

Increasing Income, Respecting the Planet, Nourishing People

Promoting the transition from livestock
farming to horticulture-based agroforestry

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EXECUTIVE SUMMARY

Brazil faces a paradox in its food system: the livestock sector, despite its economic importance, is the largest contributor to climate pressure and deforestation, yet it does not contribute to the country's food security to the same extent that it pressures the environment and utilises natural resources. Livestock occupies 20% of the land but provides only about 37% of the calories consumed by Brazilians in fresh and minimally processed foods, which the Dietary Guidelines for the Brazilian Population indicate should be the basis of the national diet. In contrast, agriculture, despite occupying only 10% of the land, provides 63% of Brazilian calories.

In search of a path that harmonises food security, increased producer income, and environmental regeneration, this report investigates the migration from livestock farming to horticulture-based agroforestry systems (AFS). This integrated study, coordinated by ProVeg Brazil and conducted by OCA, reveals that this transition both contributes to climate mitigation and adaptation, and represents a crucial strategy for a just transition, through the potential for increased rural producer income and a decisive contribution to food security and healthy, adequate nutrition.

? What are Agroforestry Systems?

Agroforestry systems (AFS), sometimes called agroforests, are sustainable forms of land use that combine agricultural species (crops, forage, or pastures) with forest species (trees and shrubs) in the same area, in a planned and managed way. These systems seek to mimic the dynamics and structure of a natural forest, promoting more diversified and integrated production, in contrast to the monoculture model. AFS can be classified into different types, such as agrosilvicultural (trees and crops), silvopastoral (trees and livestock), and agrosilvopastoral (all three components together). This report considers agrosilvicultural scenarios – i.e., agroforests with exclusive plant production – although it does refer to all AFS in a broader sense at times. To be clear, ‘horticulture-based’ is used when referring exclusively to agrosilvicultural AFS.

AFS bring numerous benefits – environmental, economic, and social. They are crucial for the recovery of degraded areas and for soil conservation (through preventing erosion and improving fertility with nutrient cycling), in addition to contributing to the preservation of fauna and flora and carbon capture. For the rural producer, AFS offer diversification of production and income, reducing financial risks and guaranteeing food and products (such as wood and fruit) in different cycles and times of the year, all with a system that values sustainability and lower use of external inputs.

The modelling results indicate that migrating to AFS can more than double the net income per hectare (+110% in the median) once the AFS matures (year 5+) – and does this while transforming the production area into a net carbon sink, combating deforestation and the climate crisis.

The transition to horticulture-based AFS¹ proved to be more economically promising than any type of livestock farming in all Brazilian biomes, offering the following co-benefits:

- In exceptional cases, when starting from low-productivity areas with degraded pasture and moving to achieve a biodiverse horticulture-based AFS with high income (due to access to special markets, high-priced products, premiums, payments for environmental services (PES), and others), the transition from beef cattle farming to horticulture-based AFS can generate an income increase reaching 1,525% (from R\$800 to R\$13,000/ha/year).
- The temporal and spatial diversification of AFS reduces losses from climate and price, stabilising income and labour throughout the year.

- Converting 12% of pastures with some level of degradation to horticulture-based AFS results in the reduction of more than 5% of the emissions Brazil committed to mitigate in its Nationally Determined Contributions (NDCs). Horticulture-based AFS emit far lower levels of methane and N₂O emissions compared to livestock, and they sequester and store carbon, making the area have negative greenhouse gas emissions (capturing more than it emits).
- Horticulture-based AFS require 12 times less land than cattle to obtain the same gross revenue, contributing to combating deforestation and regenerating degraded areas.
- Supporting family farming, the transition to AFS fosters employment and diversification of income generation, potentially reducing rural migration. For every R\$1 million of annual production in horticulture-based AFS, 30 equivalent jobs (FTE²) are generated in the chain, whereas in livestock farming, on average, the same investment results in only 7.

It is worth noting that this study was conducted in Brazil, a country of continental dimensions with immense regional and market heterogeneity.³ Thus, results vary with logistics, prices, and organisational capacity. The estimates are medians from literature and do not replace a local business plan.

The findings of this meta-analysis reinforce the view that the transition to horticulture-based AFS represents a more promising climatic and economic solution for the Brazilian agro-livestock sector, with collateral impacts on the entire food system, aligning directly with ProVeg's purpose: to promote healthier, fairer, and more sustainable food systems, focusing on encouraging increased production and consumption of plants.

For this just and structural transition to materialise at scale, it is crucial for the public sector to act decisively. This report underscores the importance of robust and integrated public policies that offer support, incentives, and specific financing for the transition from livestock to plant production.

Promoting diversification at both the production and consumption ends are essential steps to transform Brazilian food systems, ensuring the country reconciles the production of fresh food for population health with the urgency of climate mitigation and environmental regeneration.

1. In this report, 'horticulture' refers to plants grown for human consumption.

2. FTE employment means Full-Time Equivalent, a metric that measures the workload in an organisation by counting the hours of full-time and part-time employees to determine how many full-time people would be needed to meet the demand.

3. For a full description of the study's methodology, see the Appendix.



AGRICULTURAL AND FOOD PRODUCTION IN BRAZIL

The Brazilian livestock sector is marked by a paradox: although it has great economic relevance, it is simultaneously the main cause of environmental pressure, deforestation, and greenhouse gas emissions – which also associates it with hidden costs to the country. This contradiction highlights the urgency of transitioning to primarily horticulture-based systems so that food production in Brazil reflects the population's nutritional needs and fits within planetary boundaries. Diversifying the production matrix through agroforestry systems (AFS) should, therefore, also be interpreted as a risk management strategy and a guarantee of long-term economic sustainability.

In Brazil, livestock production is the largest emitter

of greenhouse gases, associated with about 60% of the country's total emissions.⁴ Partly, this is due to enteric fermentation in ruminants, which emits methane, a gas with more than 80 times the warming power of carbon dioxide.⁵ Emissions from enteric fermentation in the Brazilian cattle herd are higher than Italy's total emissions.⁶

Furthermore, more than 90% of deforestation in the Amazon was caused by pasture opening between 1985 and 2023.⁷ The constant increase in livestock production in the country – only in 2024 was there a slight drop – is directly linked to farm expansion and deforestation, whether for new pasture areas for cattle or for monoculture grain areas used mainly for animal

4. See <https://seeg.eco.br/>

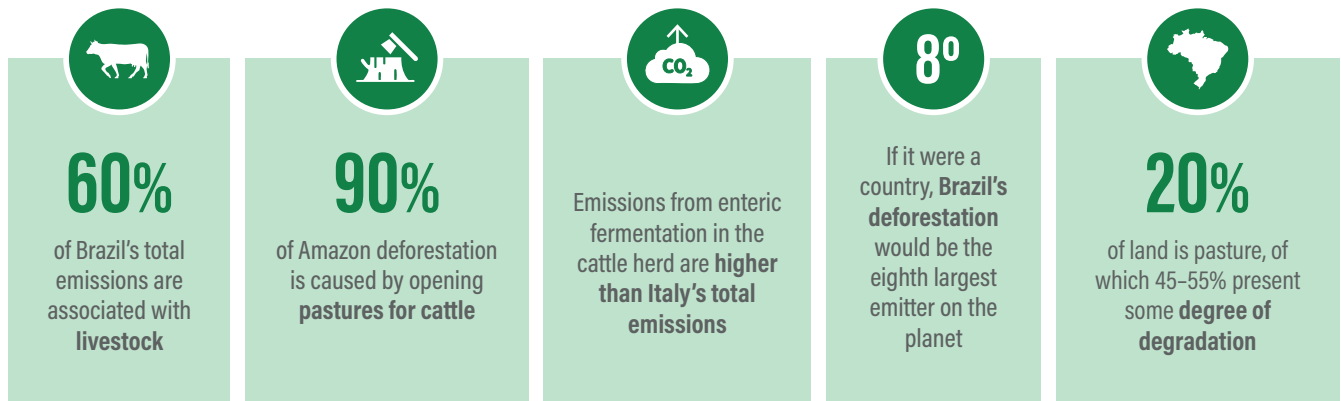
5. UNEP (2021). *As emissões de metano estão impulsionando a mudança climática. Veja como reduzi-las.* <https://www.unep.org/pt-br/noticias-e-reportagens/reportagem/emissoes-de-metano-estao-impulsionando-mudanca-climatica-veja>

6. Tsai, D. (2024) *Análise das emissões de 1970-2023 gases de efeito estufa e suas implicações para as metas climáticas do Brasil.* SEEG. <https://seeg.eco.br/wp-content/uploads/2024/11/SEEG-RELATORIO-ANALITICO-12.pdf>

7. MapBiomass (2024) *Mais de 90% do desmatamento da Amazônia é para abertura de pastagem.* SEEG. <https://brasil.mapbiomas.org/2024/10/03/mais-de-90-do-desmatamento-da-amazonia-e-para-abertura-de-pastagem>

feed. Soya accounts for the majority of deforestation in Cerrado, and it is estimated that about three-quarters of global soya is used for animal feed.⁸

Land use changes (deforestation) were, in 2023, once again responsible for the largest share of the country's gross greenhouse gas emissions (46%) – followed by



agriculture/livestock (28%), energy (18%), waste (4%), and industrial processes (4%)⁹. If it were a country, Brazil's deforestation would be the eighth largest emitter on the planet, behind Japan and ahead of Iran.¹⁰

In addition to climate impact, food systems, as configured today, are the main factor leading to biodiversity loss. Globally, it is estimated that the expansion of areas dedicated to agriculture/livestock (notably soya, cattle, and palm oil production) causes the loss of natural habitats, threatening 86% of species that are at risk of extinction.¹¹

To reverse this number, the United Nations Environment Programme (UNEP) recommends that global dietary patterns be directed towards more plant-rich diets – which would also benefit the food health of populations worldwide and help reduce the risk of pandemics – and that crops be grown in a more nature- and biodiversity-friendly way, limiting input use and replacing monoculture with polyculture agricultural practices.¹²

8. WWF (2014) *The growth of Soy: Impacts and Solutions (O crescimento da soja: impactos e soluções)*. https://d3nehc6yl9qzo4.cloudfront.net/downloads/wwf_relatorio_soja_port.pdf.

