Technical Note

PRODUCTIVITY AND SUSTAINABILITY INDICATORS OF THE BRAZILIAN AGRICULTURAL SECTOR

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1 INTRODUCTION

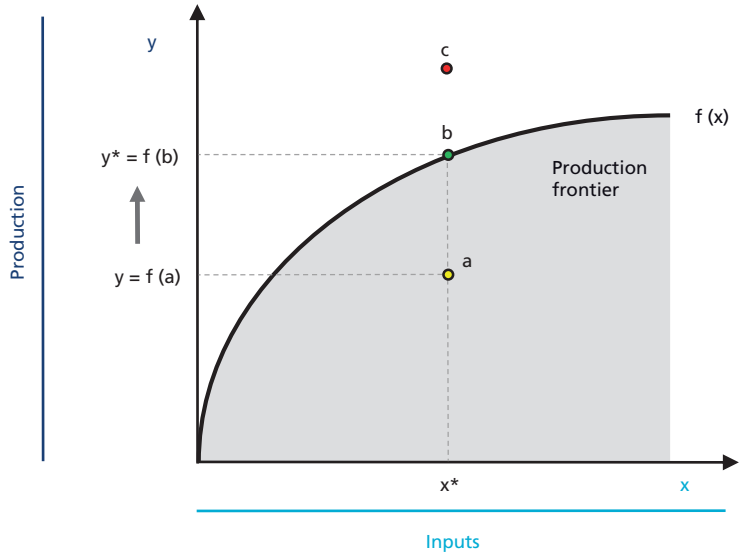
This technical note summarizes Brazilian agriculture and livestock production over the last fifteen years and presents productivity and sustainability indicators. Agribusiness[1] significantly influences the country's gross domestic product, international trade dynamics, and generating employment in the economy (Fishlow and Vieira Filho, 2020).

From 2006 to 2021, agribusiness share in national production ranged from 23.4 to 27.4 percent (Cepea, 2022). At the same time, the agribusiness trade balance demonstrated a surplus, while the balance between exports and imports of the other sectors of the economy presented a shortfall. In this regard, the agribusiness trade balance jumped from US$ 42.6 billion in 2006 to US$ 105.0 billion in 2021. Agribusiness' exports represent, on average, around 42 percent of the total exported nationally, while the imports of this sector remained at 8 percent.[2] Regarding the labor market, the population employed in agribusiness is roughly 19 million workers, representing nearly 20 percent of the total in the country.[3]

The great challenge posed is to keep this sector's productive growth connected to sustainability issues, including environmental ones. There are no doubts that, for instance, the fight against deforestation requires technological intensification in agriculture and livestock production, complying with the law (Forest Code), as well as using policies and tools that stimulate productive activity (e.g., extension, research, rural credit, and insurance) and facilitate the payment of environmental services. The farmer produces food, preserves water resources, and gives back environmental services to society.

The concept of technological intensification used in this technical note can be understood in a production possibility curve or frontier. Given a particular technology, it can be said that the production frontier presents the produced amount Y in the function of the required combination of inputs X. In figure 1, the combination of inputs (capital, land, labor, fertilizers, agrochemicals etc.) is represented on axis x and the production response on axis y. Three points can be detailed: a, b, and c. Point a means productive inefficiency, since having the given combination of inputs x^*, it would be possible to reach the potential capacity y^*, but only y is produced. At this point, production can be increased without requiring more inputs. On point b, the economy is at its highest level of productive efficiency since the potential capacity y^* is extracted with the given combination of inputs x^*. This point is at the technology production frontier. For last, the situation described by point c, given the existing technology, is not viable. One cannot produce more than what is allowed, that is, over the productive capacity y^*.

FIGURE 1
Production function and technological intensification



Author's elaboration.

1. Agribusiness is the entire commodity chain related to agriculture and livestock production, including the upstream and downstream sectors (inputs, agriculture and livestock, industry, and services). Please, note that throughout this technical note, indicators related to the agriculture and livestock sector will be addressed, but the ones that may impact the entire agribusiness commodity chain.

2. Available at: <https://bit.ly/3JU2yJZ>. Accessed on: Mar. 15, 2022.

3. Further information available at: <https://bit.ly/3xF5O9M>. Accessed on: Mar. 15, 2022.

Comprehending this dynamic in these three situations, when saying production is close to productive efficiency, presupposes that it is closer to the maximum technical efficiency (TE) – or at a point close to *b*. That is, productive efficiency will be higher the closer it is to the production curve or frontier. When referring to the maximum TE – kept technology constant – it presupposes the given combination of inputs that, on the one hand, maximizes production and, on the other hand, minimizes the cost of production. Assuming that y^* is the maximum productive capacity and x^* is the given combination of inputs, TE on point *a* is defined by $ET = y / y^*$. Therefore, productive and technical efficiency is a standard to measure the distance between the point and the production frontier. The studies presented herein[4] have analyzed stochastic production frontier models, and the results should be interpreted according to the issues discussed in this work.

Feres and Ferreira (2020) demonstrated that the stocking rate (heads of cattle per hectare of pasture) stagnated between 2006 and 2007, mainly because of the expansion of livestock production in non-traditional areas. The situation revealed itself even more concerning due to the drop in the stocking rate in the Central-West and North, regions that incorporated the axes of livestock expansion in Brazil. Consequently, the resumption of the stocking rate growth is one of the necessary conditions to increase the livestock sector's productive efficiency.

