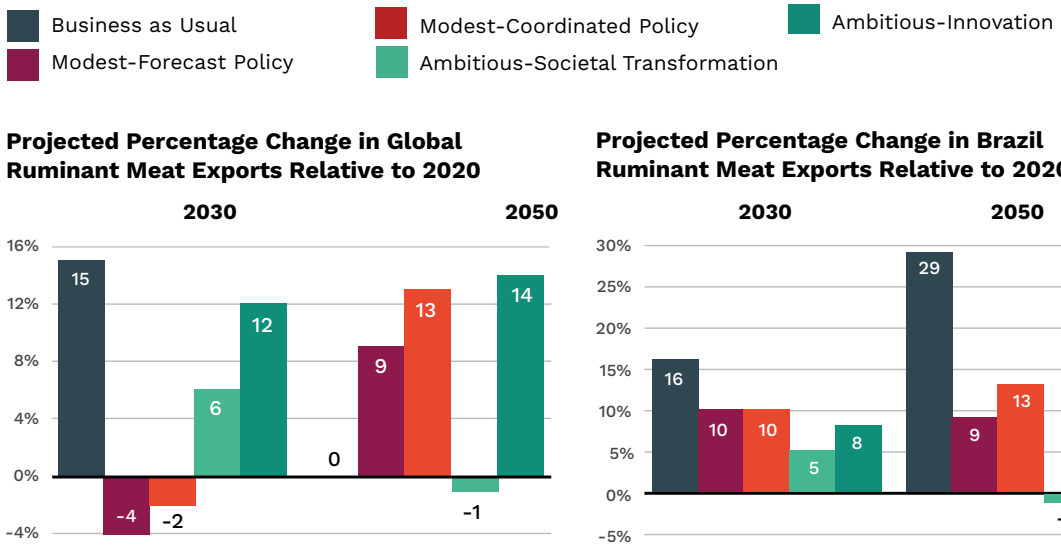
Across 2°C and 1.5°C transition scenarios, Brazilian ruminant meat exports would grow up to 14 percent.

FIGURE 13.

PROJECTED PERCENTAGE CHANGE IN RUMINANT MEAT EXPORTS RELATIVE TO 2020

Comparatively resilient ruminant meat exports point to Brazil's competitive advantage in cattle production

Despite downward demand pressure, Brazilian beef exports would remain relatively stable across all scenarios, an indication of Brazil's competitive advantage in the global market



In absolute values (MMT DM/yr)

	Business as Usual	Modest-Forecast Policy	Modest-Coordinated Policy	Ambitious-Societal Transformation	Ambitious-Innovation
2030	6.14	5.16	5.26	5.65	5.98
2050	5.38	5.86	6.07	5.28	6.09

In absolute values (MMT DM/yr)

	Business as Usual	Modest-Forecast Policy	Modest-Coordinated Policy	Ambitious-Societal Transformation	Ambitious-Innovation
2030	1.76	1.67	1.67	1.59	1.64
2050	1.95	1.65	1.72	1.50	1.72

Source: Authors' economic modeling (MAgPIE) results.

Trend 7. Growing Focus on Exports

Export markets are likely to become increasingly important due to Brazil's competitive advantage in beef production, although regulations promoting source of origin disclosure are on the rise and will restrict market access for deforestation-linked beef production.

Despite downward demand pressure, Brazilian beef exports would remain relatively stable across all scenarios, an indication of Brazil's competitive advantage in the global market (see Figure 13). Nevertheless, all policy scenarios project lower exports compared to the Business as Usual scenario in 2050. The Ambitious-Societal Transformation scenario, with its substantial diet shift, projects a rebound in Brazilian exports to 2020 levels by 2050.

All other scenarios project increases of between 9 percent and 14 percent by 2050 versus 2020 levels. At the high end of this range is the Ambitious-Innovation scenario, in which low-cost technological innovation and improved management practices would increase both the yields and the competitiveness of Brazilian beef abroad. The beef produced in Brazil in this scenario is low-emission and deforestation-free and is produced in a highly resource-efficient supply chain, resulting from investments in research and development and capital stocks. The Modest-Forecast Policy and Modest-Coordinated Policy scenarios would see a 9 percent and 13 percent rise in exports respectively by 2050. These would fare better than the Ambitious-Societal Transformation scenario but lack the immediate effects of innovation-led boosts to competitiveness in the Ambitious-Innovation scenario.

Assessing Farm-Level Resilience Through Financial Stress Testing

Shocks to the price of beef could threaten the financial stability of all but the highest efficiency producers across Brazil, while transportation cost fluctuations could result in significant regional impacts

Section 5

The profitability of cattle production varies significantly across Brazil. On average, more efficient and technologically advanced systems in the south of Brazil outpace smaller, less-efficient producers in the north (see Figure 14).[68]

Orbitas financial modeling shows that the most profitable producers are located in the south of Brazil, in the states of Santa Catarina, Paraná, Mato Grosso, Mato Grosso do Sul Rondônia and São Paulo, where profitability ranges from approximately USD 100 to USD 290 per hectare. To put these numbers in perspective, the states of Santa Catarina and Parana, on average, generate 12 times the profit per hectare than the least profitable systems in Amapa, Bahia and Pernambuco states.

Santa Catarina and Parana, on average, generate 12 times the profit per hectare than the least profitable systems in Amapa, Bahia and Pernambuco.

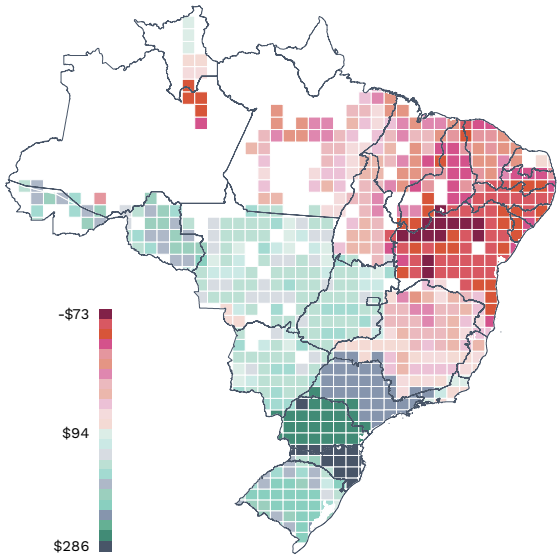
The distance between farms and slaughterhouse facilities reinforces this regional variation, which introduces an additional cost burden on lower-productivity producers in northern Brazil (see Figure 15). Production facilities in Santa Catarina, São Paulo, Parana, Goiás and Mato Grosso do Sul and other southern states typically experience transportation costs in the range of 2.5 percent to 6 percent of total production-level costs. Meanwhile, remote systems, such as those located in the northeastern states of Piauí, Bahia, Ceará, Pernambuco and Alagoas, are estimated to experience transportation costs ranging from approximately 30 percent to 56 percent of total average production-level costs. Some cattle farms in Bahia represent an extreme case in which transportation costs can be equal to or greater than the input and production costs of raising cattle in these regions. Farmers in the northeast of Brazil typically face a 600 to 1000 km journey to the nearest slaughterhouse, while the average Brazilian cattle farmer travels 100 to 160 km.

Our model shows that systems located across northern states operate with significantly lower profit margins, which indicates that producers in the north are more vulnerable to future price shocks in both production input costs and beef prices.[g]

FIGURE 14.

PROFITABILITY OF CATTLE PRODUCTION BY REGION IN USD PER HECTARE

There is a sharp geographic divide in cattle profitability with southern states outpacing northern states



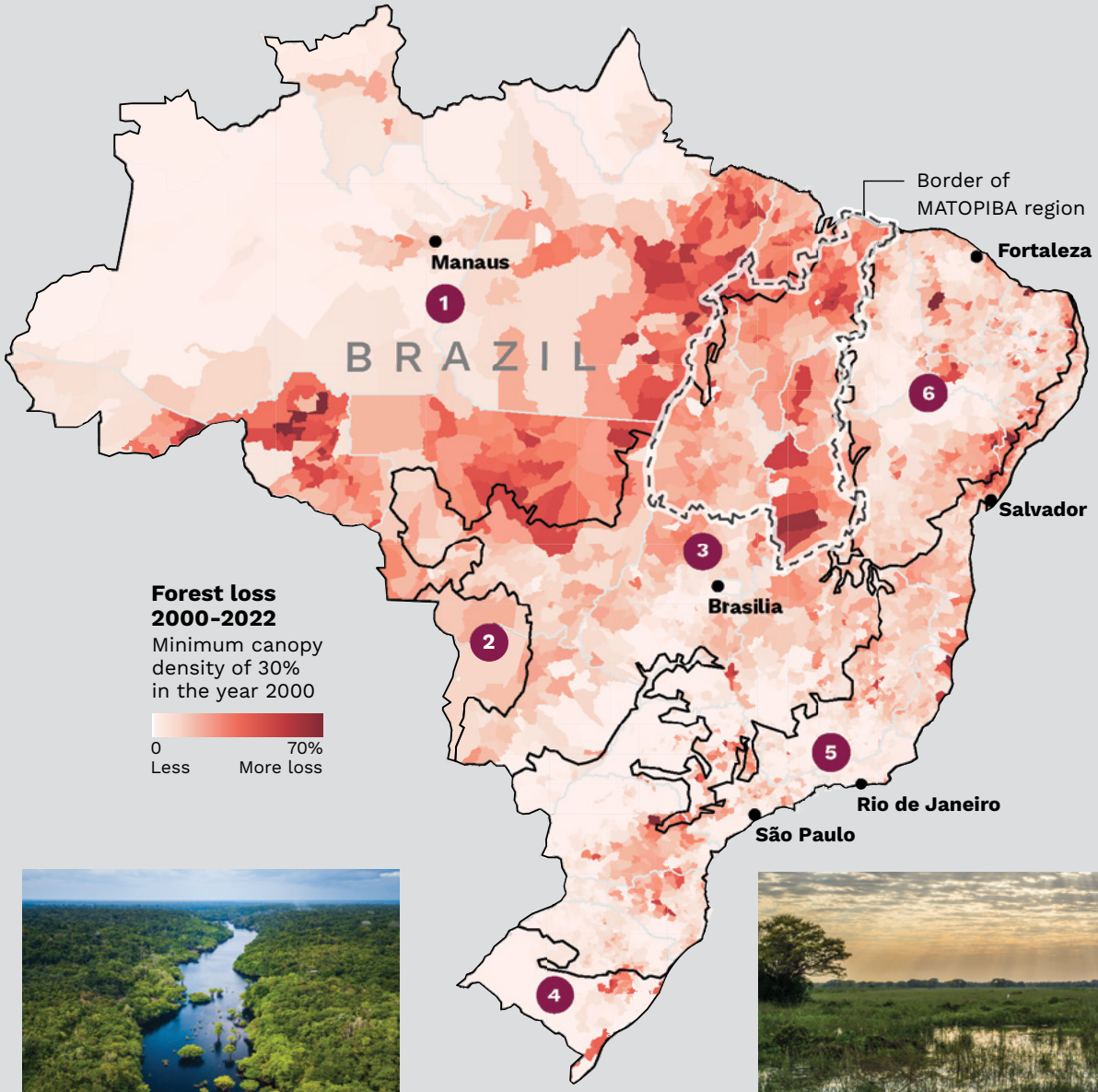
Source: Authors' spatial and financial modeling, using data from "Beef report: Overview of Livestock in Brazil 2022" by the Association of Brazilian Beef Exporters (ABIEC) and Center for Advanced Studies on Applied Economics (CEPEA).

Note: Empty regions on the map signify the absence of data or the absence of farms in that particular area.

[g] Northern farms earn approximately USD 5 to USD 45 per ha compared to the average range of approximately USD 115 to USD 275 per ha experienced throughout Southern states

UNDERSTANDING CATTLE PRODUCTION ACROSS BRAZILIAN TERRESTRIAL BIOMES

Brazil boasts favorable climatic conditions for cattle, but destruction of ecosystem services may threaten competitive advantage



1 The Amazon

The biome: Largest tropical forest on the planet supporting many species. Nearly 60% of the forest lies within Brazil, covering around 60% of its land.

The challenge: Population growth has led to conflict between the needs of the biome and economic development.

The beef sector: After years of encroachment, there are now around 90 million heads of cattle living on land that was once forest.

2 The Pantanal

The biome: The largest tropical wetland on the planet, soaking up enough water across central South America to flood nearly 156,000 km^2 of plains during rainy seasons.

The challenge: Low-impact, sustainable livestock farming has preserved around 80% of the vegetation, but cattle farming and infrastructure expansion threaten its future.

The beef sector: The region produces 3.8 million heads of cattle per year across 3,000 farms.

3 The Cerrado

The biome: Defined by its grasslands, savannas and dry forests, the Cerrado is the second largest biome in South America, covering 21% of Brazil and home to 30% of its biodiversity.

The challenge: The MATOPIBA region of the Cerrado has experienced significant agricultural expansion, due to its favorable climate and legal protections under Brazil's Forest Code which permits clearing up to 65% of areas recognized as grasslands.

The beef sector: Cattle pasture occupies 29% of land in the Cerrado, an area larger than France.

4 The Pampas

The biome: One of the largest natural grasslands in the world encompassing 70 million hectares between Argentina, Uruguay and Brazil.

The challenge: Cattle farmers have increasingly grown soy and foreign grasses more suitable to cattle digestion, resulting in a loss of biodiversity and 3.3 million hectares of native vegetation since 1985.

The beef sector: The cattle industry relies on rich agricultural lands to feed 14.1 million heads of cattle.