9. Tsai, D. (2024).

10. Tsai, D. (2024).

11. Benton, T., et al. (2021) *Food system impacts on biodiversity loss: Three levers for food system transformation in support of nature*. Chatham House. https://www.chathamhouse.org/sites/default/files/2021-02/2021-02-03-food-system-biodiversity-loss-benton-et-al_0.pdf

12. Benton, T., et al. (2021).

Resource Use vs. Food Production

Their intense resource use does not proportionally reflect livestock's contribution to food security: worldwide, livestock production uses approximately 83% of agricultural land – equivalent to the area of all the Americas¹³ – yet provides only 37% of our proteins and 18% of our calories.¹⁴

Pastures occupy between 162 and 170 million hectares in Brazil, representing approximately 20% of the land. Meanwhile, agriculture occupies between 77 and 85 million hectares¹⁵ (9–10% of the land). Despite the sector's dominant land use, foods from livestock (poultry, eggs, milk and derivatives, fish, pork, beef) are responsible for only about 37% of calories consumed by Brazilians, considering only primary products (fresh and minimally processed, which the Dietary Guidelines for the Brazilian Population indicate should be the basis of the national diet), while plant-based foods from agriculture provide the majority (63%).¹⁶ This disparity highlights that the sector occupying the most land and driving deforestation delivers the smallest portion of energy to the national diet.

This inefficiency in land use, where livestock occupies the majority of agricultural land but deliver the smallest portion of calories, is exacerbated by the country's food consumption pattern. The average per capita red meat consumption (beef, pork, and lamb) is about 346 grams per week.¹⁷ This value is 3.5 times higher than the maximum limit of 98 g per

week stipulated by the EAT-Lancet Commission for a healthy and sustainable diet.¹⁸

If the Brazilian diet were aligned with EAT-Lancet planetary health recommendations, the total caloric contribution of foods from livestock would be only 12.2%. Therefore, the current caloric impact of the sector is significantly inflated by a consumption pattern that exceeds both sustainability and health goals.

With the same amount of land, water, and resources used to produce a small amount of animal protein, a much larger amount of plant protein, notably legumes, could be produced. Besides providing various environmental services – including green manuring through biological nitrogen fixation, promoting soil health¹⁹ – legumes are fundamental from a nutritional standpoint. As healthy sources of proteins, fibres, and important micronutrients, they are highlighted as an essential part of a healthy diet. Studies indicate that mortality is lower when plant protein replaces sources like red meat, dairy, and poultry.²⁰ Similar associations are observed in reducing the risk of type 2 diabetes and coronary heart disease.²¹

In the Brazilian context, this argument is reinforced by the cultural centrality of legumes, notably beans, which make up the traditional base of the national diet. However, there has been a sharp downward trend in per capita consumption of this food, reflecting changes in the population's dietary patterns: in 15 years, the

13. Ritchie, H., & Roser, M. (2024) *Half of the world's habitable land is used for agriculture. Our World in Data.* <https://ourworldindata.org/global-land-for-agriculture>.

14. Poore, J., & Nemecek, T. (2018) *Reducing food's environmental impacts through producers and consumers.* Science 360, 987–992. <https://doi.org/10.1126/science.aag0216>.

15. MapBiomas et al. (2022) *Metodologias e Parâmetros para Estimativa de Custos de MRV e Receitas Potenciais em Programas de Pagamento por Serviços Ambientais (PSA) e Mercado de Carbono no Brasil. Covering 2017–2022 baseline projections.* See <https://observatorioda restauracao.org.br/principais-dados> and data at <https://brasil.mapbiomas.org/estatisticas/>.

16. IBGE (2018) *Pesquisa de Orçamentos Familiares, 2017–2018.*

17. IBGE (2018). To estimate per capita consumption (in ready-to-eat weight) and enable comparison with EAT-Lancet targets, a cooking factor was applied to the POF 2017–2018 data, which measures the acquisition of fresh (raw) food.

18. The Lancet (2019) *Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems.*

19. De Souza Gomes Guarino, E., et al. (2016) *A importância das leguminosas para a conservação e o manejo do solo.* Embrapa. <https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/1141608/1/Folder-A-importancia-das-leguminosas.pdf>.

20. Song M, Fung TT, Hu FB, et al. (2016) Association of animal and plant protein intake with all-cause and cause-specific mortality.

21. Wang Y, Liu B, Han H, et al. (2023) Associations between plant-based dietary patterns and risks of type 2 diabetes, cardiovascular disease, cancer, and mortality—a systematic review and meta-analysis.

average annual per capita consumption of beans fell by 52%.²² Therefore, fostering the production and consumption of diverse plant-based staples, especially

legumes, is a strategic policy for rescuing public health and food culture.



Globally

 Livestock production

83%
of agricultural land



(equivalent to the area of all the Americas)

 Animal-origin foods provide only

37%
of our proteins



18%
of our calories



In Brazil

 Agriculture

9-10%
of national land



 Plant foods

63%
of calories consumed
by Brazilians



 Livestock production

20%
of land is pasture and
grain cultivation areas
for animal feed

 Animal-origin foods

37%
of calories consumed
by Brazilians

could be **12.2%**
if Brazilians reduced
animal product
consumption, aligning
with the Planetary
Health Diet (EAT-
Lancet)

Food Comparison

By protein



Beef



x Peas

125x more
greenhouse gases

28x more land use

By litre



Cow's milk



x Soya milk

13x more land use

22. Cabral, U. (2020) *Presença do feijão nos domicílios brasileiros cai pela metade em 15 anos*. IBGE. <https://agenciadenoticias.ibge.gov.br/agencia-noticias/2012-agencia-de-noticias/noticias/27301-presenca-do-feijao-nos-domicilios-brasileiros-cai-pela-metade-em-15-anos>



Four documents, one conclusion: we need to consume predominantly plants

Healthy, Sustainable, and Just Food Systems (EAT-Lancet Commission, 2025)

The new edition of the EAT-Lancet Commission report²³, published in October 2025, reinforces the central role of food systems in the climate, biodiversity, and social justice crises, and presents the Planetary Health Diet as a model to ensure adequate nutrition within planetary limits. The report points out that a global transition to predominantly plant-based diets could prevent up to 15 million deaths annually and significantly reduce agricultural emissions and pressure on ecosystems. According to the study, food systems are today the main driver of transgression for five of the six planetary boundaries already crossed – including land use change, biosphere integrity, biogeochemical flows, and greenhouse gas emissions – and, at the same time, fail to ensure universal access to healthy diets.

Food Systems and Climate: Framework for Public Policies (MDS, 2025)

Similarly, the Reference Framework for food systems and climate²⁴, launched by Brazil's Ministry of Social Development in October 2025, states that food consumption generates significant environmental impacts, such as greenhouse gas emissions and water and ecological footprints. Globally, animal-origin foods are the main ones responsible for such impacts. In Brazil, between 1987 and 2018, greenhouse gas emissions and water and ecological footprints increased by 21%, 22%, and 17%, respectively, with emphasis on the increase in consumption of ultra-processed meats. According to the analysis of Brazilian population consumption profiles in 2008–2009, diets with high red meat consumption (158 g/day) can generate almost double the impacts of a more balanced diet with less meat (50 g/day).

23. The Lancet (2025) *The EAT-Lancet Commission on healthy, sustainable, and just food systems*. <https://www.thelancet.com/commissions-do/EAT-2025>

24. MDS (2025) *Food Systems and Climate: Framework for Public Policies*. <https://www.gov.br/mds/pt-br/acoes-e-programas/promocao-da-alimentacao-adequada-e-saudavel/marco-de-referencia-sobre-sistemas-alimentares-e-clima-para-politicas-publicas>

Dietary Guidelines for the Brazilian Population (Ministry of Health, 2014)

The *Dietary Guidelines for the Brazilian Population*²⁵ establishes as a central recommendation that the basis of the diet be composed of fresh or minimally processed foods, prioritising plant-based ones in great variety. The document explains that opting for a diet rich in plants and with limited consumption of animal-origin foods implies a socially fairer food system with lower environmental impact. Specifically, reducing demand for animal-based products contributes significantly to decreasing greenhouse gas emissions, deforestation for pastures, and intensive water use. Conversely, the guide values and encourages the consumption of legumes (such as beans, an essential part of the Brazilian diet), as well as vegetables, greens, and fruits, highlighting them both as rich sources of fibres, vitamins, and minerals, and as excellent alternatives for preparing healthy and sustainable meals.

"[A] previous systematic review of the literature on environmental impacts associated with food [...] concluded that higher consumption of animal-based foods was associated with higher estimated environmental impacts, whereas increased consumption of plant-based foods was associated with estimated lower environmental impact. Assessment of individual foods within these broader categories showed that meat – sometimes specified as ruminant meat (mainly beef) – was consistently identified as the single food with the greatest impact on the environment [...].

"[T]here is significant potential mitigation (high confidence) arising from the adoption of diets in line with dietary recommendations made on the basis of health. These are broadly similar across most countries. These are typically capped at the number of calories and higher in plant-based foods, such as vegetables, fruits, whole grains, legumes, nuts and seeds, and lower in animal-sourced foods, fats and sugar. Such diets have the potential to be both more sustainable and healthier than alternative diets."

– Intergovernmental Panel on Climate Change (UN)²⁶

25. Ministry of Health (Brazil) (2015) Dietary Guidelines for the Brazilian Population. https://bvsmis.saude.gov.br/bvs/publicacoes/dietary_guidelines_brazilian_population.pdf.

26. Mbow, C., et al. (2019) 'Food Security.' In: *IPCC, Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems* [P.R. Shukla, et al. (eds.)]. <https://doi.org/10.1017/9781009157988.007>.

The transition from livestock to primarily horticulture-based agriculture, preferably in AFS, is not just a sustainability option but a structural necessity in the face of the climate crisis. Such a transition is fundamental not only as a just climate solution, contributing to mitigation and adaptation – it is also key for quality of life and income in the countryside. Furthermore, it contributes to a healthier and more resilient food system, with the production and supply of fresh and minimally processed foods, without pesticides. This increases food security in Brazil and helps meet the right to healthy and adequate food.

Family farming, in turn, is the means by which the transition from animal to plant, and from traditional agricultural models to agroecology and agroforestry, becomes viable. It is a productive segment, but above all a pillar of socioeconomic cohesion and national food security, contrasting with a context of vulnerability exacerbated by the climate crisis and institutional barriers.

FAMILY FARMING IN BRAZIL

The Structural Role of Family Farming in Brazilian Food Security and Socioeconomics

The relevance of family farming to the Brazilian social and economic fabric is undeniable, as demonstrated by agricultural censuses. This sector brings together the largest number of productive units in the country, standing out not only for the numerical scale of establishments but for its significant contribution to job generation.²⁷ This workforce extends beyond primary activity, encompassing occupations linked to agro-industrial and artisanal chains, both in the countryside and in urban areas.

Structurally, family farming is crucial for national food security. Its production is destined mainly for domestic consumption, directly supplying local and regional food and derivative distribution chains.²⁸

This domestic-market orientation gives the sector a strategic role in food sovereignty, ensuring the availability and diversity of essential foods for the Brazilian population.