Boosting agriculture and livestock and intensifying productivity are goals to achieve the reduction of deforestation and a steady increase in sustainable food production. This way, it is intended to extract the maximum product considering the given combination of inputs. The closer agricultural and livestock production is to the technological frontier, the higher the system's productive and technical efficiency will be and the higher the technological intensification.

From this perspective, it is essential to implement intensification policies for livestock activity in Brazil. Productive sustainability agenda proves to be a priority, whether for producers or the country's greater integration into international markets. In general, Brazil has been spending its productive and technological effort. On the one hand, there is an increase in productivity through public policies of low subsidy levels. On the other hand, tools are created, such as the Sectoral Plan for Mitigation and Adaptation to Climate Change for the Consolidation of a Low Carbon Economy in Agriculture (ABC Plan) and the Forest Code, so they may ensure the efficient use of scarce resources, besides public policies that stimulate more sustainable practices as the Integration Crop-Livestock-Forestry (ICLF).

2 SECTORAL ANALYSIS[5]

2.1 Productivity

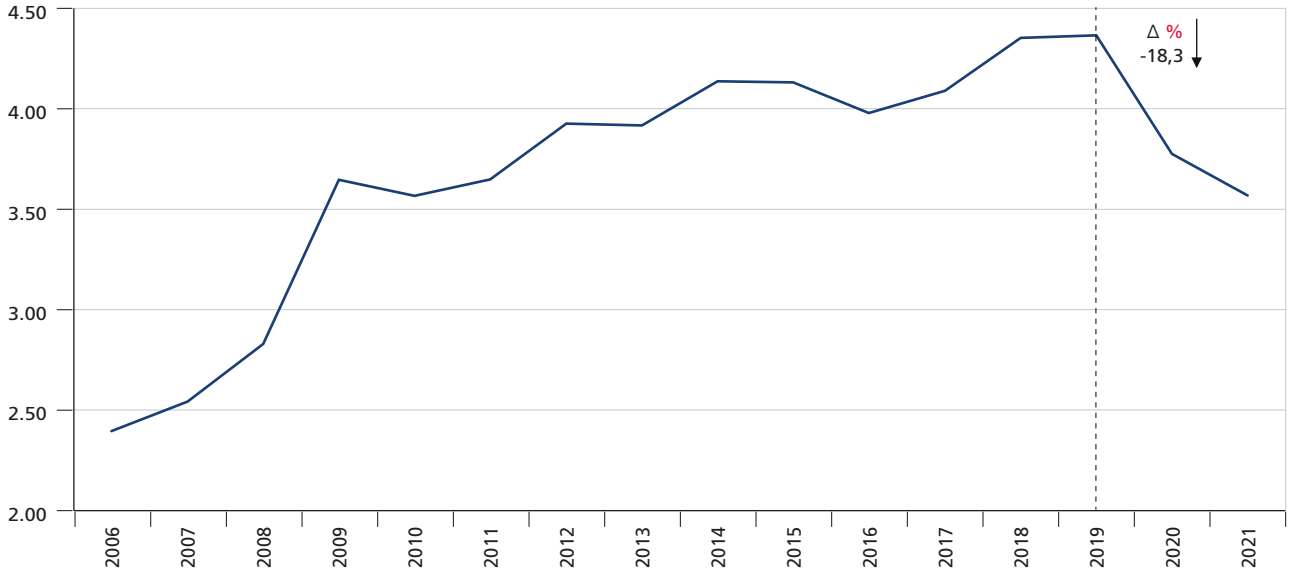
According to Gasques et al. (2020), between the last two censuses (2006 and 2017), the average growth rate of agricultural and livestock products was 3.29 percent. Such growth has occurred with the intensification of production, and the use of modern inputs has grown by 1 percent per year. Therefore, total factor productivity (TFP)[6] grew 2.21 percent per year between 2006 and 2017. This rate is higher than the one from the United States, which rose 1.2 percent per year, and the global rate of 1.71 percent per year for the same period. The data also showed that agricultural and livestock research investments impact productivity growth.

4. See Feres and Ferreira (2020); Vieira Filho, Gasques, and Ronsom (2020); Ferreira and Vieira Filho (2020); Reyna, Braga, and Morais (2020); Ramos and Vieira Filho (2021); and Costa, Vizcaino, and Costa (2020).

5. This section was based on the document that assessed the 2017 Census of Agriculture, which is the most up-to-date regarding census statistics using microdata of the Brazilian Institute of Geography and Statistics (IBGE). For a more detailed reference, see Vieira Filho and Gasques (2020).

6. It is a measure that aims at demonstrating how much is produced for every input unit invested. In general terms, TFP is calculated as the product of the difference between the product index growth and the input index growth. The product growth not explained by the input growth shall be attributed to TFP or technology growth.

FIGURE 2
Embrapa's budget in real price (2006-2021)
(In R$ 1 billion)



Source: Embrapa (2022).
Obs.: Embrapa – Brazilian Agricultural Research Corporation.

