BRAZIL'S NATIONAL INVENTORY REPORT OF ANTHROPOGENIC EMISSIONS BY SOURCES AND REMOVALS BY SINKS OF GREENHOUSE GASES

FIRST BIENNIAL TRANSPARENCY REPORT OF BRAZIL TO THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE





MINISTRY OF SCIENCE, TECHNOLOGY AND INNOVATION

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FEDERATIVE REPUBLIC OF BRAZIL

PRESIDENT OF THE FEDERATIVE REPUBLIC OF BRAZIL

Luiz Inacio Lula da Silva

STATE MINISTER OF SCIENCE, TECHNOLOGY AND INNOVATION

Luciana Barbosa de Oliveira Santos

EXECUTIVE SECRETARY

Luis Manuel Rebelo Fernandes

SECRETARY FOR STRATEGIC POLICIES AND PROGRAMMES

Andrea Brito Latgé

DIRECTOR OF THE DEPARTMENT FOR CLIMATE AND SUSTAINABILITY

Osvaldo Luiz Leal de Moraes

GENERAL COORDINATOR OF CLIMATE SCIENCE

Marcio Rojas Da Cruz

CONTRIBUTION OF THE FOLLOWING REPRESENTATIVES OF THE INTERMINISTERIAL COMMITTEE ON CLIMATE CHANGE (CIM, Comitê Interministerial sobre Mudança do Clima):

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PREPARATION, TECHNICAL REVIEW AND GENERAL EDITING OF THE REPORT

Team of the General Coordination of Climate Science of the Ministry of Science, Technology and Innovation

Márcio Rojas Da Cruz

Ricardo Vieira Araújo

Sávio Túlio Oselieri Raeder

Project Team of Brazil's Fifth National Communication and Biennial Transparency Reports to the Climate Convention

Danielly Godiva Santana Molleta

Eliana Furlaneto de Macedo

George Vasconcelos Goes

Iris Roitman

Jussara Peccini

Mariana Gutierres Arteiro da Paz

Natalia Torres D'Alessandro

Nayana Machado

Régis Rathmann

Renata Patricia Soares Grisoli

Juan Vicente Guadalupe Gallardo

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1 EXECUTIVE SUMMARY

1.1 Background Information

Joining the Paris Agreement represents a crucial global commitment to tackling climate change and limiting global warming. The active participation of countries in this agreement is fundamental for the reduction of greenhouse gas emissions and the promotion of joint actions for a more sustainable future. In this context, Brazil reaffirms its commitment to preparing and submitting, in accordance with its national capabilities, the National Inventory of Anthropogenic Emissions by Sources and Removals by Sinks of Greenhouse Gases (GHG) not controlled by the Montreal Protocol. This effort is part of the First Biennial Transparency Report (BTR1), covering the time series from 1990 to 2022, in accordance with the requirements of the Enhanced Transparency Framework (ETF), reinforcing the country's role in the transparency and global responsibility in the face of climate change.

The National Inventory of GHG Emissions and Removals submitted in this document has been prepared in accordance with the Annex to Decision 18/CMA.1, Modalities, Procedures and Guidelines for the transparency framework for action and support, referred to in Article 13 of the Paris Agreement (known as MPGs), and with Annex V to Decision 5/CMA.3, Guidance for operationalizing the modalities, procedures and guidelines for the ETF, referred to in Article 13 of the Paris Agreement.

The methodology used was the "2006 IPCC Guidelines for National Greenhouse Gas Inventories" (IPCC, 2006).

The GHGs estimated were carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). Other GHG precursors, such as carbon monoxide (CO), nitrogen oxides (NO_x) and other non-methane volatile organic compounds (NMVOC) have been included whenever possible.

Due to the various sources of anthropogenic GHG emissions, the Inventory is organized according to the activities covered by the following sectors: Energy (CRT 1); Industrial Processes and Product Use (IPPU) (CRT 2); Agriculture (CRT 3); Land Use, Land-Use Change and Forestry (LULUCF) (CRT 4); and Waste (CRT 5). On the other hand, GHG removals are only accounted for in the LULUCF sector, due to the increase in carbon stocks, for example through vegetation growth.

The estimates used the same methodological approach as the one used in the inventory submitted in Brazil's Fourth National Communication (1990-2016) (BRASIL, 2021), and updated the country's Inventory with results from 1990 to 2020, published in a national document, the 6th edition of Brazil's Annual Estimates (BRASIL, 2022).

In order to update the activity data, mainly public and official references were consulted. Data that was not published in publications or other media was requested from the institutions responsible for such data, or experts were consulted. All the technical details, such as activity data, methodologies, equations, parameters and emission factors used can be found in this **National Inventory Report (NIR 2024).**

The key categories were identified using Tier 1 level and trend assessments, as

recommended in the IPCC (2006)[1] and adopted by the MPGs. This approach identified the sources, which, when combined, contribute to 95% of total emissions, or 95% of the inventory trend in absolute terms.

In order to calculate the uncertainties of the activity data and emission factors, the error propagation method (Approach 1) was used at national level for all sectors, with the exception of the Waste sector, which used the Monte Carlo method (Approach 2), given the possibility of detailing the various parameters involved in this estimate.

It should be noted that, in accordance with Decision 18/CMA.1, all the Inventory's analyses and results are presented in kt CO_2 eq, using the Global Warming Potential (GWP) metric for a 100-year time horizon contained in the IPCC's Fifth Assessment Report (GWP AR5) (IPCC, 2014).

1.2 Aggregate trends in emissions and removals

Brazil's total net emissions were 2,039,236 kt CO_2 eq in 2022. The total emissions fell by 20.4% (or -522,009 kt CO_2 eq) compared to the 2005 ceiling (Table 1.1). In relation to the levels seen that year, there was a significant reduction in emissions from the LULUCF sector, mainly related to the reduction in deforestation, which resulted from the adoption of Action Plans for the Prevention and Control of Deforestation and Fires, implemented by the LULUCF sector from 2005 onwards.

Despite the increase in emissions in 2022 compared to 2020, there has been a decrease compared to the previous year (2021). Furthermore, there is a different profile compared to developed countries, with 70% of the estimated value in 2022 occurring in the LULUCF and Agriculture sectors; 25.5% in Energy and IPPU; and 4.5% in Waste (Figure 1.1).

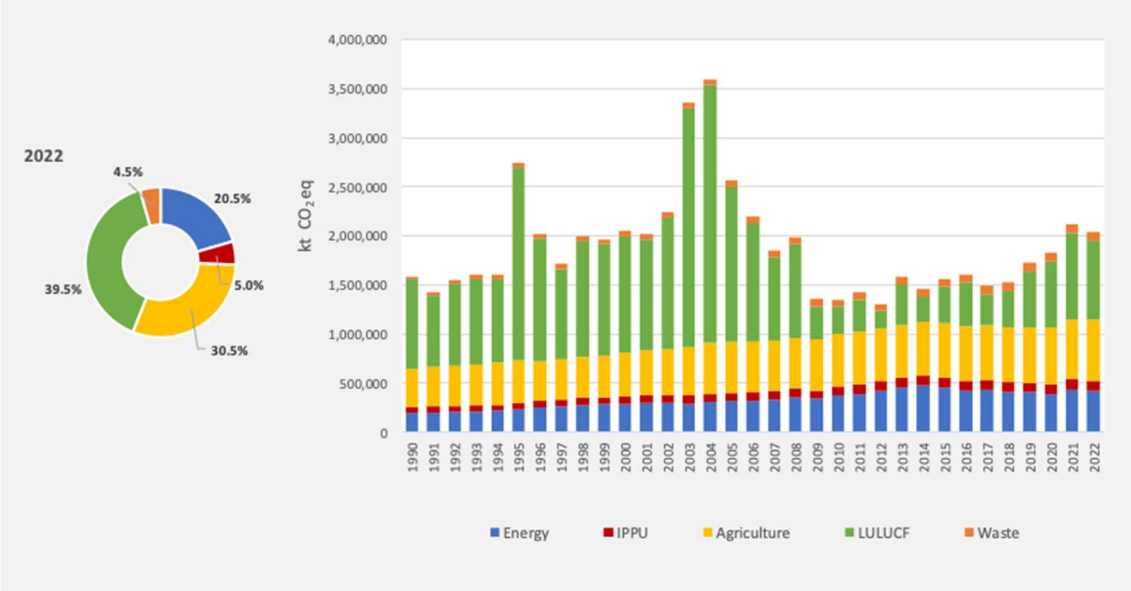


Figure 1.1. Net emissions by sector with LULUCF, in kt CO_2 eq.

[1] IPCC – Intergovernmental Panel on Climate Change. Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme. General Guidance and Reporting, v. 1, chap. 4. Methodological Choice and Identification of Key Categories, 2006.