5 The Atlantic Forest

The biome: The most populous region of Brazil, once thought to be the second largest rainforest in the world.

The challenge: Native vegetation comprises half of the territory it once did, with only 7.3% of the original forest remaining today.

The beef sector: The Atlantic Forest is responsible for significant agricultural productivity, producing roughly 62% of Brazil's livestock.

6 The Caatinga

The biome: Subject to limited rainfall, shrubs and thorny forests dominate much of the region.

The challenge: The region is heavily dependent on low yield agriculture with 26% of the population working in agriculture. Extensive cattle farming practices have resulted in significant environmental degradation.

The beef sector: The 1.4 million smallholder farmers are increasingly exposed to climate-related risks including droughts and desertification.

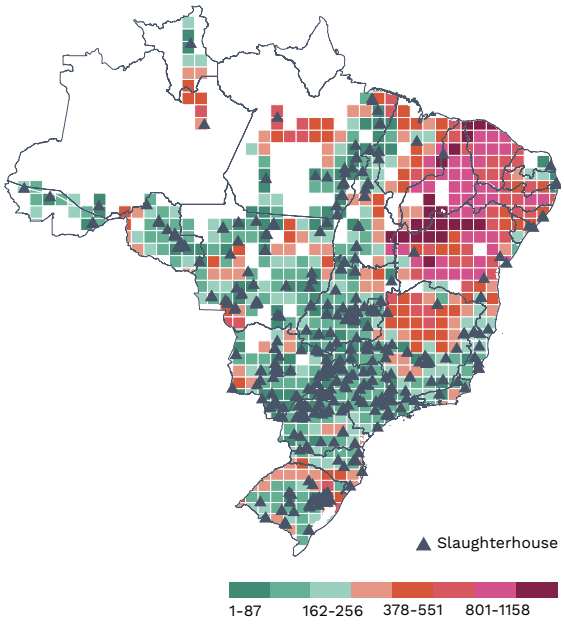
Sources: Global Forest Watch, Forest-GIS, Instituto Brasileiro de Geografia e Estatística, The World Bank, University College London, Institute de Brasilia

Under current market conditions, a substantial portion of Brazilian producers are at high risk of experiencing financial loss, especially among remote producers with low productivity and slim profit margins.

FIGURE 15.

THE ROLE OF SLAUGHTERHOUSE CONCENTRATION IN PROFITABILITY

Distances traveled to slaughterhouses are longer in areas with lower profitability (km to nearest slaughterhouse)



Source: Authors' spatial and financial modeling.

Notes: The projected distances represent the shortest route (in km) connecting any given location (centroid of 10 km resolution grid) and the closest slaughterhouse using the road transportation network. As no information on the spatial distribution of farms is used in this analysis, distance results are smoothed (averaged) and projected at a 100 km grid reference to show a broader overview of distance patterns. Empty regions on the map signify the absence of data or the absence of farms in that particular area.

The least productive systems in Bahia and Pernambuco may experience financial losses ranging on average from approximately USD 4 to USD 15 per hectare. This is attributed to the transportation costs associated with their remoteness, thereby adding additional stress to operations that are already characterized by inefficient and low production operations.[h] Both profitability and distance to slaughterhouses are indicators of resilience to climate transitions as price and transportation costs become more volatile.

Resilience to Economic Shocks: Transportation Cost and Beef Price Shocks Under Climate Transitions Present Material Financial Risk

The productivity and resilience of producers within Brazil's cattle sector to economic shocks is a predictor of the sector's ability to withstand risks and seize opportunities across transition scenarios. These economic shocks can occur for many reasons. However, beef commodity prices and transportation costs are particularly relevant, as they are both likely to experience the direct impacts of climate transitions and are material to cattle producers' profitability. Simulating shocks to each of these variables through stress testing can provide insight into the probability of regional profitability losses if Brazilian producers maintain their current levels of productivity in the face of shocks.[i]

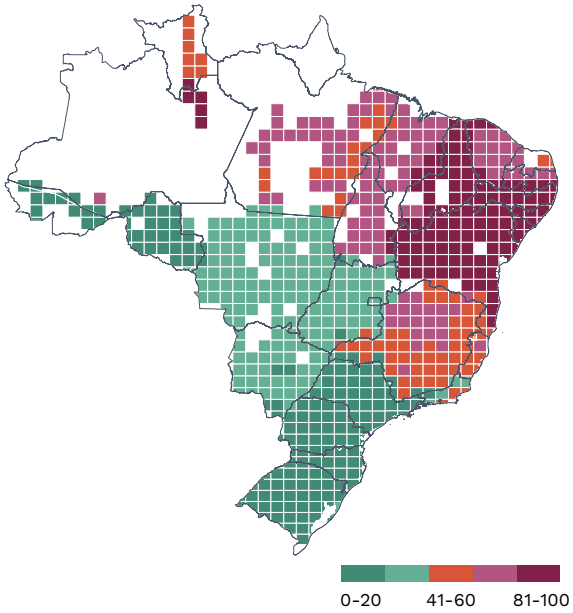
[h] Bahia and Pernambuco are located in Caatinga biome, which is characterized by semi-arid conditions with poor and sandy soils. The adverse conditions also contribute to their low profit abilities.

[i] This analysis should be considered as hypothetical, addressing a broad range of plausible near-term futures rather than a scenario-specific estimate. This highly indicative information cannot be used alone for making financial decisions.

FIGURE 16.

LIKELIHOOD OF FINANCIAL LOSS IN CURRENT MARKET CONDITIONS

Proxy indicators used to calculate the likelihood of financial loss projections



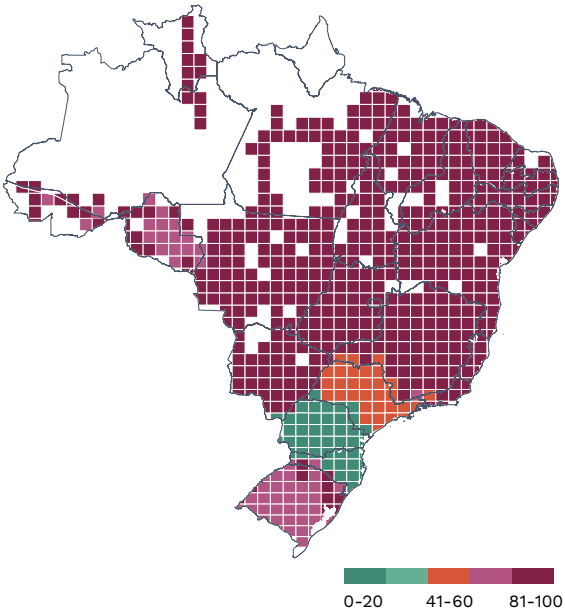
Source: Authors' spatial and financial modeling.

Notes: All datasets are shown at 100 × 100 km spatial resolution. Empty regions on the map signify the absence of data or the absence of farms in that particular area.

FIGURE 17.

LIKELIHOOD OF FINANCIAL LOSS WITH A 30 PERCENT SHOCK TO BEEF PRICES

Proxy indicators used to calculate the likelihood of financial loss projections



Source: Authors' spatial and financial modeling.

Notes: All datasets are shown at 100 × 100 km spatial resolution. Empty regions on the map signify the absence of data or the absence of farms in that particular area.

Decreasing beef prices by 30 percent makes it more likely that profits would shrink in all but the top-performing representative productions.

Stress Testing: Current Market Conditions

Under current market conditions, a substantial portion of Brazilian producers are at high risk of experiencing financial loss, especially among remote producers with low productivity and slim profit margins (see Figure 16). Lower productivity production facilities, primarily located in states in the northeast of Brazil, currently face up to a 90 percent probability of financial loss.[j] These farms have the weakest ability to buffer potential market fluctuations and are the most susceptible to profitability losses. Producers in surrounding states, are marginally more resilient and currently experience a 50 percent probability of financial loss.

Stress Testing: 30 Percent Shock To Beef Prices

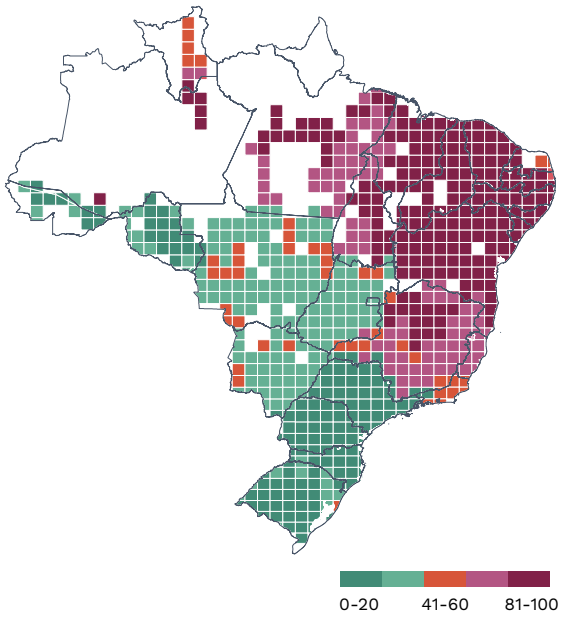
With additional economic shocks layered in, the most vulnerable farms lack the resilience to maintain positive profitability. For example, decreasing beef prices by 30 percent makes it more likely that profits would shrink in all but the top-performing representative productions found in states such as Goiás, Mato Grosso and Mato Grosso do Sul (see Figure 17). Surrounding regions that previously had a relatively low profit loss probability, under 30 percent, would see that probability spike to between 60 and 88 percent. In all other regions, the anticipated probability of profit loss for the representative production facilities would increase to a range of 80 to 100 percent, as shown above.

[j] This outlook on a hypothetical average production facility representing lower productivity farms based on regional averages is not presented as a profit forecast analysis.

FIGURE 18.

LIKELIHOOD OF FINANCIAL LOSS WITH A 100 PERCENT SHOCK TO TRANSPORTATION COSTS

Proxy indicators used to calculate the likelihood of financial loss projections



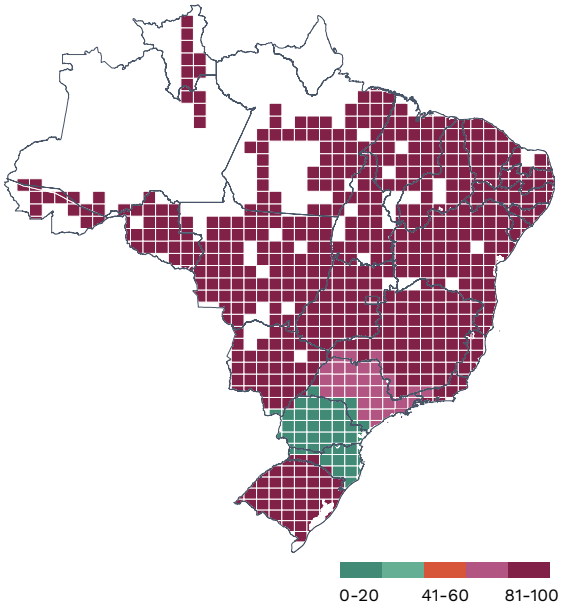
Source: Authors' spatial and financial modeling.

Notes: All datasets are shown at 100 × 100 km spatial resolution. Empty regions on the map signify the absence of data or the absence of farms in that particular area.

FIGURE 19.

LIKELIHOOD OF FINANCIAL LOSS WITH BOTH A 30 PERCENT SHOCK TO BEEF PRICES AND A 100 PERCENT SHOCK TO TRANSPORTATION COSTS

Proxy indicators used to calculate the likelihood of financial loss projections



Source: Authors' spatial and financial modeling.

Notes: All datasets are shown at 100 × 100 km spatial resolution. Empty regions on the map signify the absence of data or the absence of farms in that particular area.

Transportation costs are extremely material in low-productivity, remote facilities, where this shock would be felt more deeply on financial statements.

Stress Testing: 100 Percent Shock To Transportation Costs

However, a shock to transportation pricing would have a more uneven effect on producer performance depending on the distance to slaughterhouses. Increasing transportation costs to slaughterhouses with a 100 percent transportation cost shock is less severe than a shock to beef prices, with loss likelihood above 40 percent contained in eastern Brazil (see Figure 18). Farms with easy access to slaughterhouses and transportation costs that make up a small proportion of the total costs would be largely resilient to this shock. However, transportation costs are extremely material in low-productivity, remote facilities, where this shock would be felt more deeply on financial statements.

Stress Testing: Combined Shock To Beef Prices and Transportation Costs

A combination of both transportation and beef price shocks would put the majority of representative farms at significant risk for financial loss (see Figure 19). The only exceptions appear to be operations in Santa Catarina, São Paulo and Parana due in part to the widespread adoption of highly productive cattle farming techniques and close proximity to slaughterhouse facilities and transportation infrastructure, among other factors.

Case Study: Applying Climate Transition Scenario Analysis to Cattle Producers

The most productive operations have incorporated a range of technologies and improved management practices: agroforestry, rotational-grazing, integrated crop-livestock-forest systems and silvopastoral farming.

The impact of climate transitions on individual producers will vary based on location, proximity to critical infrastructure in the cattle value chain and operational efficiency as measured by adoption of technology and sustainable management practices. There are also opportunities and solutions available to cattle producers to mitigate risks, which can help even the most vulnerable producers, as presented in Section 6 of this report.