However, as of 2019, Embrapa's budget was reduced, with a negative percentage change of 18.3 percent (figure 2). Hereafter, it is crucial to assess if this reduction in investments in agricultural and livestock research will affect the sector's productivity. If necessary, it is also essential to define a strategy so the states do not dismantle their state agricultural and livestock research institutions since such institutions are part of Brazil's National Agricultural Research System (SNPA).[7]

2.2 Technology

Keeping the growth trajectory will depend on the investments in research in agriculture and livestock and the restructuring of SNPA for a modern national innovation system.[8] Fishlow and Vieira Filho (2020), and Vieira Filho, Gasques, and Ronsom (2020) analyzed the potential of innovation for expanding agricultural and livestock production. These authors concluded that technology – for a 100 percent increase in the gross value of production (GVP) – was responsible for approximately 60 percent of the productive growth.

In 2017, the Census of Agriculture showed that the percentage of establishments that received technical advice was very low for Brazil (20.7 percent), slightly better for commercial agriculture (27.8 percent), and very low for family farming (27.8 percent). In the 2006 Census of Agriculture, 77.9 percent of the establishments declared they had not received technical advice from any public or private source that year. In 2017, this percentage increased to 79.8 percent.

The percentage of establishments without technical advice varies widely among states and regions. In the North and Northeast, where more than half of the family farming establishments are concentrated, in all states, more than 80 percent of the establishments did not receive technical advice. In some states, this percentage reached 95 percent. Among the establishments that received technical advice in 2017, there was a variation among states and the source of service. While the advice received from the cooperative system was of paramount importance in the South, public rural extensions in the Northeast were dominant (Peixoto, 2020).

7. Through Ordinance No. 193 of August 7, 1992, of the Ministry of Agriculture, Livestock, and Food Supply (Mapa), the Brazilian government created the SNPA, authorized by the Agricultural Law (Law No. 8.171 of January 17, 1991). SNPA seeks to align agricultural and livestock strategies with development policies. This system comprises Embrapa and its units, state agricultural research organizations (Oepas), universities and research institutes at federal and state levels, and other public and private organizations connected to farming and livestock research.

8. With the economic transformations since 1990, there is a need to rethink the sector's research and innovation model. On September 29, 2021, Ipea participated in the Public Hearing of the Committee of Agriculture and Agrarian Reform (CRA) of the Federal Senate to discuss the SNPA and the creation of a digital network of agricultural and livestock research. The debate can be watched for the main challenges on the Federal Senate website, available at: <https://bit.ly/3xwkmZc>.

The last census revealed an improvement in managers' education levels in commercial agriculture and family farming. In 2006, only 6.3 percent of family farming managers completed high school or higher education; in 2017, the indicator rose to 14.7 percent. Commercial agriculture also showed an improvement in education: from 25.2 percent of managers who completed high school or higher education in 2006, it rose to 39.1 percent in 2017. Nevertheless, significant challenges persist in this area because 15.5 percent of the informants declared that they had never gone to school, 12.6 percent attended only literacy classes, and 23.8 percent finished only previous primary education. Therefore, half of the informants of those establishments did not obtain from formal education the basic requirements for implementing the technological intensification of production.

From 2006 to 2017, the indicators showed a high percentage of establishments with electricity, respectively 69.5 percent and 83.1 percent. Irrigation increased from 4.5 million hectares irrigated in 2006 to 6.7 million hectares. Internet access grew from 1.5 percent to 12.1 percent among the agricultural and livestock establishments. An increase of more than eight times in one decade. Those are positive numbers but still low regarding the existing potential and demand.

Although there are institutional renewal initiatives, e.g., the creation of a digital research network, availability of open data from different institutions, and SNPA restructuring, it is crucial to rethink operating models more deeply. As analyzed by Ronsom, Amaral, and Vieira Filho (2021), the institutions in the agriculture innovation system need to be more agile. So the interaction between primary and applied science happens more dynamically for the market and farmers. Agile mechanisms for technology development for agribusiness must be known and developed.

The institutional structure can be based on the National Agricultural Innovation System (SNIA). In this regard, figure 3 presents a framework in which the system would be divided into three levels: i) the high-level agency, in which Embrapa's leadership is crucial; ii) the strategic intelligence agency, in which new collaboration can be established, e.g., the role of Ipea in the assessment and development of public policies on the promotion of the agricultural and livestock sector; and iii) institutions developing research in agriculture and livestock – Embrapa, Oepas and other education and research institutions.

FIGURE 3
SNIA

Author's elaboration.

The Constitutional Amendment (CA) No. 109 included in § 16 of art. 37 the significance of public evaluation, pointing out that "public administration agencies and entities, individually or jointly, should evaluate *public policies*, including the *dissemination of the object* to be assessed and the *results obtained*, according to the law" (Brasil, 2021, emphasis added). Cooperation is needed, for instance, between the policies formulated by Mapa with Embrapa and partner institutions, as is the case of Ipea and universities focused on the development of research in agriculture and livestock, such as the Federal University of Viçosa (UFV), Federal University of Lavras (Ufla), as well as Luiz de Queiroz College of Agriculture (Esalq). The system shall be capable of elaborating, reformulating, and assessing public policies.