1.3 Emissions trends by sector and gas

With regard to the sectors' share of emissions, throughout the time series there has been a consistent increase in the Energy sector's share, which accounted for 12% in 1990 and 2005, rising to 20% in 2022. The increase in the IPPU and Waste sectors' share was minimal over the period, with shares of 4% and 2% in 1990; 3% for both sectors in 2005; and 5% and 4% in 2022, respectively. On the other hand, LULUCF had a significant decrease between 1990 and 2022 (57% to 40%), although this result can be separated into phases, which are related to the National Climate Change Policy and the Plans for the Prevention and Control of Deforestation and Fires: i) a consistent increase in emissions between 1990 and 2004; ii) a downward trend due to the control of deforestation from 2005 to 2017; and iii) an increase from 2018 onwards, with the exception of 2022, due to the increase in deforestation, especially in the Amazon and Cerrado biomes. Agriculture showed an increase in its share from 25% to 30% between 1990 and 2022, but it should be noted that the increase in the herd occurred at rates higher than the emissions' rates, which is supported by indicators of production efficiency, which will be described below.

Still in sectoral terms, Energy emissions reached 418,451 kt CO_2 eq in 2022. The Fuel Combustion subsector (1.A) was responsible for 94.5% of these emissions, while the Fugitive Emissions subsector (1.B) accounted for the remaining 5.5%. The Transport category was the most representative, accounting for 52% of the Energy sector's total emissions, followed by Manufacturing Industries and Construction and Energy Industries, with 17% and 14%, respectively.

Estimates of emissions from the IPPU sector totaled 102,317 kt CO_2 eq in 2022. The Metal Industry contributed with the largest share of emissions, accounting for 51% of the sector's emissions in kt CO_2 eq in 2022. In turn, the Mineral Industry subsector was the second most representative, with 32%.

Emissions from Agriculture totaled 622,014 kt CO_2 eq in 2022. Analyzing the contribution by subsector, it is possible to identify that the Enteric Fermentation subsector was the most representative of the Agriculture sector, with 65% of total emissions in 2022, followed, in order of magnitude, by the Agricultural Soils subsector, with 23%. On the other hand, the Manure Management and Liming subsectors together contributed with approximately 9% of emissions, while the Rice Cultivation, Urea Application and Field Burning of Agricultural Residues subsectors together accounted for less than 3% of the sector's total emissions for that year.

Between 1990 and 2022, there was an 11% reduction in the emission of enteric methane per head of cattle. In this key category in particular, progress has been made in terms of the efficiency and sustainability of its production systems, which has been reflected in gains in production efficiency, such as the expansion of high-yielding dairy cattle systems and cattle confinement.

Net emissions from the LULUCF sector totaled 805,694 kt CO_2 eq in 2022. The sector's most representative net emissions were from the Grassland subsector (959,862 kt CO_2 eq), mainly reflecting conversions from Forest Land to Grassland (949,958 kt CO_2 eq). The largest net removals came from the Forest Land subsector, which contributed with -312,125 kt CO_2 eq, mainly as a result of vegetation protected within Conservation Units and Indigenous Lands.

Given the effective adoption of the Action Plans for the Prevention and Control of Deforestation and Fires (BRASIL, 2023a; 2023b), emissions from the LULUCF sector in 2022 were 69% lower than the peak seen in 2004, with a decrease from 56.5 to 22.3 thousand km^2 in the area deforested in the Amazon and Cerrado biomes.

Emissions from the Waste sector totaled 90,761 kt CO_2 eq in 2022. The Solid Waste Disposal subsector contributed the most to the sector's emissions in 2022, with 53,421 kt CO_2 eq, or around 59% of the total. Wastewater Treatment and Discharge emitted 36,056 kt CO_2 eq in that year and accounted for approximately 40% of the sector's total. The other subsectors contributed with a smaller share of emissions.

In general terms, the increase in the collection and proper disposal of waste has increased the sector's emissions. Emissions from Uncategorized Waste Disposal Sites had a reduction of 24% compared to 2020, which is due to the increase in landfill disposal, which consequently reduced the rate of waste disposed of in Unmanaged Waste Disposal Sites or garbage dumps.

Table 1.1. Net emissions by sector with LULUCF, in kt CO_2 eq, in selected years.

SECTOR/CATEGORIES	1990	2005	2016	2020	2022
	NET EMISSIONS (kt CO_2 eq)				
TOTAL	**1,588,395**	**2,561,246**	**1,603,968**	**1,824,760**	**2,039,236**
1. ENERGY	**196,119**	**318,363**	**424,610**	**390,210**	**418,451**
1.A. Fuel combustion	187,161	299,732	403,235	369,462	395,626
1.A.1. Energy industries	25,308	48,620	78,925	68,134	56,565
1.A.2. Manufacturing industries and construction	37,633	65,396	71,952	62,697	69,116
1.A.3. Transport	85,195	139,226	204,239	187,220	217,378
1.A.4 and 1.A.5. Other sectors and Other (Not specified elsewhere)	39,025	46,489	48,119	51,411	52,567
1.B. Fugitive emissions	8,959	18,630	21,375	20,748	22,824
2. IPPU	**56,870**	**83,335**	**93,931**	**96,992**	**102,317**
2.A. Mineral industry	15,170	20,444	29,715	32,070	32,993
2.B. Chemical industry	8,379	13,195	8,470	7,155	7,021
2.C. Metal Industry	32,673	47,614	48,925	48,739	52,226
2.D. Non-Energy Products from Fuels and Solvent Use	520	661	763	820	843
2.E. Electronics industry	0	0	0	3	1
2.F. Product Uses as Substitutes for Ozone Depleting Substances (ODS)[1]	0	1,234	5,768	7,879	8,891
2.G. Other Product Manufacture and Use	128	187	290	325	343
3. AGRICULTURE	**394,743**	**520,260**	**567,146**	**583,740**	**622,014**
3.A. Enteric fermentation	284,981	370,824	376,932	376,720	404,062
3.B. Manure Management	17,801	21,951	27,716	27,713	29,012
3.C. Rice cultivation	9,271	10,796	11,159	11,779	11,901
3.D. Agricultural soils	71,071	104,417	131,056	141,045	145,078
3.F. Field burning of agricultural residues	1,848	2,296	551	473	477
3.G. Liming	9,141	8,097	15,844	21,593	27,087
3.H. Urea Application	631	1,878	3,888	4,417	4,397
4. LULUCF	**908,066**	**1,573,714**	**436,546**	**665,084**	**805,694**
4.A. Forest Land	-43,666	-269,055	-345,479	-326,825	-312,125
4.B. Cropland	79,305	196,422	138,607	157,403	184,499

SECTOR/CATEGORIES	1990	2005	2016	2020	2022
	NET EMISSIONS (kt CO_2 eq)				
4.C. Grassland	876,829	1,673,983	658,720	855,213	959,862
4.D. Wetlands	6,412	12,326	8,745	10,601	11,675
4.E. Settlements	6,896	7,067	5,154	5,008	5,670
4.F. Other land	1,275	5,021	8,998	11,740	12,620
4.G. Harvested wood products	-18,984	-52,050	-38,198	-48,056	-56,507
5. WASTE	**32,596**	**65,574**	**81,735**	**88,735**	**90,761**
5.A. Solid waste disposal	13,186	35,658	45,798	49,824	53,421
5.B. Biological treatment of solid waste	18	49	56	63	61
5.C. Incineration and open burning of waste	1,151	2,014	1,272	1,326	1,224
5.D. Wastewater treatment and discharge	18,241	27,854	34,608	37,522	36,056

Notes: ODS – Ozone Depleting Substances.

CO_2 was the predominant gas in Brazil's emissions, with a 62% share in 2022. Also in 2022, CH_4 and N_2O gases accounted for 29% and 8.5% respectively, while SF_6, HFCs and PFCs combined accounted for 0.47% of the total (Figure 1.2).

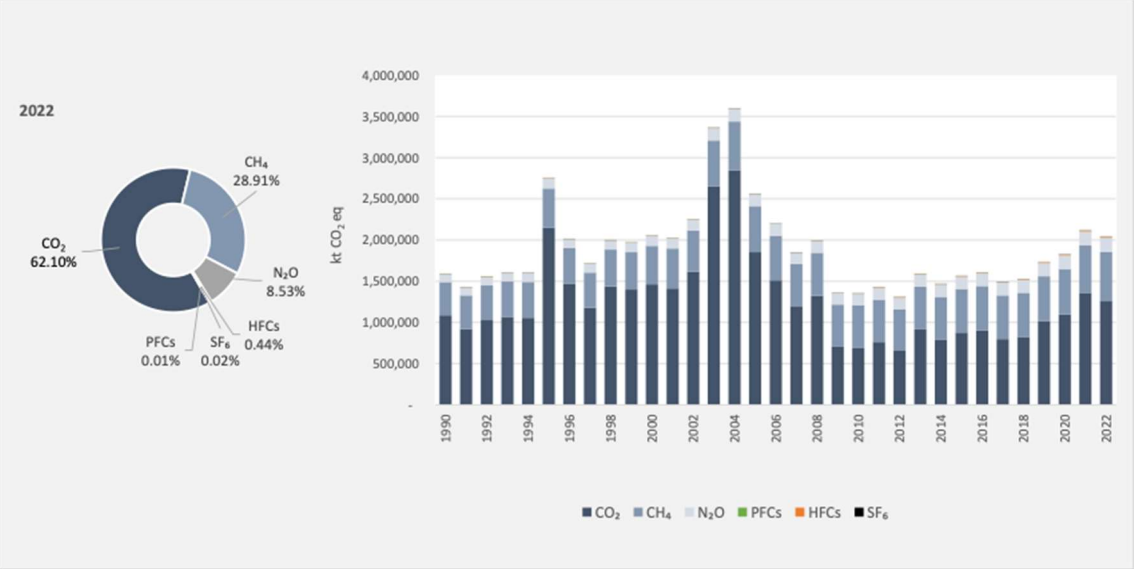


Figure 1.2. Brazil's net emissions by GHG, in kt CO_2 eq.