Projecting the profitability of representative producers across each scenario highlights differences in the context of the Brazilian cattle industry, shedding light on which strategies will be the most beneficial to more than 3.3 million employees in production, transportation and sales throughout the Brazilian cattle industry, including 2.5 million farming jobs.[69] By evaluating representative production types' – and by extension an investment portfolio's – vulnerability to these risks across climate transition scenarios, investors can gain insight into how producers can mitigate risks.

Financial Stress Testing Tool

Available at: orbitas.finance/brazil-cattle-tools

This interactive tool assesses the resilience of representative farms to climate transitions through stress testing. It evaluates the probability of financial losses in Brazilian cattle production based on hypothetical economic shocks that could impact yield, transportation costs and commodity pricing. Economic shocks are likely to be common as climate transitions increase volatility.

Currently, productivity differs greatly across cattle producers and is driven, in part, by technology and improved management practice implementation. The least productive producers have the lowest levels of technological and improved management practice adoption. Conversely, the most productive operations have incorporated a range of technologies and improved management practices: agroforestry, rotational-grazing, integrated crop-livestock-forest systems and silvopastoral farming.

FIGURE 20.

TYPES OF REPRESENTATIVE FARMS BY PRODUCTIVITY LEVEL[k]

Characteristics of representative producers		Productivity and technology adoption
Producer 1	Low technology and extensive	**1-3** arroba (**15-45** kg) per ha
Producer 2	Low technology	**3-6** arroba (**45-90** kg) per ha
Producer 3	Lower medium technology	**6-12** arroba (**90-180** kg) per ha
Producer 4	Upper medium technology	**12-18** arroba (**180-270** kg) per ha
Producer 5	High technology	**18-26** arroba (**270-290** kg) per ha
Producer 6	High technology and productivity	**26-38** arroba (**390-570** kg) per ha

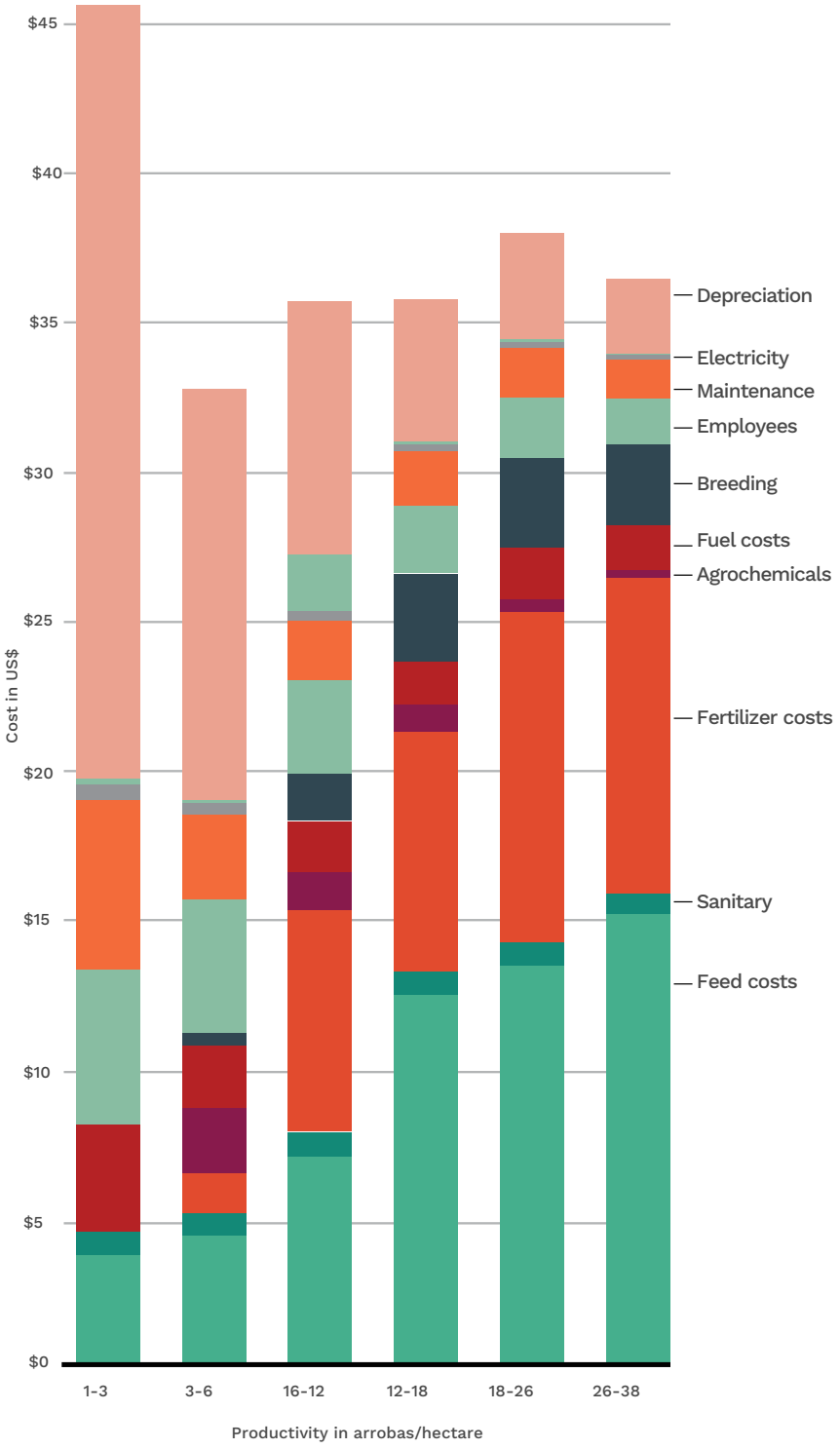
Source: "Beef Report: Overview of Livestock in Brazil 2022" by the Association of Brazilian Beef Exporters (ABIEC).

[k] Cattle producers are categorized by their productivity levels in line with the Brazilian Association of Beef Exporters (ABIEC) classifications, ranging from 1-3 arroba (15 – 45 kg) of carcass meat per ha and 26-38 arroba (390 – 570 kg) per ha.

FIGURE 21.

PRODUCTION INDICATORS USED TO CALCULATE THE LIKELIHOOD OF FINANCIAL LOSS PROJECTIONS

Low technology, extensive production methods cost the most on an arroba per hectare basis



Source: "Beef Report: Overview of Livestock in Brazil 2022" by the Association of Brazilian Beef Exporters (ABIEC).

Notes: Productivity is measured by arroba per hectare. 1 arroba is equal to 15 kg (33 pounds).

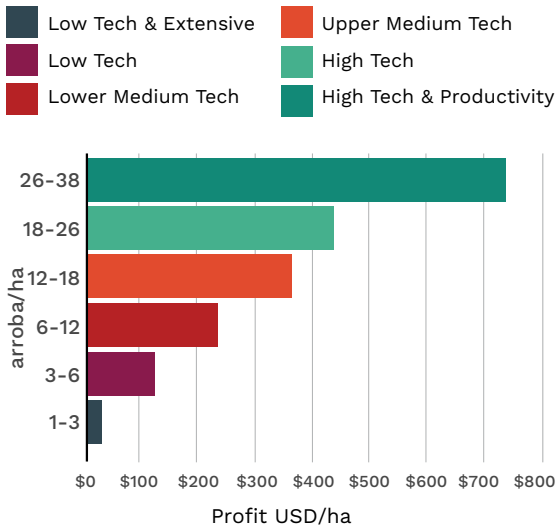
Resilience Through Productivity

Despite total costs being relatively similar across the higher-efficiency producer groups (Figure 21), profitability on a per unit of output and land-use basis grows substantially with increasing productivity, as shown in Figure 22. This contributes to these producers' resilience to the increasing volatility in costs and pricing likely under climate transitions.

FIGURE 22.

PROFITABILITY BY PRODUCTIVITY LEVELS UNDER BUSINESS AS USUAL IN 2020

High-technology production with efficient land use is the most profitable on an arroba per hectare basis



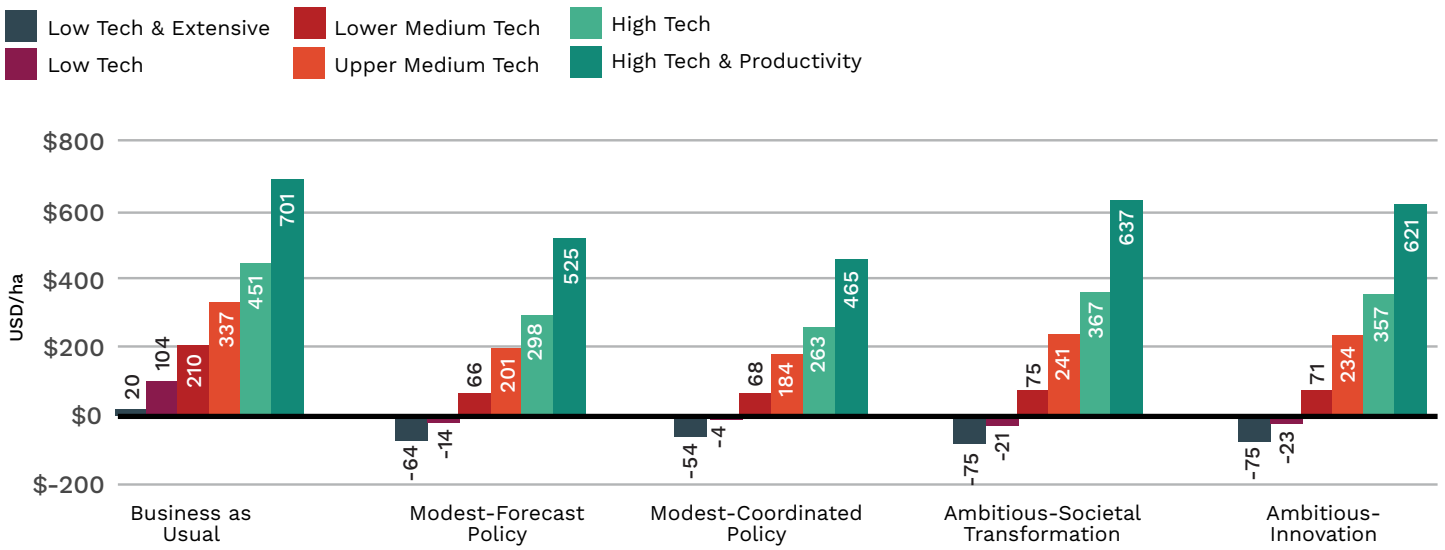
Source: Authors' financial modeling.

Notes: Productivity is measured by arroba per hectare. 1 arroba is equal to 15 kg (33 pounds).

FIGURE 23.

2030 PROFITABILITY BY FARM SYSTEMS ACROSS TRANSITION SCENARIOS

Low technology production dependent on expansion onto new land may be unprofitable by 2030 under transition scenarios



Differences relative to 2020 (USD/ha)

	Business as Usual	Modest-Forecast Policy	Modest-Coordinated Policy	Ambitious-Societal Transformation	Ambitious-Innovation
Low Tech & Extensive	-9	-93	-83	-104	-105
Low Tech	-14	-132	-122	-139	-141
Lower Medium Tech	-19	-163	-161	-154	-158
Upper Medium Tech	-21	-156	-174	-117	-124
High Tech	-26	-178	-214	-109	-120
High Tech & Productivity	-33	-209	-269	-97	-113

Source: Authors' economic and financial modeling.

The profitability of low-technology farms reliant on extensive land use is likely to dip below zero before 2030.

Profitability Across Climate Transition Pathways

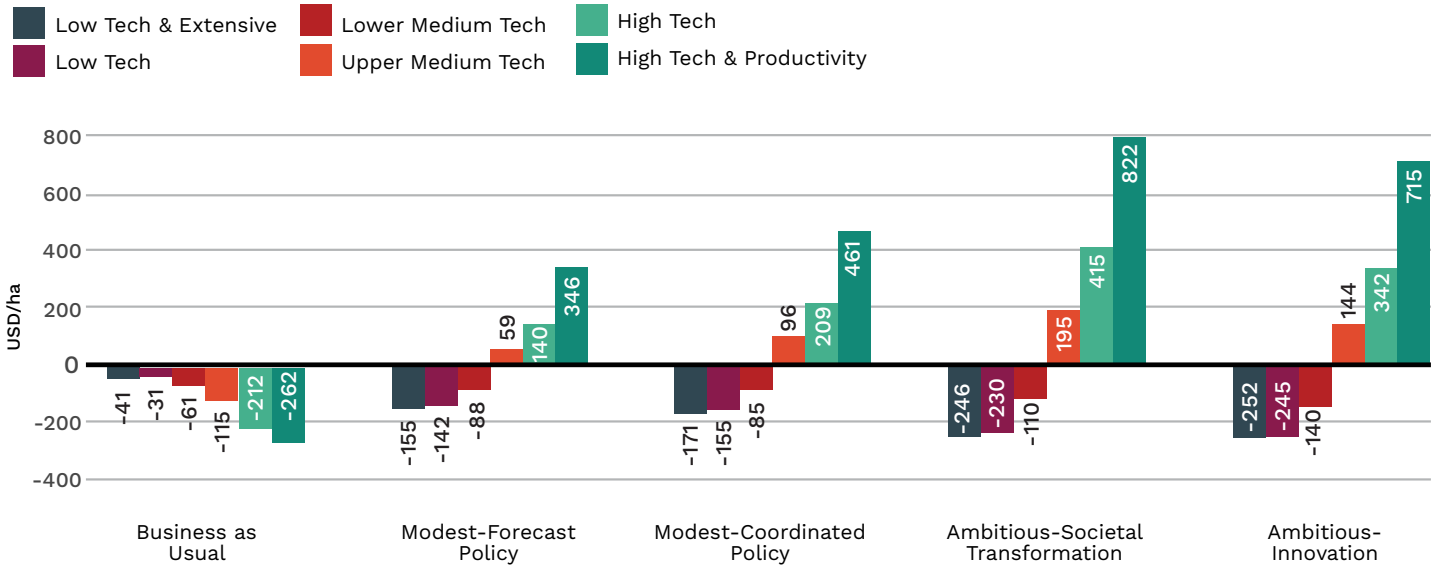
Considering each of these production types in the context of the climate transition scenarios presented in the previous sections of this report reveals that the profitability of low-technology farms reliant on extensive land use is likely to dip below zero before 2030 (Figure 23). As land availability decreases, high rent costs and competition for land from soy production and the bioeconomy are likely to challenge the business models of these farms. Furthermore, physical risks are not included in this analysis, but they would create additional pressure on profitability and should be considered.