In this respect, integrating databases of different institutions is a prerequisite. Therefore, the cross-referencing of databases of IBGE, Central Bank of Brazil (BCB), Mapa, Embrapa, and other institutions with strategies for the sector is urgent. Such integration should be a state initiative and not from a particular agency or entity. In December 2021, Ipea organized the First Panel on Agricultural and Livestock Chains and Open Data, included in the Brazilian Fifth National Action Plan on Open Government,[9] managed by the Open Government team at the Office of the Comptroller General (CGU). The work group involving different institutions, such as Ipea, CGU, Mapa, Embrapa, and the National Supply Company (Conab), among other institutions, seeks to deepen the discussion on the commitment of "agricultural and livestock chains and open data" aiming at promoting those different databases to be broadened and integrated.

For the collaborations, CA No. 95/2016, known as the Spending Ceiling, arrived as a way to balance public spending through the sustainability of public expenditure that increased considerably in the last governments. One of the immediate consequences was the restriction of public expenditure on personnel, known as cost expenses, affecting the appointment of new civil servants by public authorities of the Executive, Legislative, and Judiciary. In a situation of budget cuts, smart solutions must be structured.

In 2020, the creation of the Center for Agricultural Economics Studies (ne²agro) of Ipea and Mapa sought to offer technical advice to public administrators (Vieira Filho, 2020a). This was a successful program with an excellent benefit-cost ratio. The result was the elaboration of an up-to-date analysis[10] of the sector with 28 studies and 64 researchers from different institutions participating. It can be said that this experience was a microenvironment. With Bill No. 6.417/2019 of the Federal Senate, which discusses the organization of the SNIA, institutional partnerships and innovative collaborations may reach a macroenvironment, providing strategic information to public administrators and disseminating up-to-date knowledge to farmers.

2.3 Storage and infrastructure

The storage capacity and road expansion did not follow the agriculture and livestock production growth and its interiorization. Brazilian agriculture and livestock presented a TE of 94.6 percent in 2017, indicating that, on average, agricultural and livestock production is 5.4 percent below the potential considering the current amount of capital goods, land, labor, and other inputs. This indicates a potential for an increase in production.

Ferreira and Vieira Filho (2020) show that the storage capacity, measured in tons per hectare, has a positive relation with TE, while a 0.1 ton/ha increase in the storage capacity raises production by 2.31 percent on average. Furthermore, the increment of 0.01 km per km² in road density raises output by 1.25 percent. Such results demonstrated the role of logistical infrastructure investments in increasing production and productivity for Brazilian agriculture and livestock.

2.4 Use of agrochemicals

Reyna, Braga, and Morais (2020) examined if agrochemicals make Brazilian agricultural and livestock farmers more efficient. Therefore, the representative farms were defined – the ones representing the average characteristics of municipalities, classifying them as intensive and non-intensive regarding the use of agrochemicals. The main result showed that the farms with intensive agrochemicals were more efficient than the non-intensive ones. They had an average TE of 59.7 percent, while in the intensive farms, the efficiency was 77.2 percent.

Observing the regions of Brazil, it was verified that, almost in all of them, the intensive farms were more efficient, except in the North. Other results showed that access to technical assistance reduced productive efficiency, especially in intensive farms. For instance, receiving advice through technical assistance and rural extension policies is a factor that helps producers update their inputs more efficiently.

In addition, participating in cooperatives also produced benefits in terms of TE. Being a cooperative member increases the TE level of the representative intensive farms. The mechanism behind this increases access to information. Producers participating in cooperatives have more access to extension services and information about rural credit and new technologies.

9. For more details on Brazil's Fifth National Action Plan, access the link: <https://bit.ly/3rzjUWk>.

10. This analysis, called *Uma jornada pelos contrastes do Brasil* (Vieira Filho and Gasques, 2020), can be accessed on Ipea's website. Available at: <https://bit.ly/3BDNRsA>.

2.5 Concentration of production

The pattern of income concentration slightly altered between the 2006 and 2017 Censuses of Agriculture. On the one hand, as Vieira Filho (2020b) analyzed in 2017, 9 percent of the wealthiest establishments held a share of 85 percent of the GVP. On the other hand, in the same year, 69 percent of the poorest establishments – three-quarters of this percentage from family farming and several concentrated in the Northeast – were responsible for only 4 percent of the GVP.

The assumptions that the concentration would be associated with larger-size areas and higher-income strata were not confirmed by assessing the productive inequality. The production's Gini coefficient was as high in terms of size and income. Small establishments and the poorest producers proved unequal and concentrated, as seen in the larger-scale production and the most prosperous agents.

Although income transfer policies have reduced rural exodus in the poorest regions, such as the Northeast, economic growth still happened in traditional regions, e.g., South and Central-West. This regional inequality requires more studies to indicate the causes and solutions. The duality in production was maintained, despite an increase in gross income in all groups of productive establishments.

2.6 Family farming

Helfand, Costa, and Soares (2020) sought to evaluate family farming in two dimensions: i) the size in terms of area; and ii) the production scale related to the GVP. This approach sought to understand the future of small and medium-size producers, attempting to identify factors that might stimulate this group's competitiveness to increase income and reduce poverty.

The census data showed that the small and medium-size producers are not disappearing. The share of less than 100 ha establishments is around 90 percent of the total agricultural and livestock establishments, which has not changed over the last decades. The number of establishments of less than 1 thousand hectares has been increasing since the 1970s, going from 48 thousand to 51 thousand. Conversely, it was found that the share of production generated by large establishments – with an area of over 1 thousand hectares – tripled between 1975 and 2017, increasing from 14 to 41 percent.