CO_2 emissions resulted from activities mainly related to the use of fossil fuels for energy and to the changes in land use and land cover. Other sources that make up CO_2 emissions are the industrial processes for the production of pig iron and steel, cement, lime, soda ash, ammonia and aluminum, as well as the use of fertilizers in agriculture and the incineration or burning of solid waste.

In total, Brazilian emissions in 2022 reached 1,266,131 kt CO_2. The LULUCF sector accounted for 59.4% of total CO_2 emissions (751,467 kt CO_2). This was followed by the Energy sector, which accounted for 30.9% of emissions (391,193 kt CO_2).

National emissions of CH_4 come from agricultural activities, changes in land use and land cover, waste treatment, some industrial processes and from the extraction and refining of oil and natural gas.

The Agriculture sector accounted for the largest share of total CH_4 emissions (74.8% in 2022 or 15,754 kt CH_4). This was followed by the Waste sector, which accounted for 14.9% of CH_4 emissions (3,134 kt CH_4).

National emissions of N_2O were due to the application of Inorganic N Fertilizers and Organic N Fertilizers to the soil, as well as the treatment of domestic wastewater, the burning of fossil fuels and biomass, industrial processes and changes in land use and land cover. The Agriculture sector accounted for 85.9% (564 kt N_2O) of total N_2O emissions. The LULUCF sector accounted for 7.1% (47 kt N_2O) and the Energy sector accounted for 5.3% of the total (35 kt N_2O).

With regard to fluorinated gases, the main emission in Brazil refers to HFCs, with 8,892 kt CO_2 eq. The main contribution of this family of gases came from the use of HFC-134a in the air-conditioning and refrigeration category.

1.4 Other relevant information

The Ministry of Science, Technology and Innovation (MCTI, Ministério da Ciência, Tecnologia e Inovação) is responsible for coordinating the preparation of Brazil's National Communications, Biennial Update Reports and Biennial Transparency Reports, which includes coordinating the preparation of the Inventory, and plays an important role in coordinating the different working groups that contribute to the collection of sectoral data.

Since a large part of the methodological approach of this NIR 2024 is the result of the Inventory submitted in Brazil's Fourth National Communication, it is important to highlight the collective and multidisciplinary effort, which involved more than 150 institutions and over 300 experts from all regions of the country. Due to its scope and specificity, it had the participation of an important part of the Brazilian scientific and business community, as well as various governmental institutions, trade associations, third sector organizations, universities and research centers, largely represented by the Technical-Scientific Coordination of the Brazilian Research Network on Global Climate Change (Rede CLIMA).

The Brazilian Research Network on Global Climate Change (Rede CLIMA) plays a fundamental role in supporting Research and Development activities, with the aim of meeting national needs for knowledge on climate change and providing information for the formulation of public policies. With nationwide coverage, Rede CLIMA involves dozens of research groups at universities and institutes, and is divided into thematic sub-networks. This decentralized structure provides capillarity and enhances the transfer and dissemination of the information generated.

Several public and private entities contribute by making activity data available, or by developing national parameters and emission factors that are up-to-date and relevant to

the methodology to be used in the preparation of estimates of GHG emissions and removals for the country.

In summary, the process of drawing up the Inventory reflects a robust and collaborative effort, involving a wide range of actors and institutions from different sectors in Brazil. The continuous progress in updating GHG estimates, based on the best scientific evidence available, demonstrates the country's commitment to transparency and methodological improvement. This engagement not only strengthens the national monitoring capacity, but also places Brazil as an important player on the global stage by providing reliable climate data, which is essential for formulating public policies and promoting international cooperation in the fight against climate change.

2 NATIONAL CIRCUMSTANCES, INSTITUTIONAL ARRANGEMENTS AND CROSS-CUTTING INFORMATION

2.1 Background information on greenhouse gas inventories and climate change

Brazil periodically submits its National Inventory of Anthropogenic Emissions by Sources and Removals by Sinks of Greenhouse Gases (GHG) not controlled by the Montreal Protocol (hereinafter referred to as the Inventory), to the extent that its capacities allow, in accordance with its commitment to update these estimates and report them to the United Nations Framework Convention on Climate Change (UNFCCC).

The Paris Agreement established an ETF in 2015, which increases the ambition for transparency on climate change and the reporting requirements for all Parties to the Agreement. In 2018, countries made a commitment to submitting Biennial Transparency Reports (BTRs).

This National Inventory Document of Brazil's Anthropogenic Emissions by Sources and Removals by Sinks of Greenhouse Gases in 2024 and the Common Reporting Tables (CRT) (referred to as NIR 2024), are part of the country's First Biennial Transparency Report (BTR), and present estimates of net greenhouse gas emissions for the time series from 1990 to 2022.

This National Inventory Report[2] was prepared in accordance with the Annex to Decision 18/CMA.1, Modalities, Procedures and Guidelines for the transparency framework for action and support, referred to in Article 13 of the Paris Agreement (known as MPGs), and with Annex V to Decision 5/CMA.3, Guidance for operationalizing the modalities, procedures and guidelines for the ETF, referred to in Article 13 of the Paris Agreement.

The GHG estimates are consistent with the "2006 IPCC Guidelines for National Greenhouse Gas Inventories" (IPCC, 2006).

The same methodological approach as the one used in the Inventory submitted in Brazil's Fourth National Communication (1990-2016) (BRASIL, 2020) was used in this NIR 2024. In addition, in 2022 Brazil updated the country's Inventory, which was published in a national document, the 6th edition of Brazil's Annual Estimates, with results from 1990 to 2020 (BRASIL, 2022), taking the initiative to advance emission estimates beyond the latest data submitted to the UNFCCC.

Due to the various sources of anthropogenic GHG emissions, the Inventory is organized according to the activities covered by the following sectors: Energy (CRT 1); Industrial Processes and Product Use (IPPU) (CRT 2); Agriculture (CRT 3); Land Use, Land-Use Change and Forestry (LULUCF) (CRT 4); and Waste (CRT 5). On the other hand, GHG removals are only accounted for in the LULUCF sector, due to the increase in carbon stocks, for example through vegetation growth.

The GHGs estimated were carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). Other

[2] Available at: https://www.gov.br/mcti/pt-br/sirene/publicacoes/relatorios-bienais-de-transparencia-btrs.

precursor GHGs, such as carbon monoxide (CO), nitrogen oxides (NO_x) and other non-methane volatile organic compounds (NMVOC) have been included whenever possible.

2.2 Description of national circumstances and institutional arrangements

2.2.1 Institutional arrangements for the preparation of the Inventory

Among the regulatory frameworks and management instruments aimed at implementing the UNFCCC in the country, the National Policy on Climate Change (PNMC, Política Nacional sobre Mudança do Clima) stands out[3], which established the legal framework for action to tackle climate change in Brazil.

The Interministerial Committee on Climate Change (CIM, Comitê Interministerial sobre Mudança do Clima)[4] is a permanent body and has the purpose of monitoring and promoting the implementation of actions and public policies within the scope of the Federal Executive branch relating to the PNMC.

The CIM is composed of the following State Ministries: I – Office of the Chief of Staff for the Presidency, which will chair it; II – Federal Attorney General's Office; III – Ministry of Agriculture and Livestock; IV – Ministry of Cities; V – Ministry of Science, Technology and Innovation; VI – Ministry of Agrarian Development and Family Farming; VII – Ministry of Development and Social Assistance, Family and Fight against Hunger; VIII – Ministry of Development, Industry, Trade and Services; IX – Ministry of Education; X – Ministry of Finance; XI – Ministry of Racial Equality; XII – Ministry of Integration and Regional Development; XIII – Ministry of the Environment and Climate Change; XIV – Ministry of Mines and Energy; XV – Ministry of Women; XVI – Ministry of Planning and Budgeting; XVII – Ministry of Indigenous Peoples; XVIII – Ministry of Foreign Affairs; XIX – Ministry of Health; XX – Ministry of Labor and Employment; XXI – Ministry of Transport; XXII – General Secretariat of the Presidency of the Republic; and XXIII – Secretariat for Institutional Relations of the Presidency of the Republic.

In addition to the Ministers, representatives appointed by the Social Participation Chamber, one of whom is the Executive Coordinator of the Brazilian Forum on Climate Change – FBMC (Fórum Brasileiro de Mudança do Clima), by the Interfederative Coordination Chamber and by the Scientific Advisory Chamber, one of whom is the Scientific Coordinator of the Brazilian Research Network on Global Climate Change – Rede CLIMA, are members of the CIM without voting rights.

The Ministry of Foreign Affairs (MRE, Ministério das Relações Exteriores) acts as the National Focal Point, with the mission of promoting the Brazilian government's liaison with the UNFCCC.