By 2050, even producers with lower medium technology adoption are likely to experience financial losses under transition scenarios, while low technology and extensive farms face significant pressure. These losses are projected despite a boost in per-hectare profitability observed for all farms due to the higher producer prices paid under Ambitious scenarios, especially Ambitious-Societal Transformation.

FIGURE 24.

2050 PROFITABILITY BY FARM SYSTEMS ACROSS SCENARIOS

Low and medium technology production may be unprofitable by 2050 under transition scenarios



Differences relative to 2020 (USD/ha)

	Business as Usual	Modest-Forecast Policy	Modest-Coordinated Policy	Ambitious-Societal Transformation	Ambitious-Innovation
Low Tech & Extensive	-70	-184	-200	-275	-282
Low Tech	-150	-260	-273	-348	-363
Lower Medium Tech	-290	-317	-314	-339	-369
Upper Medium Tech	-472	-299	-261	-163	-213
High Tech	-688	-336	-267	-61	-134
High Tech & Productivity	-996	-388	-273	88	-19

Source: Authors' economic and financial modeling.

Intensity must be combined with sustainable management practices to ensure that pastures are productive in the long run.

Higher prices would be for deforestation-free beef in the low-emission futures depicted in the scenarios. Under the Ambitious-Societal Transformation scenario, prices received by producers increase 74 percent by 2050 compared to 2020. This price increase partially offsets the rise in production costs related to high GHG prices and low consumer demand. Meanwhile, a combination of relatively low yields, a modest 19 percent increase in beef price by 2050 and low consumption demand due to diet shift result in lower Modest-Forecast Policy scenario profitability projections across farm types and reduced resilience to shocks. Under the Modest-Forecast Policy scenario, cattle producers that do not increase production efficiency through new technologies and practices could face losses of USD 155 to USD 88 per hectare by 2050 (Figure 24). The lowest beef prices are projected in the Business as Usual scenario, a 53 percent decrease by 2050, which results in substantial losses for all types of producers.

Most importantly, intensity must be combined with sustainable management practices to ensure that pastures are productive in the long run. Sustainable intensification through pasture restoration and maintenance will enable cattle farmers to create long-term profitability pathways capable of withstanding climate transition risks.

Mitigating Risks and Leaning Into Opportunities

Brazilian cattle farmers can proactively adopt technology and management solutions that increase financial resilience to climate transitions and diversify revenue streams

Section 6

The risks presented by climate transitions for the Brazilian cattle sector are clear and material. However, proactive mitigation of these risks can reduce financial losses, and market leaders can even experience financial gains by leaning into climate transition opportunities. Implementing regenerative and other restorative practices in agriculture to improve soil fertility and restore pasture land can create higher and more resilient profits capable of weathering a range of climate transition-related price shocks.

Pasture management practices, increased fertilizer efficiency and a variety of sustainable farming methods, including integrated crop-livestock-forest systems and silvopasture, can all be used to increase resilience. The low-cost nature of these techniques enables the production of low-emission beef that is also cost-competitive. Cattle producers can also consider additional revenue streams, including agroforestry and non-timber forest products, as well as benefit from carbon and biodiversity markets and related credits.

One way for farmers to increase productivity without expanding to new land is through restoring degraded pasture land. Improving the productivity of moderately degraded pasture could lead to a 167 percent increase in output of beef per hectare, while improvements to severely degraded pasture could increase output of beef per hectare by 310 percent, achieving a noteworthy productivity level of 11.5 arroba per hectare (Figure 25).[70]

Proactive mitigation of these risks can reduce financial losses, and market leaders can even experience financial gains by leaning into climate transition opportunities.

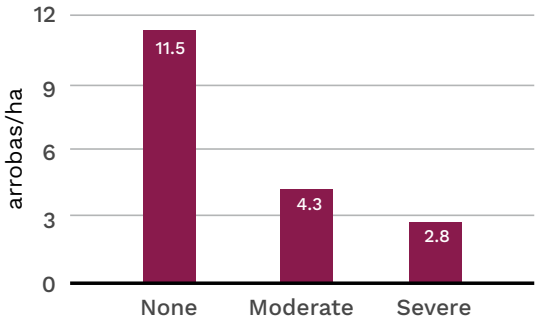
Market Leader Opportunity. Silvopastoral Farming

Silvopastoral farming is an agroforestry approach that integrates trees, bushes, pastures and livestock in a mutually beneficial way.[78] Depending on its execution, this technique can provide ecosystem services, boost dairy and beef productivity and diversify producers' incomes. In Brazil, intensive silvopastoral systems (ISPS) typically combine live fences, trees, fodder crops and plants that keep soil fertile with cattle pastures. Compared to pastures with no trees, ISPS systems store more carbon, improve soil properties, enhance environmental resilience, reduce runoff and promote greater biodiversity. ISPS systems provide more nutrient-dense and diverse fodder for livestock, which boosts meat and milk productivity. Greater fodder density also enables producers to stock more cattle per hectare, enabling more efficient land use. Although ISPS systems allow for denser production by providing an improved diet, they also lower GHG emissions per animal. Furthermore, by providing shade, they enhance cattle welfare and reduce health risks from overheating, ticks and stress.[79] ISPS farming improves economic outcomes for producers by increasing milk and beef productivity and adding additional sources of revenue, such as timber sales, while reducing the need for costly inputs, such as fertilizer and weed killers.

FIGURE 25.

CATTLE PRODUCTIVITY BY PASTURE DEGRADATION LEVEL

Material improvements in productivity possible through investments in pasture restoration



Source: Report "Costs of Recovering Degraded Pastures in the Brazilian States and Biomes" by Fundação Getulio Vargas' São Paulo School of Economics (FGV EESP).

52 percent of Brazil's pasture land is at least partially degraded, providing many producers with the opportunity for large-scale improvements.

Currently, 52 percent of Brazil's pasture land is at least partially degraded, providing many producers with the opportunity for large-scale improvements.[71] Pasture restoration opportunities are most financially rewarding in cattle systems exhibiting both low profitability and high levels of degradation. These systems are primarily located in the eastern states of Bahia, Piauí, Ceará and Pernambuco (Figure 26).

In cattle systems in the west, such as Mato Grosso and Mato Grosso do Sul, low profitability is often driven by severely degraded pasture land and could be mitigated through restoration and maintenance of pasture lands. These profitability increases come from the productivity improvements provided by healthy pastures.

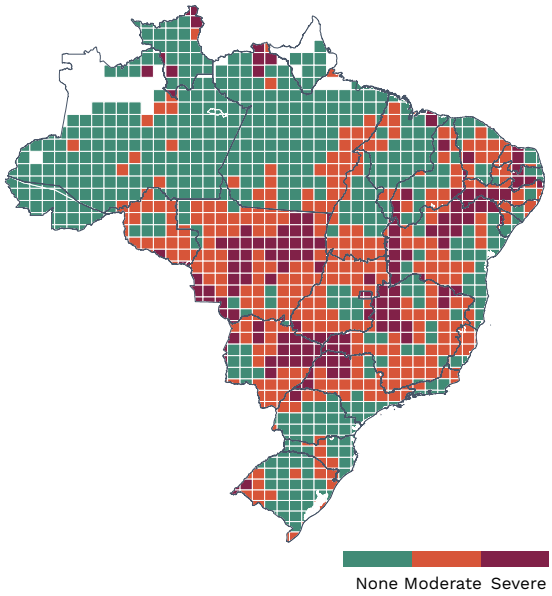
Market Leader Opportunity. Carbon and Biodiversity Markets to Supplement Cattle Farming Income

Meanwhile, the growth of global carbon and biodiversity markets has caught the attention of both the Brazilian government and the private sector. These markets can shift perspectives on what has been historically considered 'unproductive land' into valuable assets for their carbon storage and biodiversity as a result of conservation. High-integrity carbon credits, including those at a jurisdictional level, will reduce the risk of price volatility. Investments in nature-based solutions and the bioeconomy present opportunities for diversifying revenue streams for farmers facing growing climate risks.

FIGURE 26.

PASTURE DEGRADATION IN BRAZIL

Brazilian cattle farmers have ample opportunity to regenerate degraded pastures



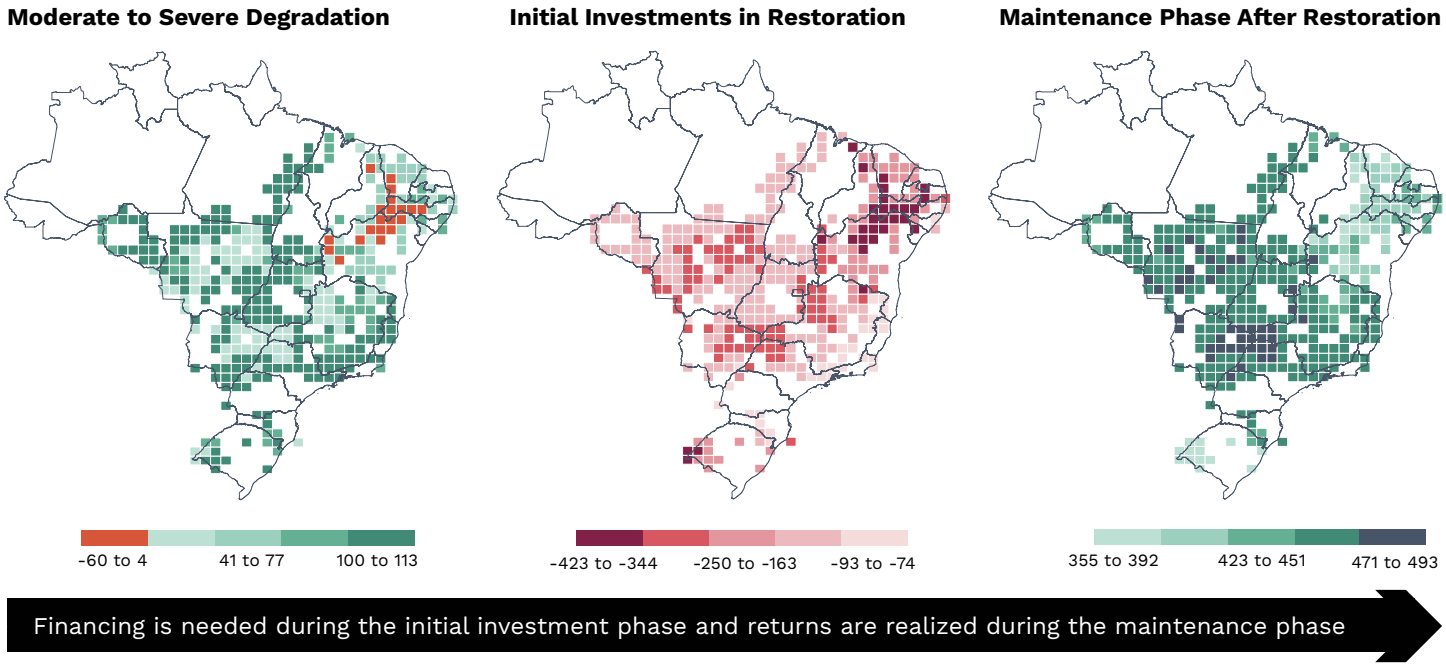
Source: Atlas das Pastagens, authors' spatial modeling.

Notes: Data are presented at a 100 km grid level.

FIGURE 27.

PROFITABILITY OF CATTLE PRODUCTION SYSTEMS BEFORE, DURING AND AFTER RESTORATION

Profitability over time in USD per hectare



Source: Authors' spatial and financial modeling.

Notes: The profitability is projected at a 100 km grid level. Empty regions on the map signify the absence of data or the absence of farms in that particular area.

Cattle production systems modeled to experience losses ... under Business as Usual conditions could increase their earnings dramatically to between USD 375 per hectare and USD 437 per hectare.

The financial case for these investments is strongest in areas of production with the lowest productivity rates. Cattle production systems modeled to experience losses ranging from USD 60 per hectare to USD 2 per hectare under Business as Usual conditions could increase their earnings dramatically to between USD 375 per hectare and USD 437 per hectare.[l] These profits are in the same order of magnitude as some of the best-performing systems across the country.[m] Similar opportunities for returns on investment are evident in Southern Amazonia, in the states of Mato Grosso and Rondônia, where producers could see an earnings increase from USD 9 per hectare to up to USD 482 per hectare (Figure 27). Additional cost savings may come from avoiding the heightened production costs associated with degraded pastures.