By focusing on the size (hectares) and the scale of production (production value), it was observed that only 641 thousand (12.6 percent) agricultural and livestock establishments produced over 10 monthly minimum wages in 2017. This group was considered the large-scale one. Around 88 percent of the establishments in this group had an area smaller than 500 ha, demonstrating the presence of small and medium-size establishments with a high-level productive scale. The large-scale group was responsible for around 89 percent of the agricultural and livestock production in 2017. Almost half of the production value was produced in properties of less than 500 ha.

Small and medium-size establishments (of 5 ha to 500 ha) were also analyzed. For this group, it was found that producers who achieved productive scale were intensive in mechanization, using more fertilizers and agrochemicals. Moreover, they participated more in cooperatives, accessing more credit and technical advice. Those producers also had a higher level of education than establishments with low-level productive scales. It can be concluded that, even in family farming, a highly competitive share incorporates inputs efficiently.

2.7 Cooperatives

In 2017, out of the total of 5.1 million agricultural and livestock establishments in Brazil, 11.4 percent were part of a cooperative, that is, 579.5 thousand agricultural and livestock establishments. Out of the total, 412.3 thousand were familial, 71 percent in cooperatives or 11 percent of the total family farming establishments. The establishments participating in cooperatives were predominant in the South. In the North and Northeast, the share of establishments participating in cooperatives was smaller than 10 percent. Out of the total participants in cooperatives, more than 63 percent received technical advice, a higher percentage than the national average of 21 percent. Among farmers associated with any producer's institution that are not cooperative, there were 1.9 million establishments, with 78 percent of family farming. The share of family farming establishments connected to the productive associations represented 40 percent of the total establishments. Evaluating the productive efficiency, the institutional presence of cooperative insertion positively affected the agricultural and livestock establishment's production value, especially in family farming (Ramos and Vieira Filho, 2021).

According to WCM (2020), out of the three hundred largest cooperatives in the world, around one-third was from the agricultural and livestock sector and 7 percent from financial service. In Brazil, according to OCB (2020), the agricultural and livestock branch was responsible for 23 percent of cooperatives and 48.5 percent of direct employment, while the credit branch represented 15.6 percent and 16.8 percent, respectively. Together, those segments represented 75.8 percent of participants in cooperatives in Brazil. Agricultural and livestock cooperatives are concentrated in the South and Southeast (50.7 percent). Similar concentration was observed among credit unions, 79 percent of the national total in these regions.

Costa, Vizcaino, and Costa (2020) demonstrated through a stochastic frontier model a medium positive effect of cooperatives on TE of family farmers. More precisely, a municipality characterized by a high proportion of family farmers associated with cooperatives has a higher TE (on average 0.0963 percentage points – p.p.) than a municipality with a lower proportion of family farmers in cooperatives. Another result observed was that, for the municipality average, being intensive regarding cooperatives and having an average rate of beneficiaries of Pronaf B credit of 62 percent raised TE in 0.11 p.p.

3 INDICATORS OF PRODUCTIVE AND ENVIRONMENTAL SUSTAINABILITY

3.1 Efficiency and sustainability

Brazil presents a high level of inefficiency in agricultural production. In this context, the country produces, on average, 26 percent less of what it could potentially achieve with the amount of input used every year (Feres and Ferreira, 2020). The average inefficiency was higher in the Northeast, suggesting that production was a third below its maximum productive potential. The Central-West region, characterized by solid dynamism in agribusiness, presents the country's highest TE index.

The waste of resources is even more explicit when particularly considering land use. According to Feres and Ferreira (2020), the country could reduce by 70 percent the amount of land used in its agricultural activities by keeping the current production levels. The land-use inefficiency is particularly critical in the North. This demonstrates a vast space for the intensification of agricultural and livestock activities in the Amazon Region, reducing the need for opening new farming areas and the pressure for deforestation.

3.2 Land use legislation

Brazil is one of the few countries implementing strict land use and conservation rules. The Forest Code (Federal Law No. 12.651/2012) regulates which ones should be the areas of permanent preservation and legal reserves. According to Chiavari and Lopes (2017), most agro-exporter countries (such as Germany, Argentina, Brazil, Canada, China, the United States, and France) allow a certain level of sustainable management of forest resources and agricultural activities. In a comparative analysis of legislation, Brazil was the only one to demand that private properties keep a percentage of conservation areas with primary vegetation (legal reserve) without any type of monetary compensation to owners (Chiavari and Lopes, 2017).

According to the data in table 1, Brazil's agricultural area compared to other selected countries is, in terms of percentage, one of the smallest ones (7.5 percent), being below France (34.7 percent), Germany (33.3 percent), United States (16.3 percent), China (14.1 percent) and Argentina (12.1 percent). When comparing the areas dedicated to agricultural and livestock use together, Brazil presents one of the lowest percentages (27.8 percent) and, again, is ranked in a more favorable position in comparison to other countries, like China (55.1 percent), Germany (46.6 percent), United States (41.3 percent) and Argentina (39 percent).

However, regarding the primary and planted forest areas, Brazil has the highest percentage of its territory preserved or 58.5 percent. In contrast, the other countries have a lower portion, usually below 35 percent (figure 4). Regarding planted forests, Brazil still occupies 1.3 percent of its territory, while Germany, which has the highest percentage, reached 16 percent of this indicator.