The Ministry of Science, Technology and Innovation (MCTI, Ministério da Ciência, Tecnologia e Inovação), through the General Coordination of Climate Science and Sustainability (CGCL, Coordenação-Geral de Ciência do Clima e Sustentabilidade), a part of the Strategic Policies and Programs (SEPPE, Políticas e Programas Estratégicos) structure, is responsible for coordinating the preparation of Brazil's National Communications, Biennial Update

[3] Law No. 12.187, dated December 29, 2009.
[4] Decree No. 12.040, dated June 05, 2024.

Reports and Biennial Transparency Reports, which includes coordinating the preparation of the Inventory, and plays an important role in coordinating the different working groups that contribute to the collection of sectoral data.

These transparency reports are financed through international resources from the Global Environment Facility (GEF), with the support of the United Nations Development Programme (UNDP), through its role as the implementing agency, and with the agreement of the Brazilian Cooperation Agency (ABC, Agência Brasileira de Cooperação).

The CGCL is also responsible for the National Emissions Registry System (SIRENE, Sistema de Registro Nacional de Emissões),[5] which is an official government instrument in the process of Measurement, Reporting and Verification (MRV) of anthropogenic greenhouse gas (GHG) emissions, and is the implementing agency of the project funded by the Capacity Building Initiative for Transparency (CBIT), "Strengthening of the national transparency system in Brazil under the Paris Agreement (DataClima+)", which ultimately aims to implement Brazil's centralized and integrated climate transparency system, with a view to preparing reports under the ETF and supporting national planning.

Through Decree nº 9.172/2017, Brazil established the National Emissions Registry System (SIRENE), with the aim of making the results of the National GHG Inventory available, as well as other emissions accounting initiatives, such as the Annual Estimates of GHG Emissions in Brazil.

SIRENE aims to make the process of preparing the Inventory permanent, accessible, secure and transparent, and to serve as an input for decision-making in governmental actions relating to climate change, with regard to the generation of scientific knowledge and the adoption of mitigation measures.

This system guarantees the publication of official national results through the presentation of charts and tables, which can be exported in different formats, according to the filters selected by the user. In addition, all official publications and transparency reports are made available on this platform for consultation by the general public.

Since a large part of the methodological approach of this NIR 2024 is the result of the Inventory submitted in Brazil's Fourth National Communication (1990-2016) (BRASIL, 2021), it is important to highlight the effort that was made. The preparation of the Inventory published in the Fourth National Communication represented a collective and multidisciplinary effort, involving more than 150 institutions and over 300 experts from all regions of the country. Due to its scope and specificity, it had the participation of an important part of the Brazilian scientific and business community, as well as various governmental institutions, trade associations, third sector organizations, universities and research centers, largely represented by the Technical-Scientific Coordination of the Brazilian Research Network on Global Climate Change (Rede CLIMA).

Rede CLIMA plays a fundamental role in supporting Research and Development activities, with the aim of meeting national needs for knowledge on climate change and providing information for the formulation of public policies. With nationwide coverage, Rede CLIMA involves dozens of research groups at universities and institutes, and is divided into thematic sub-networks. This decentralized structure provides capillarity and enhances the transfer and dissemination of the information generated.

[5] Available at: https://www.gov.br/mcti/pt-br/sirene.

The organization chart in Figure 2.1 shows the institutional arrangement and the relationship between the different players involved in the process of preparing the Inventory.

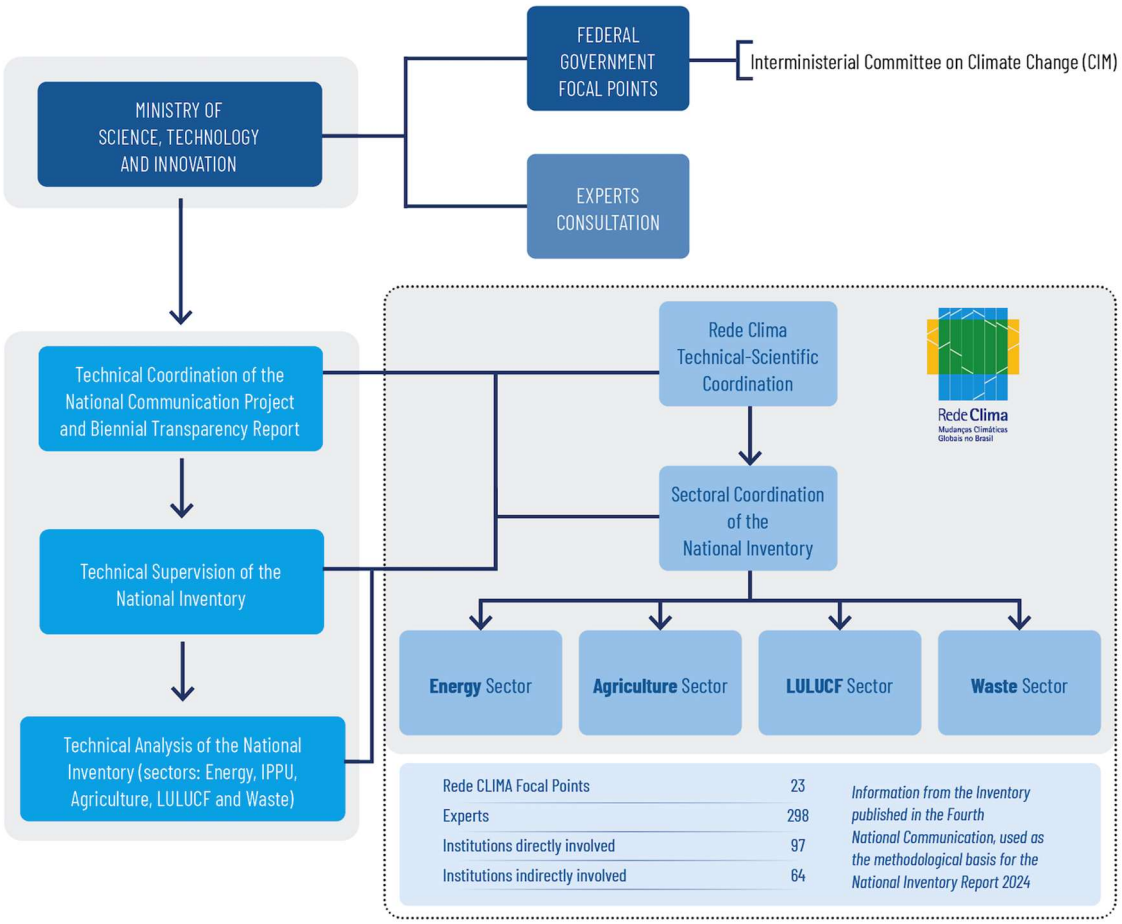


Figure 2.1. Institutional arrangement for preparing the GHG Inventory submitted in the Fourth National Communication.

2.2.2 Inventory preparation process

The Inventory cycle begins with planning based on the improvements identified in the previous Inventory and the establishment of partnerships to generate and collect data, development and survey of parameters, updating of estimates and compilation of the results.

Several public and private entities contribute by making activity data available, or by developing national parameters and emission factors that are up-to-date and relevant to the methodology to be applied in the preparation of estimates of GHG emissions and removals for the country.

The cycle follows the steps described in Figure 2.2 and ends with the planning of improvements for the next cycle.