Market Leader Opportunity. Agroforestry and Non-Timber Forest Products to Supplement Cattle Farming Income

Agroforestry systems and sustainable management of non-timber forest products (NTFPs) can be considered complementary activities to cattle ranching and other types of farming and provide additional revenue streams. They can support generating additional income for landowners, thereby reducing the pressure on native vegetation. Agroforestry involves tree or shrub planting around or among other crops and combining agriculture and forestry techniques, and it can lead to a rise in productivity and reduced emissions. NTFPs include fruits, nuts, fungi, fibers, charcoal, honey and fish, among others, from existing forestry or agroforestry systems.

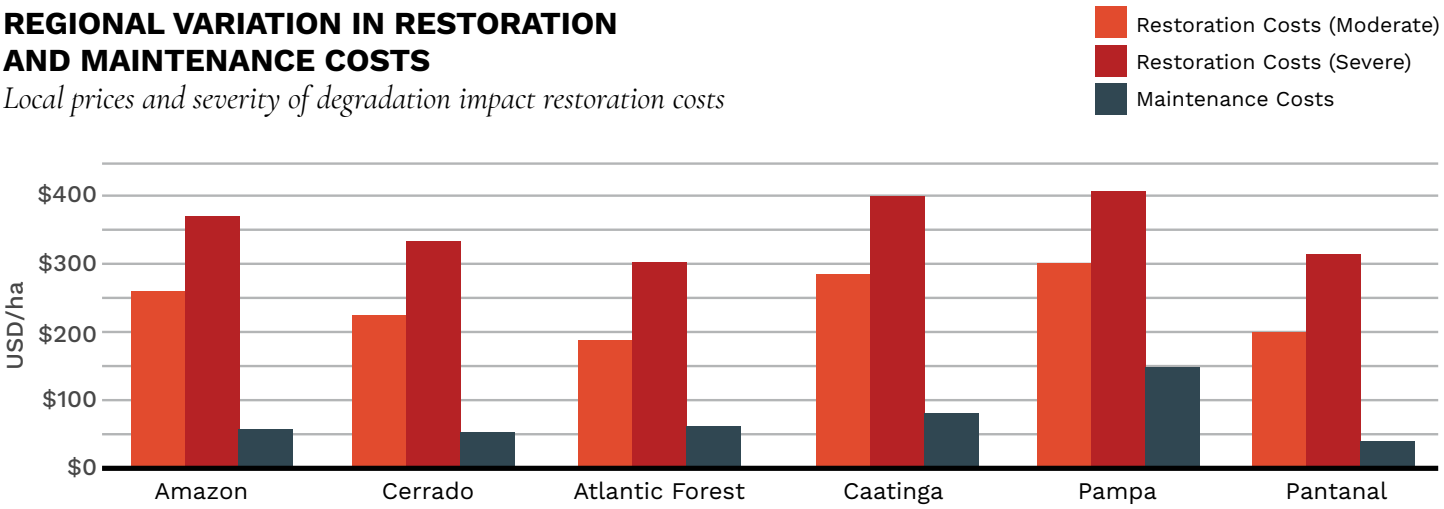
[l] See our methodology report for cattle system productivity measurement details.

[m] Although we do not model the duration of this transition, it should be noted that due to the investment needs, it would require some time to recover the invested amounts.

FIGURE 28.

REGIONAL VARIATION IN RESTORATION AND MAINTENANCE COSTS

Local prices and severity of degradation impact restoration costs



Average Expenditures for Restoration and Maintenance	Pasture Restoration Costs (USD/ha)
Capital Expenditure to Restore Moderately Degraded Pasture	201 to 317
Capital Expenditure to Restore Severely Degraded Pasture Land	321 to 432
Operational Expenses to Maintain Restored Pasture Land*	47 to 157

Source: Report "Costs of Recovering Degraded Pastures in the Brazilian States and Biomes" by Fundação Getulio Vargas' São Paulo School of Economics (FGV EESP).

Note: *Operational expenses include costs for additional fertilizers and agricultural inputs.

Profits could be boosted by investing in regenerative agriculture and other restorative practices to raise pasture quality, improve soil fertility and increase productivity.

Despite long-term improvements in per hectare profitability, upfront restoration costs ranging from USD 200 to USD 400 per hectare typically require loans from financiers. Restoration costs are driven by local prices and the severity of degradation, as shown in Figure 28. Most systems require capital expenditure financing during the restoration phase to offset temporary profit shortfalls, although productivity is not necessarily affected. In the maintenance phase, pasture improvement-related costs decrease substantially, while yields reflect the higher productivity levels produced on healthy pasture land.

The potential impact of strategic investments, particularly in soil health improvement practices, could have a significant impact on the future profitability of producers across Brazil. Profits could be boosted by investing in regenerative agriculture and other restorative practices to raise pasture quality, improve soil fertility and increase productivity. By implementing these changes, even the least productive cattle farmers could increase profitability. For the Brazilian cattle sector to access the high productivity rates that come with restoring pastures, significant mobilization of financing is needed, especially for smallholder farmers.

Section 7

Financial Mechanisms for Investing in Farm Improvements

Despite opportunities for producers to enhance profitability, existing mechanisms to finance farm improvements are more accessible to market leaders, while smallholders face difficulty securing credit due to circumstances, extensive documentation requirements and more.

Smallholders, those most in need of efficiency improvements in order to remain profitable across transition scenarios, often face the highest barriers to paying significant upfront adoption costs.

Soil fertility improvements, sustainable agriculture practices, precision livestock monitoring and other strategies represent unique approaches to improving the profitability of cattle farms while reducing the environmental impact traditionally associated with establishment expansion. However, the costs associated with strategic investments can restrict access to future profitability. Smallholders, those most in need of efficiency improvements in order to remain profitable across transition scenarios, often face the highest barriers to paying significant upfront adoption costs. For example, the restoration of moderately degraded pasture is 22 percent higher per hectare in the Caatinga, home to 61.4 percent of Brazilian smallholder farms, than in the rest of Brazil.[72] [73] [74]

As the region already experiences a near 90 percent probability of financial loss prior to the introduction of any transition-related price shock, substantial public funding from the Brazilian government has been mobilized in an effort to close the gap. Various programs supporting sustainable practices in agriculture and livestock, including Plano Safra (Harvest Plan), ABC+ Plan, RenovAgro and the National Program for Strengthening Family Agriculture (Pronaf), have been developed to provide rural credit to a diverse range of producers, from small- to large-scale operations, as well as cooperatives and agribusiness-related companies.

In recent years, the banking sector has increasingly aligned credit lines and financing for the agricultural sector, developing programs targeting socio-environmental practices outside government and regulator initiatives. Programs from BNDES (Proirriga, Prodecoon), Banco do Brasil, Rabobank (Renew Pasture), Santander (CDC Agro Sustainable), Banco do Nordeste (FNE Verde, FNE Sol) and Banco da Amazona (Amazônia Rural Verde, Energia Verde) provide credit for a variety of projects funding land restoration efforts, sustainable farming practices, renewable energy projects and more.

Apart from government and banking financing initiatives, a number of NGOs have successfully driven private sector collaboration through the use of consortiums, with efforts led by the United Nations Environment Programme, the Nature Conservancy and the Tropical Forest Alliance, mobilizing USD 10 billion in disbursements for sustainable agriculture. See Appendix 3 for an overview of the existing financial mechanisms for Brazilian cattle farmers.

Although extensive financing opportunities have been made available, credit is typically more accessible to market leaders, while smallholders often face approval challenges due to extensive documentation require-

Market Leader Opportunity. Innovative Financial Instruments to Supplement Cattle Farming Income

The voluntary carbon market has seen rapid growth, reaching USD 2 billion in 2021 up from just USD 200 million five years prior.[80] Brazil, however, is uniquely positioned to succeed in the coming years due to its potential to generate carbon credits. Some estimates suggest that 15 percent of the world's entire carbon offset potential (achievable through natural climate solutions) lies within Brazil,[81] 80 percent (1.2 – 1.9 Gt CO_2e) of which is associated with pasture restoration and reforestation projects. Producers that seize the opportunity to certify the restoration of their land have the potential to earn USD 87 per ton of CO_2e under the IPR-inspired Forecast Policy Scenario. Similar to carbon markets, the emerging biodiversity credit market is scaling to provide payments for results to protect or restore biodiversity, an important factor in sustaining quality carbon credit efforts to combat emerging threats from biodiversity loss.

Investors who can mitigate the lending issues typically associated with rural applicants could tap into a substantial market in need of credit and financing opportunities.

ments, connectivity issues and other restrictions. Overall, 38 percent of a 4,300 strong rural producer union, the Brazilian confederation of agriculture and livestock (CNA), have never received rural-specific credit approval.[75] Rejection forces producers to seek non-specific bank loans with higher interest rates and less favorable repayment terms than are available through government programs. With nearly 3.9 million smallholder farms in Brazil, investors who can mitigate the lending issues typically associated with rural applicants could tap into a substantial market in need of credit and financing opportunities.[76]

Market Leader Opportunity. Precision Agriculture and Monitoring

One of the most notable technological innovations is the adoption of precision livestock farming techniques, which leverage real-time data and sensor technology to monitor cattle health, behavior and nutrition.[82] This enables cattle farmers to make informed decisions and optimize feeding regimes, ultimately enhancing animal well-being and growth rates. Additionally, the integration of satellite-based geospatial technologies enables more efficient land and herd management, reducing overgrazing and land degradation.[83]

Section 8

Recommendations for Key Stakeholders

Collaboration across stakeholder groups and early action can prepare the Brazilian cattle sector and the wider economy for climate transitions

Quantifying and preparing for the risks and opportunities driven by climate transitions is essential to the successful future of the Brazilian cattle sector. These transitions present material risks, but they also present significant opportunities. Today's actions can pay major dividends tomorrow, especially considering that physical impacts are intensifying and closing the window of opportunity. Interest in investment in sustainable solutions that increase productivity and diversify revenue streams is rapidly increasing. Where risks may limit growth or render some forms of cattle production uneconomical, equal or potentially greater opportunities exist to support the economic development of communities now dependent on cattle production.

A future that is both sustainable and profitable will require a radical level of collaboration among major stakeholders within Brazil and the support of the international community. There is an opportunity for those who are proactive to invest in production improvements that will allow them to meet the yield efficiency and sustainability measures required to stay competitive in 2050. Identifying where those investments should be made requires understanding how climate transitions will impact the Brazilian cattle sector, which is why the findings presented in this report serve as an early warning system to mitigate the financial risks of climate transitions. To this end, stakeholders can consider enacting the following recommendations in future strategies and efforts.

Opportunities for Investors

Assess climate transition risk and vulnerability across investments.	• Investors who use historical data to calculate risk and investors that do not consider transition risks are likely to underestimate the risk profile of investments.
Prioritize investments with growth strategies reliant on sustainable yield-enhancing technologies and improved management practices over those with growth strategies dependent on geographic expansion.	• Cattle sector expansion through deforestation will likely be unprofitable in the future due to land-use restrictions, increased GHG prices and other factors. This is particularly relevant for ecologically important regions, such as the Amazon and the Cerrado.
Link investments and lending to sustainable practices.	• Incentivize supplier compliance with the Forest Code through targeted and results-based financing. • Prioritize market differentiation through transparency, thereby reducing repayment losses under climate transition pathways.
Increase investments in innovations that create competitive advantage through the production of low-emission, deforestation-free products.	• Collaborate with leading actors to identify promising new technological and management techniques to improve production practices through pilot projects. • Assess the barriers to adoption for producers that exist today and develop new financial vehicles that will provide the patient capital to support producers through their transition. • Participate in knowledge sharing among peers on industry standards for measuring impact, risk monitoring reporting and establishing science-based and nature-positive goals. • Advocate for expanded catalytic capital that is patient, risk-tolerant, concessionary and sufficiently flexible to accelerate market growth of deforestation-free cattle products that have the potential to be most competitive in future markets. • Develop new targets for sustainable agriculture deal origination and update criteria for acceptable risk in financial vehicles.
Collaborating with producers to provide assistance in navigating transitions.	• Create financial instruments that are accessible to facilitate uptake among smallholders and family-level operations, prioritizing affordability and low bureaucratic hurdles.
Identify new opportunities for investment to support new, diversified revenue streams.	• Continuously evaluate new types of investments that improve the productivity of cattle farming and diversify revenue streams for cattle farmers. • Invest in new sectors to support economic growth, including soil health improvements, agroforestry systems, carbon markets and biodiversity markets.

Opportunities for Cattle Producers

Adopt agricultural management practices and techniques that sustainably increase land productivity and profitability. These could include:

- Practices that maintain pastureland through improving soil health to increase yields and resilience to pests and extreme weather events.
- Sustainable management practices like agro-ecological zoning, which can help mitigate water availability challenges, especially amid drier and hotter transitions in Matopiba.
- Integrated crop-livestock-forestry systems that integrate agricultural, livestock and forestry to optimize land use, reduce GHG emissions and sustainably increase production.
- Pasture restoration practices that can improve the yield of previously degraded grazing land, significantly increasing productivity and creating more resilient profits for cattle farmers.

Identify and advocate for financing opportunities that allow farmers to better prepare for climate transitions.

- Upfront investment costs in technological and productivity improvements may necessitate loans from financial institutions, development banks and government.

Consider revenue diversification opportunities.

- Explore the potential for earning revenue through nature-based solutions or producing inputs for alternative protein markets.

Opportunities for Meatpackers and Processors

Adopt comprehensive monitoring practices to ensure the traceability of all inputs involved in the supply chain.

- Effective monitoring plays a pivotal role in eradicating deforestation-linked cattle from the entire supply chain, ultimately enhancing the reputation and market access of products in both domestic and international markets.

Promote and implement programs to achieve zero deforestation throughout the entire supply chain and provide financing for technological investments that sustainably increase yield for suppliers[84].