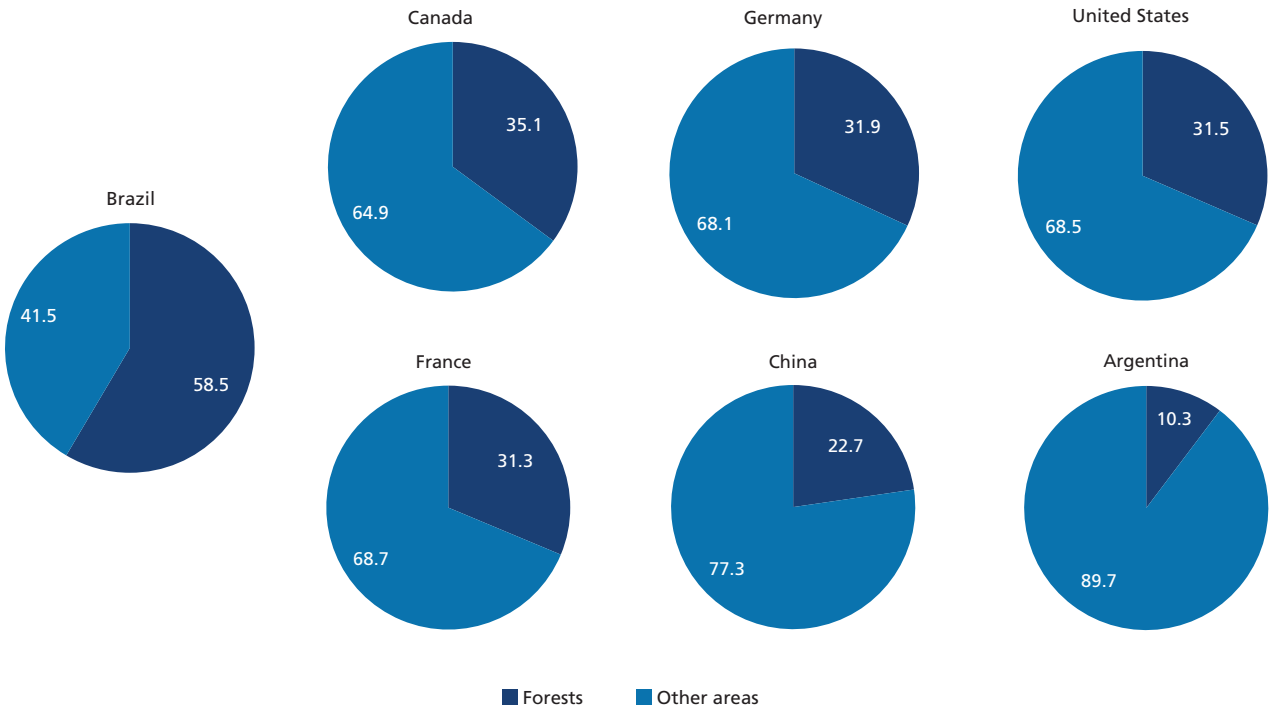
TABLE 1
Land use per selected agro-exporter countries (2019)

Unit	Land use	Argentina	Brazil	Canada	China	France	Germany	United States
Area (1 thousand hectares)	Agriculture and livestock	108,382	236,879	58,157	528,509	28,621	16,666	405,810
	Agriculture	33,701	63,518	38,815	135,675	19,075	11,913	160,437
	Forests	28,681	497,799	346,965	218,099	17,170	11,419	309,795
	Primary forests	27,276	486,935	329,229	134,515	14,771	5,710	282,274
	Planted forests	1,405	10,864	17,736	83,584	2,399	5,710	27,521
	Country's territory extent	278,040	851,577	987,975	960,001	54,909	35,758	983,151
Share (percent)	Agriculture and livestock	39.0	27.8	5.9	55.1	52.1	46.6	41.3
	Agriculture	12.1	7.5	3.9	14.1	34.7	33.3	16.3
	Forests	10.3	58.5	35.1	22.7	31.3	31.9	31.5
	Primary forests	9.8	57.2	33.3	14.0	26.9	16.0	28.7
	Planted forests	0.5	1.3	1.8	8.7	4.4	16.0	2.8
	Country's territory extent	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Food and Agriculture Organization (FAO). Available at: <https://bit.ly/3xAqNKM>. Accessed on: Mar. 15, 2022.
Author's elaboration.

Figure 4 presents the shares of primary and planted forests in each territory. Compared to other countries, Brazil has the highest percentage of preservation areas. In visual terms, the national share is more evident compared to other countries.

FIGURE 4
Share of forests (primary and planted) in the selected agro-exporter countries' total territory (2019)
(In percent)



Source: FAO. Available at: <https://bit.ly/3xAqNKM>. Accessed on: Mar. 15, 2022.
Author's elaboration.

Therefore, the numbers show that Brazil has preserved a significant area with native forests, even with the strong growth of agriculture and livestock and relatively low use of lands dedicated to agricultural and livestock production, whether with pasture or rural areas.[11] Brazil is committed to achieving the goal of restoration and preservation of forests internationally. In this context, Brazilian legislation has the potential to stimulate the efficient use of productive resources and become an effective instrument for environmental sustainability.