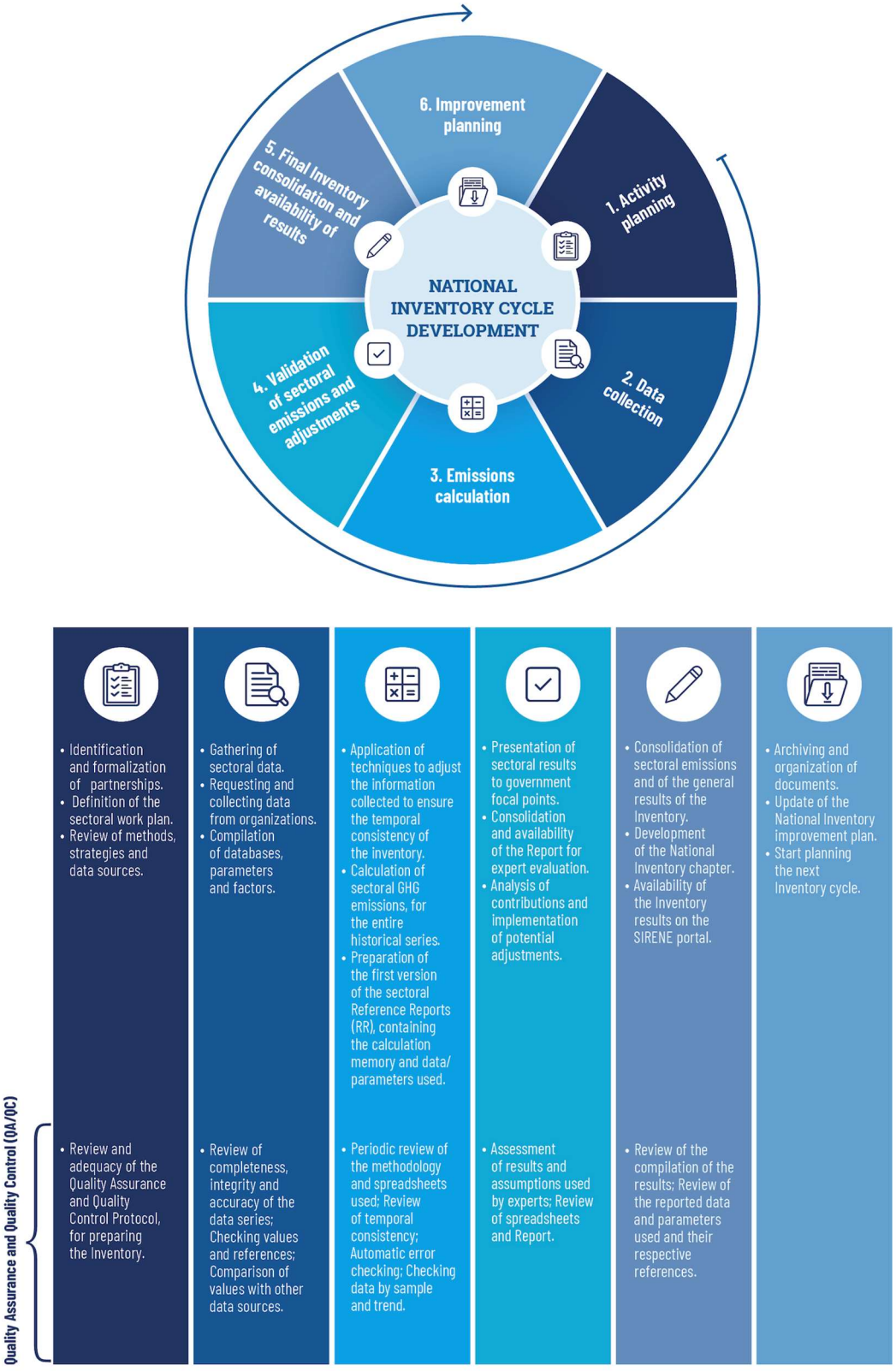


Figure 2.2. Cycle for preparing Brazil's GHG Inventory.

2.2.3 Archiving of information

The information related to Brazil's GHG National Inventory is archived on MCTI's institutional network. All data, including all disaggregated emission factors and activity data, all documentation on data generation and aggregation, including quality assurance/quality control (QA/QC), the results of the review, as well as metadata used throughout the process, from scientific articles to the spatial database used in the LULUCF sector, are archived.

The sectoral reports prepared in the Fourth National Communication, which transparently describe the methodological details, indicating the data sources and assumptions adopted, are also archived by the MCTI. These reports (in Portuguese) are made publicly available on SIRENE'S website,[6] along with the results of emissions and removals of all GHGs not controlled by the Montreal Protocol.

It will be on this institutional network that all the Inventory data will be archived, as well as the NIR and the BTR,[7] in both the Portuguese and the English versions.

2.2.4 Report approval process

The approval process for the National Inventory Report, part of Brazil's First Biennial Transparency Report, despite being the country's first submission in this format, followed similar procedures to those adopted for other publications submitted to the UNFCCC. Initially, after it was completed, the report underwent a quality assurance (QA) step, which included consultation with sectors' experts, as described in Section 2.5.

After the necessary analyses and adjustments were carried out, the consolidated report was shared with the ministries that are members of the Interministerial Committee on Climate Change (CIM). Once approved by the CIM, the report was forwarded for submission by the Ministry of Foreign Affairs (MRE), which acts as the National Focal Point and is responsible for coordinating the Brazilian government's liaison with the UNFCCC.

2.3 Brief general description of the methodologies and data sources used

2.3.1 Methodologies, parameters and data

This National GHG Inventory has been prepared in accordance with the Annex to Decision 18/CMA.1 and Annex V to Decision 5/CMA.3. Since the Inventory published in the Fourth National Communication (BRASIL, 2021), Brazil has used the 2006 IPCC Guidelines for National Greenhouse Gas Emissions Inventories, demonstrating its commitment to improving its estimates, which makes it possible to improve the planning and the inputs for decision-making.

The IPCC methodologies for quantifying emissions are divided into three levels (or Tiers) which correspond to the methodological complexity and representation of the specificities of each country. Tier 1 is considered the basic method, using default emission factors recommended by the IPCC's own methodology; Tier 2 is intermediate; and Tier 3 is more demanding in terms of the requirements for data obtained nationally. Tiers 2 and 3 are considered to be the most accurate estimation methods.

[6] Available at: https://www.gov.br/mcti/pt-br/sirene/publicacoes/relatorios-de-referencia-setorial.
[7] Available at: https://www.gov.br/mcti/pt-br/sirene/publicacoes/relatorios-bienais-de-transparencia-btrs.

For this Inventory, different Tiers were used, the application of which, for the various categories, can be understood in the sectoral breakdown presented in the Dataframes with information on the "methodological levels applied by gas" (Dataframes 4.1, 5.1, 6.1, 7.1 and 8.1 in Chapters 4, 5, 6, 7 and 8 of this document, respectively).

The GHGs estimated were carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). Other precursor GHGs, such as carbon monoxide (CO), nitrogen oxides (NO_x) and other non-methane volatile organic compounds (NMVOC) have been included whenever possible.

In order to update the activity data, mainly public and official references were consulted. Data that was not published in publications or other media was requested from the institutions responsible for such data, or experts were consulted. All the technical details, such as activity data, methodological assumptions, equations, parameters and emission factors used are presented by sector in this NIR 2024. A summary of the methods and emission factors by sector and GHG can be seen in Dataframe 2.1.

Dataframe 2.1. Summary of the methodological levels and emission factors (EF) used in Brazil's Inventory.[8]

SECTOR/SUBSECTOR/CATEGORIES	GASES, METHODS AND EMISSION FACTORS											
	CO_2		CH_4		N_2O		HFCs		PFCs		SF_6	
	Method	EF	Method	EF	Method	EF	Method	EF	Method	EF	Method	EF
1. Energy	T2, T3, T3a, NO	CS, D	T1, T2, T3, T3a, NO	CS, D, OTH	T1, T2, T3, T3a, NO, NA	CS, D, OTH						
1.A. Fuel Combustion Activities	T2, T3, T3a	CS, D	T1, T2, T3, T3a, NO	CS, D, OTH	T1, T2, T3, T3a	CS, D, OTH						
1.A.1 Energy industries	T2	CS	T2	OTH, D	T2	OTH, D						
1.A.2 Manufacturing Industries and Construction	T2	CS	T2	OTH, D	T2	OTH, D						
1.A.3 Transport	T2, T3a	CS	T1, T2, T3, T3a	CS, D	T1, T2, T3, T3a	CS, D						
1.A.4 Other sectors	T2	CS	T2	OTH	T2	OTH						
1.A.5 Other (Not specified elsewhere)	T2, NO	CS	T2, NO	D	T2, NO	D						
1.B. Fugitive emissions	T2, T3, NO	CS	T1, T2, T3, NO	CS, D	T2,T3,NO	CS						
1.B.1 Solid fuels	NO	NA	T1, NO	D	NA, NO	NA						
1.B.2 Oil and natural gas and other emissions from energy production	T2, T3	CS	T2,T3	CS	T2,T3	CS						
1.C.CO_2 Transport and storage	NO	NA										
2. Industrial Processes and Product Use (IPPU)	T1, T2, T3, IE, NO, NA	D, CS	T1, NO, NA	D	T1, T3, NO, NA	D, CS	IE,NE, NO, NA T2a	CS	IE,NE, NO, NA, T2a	CS	T1, NO, NA	D
2.A. Mineral Industry	T2, T3	CS										
2.B. Chemical Industry	T1, T3, NO, NA	D, CS	T1, NO, NA	D	T1, T3, NO, NA	D, CS	NA	NA	NA	NA	NA	NA

[8] The reporting structure presented in this Dataframe is consistent with the Common Reporting Tables (CRT): Summary3_ Summary Report for Methods and Emission Factors Used.

SECTOR/SUBSECTOR/CATEGORIES	GASES, METHODS AND EMISSION FACTORS											
	CO_2		CH_4		N_2O		HFCs		PFCs		SF_6	
	Method	EF	Method	EF	Method	EF	Method	EF	Method	EF	Method	EF
2.C. Metal Industry	T1, T2, T3, IE, NA	D, CS	T1, NA	D	T1, NA	D	NA	NA	NA	NA	NA	NA
2.D. Non-energy products from fuels and solvent use	T1, IE	D	NA	NA	NA	NA						
2.E. Electronics industry					NA	NA	IE,NE, T2a	CS	IE, NE, T2a	CS	NA	NA
2.F. Product uses as substitutes for ODS							T2a, NE, NO	CS	NE, NO, NA	NA	NA	NA
2.G. Other product manufacture and use	NO	NA	NO	NA	NO, NE	NA	NO,NA	NA	NO, NA	NA	T1, NO, NA	D
2.H. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3. Agriculture	T1, NO	D	T1, T2, NO, NE	D, CS	T1, T2, NO, NE	D, CS						
3.A. Enteric fermentation			T1, T2	D, CS								
3.B. Manure management			T1, T2	D, CS	T1, T2, NO	D, CS						
3.C. Rice cultivation			T1, T2, NO	D, CS	IE	D						
3.D. Agricultural soils			NA	NA	T1, T2	D, CS						
3.E. Prescribed burning of savannahs			NE	NA	NE	NA						
3.F. Field burning of agricultural residues			T1, T2	D, CS	T1, T2	D, CS						
3.G. Liming	T1	D										
3.H. Urea Application	T1	D										
3.I. Other carbon-containing fertilizers	NO	NA										
4. Land Use, Land-Use Change and Forestry (LULUCF)	T1, T2	CS	T1, T2	D	T1, T2	D						
4.A. Forest Land	T1, T2, NO	CS	T1, T2	D	T1, T2	D						
4.B. Cropland	T1, T2, NO	CS	T1, T2	D	T1, T2	D						