- Work with other stakeholders to test financial products that increase supply chain transparency and feature clear deforestation and conversion-free labeling on product packaging to allow sustainable producers to maintain market access and potentially benefit from differentiated pricing and resources.
- Finance technical assistance for producers to expand adoption of solutions that sustainably improve productivity while achieving deforestation-free agriculture.

Opportunities for Brazilian Policymakers

Improve clarity through consistent and reliable policy making.

- Follow through on the full implementation of landmark policies, such as the Forest Code and the revised Action Plan for Deforestation Prevention and Control in the Legal Amazon (commonly known as the PPCDAm).
- Provide clarity on land-use rights and tenure, especially for smallholder and family-level operations.

Support data collection and monitoring to serve more efficient land use strategies.

- Advanced monitoring systems and high-quality data can lead to land management improvement, increasing land use efficiency and high carbon stock land conservation.

Provide support for cattle farmers during climate transitions.

- Foster a financial regulatory environment that enables farms to fund efforts to transition to more resilient systems.
- Link a greater share of Brazilian agricultural subsidies with sustainable land use practices to encourage cattle farmers to adopt advanced technology and improved management practices.
- Expand extension services and access to technical assistance to increase the capacity of farmers of all types to adopt technically complex and innovative practices.
- Consider long-term metrics for measuring progress to unlock patient capital. Although these policies require large initial investments, they increase yield and profitability in the long term and will help the Brazilian cattle sector maintain competitiveness in international trade.

Opportunities for International Policymakers

Develop future climate, biodiversity and sustainability policies collaboratively with Brazilians.

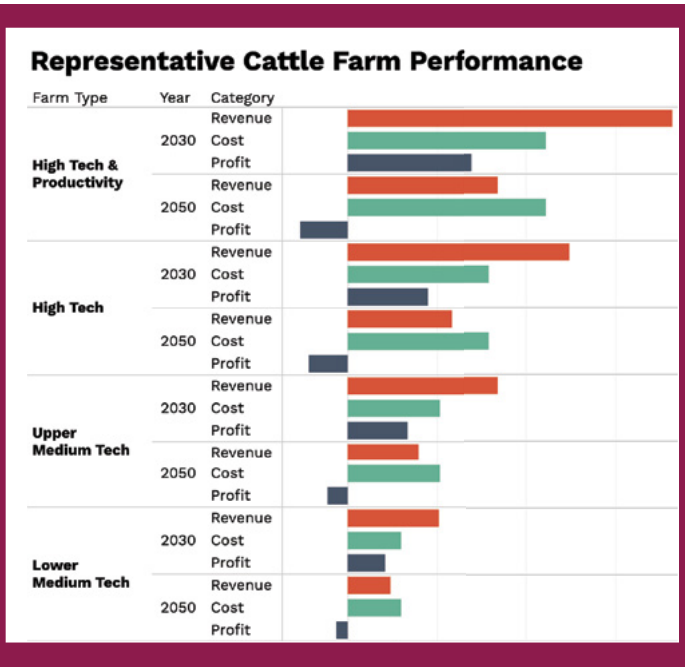
- Create new international trade arrangements that will enable Brazil's agricultural sector to meet the growing global demand for food while increasing the resilience of the food supply through transitioning to sustainable production.
- Work through established initiatives, such as the Amazon Fund, to support Brazil's sustainable economic development.[85] This proven funding mechanism can incentivize the reduction of deforestation through programs that support improved cattle production practices and strengthen rural community economies.

Orbitas Brazil Project: Digital Risk Assessment Tools

These tools delve into the material risks and opportunities that cattle and soy farmers may encounter under climate transitions through 2050. This equips users with the essential information to navigate climate-related challenges, offering insights into investment opportunities and enabling informed decision-making within the agricultural sector.

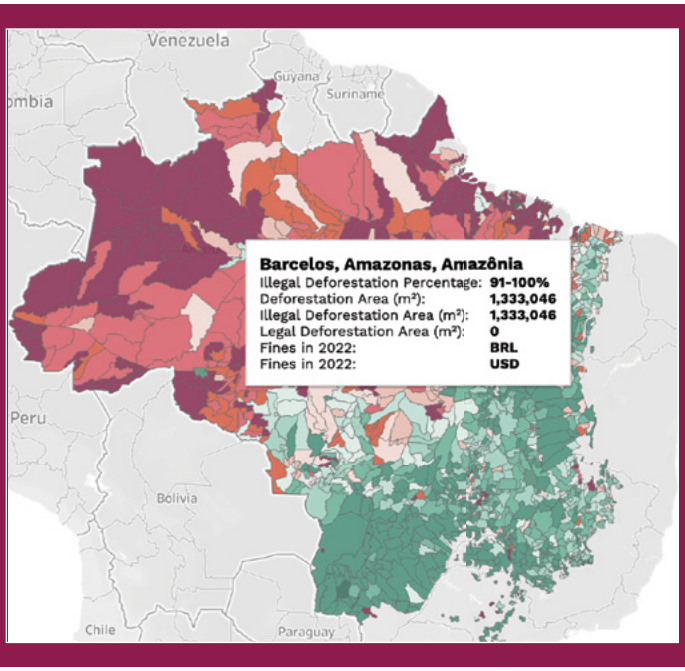
USE THE TOOLS

Available at:
orbitas.finance/brazil-agriculture-tools



Cattle Sector Analyzer

Understand the material risks and opportunities associated with climate transitions and the financial risks associated with potential shocks for yield, transportation costs and product prices that cattle farmers are likely to encounter between now and 2050.



Illegal Deforestation Risk Analyzer

Examine the distribution of illegal deforestation risk and enforcement fines across Amazônia, Cerrado and Pantanal biomes in Brazil.

ORBITAS
A Climate Advisers Initiative

Brazil's Cattle Sector Amidst Climate Transitions

Appendices

Orbitas
April 2024

Appendix 1: Evolution of Materialized Physical Risks by Biome

Results from weather station data across the Cerrado and, in particular, the MATOPIBA

FIGURE A1.

COMPARISON OF CLIMATE AVERAGES BETWEEN 1991–2020 AND 1961–1990 IN CERRADO AND MATOPIBA

	SUMMER			AUTUMN			WINTER			SPRING		
	1961-1990	1991-2020	Dif.	1961-1990	1991-2020	Dif.	1961-1990	1991-2020	Dif.	1961-1990	1991-2020	Dif.
Cerrado												
TMax (°C)	30.0	31.0	1.0	29.9	30.6	0.7	29.7	30.6	0.9	31.3	32.7	1.4
TMean (°C)	24.0	24.9	0.9	23.3	24.0	0.7	21.6	22.6	1.0	24.4	25.6	1.2
TMin (°C)	20.0	20.8	0.7	18.8	19.5	0.7	15.5	16.4	1.0	19.3	20.3	1.0
Rainfall (mm)	662.5	657.4	-5.1	356.2	365.8	9.6	38.0	26.9	-11.2	322.9	303.1	-19.9
Evaporation (mm)	271.8	307.8	35.9	250.8	284.4	33.7	336.4	391.3	55.0	366.9	437.4	70.4
Relative Humidity (Percent)	78.8	75.8	-3.0	75.8	73.0	-2.8	62.5	58.1	-4.4	66.6	60.5	-6.0
MATOPIBA												
TMax (°C)	31.2	32.3	1.2	31.3	32.3	0.9	32.8	33.8	1.0	33.6	35.2	1.6
TMean (°C)	25.2	26.5	1.3	25.3	26.4	1.2	24.9	26.3	1.4	26.7	28.3	1.6
TMin (°C)	21.3	22.2	0.9	21.0	21.8	0.8	18.6	19.7	1.1	21.3	22.4	1.0
Rainfall (mm)	609.2	584.8	-24.4	492.6	472.4	-20.2	36.1	24.4	-11.7	247.2	220.7	-26.5
Evaporation (mm)	242.4	285.8	43.5	265.0	313.9	48.9	586.9	655.2	68.3	485.3	586.1	100.8
Relative Humidity (Percent)	79.6	76.9	-2.6	78.5	75.2	-3.4	61.0	56.9	-4.1	64.2	58.3	-5.9

Source: Authors' modeling. Data: Brazilian National Meteorological Institute (INMET – Instituto Brasileiro de Meteorologia)

Appendix 2: Detailed Modeling Assumptions

The scale and pace of climate transitions are still unknown, but scenarios can project how the Brazilian cattle industry would perform across various climate transition pathways

FIGURE A2.

	BASELINE	MODEST ACTION		AGGRESSIVE ACTION	
Scenarios	Business as Usual Scenario (BAU)	Forecast Policy Scenario by Inevitable Policy Response	Coordinated Policy Scenario	Societal Transformation Scenario	Innovation Scenario
Warming Target (Degrees Celsius)	> 3	< 2	< 2	< 1.5	< 1.5
GHG Prices by 2050* (2005 USD per ton of CO_2 emissions)	USD 4	USD 87	USD 100	USD 153	USD 153
Bioenergy Demand (EJ/year in 2050)	< 10 1st generation biomass	90 2nd generation	90 2nd generation	100 2nd generation	130 2nd generation
Diet Shifts (Demand for livestock products between 2020 and 2050, kcal/cap/day)	No shift	< 600	< 600	< 450	< 600
Protected Areas**	WDPA (~15% globally) by 2050	WDPA (~15% globally) + Biodiversity hotspots by 2035	WDPA (~15% globally) + Biodiversity hotspots by 2030	Expand current WDPA (~15%) toward 30% by 2030	WDPA (~15% globally) + Biodiversity hotspots by 2030
Input Efficiency (Nitrogen Uptake Efficiency by 2050)	60%	65%	65%	65%	75%
Yield-Enhancing Tech	Low change	Medium change	Medium change	Medium change	High change
Food Waste Reductions (Percent of food wasted by 2050)	33%	20%	20%	16.5%	20%
Other Climate Policies	Existing national policies on reforestation and reduced deforestation. Does not include ambitious pledges in support of the Paris Agreement	Include Ambitious pledges for reforestation and reduced deforestation in support of the Paris Agreement			
Timber Demand	Low level	Moderate level	Moderate level	Moderate level	High level

Note: Orbitas is collaborating with World Business Council for Sustainable Development (WBCSD) and Vivid Economics to drive greater alignment around climate transition scenarios assumptions. The scenarios are based on the WBCSD transition scenario tool, which was inspired by Orbitas phase 1 scenarios, with modifications to incorporate recent developments. See here for the earlier WBCSD tool: https://www.wbcsd.org/Programs/Redefining-Value/ TCFD/News/WBCSD-releases-new-climate-transition-scenario-tool-for-companies-in-the-Food-Agriculture-and-Forest-Products-sectors

*GHG prices presented are averaged global values in 2005 USD. They reflect the assumed prices of GHG emissions from agriculture, forestry and other land use; **"Protected areas," based on the World Database for Protected Areas, include all areas under legal protection meeting the International Union for Conservation of Nature (IUCN) and Convention on Biological Diversity protected area definitions (including IUCN categories Ia, Ib, III, IV, V, VI);

Appendix 3: Existing Mechanisms for Financing Investments in Climate Resilience

Numerous opportunities exist for market leaders to enhance profitability through diversification of revenue streams and for the broader Brazilian cattle sector to invest in innovation.

The collaborative efforts of the following initiatives are improving the environment for investors to understand the risks and potential opportunities for financing cattle production that are rapidly diverging from traditional practices. However, significant progress is needed to ensure that access to resources to mitigate climate transition risks and lean into opportunities is equitable and accessible.

Significant progress is needed to ensure that access to resources to mitigate climate transition risks and lean into opportunities is equitable and accessible.

Brazilian Government Financing Initiatives

- Plano Safra is the primary governmental policy aimed at encouraging agricultural activity. In the past year, it provided a record USD 72.8 billion in credit, while introducing mechanisms to promote socio-environmental attributes and preventing credit issuance to individuals engaged in illegal activities. The project allocated USD 1.4 billion for credit lines aimed at stimulating low-carbon agricultural activities. Moreover, the government unveiled the Plano Safra for Family Farming 2023/2024, with a budget of USD 14.32 billion.
- The ABC+ Plan 2020-2030 represents the second phase of the Sectoral Plan for Mitigation and Adaptation to Climate Change for the Consolidation of a Low Carbon Economy in Agriculture. Its objective is to reduce carbon emissions by 1.1 billion tons in agribusiness by promoting the adoption of sustainable technologies, such as recovery of degraded pastures, the No-Tillage System (SPD) and the integration of agriculture, livestock and forestry (ILPF). The plan also provides a financing line focused on the adoption of sustainable technologies, now known as the Program for Financing Sustainable Agricultural Production Systems (RenovAgro).
- Finally, institutions like Banco da Amazônia manage financial resources from government programs aimed at the development of states in the Northern region, which includes supporting rural producers and promoting sustainable practices in the field.

Private Sector Financing Initiatives

- BNDES offers a range of financing options for the agribusiness sector aimed at reducing environmental impacts, including equipment purchases. BNDES Proirriga supports the development of sustainable irrigated agriculture, while Prodecoop focuses on modernizing productive systems and marketing for cooperatives, among others. The Climate Fund, a specific federal government program for climate change, supports projects related to climate mitigation and adaptation, with an allocation of USD 0.6 billion for 2023. The priority is to invest in renewable energy projects and energy efficiency.
- Banco do Brasil offers rural credit solutions following an analysis of financial, climate and market risks. The goal is to incentivize producers to implement business management improvements and adopt socio-environmental practices. Some programs include Low Carbon Agriculture, Innovation and Best Practices and BB Reforesting Brazil, in addition to other options focused on sustainable agribusiness practices, such as integrated agriculture-livestock-forestry, recovery of degraded pastures and compliance with legal reserve and permanent preservation areas.
- Rabobank positions itself as a specialized bank that provides financial and strategic solutions for agribusiness. It offers

financing focused on sustainability and has recently collaborated with the United Nations Environment Programme and other international partners to develop "Renew Pasture," a loan with a three-year grace period aimed at enabling clients to recover low productivity and degraded pastures.