It is estimated that family farming is responsible for 42% of food reaching Brazilian consumers' tables, according to studies matching production and consumption data.²⁹ It is important to highlight its servicing of the domestic market, and for the production of a vast variety of foods (in contrast to commodity production aimed at export).

27. IBGE, Agricultura Familiar, https://www.ibge.gov.br/apps/atlasrural/pdfs/11_00_Texto.pdf.

28. IBGE, Agricultura Familiar, https://www.ibge.gov.br/apps/atlasrural/pdfs/11_00_Texto.pdf.

29. José Bergamin (2023) *Who produces what we eat? An investigation into the origin of food production consumed in Brazil*.

COMPARISON OF BRAZILIAN CONSUMPTION OF FOOD ITEMS WITH THE PROPORTION CONTRIBUTED BY FAMILY FARMING

Food	Consumption Frequency (POF/IBGE) ³⁰	% of Family Farming Participation in Production Value (VP) ^{31,32}
Coffee	78,1%	33,8%
Rice	76,1%	11,6%
Beans	60,0%	25,0%
Cassava	4,0%	80,0%
Banana	14,7%	48,6%
Beef	38,2%	10,0%
Poultry (Chicken Meat)	30,8%	32,4%
Cow's Milk	6,5%	61,3% (Sales Value)
Chicken Eggs	13,9%	10,6% (Sales Value)



30. Refers to the percentage of the Brazilian population that reported consuming the food in the reference period of the Family Budget Survey (IBGE, 2018). This measures the presence of the food in the diet.

31. IBGE (Instituto Brasileiro de Geografia e Estatística (Brazilian Institute of Geography and Statistics)). See <https://www.ibge.gov.br/en/statistics/economic/agriculture-forestry-and-fishing/21929-2017-2017-censo-agropecuário-en.html> and data at <https://cdae.ufrr.br/projetos/projeto-ibge/sidra-banco-de-tabelas-estatisticas-do-ibge/>.

32. This percentage indicates the economic participation of family farming in the total Production Value (VP) of that item in Brazil. VP is the monetary value of all production, measured by the source in thousand reais (R\$1,000). In cases where VP was not available, Sales Value (the value actually marketed) was used.

? What is family farming?

In Brazil, family farming is defined by Law No. 11,326 of 2006,³³ giving it a different definition than in other countries. There the term relates more to ownership and management of the agricultural unit than to its size or purpose.

In Brazil, a family farmer and rural family entrepreneur is considered one who practices activities in rural areas and simultaneously meets the following requirements:

- Does not hold, under any title, an area larger than four fiscal modules.
- Predominantly uses the family's own labour in the economic activities of their establishment or enterprise.
- Has a minimum percentage of family income originating from economic activities of their establishment or enterprise, as defined by the Executive Branch (Wording given by Law No. 12,512 of 2011).
- Manages their establishment or enterprise with their family.

Challenges and Vulnerabilities

Despite its structural importance, family farming faces deep vulnerabilities that limit its capacity for adaptation and transition to more sustainable models such as AFS. Populations dependent on family or subsistence farming are classified among the most susceptible to the impacts from a shifting climate,³⁴ highlighting the need for institutional strengthening and improvements in social and economic conditions.

The main impediment lies in institutional and financial barriers. Access to credit, notably via the National Program for Strengthening Family Farming (Pronaf), needs to be better distributed, preventing farmers in greater social vulnerability from facing

the biggest bureaucratic obstacles.³⁵ Bank agents often find it difficult to deal with the diversity of family farming, whose processes and projects (especially agroecological or non-conventional ones) clash with traditional financial spreadsheets.

Data also show the high number of Pronaf operations going to livestock activities: despite recommendations to reduce consumption and production of animal-origin foods and their known impact on the environment, livestock receives nearly as much as agriculture. And in 2024 and 2025, the total value of Pronaf operations destined for livestock and agriculture was the same.³⁶

33. For the text of the law: https://www.planalto.gov.br/ccivil_03/ato2004-2006/2006/lei/l11326.htm.

34. Lindoso, D., et al. (2009) *Vulnerabilidade socioeconômica da agricultura familiar Brasileira às mudanças climáticas: O desafio da avaliação de realidades complexas*. IPEA. https://portalantigo.ipea.gov.br/agencia/images/stories/PDFs/boletim_regional/101129_boletimregional4_cap3.pdf.

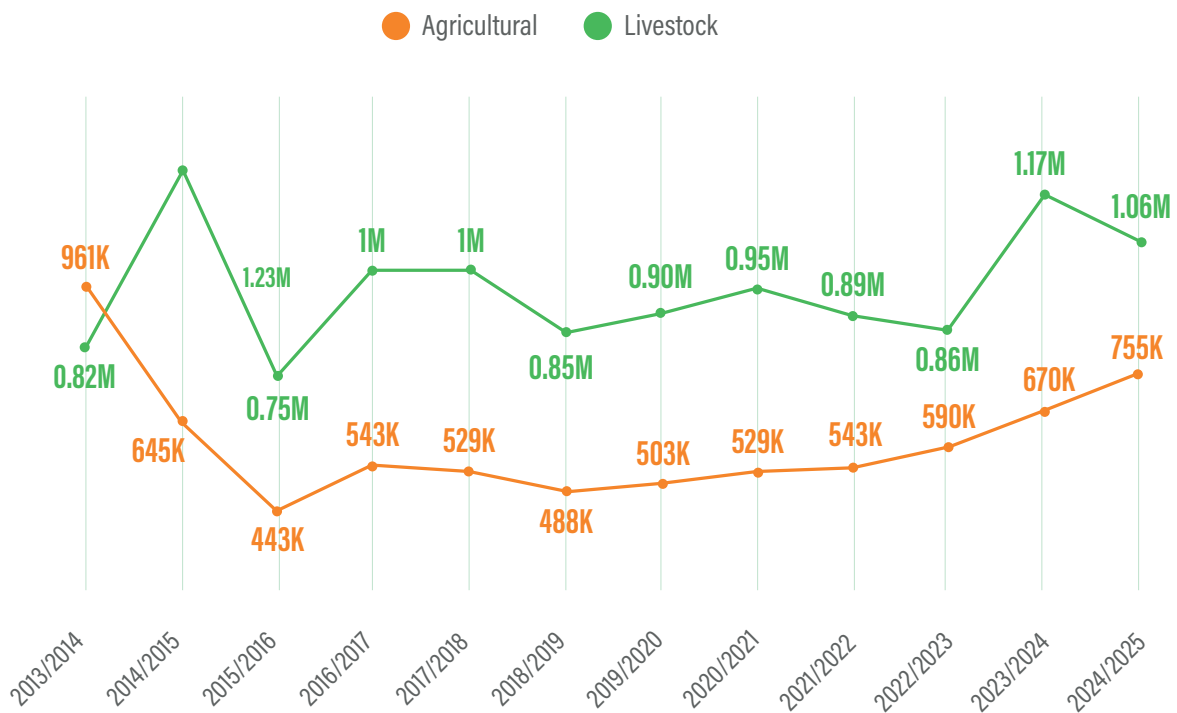
35. Lindoso, D., et al. (2009).

36. Pronaf (n.d.) *Quantidade de Operações*. <https://app.powerbi.com/view?r=eyJrljoiMTI2ZmRmNjktYzYyY0Y0YTM2LWEzNWZGRiZWQwNmUzMWVliiwidCI6IjZjZmZlTE3ZWItNDM1OC1hNjY1LTVjYTViZGZlZjBjMiJ9>.

This misalignment of Pronaf investments is not just a resource-allocation issue but a strategic one too: if public policy seeks sustainability and population health, food production incentives should align with consumption recommendations. Diet models aligned with these goals, such as the Planetary Health Diet (EAT-Lancet),³⁷ recommend a diet's foundation be plant-based, with approximately 88% of calories from plants and a maximum of 12.2% from animal origin.

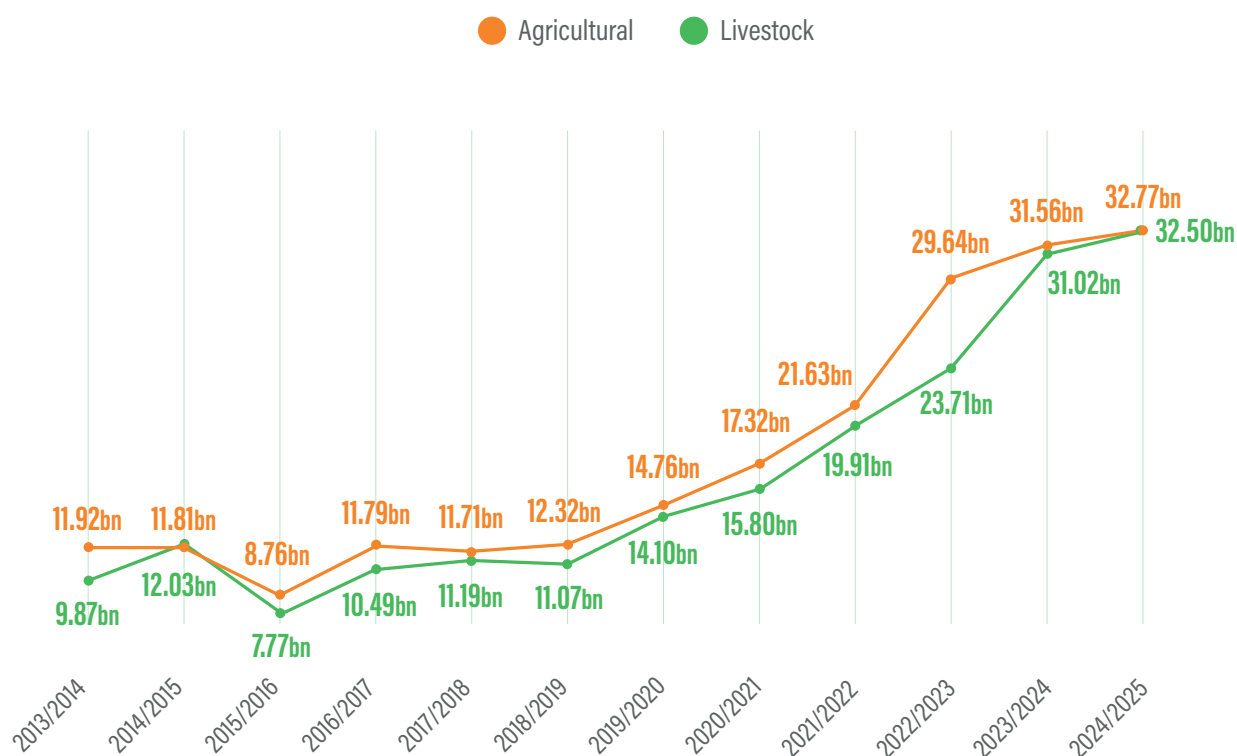
By encouraging livestock operations to the detriment of plant food production, credit policy moves in the opposite direction of this goal. For Brazil to advance towards a resilient and healthy food system, it is imperative that public investment reorient its priorities, majorly fostering plant production systems, primarily AFS, which are the true basis of food security and climate mitigation.