SECTOR/SUBSECTOR/CATEGORIES	GASES, METHODS AND EMISSION FACTORS											
	CO_2		CH_4		N_2O		HFCs		PFCs		SF_6	
	Method	EF	Method	EF	Method	EF	Method	EF	Method	EF	Method	EF
4.C. Grassland	T1, T2, NO	CS	T1, T2	D	T1, T2	D						
4.D. Wetlands	T1, T2	CS	T1, T2	D	T1, T2	D						
4.E. Settlements	T1, T2	CS	T1, T2	D	T1, T2	D						
4.F. Other Land	T1, T2	CS	T1, T2	D	T1, T2	D						
4.G. Harvested Wood Products	T1	D	IE	D	NA	NA						
5. Waste	T1, T2a	CS	T1, T2, NA, IE	CS, D	T1, NE, NA	D						
5.A. Solid waste disposal			T2, IE	CS, D								
5.B. Biological Treatment of Solid Waste			T1, IE	D	T1, NA	D						
5.C. Incineration and open burning of waste	T1, T2a	D, CS	T1, NA	D	T1	D						
5.D. Wastewater treatment and discharge			T2	CS	T1, NE	D						

Note: Methodological levels (IPCC, 2006) – T1: Tier 1; T2: Tier 2; T3: Tier 3.
Notations: NA (Not applicable) – Activity in a given source/sink category that occurs in the country, but did not result in emissions or removals of a specific gas; IE (Included elsewhere) – Included in another location/category of emissions or removals; NO (Not occurring) – Categories and processes that do not occur in the country; NE (Not estimated) – Activity data and/or emissions by sources and removals by sinks of GHG that have not been estimated, but for which a corresponding activity may occur in the country
Acronyms: CS – country-specific; D – IPCC default value; OTH[9] – other.

[9] The OTH classification for the categories of Energy industries (1.A.1), Manufacturing industries and construction (1.A.2) and Other sectors (1.A.4) stems from the adoption of the factors of the European Monitoring and Evaluation Programme (EMEP) and the European Environment Agency (EEA).

2.3.2 Consistency and recalculations of the time series

In order to ensure the consistency of the time series, the same methods, activity data sources and emission factors adopted in previous emissions inventories (BRASIL, 2021; 2022) were followed. Therefore, the recalculations were generally due to the revisions of the activity data by the data providers, thus having little impact on the emissions estimated between 1990 and 2020.

Comparing the consolidated results of the previous Inventory (time series of 1990 to 2020) (BRASIL, 2022) with the results of this NIR 2024, the largest proportion of adjustments is seen in 2018, with a 3% difference between estimated emissions. In particular, this is due to data adjustments in the Metal Industry (2.C), Enteric Fermentation (3.A) and Harvested Wood Products (4.G) subsectors, for the reasons described below. Between 2017 and 2020, the average adjustment in aggregate emissions was only of 1.9%, and in the period from 1990 to 2020, it was of 0.2%, thus demonstrating the consistency of the time series of this inventory (Figure 2.3).

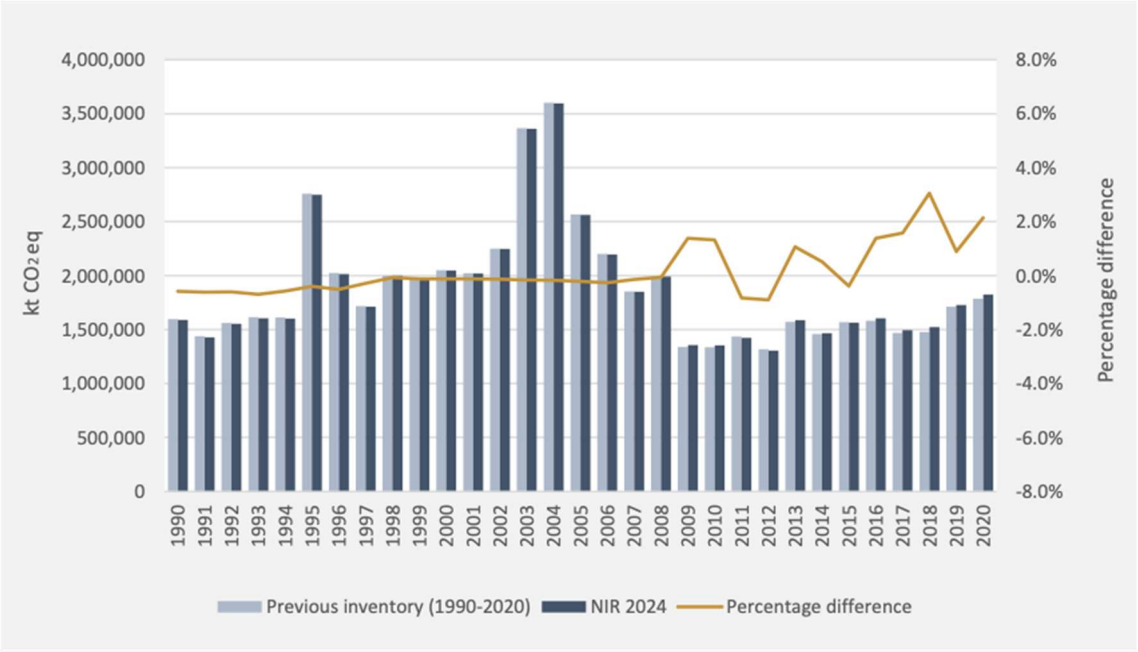


Figure 2.3. Comparison of total estimated emissions, in kt CO_2 eq and percentages, between inventories.

The Energy sector saw a change in emissions due to the review by the Energy Research Office (EPE, Empresa de Pesquisa Energética) of the open energy matrices of the National Energy Balance (EPE, 2023). The adjustment of this information had the greatest impact on the revision of total emissions for 2016, with 0.7%. However, in the time series, the average adjustment was of 0.1% (Figure 2.4).

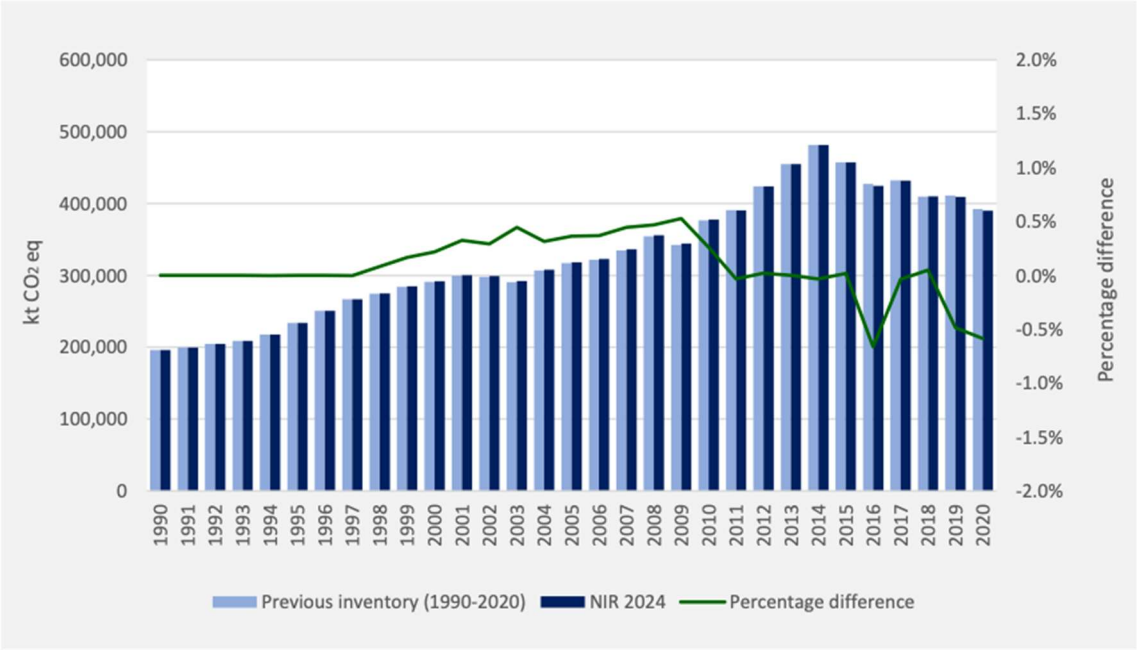


Figure 2.4. Comparison of total estimated emissions from the Energy sector (CRT 1), in kt CO_2 eq and percentages, between the inventories.

The IPPU inventory uses yearbooks drawn up by government bodies and associations representing the sectors as sources of activity data. However, the last revision of the inventory lacked up-to-date information from these sources, making it necessary to extrapolate the time series, particularly the production data, for the years of 2019 and 2020 for the Mineral Industry (2.A) and Metal Industry (2.C) subsectors. In the NIR 2024, these extrapolations were replaced with data from the sources mentioned in Dataframe 5.1, consequently generating a greater adjustment in emissions in those years, with a recalculation peak of 6.7% in 2019. However, looking at the time series from 1990 to 2020, the average adjustment was only of 0.3% (Figure 2.5).