Even with all the critics of the country, it is clear that the Brazilian contribution is significant compared to other countries. Moreover, regarding environmental legislation, Brazil is also revealed to be ahead of its main competitors.

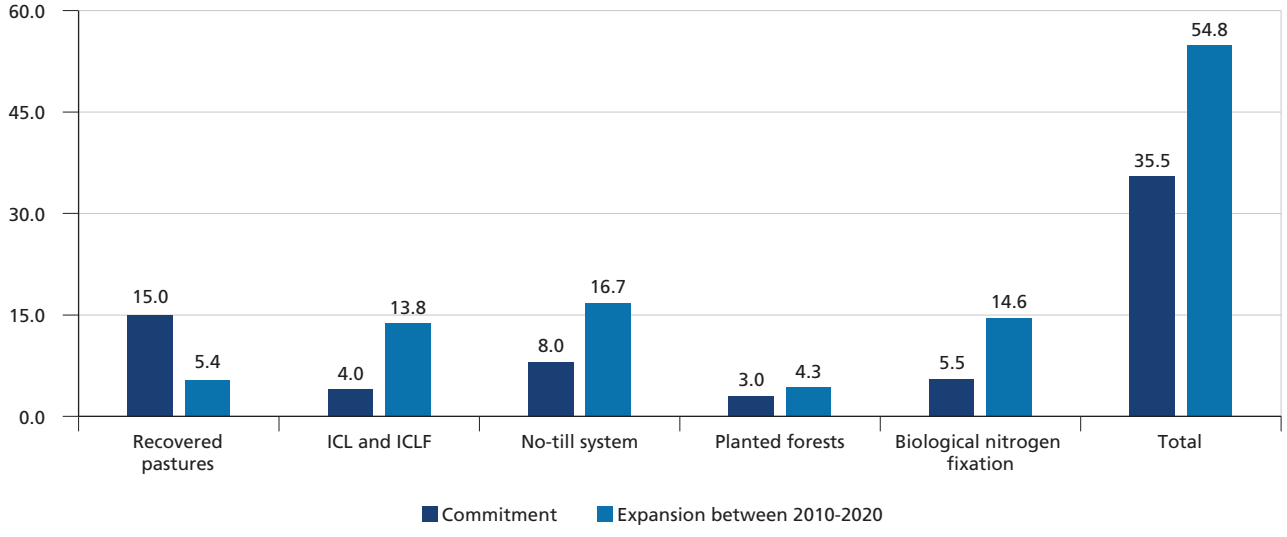
3.3 Low-carbon agriculture

Indicators showed that the agricultural and livestock production per unit of greenhouse gases (GHGs) is increasing, representing a measure of productivity (Vieira Filho, 2018). In 2009, at the Fifteenth Conference of the Parties of the United Nations Framework Convention on Climate Change (COP15), the Brazilian government committed to reducing the GHGs by 2020. Law No. 12.187/2009 established the National Policy on Climate Change. As part of the actions of such policy, in 2010, the ABC Plan[12] was created. In this regard, the practices promoted by the ABC Plan include:

- recovery of degraded pastures;
- adoption of an integrated crop-livestock system (ICLS) and crop-livestock-forest system (ICLFS) – a measure supported by Law No. 12.805 of April 29, 2013, that established the National Integrated Crop-Livestock-Forestry Policy;
- incorporation of the no-till system;
- diffusion of biological nitrogen fixation (BNF);
- expansion of the planted forest areas; and
- animal waste processing.

According to figure 5 and the evaluation from Telles et al. (2021), regarding the expansion of the area (in 1 million hectares), except for the recovery of pastures, the other practices revealed an increase above the commitment defined. The expansion of the area was equivalent to 154 percent of the goal defined by the ABC Plan.

FIGURE 5
National commitment to the expansion of areas of low-carbon emission practices in the agricultural and livestock sector in Brazil (2010-2020)
(In 1 million hectares)



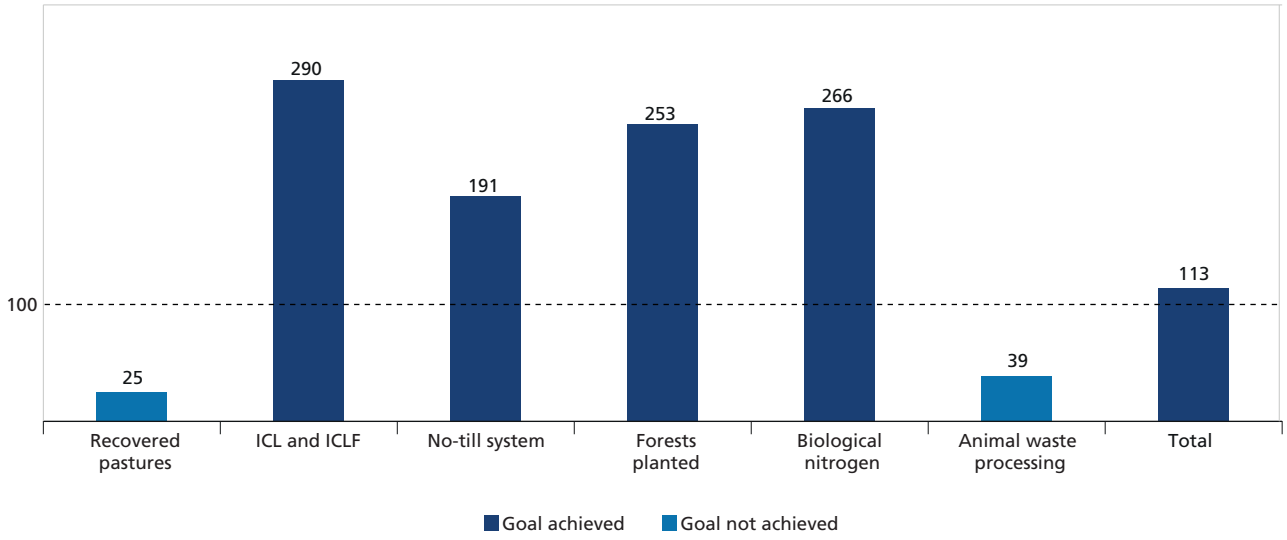
Source: Telles et al. (2021).
Author's elaboration.