NUMBER OF PRONAF OPERATIONS PER YEAR³⁶



37. The Lancet (2019).

VOLUME OF PRONAF OPERATIONS PER YEAR³⁶



Family Farming, Agroecology, and Shifts in the Climate

Shifts in the climate will pose significant challenges for family farming, intensifying the socioeconomic vulnerability of millions of producers who are the basis of food production in the country.

A recent survey of more than 500 agroecology participants across the country corroborates this perception.³⁸ The study revealed that, for the mapped initiatives, the changing climate has already led to decreased production (56.3%) and to food loss (48.1%). Additionally, 73.4% of participants perceived increased temperature and 70.8% identified changes in rainfall calendars – impacts that, for 66% of groups, became more evident in the last 10 years.

The irregularity and intensity of extreme climate events already cause crop losses and reduce productivity in almost all regions of Brazil, with family farmer productivity being more sensitive to shifts in the climate. Projections indicate that subsistence crops essential for food security – such as corn, beans, and cassava – are among the most vulnerable, while big ag commodities like sugarcane and soya may even gain productivity in the main producing regions.³⁹

38. Agroecology, Territory, and Climate Justice, 2025. National Agroecology Articulation (ANA).

39. Tanure, T.M.d.P. (2020) *Mudanças climáticas e agricultura no Brasil: impactos econômicos regionais e por cultivo familiar e patronal*. <https://repositorio.ufmg.br/items/b6bc21fc-ba7e-427a-af5b-62176431ef1e>.

Long-term analyses (2050–2080) suggest that the North and Northeast regions will be negatively affected economically, the Midwest and Southeast will suffer moderate impacts, and the South will mostly benefit. The national GDP would experience, however, a small retraction, with the drop being softened by

economic growth in São Paulo, Paraná, and Rio Grande do Sul. The drop in growth in other states could contribute to increased intra-regional disparities and deterioration of food security conditions in Brazil, as it would negatively affect less developed regions and crops relevant to family farmers.⁴⁰



Despite high vulnerability, family farming is also one of the main strategies for climate resilience and adaptation – especially when anchored in AFS and other agroecological practices. AFS promote productive diversification and ecological restoration, constituting sustainable land use forms⁴¹ and a transversal, interconnected approach contrasting with the sectoral and productivist view dominating traditional credit and technical assistance.

Regarding mitigation, by involving more biomass than conventional agriculture, these systems can store more carbon in plants and soils. Compared to livestock, they emit lower levels of methane and N₂O emissions, and require a smaller area to produce

more food and generate more income – contributing significantly less to deforestation, which is currently Brazil's largest emissions source.

In terms of ecological resilience and adaptation, AFS strengthen food production systems, making them more robust against climate shocks. The use of locally adapted varieties and the presence of diverse species in the same system allows cultivation to adapt to a range of climate conditions⁴² such as fires, droughts, or storms.

This resilience manifests in several ways. First, the shade provided by trees creates a microclimate protecting crops from high temperature fluctuations.

40. Tanure, T.M.d.P. (2020).

41. European Parliamentary Research Service (EPRS), 2020. Agroforestry in the European Union.

42. Vilanova, C., et al. (2023) 'Agroecologia e resiliência às mudanças climáticas: Fundamentos e práticas o desenvolvimento territorial do semiárido Brasileiro'. In: *Transição agroecológica e territorialidades: concepções, experiências e desafios* (pp.44-67). <https://doi.org/10.22533/at.ed.0332305093>.

Trees can also serve as an alternative income source in case of harvest losses due to climate events.⁴³ Specifically regarding drought, resistance is reinforced by soil management: adding crop residues or organic compounds and using cover crops or green manures increase soil organic matter content and decrease water evaporation, increasing soil water retention capacity.⁴⁴

Field research indicates that agroecological-based productive systems using polycultures and soil

management demonstrate greater yield stability and lower production drops under drought conditions than monocultures in, for example, Brazil's semi-arid Northeast region, where shifts in the climate will affect food production most severely.⁴⁵



Climate Adaptation in Agroforestry Systems

- Greater adaptability through use of local varieties and crop diversity;
- Tree shade reduces temperature fluctuations;
- Trees composing agroforestry can serve as income source in case of crop loss;
- Use of compounds, fertilisers, and plant cover increase soil water retention.

By combining agricultural activities with tree species conservation, AFS create habitats and ecological corridors, helping preserve critical biodiversity for local fauna and flora. Transitioning to horticulture-based AFS is, therefore, the logical and sustainable answer to increase productivity, ensure biodiversity, and carbon storage in already deforested areas.

The change also has profound implications for social justice. Transitioning to AFS and supporting family

farming promotes income generation diversification, fosters employment, and can decrease rural migration. Unlike the livestock model, where economic gain is intrinsically linked to climate cost, the horticulture-based system in AFS creates a virtuous cycle of co-benefits (health, climate, employment, and biodiversity).

43. Vilanova, C., et al. (2023).

44. Vilanova, C., et al. (2023).

45. Vilanova, C., et al. (2023).

In terms of public health, local and diversified vegetable production promoted by agroecology ensures better quality and traceable food, strengthening nutrition and food security.

For climate benefits to be maximised, it is imperative that fostering the expansion of these viable systems also includes large rural properties, overcoming the predominance of monocultures and livestock production.

STUDY RESULTS: TRANSITION ANALYSIS

Income Potential and Economic Viability

Analysis by ProVeg Brazil and the Organization for Cooperation on Agroecology (OCA) shows that, based on a meta-analysis of Brazilian studies and hectare budget modelling, it is plausible to increase income by, on average, 110% (minimum 60%, maximum 230% in net income per hectare at maturity, year 5+) when

migrating from extensive livestock farming on low-productivity pastures to diversified 100% horticulture-based agroforestry systems (AFS).⁴⁶ That is, horticulture-based agroforests can more than double the family producer's income compared to some types of livestock farming.

"Horticulture-based agroforests can more than double the family producer's income compared to some types of livestock farming"

In low-productivity areas – for example, due to degraded pasture – transitioning from beef cattle farming to exceptional horticulture-based AFS (biodiverse plant AFS, with high income due to special market access, high-priced products, premiums, payments for environmental services

(PES), and others) can bring an income increase of +1,525% (from R\$800 to R\$13,000/ha/year). Similarly, transitioning from low-productivity dairy farming to exceptional horticulture-based AFS can bring an income increase of +420% (from R\$2,500 to R\$13,000/ha/year).

⁴⁶ These data consider the average gains of livestock farming (e.g., with healthy pasture) versus a mature AFS (after the implementation period), and exclude from the analysis exceptional cases such as extremely high-profitability AFS and low-productivity livestock farming.



110%

Average income increase from productive extensive beef cattle to horticulture-based AFS (healthy pasture and mature AFS)

1,525%

Income increase from low-productivity beef cattle (e.g., degraded pastures) to biodiverse horticulture-based AFS with high income and special market access (exceptional cases)

420%

Income increase from low-efficiency dairy farming to exceptional horticulture-based AFS

COMPARISON OF INCOME FROM DIFFERENT FARMING ACTIVITIES

Activity	Income per hectare ⁴⁷
Beef cattle (extensive)	R\$500–1,500/ha/year (varies by region)
Dairy (intensified pasture)	R\$10,000–14,000/ha/year; margin ~R\$1,500–3,500/ha/year (strong seasonality)
Poultry	Data not available ⁴⁸
Swine	Data not available ⁴⁹
Mature food AFS (Pará/Amazon and Southeast; açai, cacao, banana, regional fruits, and vegetables mix)	R\$20,000–40,000/ha/year; margin ~R\$8,000–20,000/ha/year 20,000/ha/year

⁴⁷. Calculation made by combining typical yields per hectare, average prices 2021–2023 (CEPEA/Hortifruti Brasil (<https://www.hfbrasil.org.br/br/banco-de-dados-precos-medios-dos-hortifruticolas.aspx>); IBGE (<https://cbae.ufri.br/projetos/projeto-ibge/sidra-banco-de-tabelas-estatisticas-do-ibge/>); CONAB (<https://portaldeinformacoes.conab.gov.br/produtos-360.html>)), and technical budgets (Embrapa (<https://geoinfo.dados.embrapa.br/metadados/srv/por/catalog.search#/home>); Emater (regional portals, e.g. <https://www.emater.mg.gov.br/>); CEPLAC (<https://www.gov.br/agricultura/pt-br/assuntos/ceplac>); ICRAF (<https://www.landscapealliance.org/knowledge/dataset/4898E4/>)) to obtain revenue and costs per system.

⁴⁸. For poultry and swine, the comparison requires reconfiguration of the productive unit; there is no direct equivalence per hectare.

⁴⁹. For poultry and swine, the comparison requires reconfiguration of the productive unit; there is no direct equivalence per hectare

Transition Scenarios

Scenario A: Producer migrating from extensive beef cattle on low-productivity pasture to AFS diversified with perennial fruit trees and annuals

- Years 0–2: Baseline net income: R\$300–700/ha/year
- Year 1–2: R\$500–1,500/ha/year (annuals + soil subsidies; may break even with baseline)
- Year 3–4: R\$2,500–6,000/ha/year
- Year 5+: R\$5,000–12,000/ha/year.
- Median percentage increase year 5+: ~110% (IQR 60–230%) vs. baseline; typical payback 3–6 years⁵⁰

Scenario B: Producer migrating from family dairy production to AFS with fruit and condiments

- Average gains of 50–120% in net income per hectare in year 5+, with greater dependence on market access and refrigerated logistics vs. minimally processed fruits
- Reduction of indebtedness risk⁵¹

Scenario C: Producer migrating from poultry/swine to AFS

Comparison must be made by total productive unit, as poultry and swine are feed/capital intensive and not land intensive. Reallocating support area (corn/soya/pasture) to AFS and ending livestock production sees:

- Drop in cash volatility (exposure to corn/soya and health)
- Equivalent Annual Annuity (EAA) similar in year 3 and higher in year 5 in projects with established sales channels
- Median gains of 30–90% per productive unit⁵²

50. Buttoud, G. (2013) *Advancing Agroforestry on the Policy Agenda: A guide for decision-makers*. FAO; Nair, P., & Garrity, D. (Eds.) (2012). *Agroforestry—The Future of Global Land Use* (Vol. 9, pp. 391–428). Springer, Dordrecht. https://doi.org/10.1007/978-94-007-4676-3_20; Miccolis, A., et al. (2016) *Restoration through Agroforestry: Options for Reconciling Livelihoods with Conservation in the Cerrado and Caatinga Biomes in Brazil*. ICRAF & IEB; Schroth, G., et al. (2015) *Contribution of agroforests to landscape carbon storage. Mitigation and Adaptation Strategies for Global Change* 20(7), 1175–1190. <https://doi.org/10.1007/s11027-014-9541-0>; Porro, R., et al. (2012) *Agroforestry in the Amazon Region: A Pathway for Balancing Conservation and Development*. In Nair & Garrity (2012).