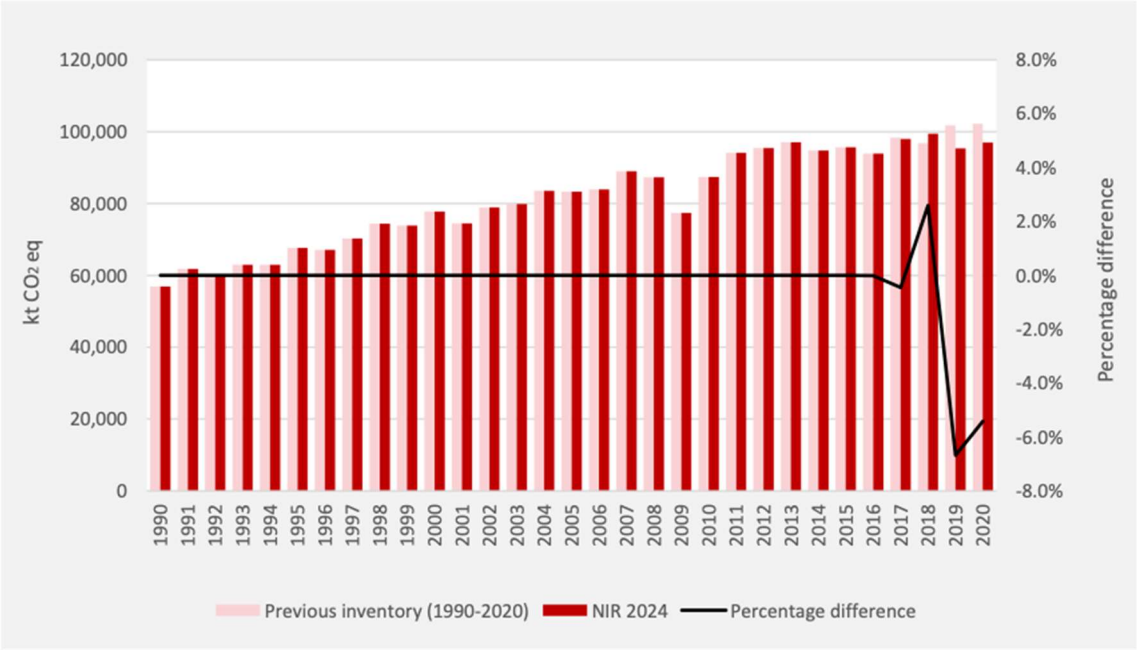


Figure 2.5. Comparison of total estimated emissions from the Industrial Processes and Product Use sector (CRT 2), in kt CO_2 eq and percentages, between the inventories.

Enteric fermentation is the main emitting category in the Agriculture sector, and, in the national context, it is explained by the representativeness of beef and dairy cattle farming. This is an economic activity of national importance, and the main parameters used to estimate its emissions refer to population, type of confinement, digestibility, weight and animal productivity. In the case of NIR 2024, compared to the previous inventory, the Brazilian Institute of Geography and Statistics (IBGE) revised the cattle population data for 2017 and 2020 (IBGE, 2024a). Consequently, emissions were revised in this period, with an average adjustment of 4.1% in the sector's emissions. However, no changes were identified in the activity data for the other years, resulting in a total average adjustment of emissions of only 0.5% in the time series (Figure 2.6).

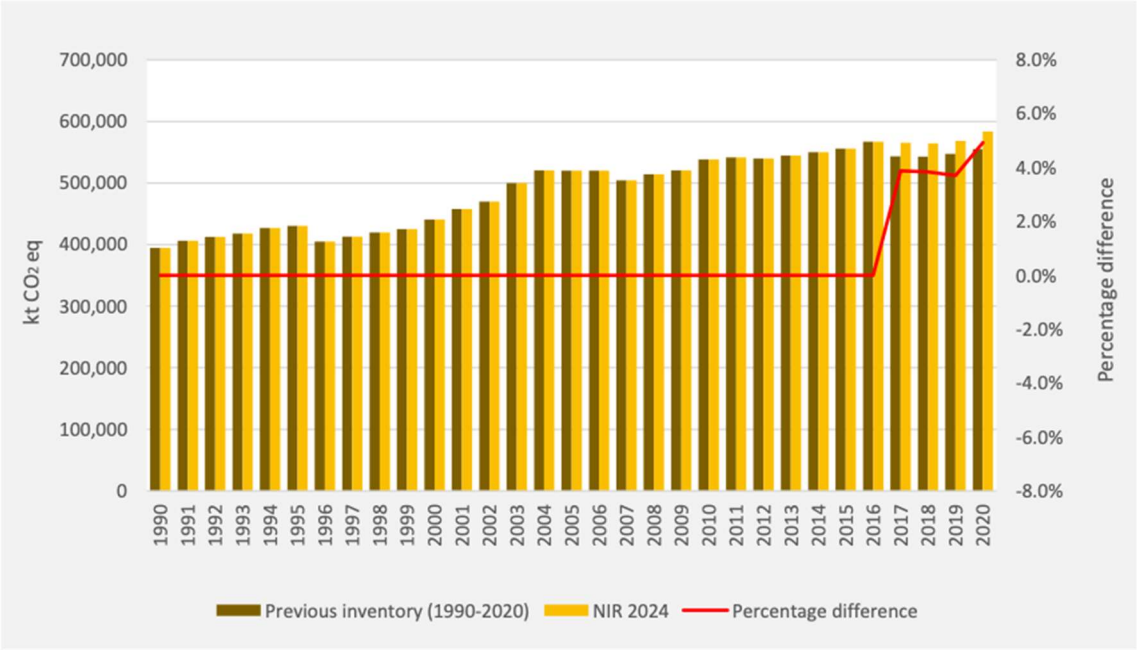


Figure 2.6. Comparison of the total estimated emissions from the Agriculture sector (CRT 3), in kt CO_2 eq and percentages, between the inventories.

The Land Use, Land-Use Change and Forestry sector represents the main sector in terms of emissions in the time series, with emissions being estimated using data from official sources, especially the deforestation rates reported by the National Institute for Space Research (INPE, Instituto Nacional de Pesquisas Espaciais) for the Amazon and Cerrado biomes (INPE, 2024). Furthermore, in order to better represent the variations in carbon stocks in its territory, the country estimates emissions and removals from the sector using various layers of information and emission factors – Approach 3 of the IPCC (2006).

In terms of adjustments to the time series, INPE has updated the data from the time series of annual deforestation in the Cerrado, due to the new official delimitation of Brazil's biomes, published by IBGE (IBGE, 2019). Part of the adjustments in emissions stems from this revision of the activity data, with the biggest difference seen in 2016 (11.3%).

In addition, the Harvested Wood Products subsector had its emissions revised throughout the times series, which was due to the revision of FAOSTAT's data on wood imports, exports and production throughout the time series (FAO, 2024). The biggest differences compared to the previous inventory occurred between 1990 and 1996, with an average increase of 52% in CO_2 removals. From 2003 onwards, removals decreased, especially between 2009 and 2022, when the average reduction in emissions was of 11%.

Given these main and other specific changes to the data mentioned in the LULUCF inventory, the average adjustment to the emissions time series was of 0.6% (Figure 2.7).

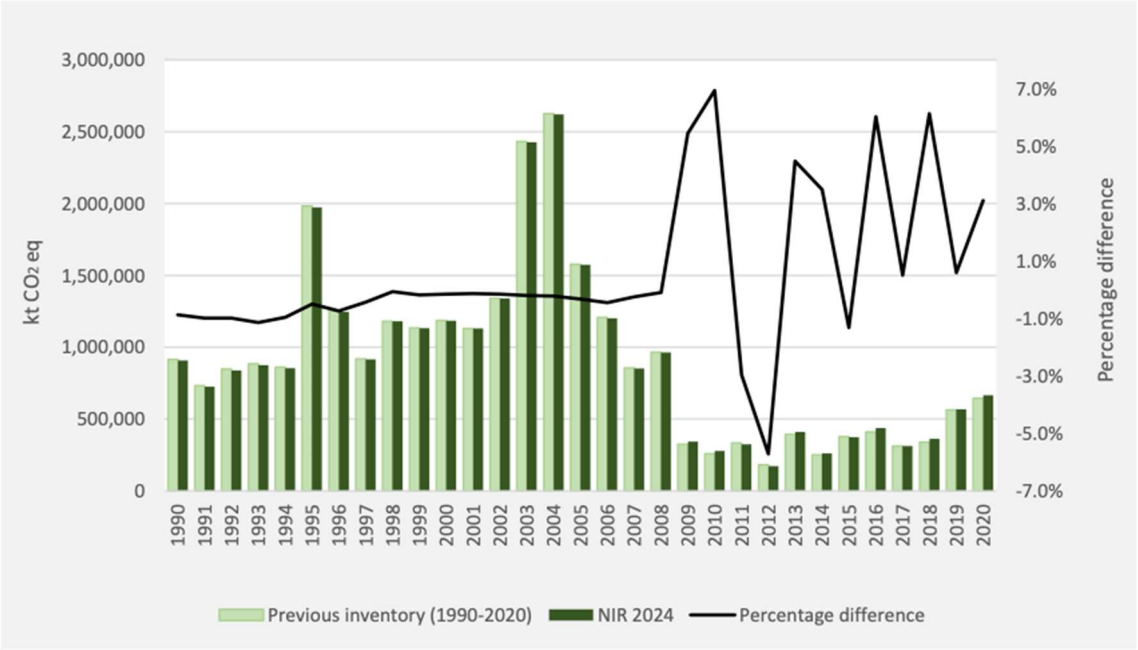


Figure 2.7. Comparison of total estimated emissions from the Land Use, Land-Use Change and Forestry sector (CRT 4), in kt CO_2 eq and percentages, between the inventories.