11. It is also true that there is a lot of illegal deforestation and that the data presented are from the entire territory. There are many challenges ahead, especially in an evaluation per biomes – the Atlantic Forest shows a high level of deforestation, and the *Cerrado*, if not monitored, could present an uncontrolled trajectory.

12. For more details, refer to appendix A.

Based on figure 6, regarding the mitigation of carbon dioxide (CO_2) emissions into the atmosphere, Brazil almost met its total goal of 113 percent. Except for the recovery of pastures and animal waste processing, all practices were way above the goals set.

FIGURE 6
Achievement of Brazilian goals of mitigation of CO_2 compared to international commitments (2010-2020)
(In percent)



Source: Telles et al. (2021).

4 IMPLICATIONS FOR PUBLIC POLICIES

Brazil has been continuously increasing its agricultural and livestock productivity due to improved productive TE indexes in the sector. However, attention should be drawn to the fact that there is still a vast space to better use credit and tax policy instruments, for instance, economic incentive mechanisms for the intensification of Brazilian agriculture and livestock, whose growth potential is unequal, depending on the sector and region of the country. The direction goes through the reformulation of public policies to align them with the environmental goals of sustainability.

To keep the environment favorable to the creation of innovation in the agricultural and livestock sector, SNIA's restructuring is crucial in three ranks: i) the high-level agency, in which Embrapa would centralize the main demands; ii) the intelligence agency, in which Mapa and Embrapa would build collaborations to enhance the effectiveness of the sector's development public policies (Ipea would be a cooperation institution in this structure); and iii) the institutions carrying out research. Access to and cross-referencing databases from different intuitions are vital to evaluate policies better and verify their results. The open data policy for agricultural and livestock chains should be a state measure and not an individual issue of institutions.

More precisely, regarding the ABC Plan, the bottleneck of the goals for low-carbon agriculture is at: i) recovering pastures; and ii) processing animal feces. However, in the first case, one should understand that the integrated systems (ICL and ICFL) also recover pastures, and its goal reached 290 percent. In the second case, one must consider that Brazil's statistics are scarce and do not show an accurate overview. Therefore, Brazil is believed to be better than presented herein.

Brazil stands out as one of the leaders and a protagonist in building a low-carbon economy. The country's agricultural and livestock production is strengthened by the transition of such an economy. Based on the indicators analyzed, the national contribution and Brazilian effort in sustainable production could be verified. Undoubtedly, Brazil is an example to highlight agricultural and livestock production with sustainable productivity in the international context.

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APPENDIX A

TABLE A.1
Mitigation of GHGs in livestock adopting low-carbon emission technologies in ABC Plan

Technologies and practices and their corresponding indicators, commitments, and goals	Recovery of pastures	Integrated systems (ICL, ICFL, and SAFs)	Direct planting system	Planted forests	Biological nitrogen fixation	Processing animal feces	Total
Commitment (1 million hectares)	15.00	4.00	8.00	3.00	5.50	-	35.50
Commitment (1 million cubic meters)	-	-	-	-	-	4.40	4.40
Minimum potential (1 million Mg CO_2eq.)	83.00	18.00	16.00	8.00	10.00	6.90	135.00
Area 2010 (1 million hectares)	84.67	5.51	22.35	5.90	24.18	-	142.61
Area 2020 (1 million hectares)	90.12	19.27	39.09	10.21	38.73	-	197.42
%Δ 2010-2020 (1 million hectares)	5.44	13.76	16.74	4.31	14.55	-	54.80
Expansion goal achieved (percent)	36.30	343.94	209.22	143.74	264.56	-	154.38
%Δ 2013-2018 (1 million cubic meters)	-	-	-	-	-	1.71	1.71
Expansion goal achieved (percent)	-	-	-	-	-	38.86	38.86
Emission factor (Mg CO_2eq. ha^{-1} $year^{-1}$)	3.79	3.79	1.83	4.69	1.83	-	-
Emission factor (Mg CO_2eq. M3)	-	-	-	-	-	1.56	-
Mitigation (1 million Mg CO_2eq.)	20.63	52.14	30.63	20.22	26.63	2.67	152.93
Mitigation goal achieved (percent)	24.86	289.67	191.44	252.80	266.28	38.70	113.28

Source: Telles et al. (2021, p. 41).
Obs.: GHGs – greenhouse gases; ICL – integration crop-livestock; ICLF – integration crop-livestock-forestry; and SAFs – agroforestry systems.

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