51. CEPEA Milk (<https://www.cepea.esalq.usp.br/br/indicador/leite.aspx>); FAO (2015) *Agroforestry for landscape restoration: Exploring the potential of agroforestry to enhance the resilience of degraded landscapes*; Miccolis, A., et al. (2016).

52. Buttoud, G. (2013); *Embrapa Swine and Poultry* (see <https://www.embrapa.br/web/suinos-e-aves/cias>); Nair & Garrity (2012).

Income Comparison by Biome

Income increase from transitioning to horticulture-based AFS occurs in all evaluated scenarios, crossing different types of livestock production (extensive beef cattle, semi-extensive dairy, and poultry/swine for meat were evaluated) and plant crops (crops with highest economic potential

were chosen for each Brazilian biome). That is, horticulture-based agroforests proved more promising than any type of livestock farming in all Brazilian biomes when evaluating the potential income increase for the producer.

Horticulture-based agroforests proved more promising than any type of livestock farming in all Brazilian biomes when evaluating the potential income increase for the producer.

The largest income increases were observed when starting from extensive beef cattle farming, which can result in a 900% and 1,000% income increase in Caatinga and Pantanal, respectively. Starting from beef cattle, in all biomes, producer income would at least double when transitioning to horticulture-based agroforests.

A transition from dairy farming presents a minimum income increase of 50% in Atlantic Forest and Pampa, reaching up to 240% in Pantanal and Caatinga.

More modest income increases were found in the poultry and swine transition, yet even in these scenarios, the transition can represent an income increase of up to 180% in biomes like Amazon and Caatinga, with a minimum increase of 20% (Pampa).



GEOGRAPHICAL COMPARISON OF OPTIMAL AFS DESIGN, WITH PROFITABILITY DIFFERENCES TO ANIMAL-BASED SYSTEMS

Amazon

AFS Design

Açaí + cacao + banana;
vegetables in early stages

Net Profitability

R\$18,000–35,000/ha/year

Increase from Beef Cattle (extensive)

+150% to +400%

Increase from Semi-extensive Dairy

+80% to +220%

Increase from Poultry/Swine (per equivalent ha)⁵³

+60% to +180%

Caatinga

AFS Design

Vegetables + banana + regional
fruits (cashew, umbu, palm,
gliricidia, cassava, millet).
No heavy irrigation.

Net Profitability

R\$16,000–30,000/ha/year

Increase from Beef Cattle (extensive)

+250% to +900%

Increase from Semi- extensive Dairy

+60% to +240%

Increase from Poultry/Swine (per equivalent ha)⁵³

+30% to +180%

Pantanal

AFS Design

Irrigated horticulture + banana +
regional fruits (baru, pequi)

Net Profitability

R\$16,000–34,000/ha/year

Increase from Beef Cattle (extensive)

+300% to +1.000%

Increase from Semi-extensive Dairy

+60% to +240%

Increase from Poultry/Swine (per equivalent ha)⁵³

+30% to +150%

Cerrado

AFS Design

Coffee + banana + vegetables
+ native crops

Net Profitability

R\$18,000–38,000/ha/year

Increase from Beef Cattle (extensive)

+100% to +250%

Increase from Semi-extensive Dairy

+60% to +180%

Increase from Poultry/Swine (per equivalent ha)⁵³

+30% to +100%

Pampa

AFS Design

Grape/apple + vegetables +
coffee/banana in microclimates

Net Profitability

R\$18,000–36,000/ha/year

Increase from Beef Cattle (extensive)

+250% to +700%

Increase from Semi-extensive Dairy

+50% to +200%

Increase from Poultry/Swine (per equivalent ha)⁵³

+20% to +120%

Atlantic Forest

AFS Design

Cacao/coffee + banana
+ vegetables

Net Profitability

R\$15,000–32,000/ha/year

Increase from Beef Cattle (extensive)

+120% to +300%

Increase from Semi-extensive Dairy

+50% to +180%

Increase from Poultry/Swine (per equivalent ha)⁵³

+40% to +150%

53. For territorial comparability, we converted farms to "equivalent feed hectare": $\text{area_eq} = (\text{corn/soy feed consumed} \div \text{local corn/soy productivity}) + \text{physical area}$. The margin per hectare is then the farm's annual margin divided by area_eq . Sources of parameters: Embrapa Swine and Poultry (see <https://www.embrapa.br/web/suinos-e-aves/cias>); CONAB; CEPEA; regional integration data.

Where is the greatest gain?

Areas with degraded pastures, good logistics for differentiated markets, and continuous technical assistance. AFS with high-value perennial species (cacao, açai, quality coffee, nuts, Amazonian/Atlantic fruits) give the best results.

Where is the gain smaller or requires more time?

Regions with logistical bottlenecks, low market density, or when seeking to replace income from intensive systems (e.g., integrated swine) without commercial planning. In these cases, income surpasses baseline after 4–6 years and depends on integration with institutional purchases (PNAE, PAA)⁵⁴ and cooperatives.

Main Manageable Risks

- Seedling mortality due to drought/compacted soils.
- Pests in fruit trees without ecological management.
- Commercialisation failures.

Risk Mitigation

- Successional agroforestry design.
- Rescue irrigation.
- Adapted clones.
- Contracts with cooperatives and PNAE/PAA.

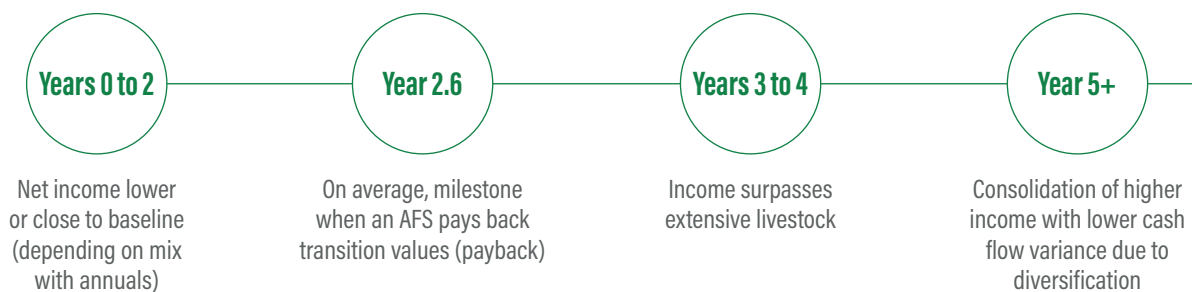
⁵⁴ PNAE and PAA refer to the National School Feeding Program and the Food Acquisition Program, respectively. These are Brazilian institutional procurement policies that mandate or prioritise the purchase of food from family farmers to supply public schools, hospitals, and food assistance networks, providing a stable market for agroforestry products.

Generally, it is expected that in the initial transition years, net income will be close to or lower than the baseline income obtained from livestock. At this stage, intercropping with short-term crops like banana, cassava, and vegetables can generate income more immediately and smooth cash flow.

This scenario is reversed in years 3 and 4, when plant income surpasses livestock. From year 5, when the AFS matures, income increase reaches its full potential.

It is estimated that an AFS, upon reaching its stable productive phase, pays back transition values, on average, in 2.6 years (investment return period/ payback). Investments (capital expenditure), calculated at 32,000/ha,⁵⁵ involve area preparation (subsoiling, correction), fencing, temporary shading, planting fertilisation, perennial/semi-perennial seedlings, intercropping with cover annuals, initial inputs, implementation labour for one or two crops, and technical assistance.

PROFITABILITY VS. TRANSITION DURATION⁵⁶



AFS transcend their productive role by becoming active platforms for generating ecosystem services, opening a new revenue frontier for producers through PES. PES is direct remuneration to the producer for the benefits their practices generate for society, which can include native vegetation conservation, degraded area

restoration, water quality improvement, biodiversity conservation, and, notably, carbon removal from the atmosphere.⁵⁷

Thus, there is also the possibility for AFS to increase their revenue through other sources.

AFS REVENUE POTENTIAL FROM ALTERNATIVE SOURCES



⁵⁵ The real value varies significantly by biome, AFS design, planting density, access to seedlings, mechanisation, irrigation, and post-harvest infrastructure.

⁵⁶ Buttoud, G. (2013); Nair & Garrity (2012).

⁵⁷ WRI Brasil (2021) *Como funciona o pagamento por serviços ambientais a quem protege e restaura florestas*. <https://www.wribrasil.org.br/noticias/como-funciona-o-pagamento-por-servicos-ambientais-quem-protege-e-restaura-florestas>.

Besides income-increase potential, transitioning from livestock to horticulture-based AFS brings other advantages to the producer:

FURTHER POTENTIAL BENEFITS TO AFS PRODUCERS

Cost Reduction

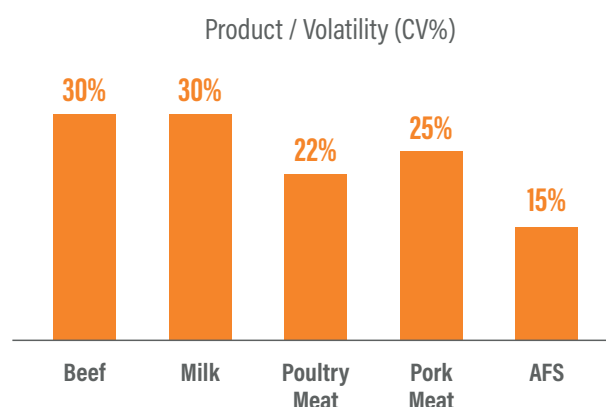
Mature AFS reduce spending on inputs (fertilisers, concentrates, pesticides) via green manuring, nutrient cycling, and shading – decreasing variable costs by 20–40% compared to comparable monocultures and intensified livestock systems.⁵⁸

Non-monetary Benefits

- Food security for the family and its community due to greater diversity of produced food.
- Autonomy, mental health/wellbeing due to increased autonomy and reduced indebtedness.⁶⁰
- Ecosystem services (shading, water, pollinators) with climate co-benefits.⁶¹
- Agroforestry activities open value-addition and rural entrepreneurship opportunities for women and youth, avoiding the rural exodus.

Volatility and Risk

Horticulture-based AFS offer lower volatility, i.e., revenue fluctuations from one year to another, which is a risk for the producer: while in beef and dairy cattle annual revenue variation coefficient is about 30%, in AFS this number drops to 15%.