- Santander facilitates the transfer of credit lines from government programs and also offers its own program, CDC Agro Sustainable. This program supports the purchase of machinery and low environmental impact planting and livestock technical solutions, the implementation of renewable energy systems, drip irrigation and other sustainable practices.

- Banco do Nordeste offers FNE Verde (Green FNE), an initiative aimed at financing projects and activities that seek environmental conservation and recovery for rural producers and cooperatives. FNE Sol (FNE Sun) finances micro-and mini-generation projects of energy from renewable sources for self-consumption or leasing.

- Banco da Amazônia offers Amazônia Rural Verde (Green Rural Amazon), targeting rural producers and traditional populations in the region to finance sustainable activities. This includes the transformation of timber forest products from managed areas, reforestation and land recovery. Energia Verde (Green Energy) is another credit line focused on the purchase of vehicles that use renewable energy.

Consortium and NGO-Driven Financing Initiatives

- The Innovative Finance for the Amazon, Cerrado and Chaco initiative led by the United Nations Environment Programme, the Nature Conservancy and the Tropical Forest Alliance has committed to mobilizing USD 10 billion in commitments and disbursements of funds for the sustainable agricultural transition by 2030. The initiative sees the development of deforestation-free cattle, soy, agroforestry and non-timber forest products across critical South American biomes, including the Brazilian Amazon and Cerrado, as a USD 30 billion opportunity for investors.

- The Investors Policy Dialogue on Deforestation (IPDD) is a consortium of financiers with USD 8.5 trillion in assets under management led by a secretariat established by the World Economic Forum and supported by the Principles for Responsible Investment. IPDD, established in 2020, is composed of 58 financial institutions and investors concerned about the "financial impacts that deforestation and the violation of the rights of indigenous peoples and local communities may have on their clients and investee companies by potentially increasing reputational, operational and regulatory risks." It identifies three channels by which deforestation risks create financial risk for issuers and investors: Environmental Social Governance risks, supply chain risks and finance sector risks.

- Capital for Climate provides a platform for large-scale investors to focus primary capital on sustainable livestock management, restoration of degraded pastureland, regenerative agriculture, agroforestry, the bioeconomy and other relatively new bankable assets.

Innovative Financial Instruments: Nature-Based Solutions and Bioeconomy Financing Initiatives

The voluntary carbon market has seen rapid growth in recent years, especially among nature-based solution projects and programs. Brazilian policymakers, private sector leaders and Indigenous communities are proactively seeking opportunities to work with financiers and carbon market stakeholders to grow the nation's market. For example, the LEAF Coalition is working with the Amazonian Brazilian states of Amapá, Amazonas, Acre, Mato Grosso and Para to generate jurisdictional carbon credits that will be sold on the voluntary carbon market. Carbon markets are set to expand as Article 6 negotiations become finalized, allowing the Brazilian national government to seek more investment from other nations to purchase carbon credits generated by conserving and restoring the nation's natural habitats.

References

1 Zia, Mustafa, James Hansen, Kim Hjort and Constanza Valdes, "Brazil Once Again Becomes the World's Largest Beef Exporter," *U.S. Department of Agriculture (USDA) Economic Research Service.* July 1, 2019. https://www.ers.usda.gov/amber-waves/2019/july/brazil-once-again-becomes-the-world-s-largest-beef-exporter/

2 FAO. FAOSTAT Statistical Database. License: CC BY-NC-SA 3.0 IGO. Data of Access: 01-08-2023.

3 Nogueira, Saulo. "Livestock and Products Semi-annual." Report Number BR2023-0004. *U.S. Department of Agriculture (USDA)* Foreign Agricultural Service. March 03, 2023. https://apps.fas.usda.gov/newgainapi/api/Report

4 FAO. FAOSTAT Statistical Database. License: CC BY-NC-SA 3.0 IGO. Data of Access: 01-08-2023.

5 Zu Ermgassen, Erasmus KHJ, Javier Godar, Michael J. Lathuillière, Pernilla Löfgren, Toby Gardner, André Vasconcelos and Patrick Meyfroidt. "The origin, supply chain and deforestation risk of Brazil's beef exports." Proceedings of the National Academy of Sciences 117, no. 50 (2020): 31770-31779. https://doi.org/10.1073/pnas.2003270117

6 "ARTIGO: Empregos, salários e impacto social da carne bovina." *The Brazilian Association of Beef Exporters (ABIEC).* May 11, 2020. https://www.abiec.com.br/artigo-empregos-salarios-e-impacto-social-da-carne-bovina/

7 ibid.

8 Mano, Ana. "China agrees to resume imports of Brazilian beef, authorizes four new plants." *Reuters*. March 23, 2023. https://www.reuters.com/article/china-beef-brazil/china-agrees-to-resume-imports-of-brazilian-beef-authorizes-four-new-plants-idUSKBN2VP0M8.

9 Freitas, Tatiana. "Brazil, the World's Top Beef Exporter, Is Now Turning Away from Meat," *Bloomberg*. December 12, 2022. https://www.bloomberglinea.com

10 Garra International. "Brazilian Beef Exports Rise 26% in 2022." *Garra International.* January 20, 2023. https://www.garrainternational.com/brazilian-beef-exports-rise-26-in-2022/

11 ibid.

12 "2020 ESG Report." *Itau Unibanco.* December 31, 2020. https://www.itau.com.br/download-file/v2/d/7e52c211-7192-4231-abba-b349721b6a07/efba3f0a-1a30-5d0c-4aa5-fbbf326a9569?origin=2

13 Slob, Bart, Gerard Rijk and Matt Piotrowski. "JBS, Marfrig and Minerva: Material Financial Risk from Deforestation in Beef Supply Chains." *Chain Reaction Research.* December 3, 2020. https://chainreactionresearch.com/report/jbs-marfrig-and-minerva-material-financial-risk-from-deforestation-in-beef-supply-chains/

14 Ashford, Moyra and Sue Branford. "Foreign capital powers Brazil's meatpackers and helps deforest the Amazon." *Mongabay Series Amazon Cattle Investigations.* June 7, 2022. https://news.mongabay.com/2022/06/foreign-capital-powers-brazils-meatpackers-and-helps-deforest-the-amazon/

15 ibid.

16 Filho, Vieira and José Eustáquio Ribeiro. "Agricultura e pecuária, energia e o efeito poupa-florestas: um comparativo internacional." *Instituto de Pesquisa Econômica Aplicada (Ipea).* 2022. https://repositorio.ipea.gov.br/handle/11058/11210

17 ibid.

18 Ritchie, Hannah, Pablo Rosado and Max Roser "CO_2 and Greenhouse Gas Emissions." *Our World In Data.* 2023. https://ourworldindata.org/co2-and-greenhouse-gas-emissions

19 Cederberg, Christel, Daniel Meyer and Anna Flysjö. "Life cycle inventory of greenhouse gas emissions and use of land and energy in Brazilian beef production." *Institutet för livsmedel och bioteknik (SIK)*. June 2009. https://www.diva-portal.org/smash/get/diva2:943348/fulltext01.pdf

20 "Leading methane action since 2004." *Global Methane Initiative (GMI).* 2024. https://www.globalmethane.org/index.aspx

21 Emissões totais 2023. *Sistema de Estimativas de Emissões e Remoções de Gases de Efeito Estufa (SEEG).* Plataforma de dados. Available at: http://plataforma.seeg.eco.br/total_emission#

22 "The Impact of the Global Methane Pledge on the Brazilian Beef Industry." *Charles River Associates*. April 4, 2022. Originally published by WebAdvocacy. https://www.crai.com/insights-events/publications/the-impact-of-the-global-methane-pledge-on-the-brazilian-beef-industry/

23 Paraguassu, Lisandra. "Brazil food sector accounts for 74% of emissions: Study." *Reuters*. October 24, 2023. https://www.reuters.com/sustainability/cop/brazil-food-sector-accounts-74-emissions-study-2023-10-24/

24 Eisenhammer, Stephen. "One Brazilian farmer tried – and failed – to ranch more responsibly in the Amazon." *Reuters Investigates.* August 28, 2020. https://www.reuters.com/investigates/special-report/brazil-deforestation-cattle/

25 Libera, Carlos, Silvio Marote and Anna Lúcia Horta. "Brazil's Path to Sustainable Cattle Farming." *The Nature Conservancy and Bain & Company.* https://www.bain.com/insights/brazils-path-to-sustainable-cattle-farming/

26 ibid.

27 Mano, Ana. "Brazil cattle die as cold temperatures batters large beef state." *Reuters*. June 21, 2023. https://www.reuters.com/world/americas/brazil-cattle-die-cold-temperatures-batters-large-beef-state-2023-06-21/

28 Daniel Ingold, iAGRO Agencia Estadual de Defensa Sanitaria Animal e Vegetal. July 30, 2023

29 Almeida, C. T., J. F. Oliveira-Júnior, R. C. Delgado, P. Cubo and M. C. Ramos. "Spatiotemporal rainfall and temperature trends throughout the Brazilian Legal Amazon, 1973–2013." *International Journal of Climatology* 37, no. 4 (2017): 2013-2026. https://doi.org/10.1002/joc.4831

30 Hofmann, Gabriel S., Manoel F. Cardoso, Ruy JV Alves, Eliseu J. Weber, Alexandre A. Barbosa, Peter M. de Toledo, Francisco B. Pontual et al. "The Brazilian Cerrado is becoming hotter and drier." *Global Change Biology* 27, no. 17 (2021): 4060-4073. https://doi.org/10.1111/gcb.15712

31 Marengo, José A., Juan C. Jimenez, Jhan-Carlo Espinoza, Ana Paula Cunha and Luiz EO Aragão. "Increased climate pressure on the agricultural frontier in the Eastern Amazonia–Cerrado transition zone." *Scientific Reports* 12, no. 1 (2022): 457. https://doi.org/10.1038/s41598-021-04241-4

32 Choi, Jung, Seok-Woo Son, Jian Lu and Seung-Ki Min. "Further observational evidence of Hadley cell widening in the Southern Hemisphere." *Geophysical Research Letters* 41, no. 7 (2014): 2590-2597. https://doi.org/10.1002/2014GL059426

33 Hofmann, Gabriel Selbach, Rafael Cesar Silva, Eliseu Jose Weber, A. A. Barbosa, L. F. B. Oliveira, Ruy Jose Valka Alves, Heinrich Hasenack, Venisse Schossler, Francisco Eliseu Aquino and Manoel Ferreira Cardoso. "Changes in atmospheric circulation and evapotranspiration are reducing rainfall in the Brazilian Cerrado." *Scientific Reports* 13, no. 1 (2023): 11236. https://doi.org/10.1038/s41598-023-38174-x

34 Cardoso, Abmael S., Alexandre Berndt, April Leytem, Bruno JR Alves, Isabel das NO de Carvalho, Luis Henrique de Barros Soares, Segundo Urquiaga and Robert M. Boddey. "Impact of the intensification of beef production in Brazil on greenhouse gas emissions and land use." *Agricultural Systems* 143 (2016): 86-96. https://doi.org/10.1016/j.agsy.2015.12.007

35 Gurgel, Ângelo Costa and Cecília Fagan Costa. "Invertendo o sinal de carbono da agropecuária brasileira: uma estimativa do potencial de mitigação de tecnologias do Plano ABC de 2012 a 2023." *Observatório do Plano ABC.* 2015. https://hdl.handle.net/10438/15313

36 Rajão, Raoni, Argemiro Leite-Filho and Britaldo Soares-Filho. "O IMPACTO DAS MUDANÇAS CLIMÁTICAS LOCAIS, REGIONAIS E GLOBAIS NA AGROPECUÁRIA BRASILEIRA." Fórum do Futuro. March 16, 2022. https://www.forumdofuturo.org/post/o-impacto-das-mudan%C3%A7as-clim%C3%A1ticas-locais-regionais-e-globais-na-agropecu%C3%A1ria-brasileira

37 Habermann, Eduardo, Eduardo Augusto Dias de Oliveira, Daniele Ribeiro Contin, Gustavo Delvecchio, Dilier Olivera Viciedo, Marcela Aparecida de Moraes, Renato de Mello Prado, Kátia Aparecida de Pinho Costa, Marcia Regina Braga and Carlos Alberto Martinez. "Warming and water deficit impact leaf photosynthesis and decrease forage quality and digestibility of a C4 tropical grass." *Physiologia Plantarum* 165, no. 2 (2019): 383-402. https://doi.org/10.1111/ppl.12891

38 Carrança, Thais. "Carne ainda mais cara e pecuária mais poluente: os efeitos da mudança climática." *BBC NEWS Brasil.* September 12, 2021. https://www.bbc.com/portuguese/brasil-58351344

39 Correia Filho, Washington Luiz Félix, José Francisco de Oliveira-Júnior, Dimas de Barros Santiago, Hazem Ghassan Abdo, Hussein Almohamad, Ahmed Abdullah Al Dughairi and Carlos Antonio da Silva Junior. "The assessment of climatic, environmental and socioeconomic aspects of the Brazilian Cerrado." *Ecological Processes* 12, no. 1 (2023): 1-12. https://doi.org/10.1186/s13717-023-00433-0

40 Campos, Juliana de Oliveira and Henrique Marinho Leite Chaves. "Trends and variabilities in the historical series of monthly and annual precipitation in cerrado biome in the period 1977-2010." *Revista Brasileira de Meteorologia* 35 (2020): 157-169. https://doi.org/10.1590/0102-7786351019

41 Marengo, José A., Juan C. Jimenez, Jhan-Carlo Espinoza, Ana Paula Cunha and Luiz EO Aragão. "Increased climate pressure on the agricultural frontier in the Eastern Amazonia–Cerrado transition zone." *Scientific Reports* 12, no. 1 (2022): 457. https://doi.org/10.1038/s41598-021-04241-4

42 ibid.