Temporal and spatial diversification reduces losses from climate and price, stabilising income and labour throughout the year.⁵⁹ Additionally, transitioning to plant production cuts exposure to feed shocks and mitigates stranded asset risk of animal chains facing climate and deforestation regulations.

⁵⁸ Buttoud, G. (2013); Miccolis, A., et al. (2016).

⁵⁹ Torralba, M. et al. (2016) *Do European agroforestry systems enhance biodiversity and ecosystem services? A meta-analysis*. Agriculture, Ecosystems & Environment 230, 150–161.

⁶⁰ Buttoud, G. (2013); IPCC (2019) *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems* [P.R. Shukla, et al. (eds.)]; Torralba, M., et al. (2016).

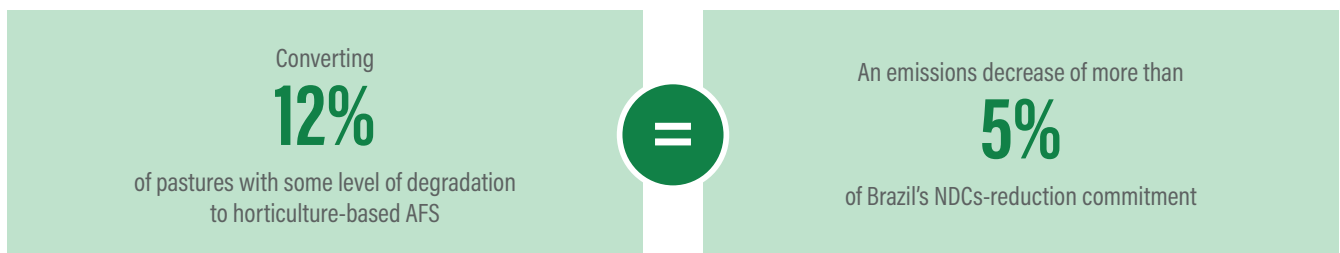
⁶¹ Nair & Garrity (2012); FAO (2015).

Environmental, Climate, and Social Impacts and Benefits

Regarding greenhouse gas emissions, horticulture-based AFS present clear advantages, such as lower methane and N₂O emissions compared to livestock. Besides emitting lower levels of greenhouse gases, they also sequester and store gases from the atmosphere, making the area a net carbon sink.

In Brazil, between 45% and 55% of pastures present some degree of degradation in technical evaluations (a low-productivity indicator)⁶², creating an immediate opportunity for conversion to AFS. If 13 million hectares,⁶³ or 12% of pastures with some level of degradation, were converted from livestock to horticulture-based AFS, this would avoid the accumulation of 88 MtCO₂e of emissions by 2035.

Brazil's Nationally Determined Contributions (NDCs) establish emission reduction targets for 2035, referencing total net emissions from 2005. The document proposes two scenarios: a conservative one, aiming for a 59% reduction (a total cut of 1,511.2 MtCO₂e), and an ideal one, of 67% (cut of 1,711.2 MtCO₂e).⁶⁴ The reduction of 88 MtCO₂e (88,000 ktCO₂e) accumulated by 2035 through converting pastures to horticulture-based AFS would represent 5.82% of the national mitigation target in the conservative scenario and 5.14% in the ideal scenario. This contribution could be significantly higher if the carbon sequestration typical of AFS is accounted for.



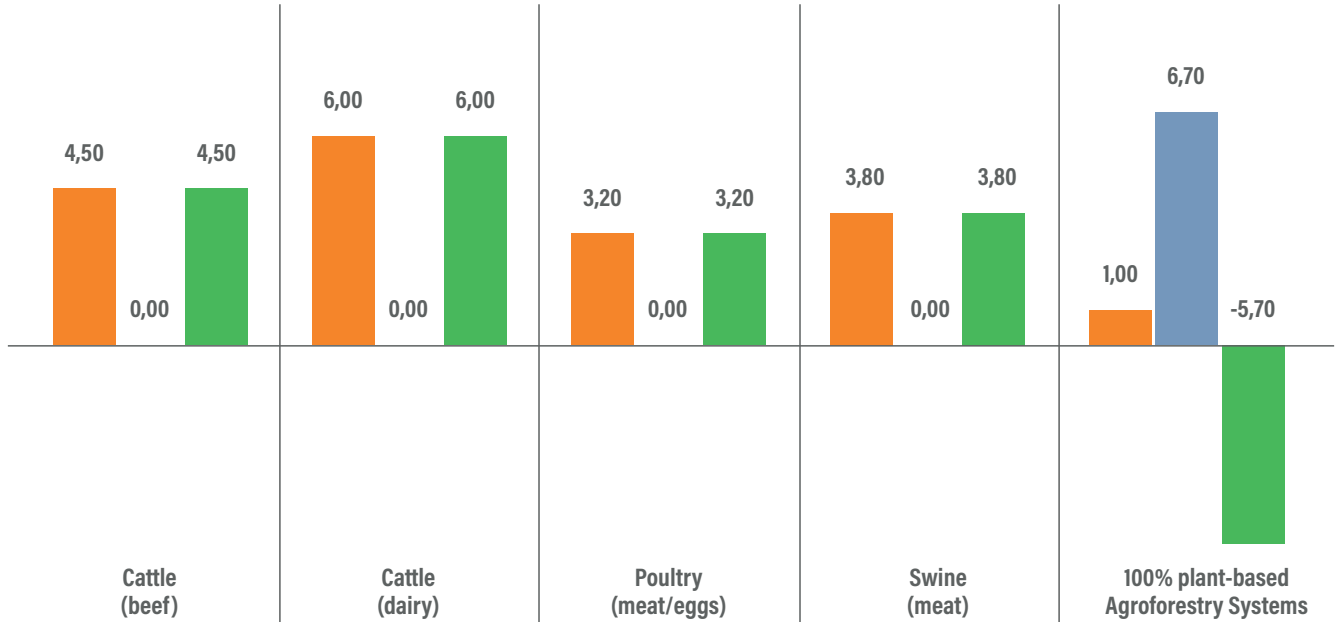
⁶². MapBiomass et al. (2022).

⁶³. 13 million is a threshold that balances (a) the technical potential for substitution, (b) the available credit/technical assistance capacity, (c) the viability of restoration/PES, and (d) the requirement to maintain food production stable during the transition, considering the 109.7 million hectares of pasture with some level of degradation estimated to exist in Brazil (Bolfe, É.L., et al. (2024) *Potential for Agricultural Expansion in Degraded Pasture Lands in Brazil Based on Geospatial Databases*. Land 13, 200. <https://doi.org/10.3390/land13020200>).

⁶⁴. The Brazilian Government. Brazil's NDC National determination to contribute and transform. https://unfccc.int/sites/default/files/2024-11/Brazil_Second%20Nationally%20Determined%20Contribution%20%28NDC%29_November2024.pdf

GHG EMISSIONS PER HECTARE: LIVESTOCK VS. AFS

● Gross emissions tCO₂e/ha/year
 ● Sequestration tCO₂e/ha/year
 ● Net balance tCO₂e/ha/year

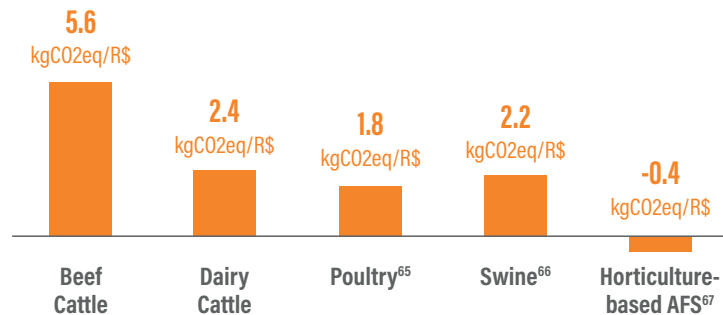


Since horticulture-based agroforests are more profitable than livestock and simultaneously emit lower levels of greenhouse gases, this results in substantially negative emissions per real (£\$) earned. That is, the increase of producer income in horticulture-based AFS is associated with negative emissions of the gases that contribute to shifts in the climate.

For every real earned by the producer, a horticulture-based AFS emits –0.4 kgCO₂eq (i.e., captures more than it emits), whereas beef cattle farming emits 5.6 kgCO₂eq. Even livestock with the lowest carbon footprint (broiler poultry) emits substantially more per real earned than horticulture-based AFS (1.8 kgCO₂eq).

GREENHOUSE GAS (GHG) EMISSIONS OF DIFFERENT ACTIVITIES

per real (R\$) of margin

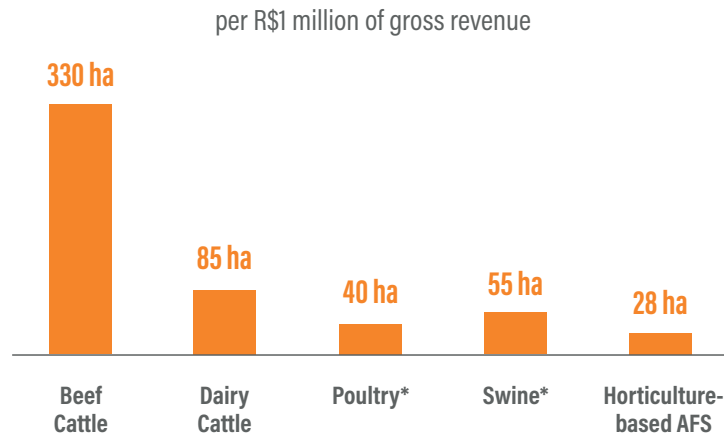


65. A form of land use accounting that attributes to livestock production the agricultural area needed, wherever it is, to produce the corn and soy consumed as feed. In the case of poultry and swine, the farm's 'direct' area is small, but production depends on feed. We internalised the 'equivalent feed area' by calculating how many hectares of corn and soy are needed, with average CONAB productivities, to produce the feed consumed.

Similarly, to obtain the same amount of gross revenue, horticulture-based AFS need 12 times less land than beef cattle and three times less land than swine

production. By transitioning, land area is freed up for restoration, payments for environmental services, and bioeconomy.

LAND USE OF DIFFERENT FARMING ACTIVITIES



*Accounting for indirect feed area.

Besides having lower environmental and climate impact, transitioning to plant production has important social impacts. The first is the contribution to food security through land use efficiency: beef cattle farming, which currently occupies the majority of agricultural land in Brazil, is the least efficient form of producing protein per hectare.

In a direct comparison, soya production (monoculture) could increase protein production per hectare by 80 times compared to beef cattle, while horticulture-based agroforests have the potential to increase this value by 30 times.

66. See note 64.

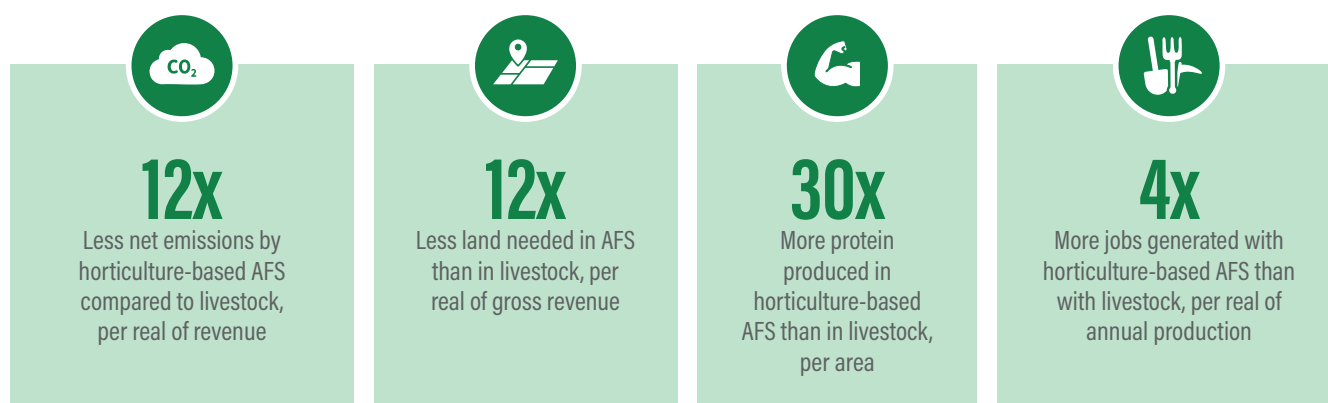
67. Perennial agroforestry arrangement with 2 to 4 main plant species and support species (fertilisers/shading). Plausible interval for well-managed AFS without heavy industrial post-harvest based on data and case studies from Embrapa, CEPLAC, Emater, and ICRAF.

PROTEIN PRODUCTION OF DIFFERENT FARMING ACTIVITIES, BY LAND AREA

Activity	Protein produced per hectare
Beef Meat	0.016 t/ha/year
Soya (non-AFS) ⁶⁸	1.30–1.37 t/ha/year
Corn (non-AFS) ⁶⁹	0.45–0.54 t/ha/year
Beans (non-AFS) ⁷⁰	0.24–0.29 t/ha/year
Food AFS (açai-cacao-banana intercropped with food legumes)	0.5 t/ha/year of equivalent plant protein (conservative estimates)

However, the transition impact goes beyond mere protein efficiency, focusing also on the nutritional quality and diversity of what is produced, and consequently consumed, and its contribution to food sovereignty. This change is crucial for adherence to diets rich in vegetables aligned with major global public health recommendations, like the Dietary Guidelines for the Brazilian Population and that of the EAT-Lancet Commission, which point to increased consumption of fresh and minimally processed vegetables as fundamental to prevent chronic non-communicable diseases.

Finally, this transition has the potential to alter the very social and economic structure of the countryside. Extensive livestock farming is characterised by low labour needs and high land concentration. In direct contrast, the job generation potential of horticulture-based agroforests is massive: for every R\$1 million of annual production in these systems, 30 direct jobs are generated, whereas in livestock, on average, the same investment results in only 7.⁷¹ Transitioning from livestock to horticulture-based AFS is, therefore, an opportunity to encourage just transition, local qualification, and income retention in rural areas.



68. CONAB (crop series 2022/23 and 2023/24).

69. CONAB (crop series 2022/23 and 2023/24).

70. CONAB (crop series 2022/23 and 2023/24).

71. Calculations made based on (i) employment multipliers per real of production/value added from the Input-Output Matrix (IBGE/IPEA) and (ii) labor coefficients per hectare from the 2017 Agricultural Census and technical budgets of crops/AFSs.

PUBLIC POLICIES TO INCENTIVISE TRANSITION

Transitioning to agroforestry systems (AFS), although ecologically robust and socially beneficial, is still hampered by lack of information, adverse policies, legal restrictions, and lack of coordination between government and financial sectors. Thus, the political and institutional context plays a crucial role in developing these systems.⁷² More important

than simply creating regulations, public policy must function as a set of tools to create favourable conditions for transition. Success depends on access to information, Technical Assistance and Rural Extension (ATER), adequate technologies, partnerships, incentives (like payments for environmental services (PES)), and financing.

Financial and Market Incentives

Adequate and specific financing and incentives for transitioning from livestock to horticulture-based AFS is fundamental for its scalability, without which this

strategy will not reach sufficient amplitude to become a climate solution.

Adequate and specific financing and incentives for transitioning from livestock to horticulture-based AFS is fundamental for its scalability, without which this strategy will not reach sufficient amplitude to become a climate solution.

Recent analysis shows that 443 billion dollars annually in climate finance are needed to support family farmers in adapting to global warming impacts.⁷³ This value is less than the 470 billion dollars annually spent on agricultural subsidies harmful to the planet and people. Meanwhile, the current financial flow to family farmers represents only 0.36% of what is needed.

Adopting AFS faces a central barrier: financial return can be slow for farmers depending on

production for their income, creating an investment gap that discourages the producer. Necessary incentives can range from tax exemptions and microcredit to, crucially, long-term credit lines, essential to cover the period until the system becomes profitable. Furthermore, policy must be designed to strengthen farmers' access to forest product markets, as profitability guarantees adoption.⁷⁴

72. Buttoud, G. (2013).

73. Family Farmers for Climate Action (2025) *Feeding the world in a changing climate: Adaptation finance needs of small-scale producers*. https://familyfarmersclimateaction.org/wp-content/uploads/2025/10/FINAL_Feeding_the_world_report_EN.pdf.

74. Buttoud, G. (2013).

Financial and Market Incentives

Policy/Action Recommendations to Leverage Transition to Horticulture-based Agroforests

- Create specific credit lines to incentivise transition to 100% horticulture-based AFS with a minimum grace period of 24–36 months, an 8–12-year term, and equalised interest (combining Pronaf/ABC+ and state funds), for family and patronal agriculture.
- Provide incentives to producers, structuring payments for environmental services (PES) with remuneration for carbon, water, and biodiversity and long-term credit to compensate them for the initial ‘investment gap’
- Strengthen market access, removing political barriers, creating a fair competition environment, and involving producer organisations in negotiations.
- Price guarantees and public purchases: expand PNAE and PAA to absorb AFS mix; specific targets for regional fruits / native crops and stimulus for plant-based nutrition (planetary diet) in public institutions..
- Strengthen cooperatives and regional cold storage hubs, processing, and reverse logistics for packaging.
- Introduce quality seals and awards (organic, socio-biodiversity, geographical indication).

Governance and Institutional Engagement

Reformulating legal frameworks and governance is one of the most critical action axes, as the biggest barriers to AFS adoption are often institutional. Outdated laws, for example, can stall transition: environmental agencies are often seen as obstacles due to excessive bureaucracy and restrictions imposed on forest management.⁷⁵ This regulatory failure extends to markets, where a lack of certification and regulation for agroforestry products hinders competition with conventional products.

In parallel, farmers face challenges obtaining adequate financing and technical assistance, rarely adapted to AFS.⁷⁶ An effective public policy must, therefore, revise this entire adverse context and, fundamentally, ensure land tenure, a crucial factor for stimulating long-term investment in the countryside.⁷⁷

⁷⁵ Ribeiro, J.C.P. (2022) *Aspectos determinantes para a adoção de sistemas agroflorestais no Brasil: Revisão sistemática e metanálise*. MSc Thesis. <https://locus.ufv.br/items/2bbca75e-9d01-4b99-9cd1-03358ff5a411>.

⁷⁶ Ribeiro, J.C.P. (2022).

⁷⁷ Buttoud, G. (2013).

Governance and Institutional Engagement

Policy/Action Recommendations to Leverage Transition to Horticulture-based Agroforests

- Create effective coordination between ministries (Agriculture, Environment, etc.) to avoid conflicting policies and implement a clear political strategy.
- Ensure good governance and correct law implementation, as weak legal structures make illegal practices (like deforestation) more attractive than AFS.
- Develop 'bottom-up' policies, based on real farmer needs and traditional knowledge.
- Articulate coalitions: state/municipal governments, public banks, cooperatives, and technical organisations to scale regional pilots.
- Reform laws and regulations restricting agroforestry development, especially those regarding financial mechanisms.
- Integrate agroforestry into agricultural policies, overcoming traditional separation (agriculture/forest) and focusing on environmental conservation, economic performance, and social equity (e.g., via tax reform).

Strengthening Research, Extension Services, and Knowledge Diffusion

Finally, the third axis is strengthening research and extension services (ATER)⁷⁸, as the complexity of AFS is itself an adoption barrier. Implementing and maintaining agroforests requires the producer to master management knowledge and practices very different from those of pastures or traditional monocultures, which can discourage many farmers.⁷⁹

Policies must, therefore, invest in disseminating this knowledge, prioritising participatory methods, like 'farmer-to-farmer' diffusion. This requires policies to be formulated 'bottom-up', actively including stakeholders and traditional knowledge in the process, instead of imposing technologies inadequate to the local context.⁸⁰

⁷⁸. ATER refers to Assistência Técnica e Extensão Rural (Technical Assistance and Rural Extension). It is a strategic public service in Brazil that provides farmers with agronomical training, technology transfer, and management support.

⁷⁹. Embrapa Amazônia Oriental (2008) *Barreiras à Adoção de Sistemas Silvopastoris no Brasil*.

⁸⁰. Buttoud, G. (2013).

In Brazil, this participatory approach is exactly what the National Policy on Technical Assistance and Rural Extension (Pnater) proposes: offering guidance to rural producers related to production planning and management techniques, to stimulate sustainable

development, social participation, and agroecological-based production.⁸¹ However, implementing this policy faces major challenges in its reach: the 2017 Agricultural Census (IBGE) revealed that only 20.1% of producers declared receiving technical assistance.

Policy/Action Recommendations to Leverage Transition to Horticulture-based Agroforests: Strengthening Research and Extension

- Invest in specialised, participatory technical assistance (ATER) and increase the availability of quality seedlings/seeds.
- Offer continued agroecological ATER (3–5 years) focused on successional design, regional nurseries, and post-harvest management.
- Raise awareness among decision makers, producers, and society about economic and environmental benefits of AFS.
- Develop applied research on adapted clonal cultivars, regional intercropping, and light mechanisation for AFS.
- Create regional reference centres and learning routes (e.g., demonstration units).

Other Policy/Action Recommendations

- Debureaucratise AFS licensing in APPs/Legal Reserves when involving productive restoration with native crops.
- Ensure security of land and tree tenure, defining rules to allow long-term investment.