43 Libonati, Renata, João L. Geirinhas, Patrícia S. Silva, Ana Russo, Julia A. Rodrigues, Liz BC Belém, Joana Nogueira et al. "Assessing the role of compound drought and heatwave events on unprecedented 2020 wildfires in the Pantanal." *Environmental Research Letters* 17, no. 1 (2022): 015005. https://doi.org/10.1088/1748-9326/ac462e

44 "Statement: Glasgow Leaders Issue Declaration on Forests and Land Use." *World Resources Institute.* November 2, 2021. https://www.wri.org/news/statement-glasgow-leaders-issue-declaration-forests-and-land-use/

45 Moreira, Assis. "EU New Rules Against Deforestation Reach 80% of Brazil's Agricultural Exports," *Valor International (Globo.com)*. September 14, 2022. https://valorinternational.globo.com/agribusiness/news/2022/09/14/eu-new-rules-against-deforestation-reach-80percent-of-brazils-agricultural-exports.ghtml

46 Moreira, Assis. "Brazil Criticizes Unilateral Measures of the European Union at WTO," *Valor International (Globo.com).* June 5, 2023. https://valorinternational.globo.com/politics/news/2023/06/05/brazil-criticizes-unilateral-measures-of-the-european-union-at-wto.ghtml

47 "Climate-Related Financial Regulation Explorer." *Orbitas.* https://orbitas.finance/climate-related-regulations-map/

48 Canby, Kerstin, Genevieve Bennett and Verena Manolis. "China and Brazil have a Joint Commitment to End Illegal Deforestation Driven by Trade. What Does This Mean for Major Importers like the EU, UK and US?" *Forest Trends.* April 21, 2023. https://www.forest-trends.org/blog/china-and-brazil-have-a-joint-commitment-to-end-illegal-deforestation-driven-by-trade/

49 "'Green claims' directive: Protecting consumers from greenwashing." *European Parliament.* October 2023. https://www.europarl.europa.eu/RegData/etudes/BRIE/2023/753958/eprs_bri(2023)753958_EN.pdf

50 Harvey, Simon. “COP26 – JBS, Cargill join ten-strong commodity group pledging to end deforestation.” *Just-Food.* November 2, 2021. https://www.just-food.com/news/cop26-jbs-cargill-join-ten-strong-commodity-group-pledging-to-end-deforestation

51 Climate Champions. “Leading financial institutions commit to actively tackle deforestation.” *Climate Champions.* November 2, 2021. https://climatechampions.unfccc.int/leading-financial-institutions-commit-to-actively-tackle-deforestation/

52 Spring, Jake. “Exclusive: European investors threaten Brazil divestment over deforestation,” *Reuters*. June 19, 2020. https://www.reuters.com/article/idUSKBN23Q1MS/

53 Horton, Helena. “A third of companies linked to deforestation have no policy to end it.” *The Guardian*. February 15, 2023. https://www.theguardian.com/environment/2023/feb/15/a-third-of-companies-linked-to-deforestation-have-no-policy-to-end-it

54 Köberle, Alexandre. “Agribusiness Not Ready for the Sudden Shocks of Climate Change.” *Imperial College Business School.* July 7, 2021. https://www.imperial.ac.uk/business-school/ib-knowledge/finance/agribusiness-not-ready-the-sudden-shocks-climate-change

55 “What is 30x30?” *Conservation Corridor*, https://conservationcorridor.org/what-is-30x30/

56 de Oliveira Silva, R., Luis G. Barioni, Julian AJ Hall, Marilia Folegatti Matsuura, Tiago Zanett Albertini, Fernando A. Fernandes and Dominic Moran. “Increasing beef production could lower greenhouse gas emissions in Brazil if decoupled from deforestation.” *Nature Climate Change* 6, no. 5 (2016): 493-497. https://doi.org/10.1038/nclimate2916

57 ibid.

58 Kleen, Joachim Lübbo and Raphaël Guatteo. “Precision Livestock Farming: What Does It Contain and What Are the Perspectives?” *Animals* 13, no. 5 (2023): 779. https://doi.org/10.3390/ani13050779.

59 Silva, Rafael De Oliveira, Luis Gustavo Barioni, Giampaolo Queiroz Pellegrino and Dominic Moran. “The role of agricultural intensification in Brazil’s Nationally Determined Contribution on emissions mitigation.” *Agricultural Systems* 161 (2018): 102-112. https://doi.org/10.1016/j.agsy.2018.01.003

60 Köberle, Alexandre C., Pedro RR Rochedo André FP Lucena, Alexandre Szklo and Roberto Schaeffer. “Brazil’s emission trajectories in a well-below 2 C world: the role of disruptive technologies versus land-based mitigation in an already low-emission energy system.” *Climatic Change* 162 (2020): 1823-1842. https://doi.org/10.1007/s10584-020-02856-6

61 Strassburg, Bernardo BN, Agnieszka E. Latawiec, Luis G. Barioni, Carlos A. Nobre, Vanderley P. Da Silva, Judson F. Valentim, Murilo Vianna and Eduardo D. Assad. “When enough should be enough: Improving the use of current agricultural lands could meet production demands and spare natural habitats in Brazil.” *Global Environmental Change* 28 (2014): 84-97. https://doi.org/10.1016/j.gloenvcha.2014.06.001

62 Libera, Carlos, Silvio Marote and Anna Lúcia Horta. “Brazil’s Path to Sustainable Cattle Farming.” *The Nature Conservancy and Bain & Company.* https://www.bain.com/insights/brazils-path-to-sustainable-cattle-farming/

63 Merry, Frank and Britaldo Soares-Filho. “Will intensification of beef production deliver conservation outcomes in the Brazilian Amazon?.” *Elem Sci Anth* 5 (2017): 24. https://doi.org/10.1525/elementa.224

64 Deely, John, Stephen Hynes, José Barquín, Diane Burgess, Jose Manuel Álvarez-Martínez, Ana Silió and Graham Finney. “Are consumers willing to pay for beef that has been produced without the use of uncontrolled burning methods? A contingent valuation study in North-West Spain.” *Economic Analysis and Policy* 75 (2022): 577-590. https://doi.org/10.1016/j.eap.2022.06.014

65 Magalhaes, Danielle Rodrigues, María Teresa Maza, Ivanor Nunes do Prado, Giovani Fiorentini, Jackeline Karsten Kirinus and María del Mar Campo. “An exploratory study of the purchase and consumption of beef: Geographical and cultural differences between Spain and Brazil.” *Foods* 11, no. 1 (2022): 129. https://doi.org/10.3390/foods11010129

66 Freitas, Tatiana. “Brazil, the World’s Biggest Beef Exporter, Is Turning Away From Meat.” *Bloomberg*, December 12, 2022. https://www.bloomberg.com/news/articles/2022-12-12/meat-consumption-falls-for-67-in-brazil-top-beef-exporter

67 Sanghi, Kanika, Aparna Bharadwaj, Lauren Taylor, Léa Turquier and Indira Zaveri, “Consumers Are the Key to Taking Green Mainstream.” *Boston Consulting Group.* September 13, 2022. https://www.bcg.com/publications/2022/consumers-are-the-key-to-taking-sustainable-products-mainstream

68 “Beef Report Overview of Livestock in Brazil 2022.” *Association of Brazilian Beef Exporters (ABIEC),* https://www.abiec.com.br/wp-content/uploads/Beef-Report-2022_INGLES_Em-baixa.pdf

69 ibid.

70 Carlos, S.M., E.D. Assad, C.G. Estevam, C.Z. de Lima, E.M. Pavão and T.P. Pinto, “Custos da Recuperação de Pastagens Degradadas nos Estados e Biomas Brasileiros,” Observatório de Conhecimento e Inovação em Bioeconomia, Fundação Getulio Vargas - FGV-EESP, São Paulo, SP, Brasil, 2022, https://agro.fgv.br/sites/default/files/2023-02/costs_of_recovering_degraded_pastures_in_the_brazilian_states_and_biomes_0.pdf

71 “Costs Of Recovering Degraded Pastures In The Brazilian States And Biomes,” *Fundação Getulio Vargas’ São Paulo School of Economics (FGV EESP)* https://agro.fgv.br/sites/default/files/2023-02/costs_of_recovering_degraded_pastures_in_the_brazilian_states_and_biomes_0.pdf

72 Niemeyer, Julia and Mariana M. Vale. “Obstacles and opportunities for implementing a policy-mix for ecosystem-based adaptation to climate change in Brazil’s Caatinga.” *Land Use Policy* 122 (2022): 106385. https://doi.org/10.1016/j.landusepol.2022.106385

73 Herrera, Gabriel Paes, Reginaldo Brito da Costa, Paula Martin de Moraes, Dany Rafael Fonseca Mendes and Michel Constantino. “Smallholder farming in Brazil: An overview for 2014.” *African Journal of Agricultural Research* 12, no. 17 (2017): 1424-1429. https://doi.org/10.5897/AJAR2017.12137

74 Source: Authors’ financial modeling results.

75 “Prioridades E Principais Dificuldades No Acesso Ao Crédito E Seguro Rural Plano Agrícola E Pecuário.” *Confederação da Agricultura e Pecuária do Brasil (CNA) and Serviço Nacional de Aprendizagem Rural (SENAR).* https://www.cnabrasil.org.br/assets/arquivos/RESULTADO_PESQUISA_PRODUTORES_ATEG-PAP2021_2022.pdf

76 de Albuquerque, Amanda, Juliano Assunção, Pablo Castro, Natalie Hoover and Giovanna de Miranda. “Smallholders in the Caatinga and the Cerrado: A Baseline Analysis for a Rural Just Transition in Brazil.” *Climate Policy Initiative.* February 13, 2023. https://www.climatepolicyinitiative.org/publication/smallholders-in-the-caatinga-and-the-cerrado-a-baseline-analysis-for-a-rural-just-transition-in-brazil/

77 Dietrich, Jan Philipp, Christoph Schmitz, Christoph Müller, Marianela Fader, Hermann Lotze-Campen, and Alexander Popp. “Measuring agricultural land-use intensity–A global analysis using a model-assisted approach.” *Ecological Modelling* 232 (2012): 109-118. https://doi.org/10.1016/j.ecolmodel.2012.03.002

78 Chará, J., E. Reyes, P. Peri, J. Otte, E. Arce and F. Schneider. “Silvopastoral systems and their contribution to improved resource use and sustainable development goals: evidence from Latin America.” (2019). https://www.fao.org/3/ca2792en/ca2792en.pdf

79 Lebrazi, Sara and Kawtar Fikri-Benbrahim. “Potential of tree legumes in agroforestry systems and soil conservation.” In *Advances in Legumes for Sustainable Intensification*, pp. 461-482. Academic Press, 2022. https://doi.org/10.1016/B978-0-323-85797-0.00004-5

80 Dawes, Allegra, Cy McGeady and Joseph Majkut. “Voluntary Carbon Markets: A Review of Global Initiatives and Evolving Models.” *Center for Strategic & International Studies*. May 31, 2023. https://www.csis.org/analysis/voluntary-carbon-markets-review-global-initiatives-and-evolving-models

81 “The green hidden gem – Brazil’s opportunity to become a sustainability powerhouse.” McKinsey & Company. November 4, 2022. https://www.mckinsey.com/br/en/our-insights/all-insights/the-green-hidden-gem-brazils-opportunity-to-become-a-sustainability-powerhouse

82 Kleen, Joachim Lübbo and Raphaël Guatteo. “Precision Livestock Farming: What Does It Contain and What Are the Perspectives?” *Animals* 13, no. 5 (2023): 779. https://doi.org/10.3390/ani13050779.

83 Lujan, Breanna “A Comparison of Supply Chain Tracking Tools for Tropical Forest Commodities in Brazil,” Environmental Defense Fund. https://www.edf.org/sites/default/files/documents/Supply_Chain_Tracking_Tools.pdf

84 OECD/FAO, "OECD-FAO Business Handbook on Deforestation and Due Diligence in Agricultural Supply Chains." OECD Publishing, Paris, 2023. https://doi.org/10.1787/c0d4bca7-en.

85 “Revitalizing US & Brazilian Cooperation On Climate.” Climate Advisers. February 6, 2023. https://www.climateadvisers.org/insightsfeed/revitalizing-us-brazilian-cooperation-on-climate/

ORBITAS
A Climate Advisers Initiative

CLIMATE ADVISERS

Brazil's Cattle Sector Amidst Climate Transitions

Contact us

—

info@orbitas.finance
www.orbitas.finance

info@climateadvisers.org
www.climateadvisers.org

Follow us

—

X/twitter:
@OrbitasFinance
@ClimateAdvisers

LinkedIn:
@Orbitas
@ClimateAdvisers