81. Governo do Brasil (2017, updated 2024) *Agricultura familiar e compras públicas: Pnater*. <https://www.gov.br/secretariageral/pt-br/consea/noticias/2017/agricultura-familiar-e-compras-publicas-pnater>.

- Just transition for poultry/swine producers: creating income recomposition programs focused on asset demobilisation, requalification, and reuse of structures for plant processing.
- Provide assistance to reallocate area and labour to AFS and family agro-industries (pulp, flours, dehydrated goods).

In short, transitioning to AFS does not depend on a single law or isolated program, but on creating favourable and integrated public policies. The success of this agenda depends on synergy built between decision makers, scientists, extension

agents, and farmers, allowing AFS to cease being a secondary alternative and become a priority in sustainable rural development.

CONCLUSION AND NEXT STEPS

The present report demonstrates, unequivocally, that transitioning from livestock to 100% horticulture-based agroforestry systems (AFS) represents an economically rational, less risky, and environmentally superior solution for the Brazilian agro-livestock sector. The study confronts the central paradox of the current food system: the livestock sector is the main cause of climate pressure and deforestation in Brazil, associated with approximately 60% of the country's total emissions and more than 90% of deforestation in the Amazon. Furthermore, livestock occupies 20% of the land but contribute only about 37% of calories in the Brazilian diet from fresh or minimally processed foods.

Horticulture-based AFS reversed this negative impact, becoming net carbon sinks. They also proved more efficient and economically promising in all Brazilian biomes while producing foods that, according to the Dietary Guidelines for the Brazilian Population, should compose the basis of our diet.

Transitioning to horticulture-based AFS is, above all, an opportunity for prosperity and social justice. Our analysis suggests that migrating to these systems can more than double net income per hectare (+110% in the median, in the mature AFS, year 5+), and in exceptional cases of extremely high productivity and special market access the increase can reach 1,525%. This economic superiority translates into efficiency in using critical natural resources: horticulture-based AFS require 12 times less land than cattle to obtain the same gross revenue. Additionally, they generate more employment (30 equivalent jobs per R\$1 million produced, against only 7 in livestock) and drastically reduce income volatility to about 15%, versus 30% in livestock.

For this just and structural transition to materialise at scale, it is crucial that public managers act in a decisive and coordinated way, with robust and integrated public policies. In this sense, developing specific incentives and financing to promote the

transition from livestock to horticulture-based agroforests is necessary as part of social, agrarian, food, and climate policies.

Furthermore, the transition also needs the correct implementation of the National Policy on Agroecology and Organic Production (Pnapo), a strengthening of the Technical Assistance and Rural Extension (ATER), and the development of a clear political strategy that cuts across government ministries. Government action must ensure the country reconciles healthy and adequate food production with the urgency of climate mitigation and environmental regeneration.

The financial sector has an indispensable transformative role. AFS scalability is currently impeded by institutional and financial barriers, such as unequal credit access and obstacles to managing agroecological projects from credit institutions. Financial institutions, alongside committing not to finance cattle operations linked to deforestation, must redirect these investments to the transition to horticulture-based agroforests. Changing the capital landscape is changing the production landscape.

In sum, this report points to a future in which Brazil can lead the way towards truly sustainable food systems. Transitioning to horticulture-based AFS is the most rational and promising trajectory, capable of transforming degraded pastures into carbon sinks, high-income generators, and cradles of food diversity. With decisive engagement from public managers and the financial sector, Brazil can increase its countryside's income, respect the planet, and nourish its population. This reality is within our reach.

APPENDIX: METHODOLOGY

The study was built on a rigorous methodological backbone anchored in high-quality Brazilian public databases. In addition to the classic body of international literature on agroforestry and ecological intensification⁸² and the Agribusiness Projections 2023/24–2033/34 for macro scenarios,⁸³ the study explicitly integrates series and indicators from CONAB,⁸⁴ CEPEA/ESALQ,⁸⁵ the 2017 Agricultural Census (IBGE),⁸⁶ and MapBiomias (Collections 8 and 9).⁸⁷ This triangulation provides empirical backing for the comparison between livestock (beef and dairy cattle, broiler and laying poultry, swine) and 100% horticulture-based systems – especially agroforestry (AFS) – providing scale, granularity, and currency to estimates of income, costs, management, and risk.

The methodology combines three integrated layers: (i) systematic review and meta-synthesis of evidence (national and international) on the economic and operational performance of livestock, plant crops, and AFS; (ii) comparative benchmarking of economic indicators, normalised per hectare and per year; and (iii) income scenario modelling with sensitivity analysis and risk simulations. The review applies transparent inclusion criteria (methodological quality, relevance to the Brazilian tropical context, and replicability) and consolidates standardised effects that feed the benchmarking. Agribusiness Projections⁸⁸ are the axis of intertemporal calibration, while agroforestry literature defines biophysical and management parameters influencing costs and productivity in perennial-annual intercropped arrangements.

To support the economic–financial comparisons, the CONAB database was used extensively: Crop Monitoring (productivity and supply), Historical

Wholesale Price Series (including PROHORT for fruits and vegetables), and cost references when available. These data were deflated and harmonised by product and Federated Unit (UF), composing the core of prices and productivities for plant crops and serving as a counterfactual for livestock income where relevant. Complementarily, the CEPEA/ESALQ series provided prices for sectoral indicators (grains, fruits, fibres, timber, dairy, and meats), cost indices, and sectoral margins, allowing robustness testing of results under different price-formation bases, including volatility and correlations with critical inputs (feed, fertilisers) that burden intensive livestock farming in particular.

The structural characterisation of establishments and the territorial basis of the transition were identified using the 2017 Agricultural Census (IBGE), including distribution by property size, labour use, mechanisation level, access to technical assistance, and revenue structure. These attributes entered as constraints and conditioners in the scenarios, determining adoption curves, capital expenditure needs, labour availability, and compatibility with credit lines. To map land availability and suitability, and to project the substitution of pastures with 100% horticulture-based arrangements, the MapBiomias series (land use and cover collections and pasture dynamics) was used, including conversion, degradation, and regeneration rates. This allowed building priority maps, conversion risks, and opportunities for productive restoration via AFS, with income gains per hectare and reduction of climatic/ecological risk.

The heart of the study is the systematisation matrix that organises, by axis, comparisons between 'Animal

82. Buttoud, G. (2013); Nair & Garrity (2012).

83. MAPA/SPA (Ministério da Agricultura e Pecuária (Ministry of Agriculture and Livestock) – Secretaria de Política Agrícola (Secretariat of Agricultural Policy)) (2024). Data at <https://www.gov.br/agricultura/pt-br/assuntos/politica-agricola/todas-publicacoes-de-politica-agricola/estatisticas-e-dados-basicos-de-economia-agricola>.

84. Companhia Nacional de Abastecimento (National Supply Company). See <https://www.gov.br/conab/pt-br>, and data at <https://portaldeinformacoes.conab.gov.br/>.

85. Centro de Estudos Avançados em Economia Aplicada (Center for Advanced Studies on Applied Economics) / Escola Superior de Agricultura Luiz de Queiroz – Universidade de São Paulo (USP). See <https://cepea.org.br/br>.

Production vs. Income,' Plant Crops vs. Income,' and 'AFS vs. Income,' and replicates the arrangement, replacing 'Income' with 'Costs,' 'Management,' and 'Credit.' Each cell consolidates: standardised metrics (net income/ha/year, margin, payback, capital/operating expenditure, labour demand) and weights of evidence by quality, territorial conditioners (logistics, climate, aptitude), and risks with respective mitigation strategies. The matrix also incorporates cuts by chain (cattle, poultry, swine), allowing cross-sectional reading and avoiding cherry-picking. Harmonisation between CONAB, CEPEA/ESALQ, IBGE, and MapBiomas bases was essential to ensure consistency between prices, productivities, cost structure, and land availability – reducing sample biases and increasing the transferability of conclusions.

In benchmarking, typical livestock systems were compared with two 100% horticulture-based counterfactuals: (i) conventional rotations/intercropping; and (ii) AFS with combinations of high-value perennials (fruits, timber, oils/fibres) and quick cash flow annuals. Maturation adjustments for perennials (J-curve: initial drop followed by increase) and intercalated revenues from annuals in years 1–3 were applied, according to literature. Risk assessment included interannual income variance, price shocks (using CEPEA/ESALQ and CONAB series), exposure to input costs (feed and fertilisers), and the ecological/operational buffering of AFS. Scenarios tested a base case (prices and quantities anchored in MAPA/SPA, 2024), an optimistic scenario (quality premiums, local niches, and timber/fruit appreciation), and a stressed scenario (price drops and moderate climate shock), with sensitivity

analyses for productivity, prices, capital cost, and implementation delays.

It is relevant to highlight the use of artificial intelligence and Python scripts to ensure reproducibility, data quality, and analytical agility. The team automated the ingestion of CONAB and CEPEA/ESALQ series, pre-processing (cleaning, deflation, harmonisation by UF/month), and spatial integration with MapBiomas using libraries such as pandas, numpy, statsmodels, and geopandas. Lightweight AI models were utilised for: (a) gap imputation and outlier detection in price and productivity series (e.g., random forest for imputation, isolation forest for outliers); (b) clustering of microregions by aptitude/market profile (k-means); and (c) Monte Carlo simulations for uncertainty envelopes in income and payback. Versioned notebooks and reproducible pipelines (with logs and seeds) ensured transparency and auditability of transformations and estimates.

Finally, the report preserves good transparency practices: limitations and critical discussions acknowledge territorial heterogeneity, gaps in cost microdata, and the learning curve in AFS. Even so, the convergence of robust public sources,⁸⁹ technical-scientific literature,⁹⁰ and scenarios anchored in official projections,⁹¹ supported by analytical automation with AI and Python, gives high confidence in the results: replacing livestock with 100% horticulture-based systems is economically rational, less risky, and environmentally superior in Brazil – and, with adequate policy design and credit, is fully scalable.

86. IBGE (Instituto Brasileiro de Geografia e Estatística (Brazilian Institute of Geography and Statistics)). See <https://www.ibge.gov.br/en/statistics/economic/agriculture-forestry-and-fishing/21929-2017-2017-censo-agropecuário-en.html> and data at <https://cdae.ufrr.br/projetos/projeto-ibge/sidra-banco-de-tabelas-estatisticas-do-ibge/>.

87. See <https://brasil.mapbiomas.org/en/> and <https://plataforma.brasil.mapbiomas.org/>.

88. MAPA/SPA (2024).

89. CONAB, CEPEA/ESALQ, 2017 Ag Census (IBGE), MapBiomas.

90. Buttoud, G. (2013); Nair & Garrity (2012).

91. MAPA/SPA (2024).