In the Waste sector, the main change that impacted emissions was the IBGE's population estimates (IBGE, 2023; 2024b). In the Solid Waste Disposal subsector (5.A), estimates of the population served with waste collection and methane recovery values in CDM projects reported to the UNFCCC (UNFCCC, 2024) were also reviewed. Other adjustments to activity data are mentioned in Sections 8.3.3, 8.4.3, 8.5.3 and 8.6.3 of this document.

Comparing the consolidated results of the previous Inventory with the results of this NIR 2024, the largest proportion of adjustments in the Waste sector is seen in 2001, with a 3.1% difference between estimated emissions. Between 2017 and 2020, the average adjustment in aggregate emissions was of 0.9%, and in the period from 1990 to 2020, it was of 2.4% (Figure 2.8).

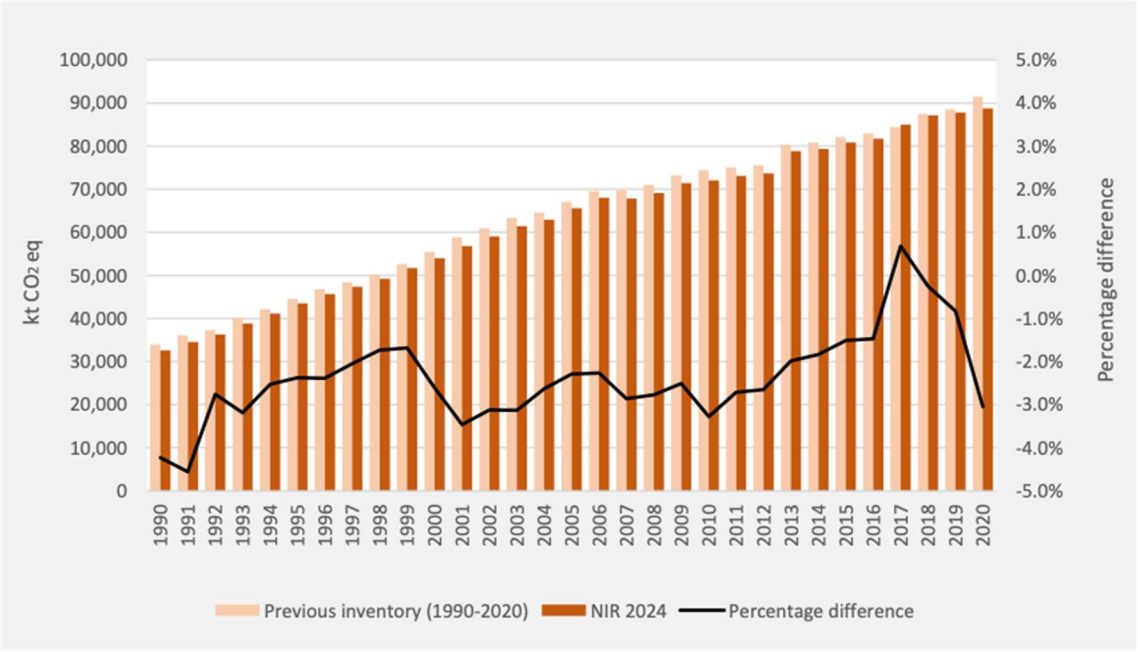


Figure 2.8. Comparison of total estimated emissions from the Waste sector (CRT 5), in kt CO_2 eq and percentages, between inventories.

2.4 Brief description of the key categories

In this NIR 2024 the key categories were identified using Tier 1 level and trend assessments, as recommended in the IPCC (2006)[10] and adopted by the MPGs. This approach identified the sources, which, when combined, contribute to 95% of total emissions, or 95% of the inventory trend in absolute terms.

In Brazil, when the LULUCF sector is considered, CO_2 emissions from Land Converted to Grassland (4.C.2), Forest Land Remaining Forest Land (4.A.1) and Road Transportation (1.A.3.b) are the most significant key categories. When the LULUCF sector is excluded from the analysis, the most significant key categories are CO_2 emissions from Road Transportation (1.A.3.b), and CH_4 emissions from Enteric Fermentation (female beef cattle over 2 years old, not confined) (3.A.1.a.iii) and Enteric Fermentation (cattle between 1 and 2 years old) (3.A.1.a.vi).

The full results of the analysis of the key categories are presented in Appendix I of this document.

2.5 Description of the quality assurance and quality control (QA/QC) plan and implementation

The main objective of the QA/QC plan is to ensure that the Inventory follows the good practice principles that guide the preparation and publication of inventories, namely: transparency, accuracy, comparability, consistency and completeness.

Quality Assurance (QA) is a planned system of review procedures, conducted by actors not directly involved in the development and compilation of the inventory. On the other hand, Quality Control (QC) is a system of routine technical activities to evaluate and maintain the

[10] Methodological Choice and Identification of Key Categories (IPCC, 2006, v. 1, chap. 4).

quality of the inventory while it is being compiled. In order to meet the criteria for good QC practices recommended by the IPCC, checks are carried out on activity data, parameters, emission factors and calculations.

As mentioned in Section 2.2 of this document, the Ministry of Science, Technology and Innovation (MCTI), through the General Coordination of Climate Science, was responsible for preparing the NIR 2024. The technical team responsible for the document is made up of the following actors: National Directorate; General Coordination, Technical Coordination; Inventory Supervision; Expert Analysts in the sectors covered by the inventory.

In terms of validation processes, Rede CLIMA supports the process in the QA phase, which is also carried out at government level by the Federal Government's focal points. The latter, in turn, complements this stage by validating the document and submitting it to the Interministerial Committee on Climate Change (CIM) for approval.

The QA/QC plan developed for the national GHG inventory is an ongoing exercise of adopting short-, medium- and long-term actions that begin with the identification, at the end of each cycle of preparation of emissions estimates, of lessons learned that prompt the planning of improvements to be adopted in the updating of the national inventory, as shown at the end of Chapters 4 to 8 of this document (Improvement Plan).

The QA/QC procedures are detailed below, including the QC checklist adopted in the NIR 2024, as well as the improvement plan to be adopted in the inventories to be prepared biannually.

QC procedures

Quality control procedures consist of routine technical checks to measure and control the quality of the inventory; guarantee the consistency, completeness, correctness and integrity of the data; and identify and correct errors and omissions. The QC procedures used during the inventory development cycle target a wide range of processes, including the attainment and handling of data, the application of approved procedures and methods, and the calculation of estimates and documentation.

A series of systematic Tier 1 quality control checks, in accordance with Volume 1, Section 6.6, of the 2006 IPCC Guidelines, is carried out annually by the technical inventory team in the main categories and in all sectors. Before the document is submitted to the UNFCCC, cross-cutting QC checks are carried out on the final NIR documents, as well as quality assessments on the data entered into the *online tool* of the Common Reporting Tables (CRT).

Category-specific Tier 1 QC procedures complement the general inventory QC procedures and are targeted at specific types of data. These techniques require knowledge of the specific category, including methodologies, available information and parameters associated with emissions or removals. In order to facilitate these checks, a checklist was developed to standardize and document the quality procedures. This list (Dataframe 2.2) includes a record of any corrective action taken and refers to the supporting documentation.

A comprehensive assessment is needed to ensure that the category remains up-to-date and relevant for several years after the year of analysis. This investigation is usually wide-ranging and uses a variety of sector-specific approaches, including assessments of the continuous applicability of methods, emission factors, activity data, uncertainty and

others, and establishes the basis for future activities by developing and prioritizing recommendations for improvement.

The operational measures adopted to support the implementation of the NIR 2024 QC process include:

- Hiring of sectoral analysts dedicated to preparing emissions estimates and mapping and proposing medium- and long-term actions aimed at improving estimates, as listed in the specific "Improvement Plans" for the subsectors of this NIR 2024 (Chapters 4 to 8);
- Review by the Inventory Technical Supervision and Coordination of the methodological consistency of activity data, emission factors and calculation procedures adopted in the accounting of emissions by gases and sectors in the time series from 1990 to 2022;
- Weekly meetings to monitor the technical activities carried out by the Inventory team;
- Inventory validation meetings with the National Directorate and the Coordination of the Fifth National Communication and Biennial Transparency Reports project; and
- Participation of the technical team in training courses on the methodologies for the preparation of the inventory and tools developed under the Enhanced Transparency Framework (ETF) of the Paris Agreement.

QA procedures

The quality assurance (QA) process helps to assure that the inventory represents the best possible estimates of emissions and removals based on the state of the art in scientific knowledge and data availability, and increases the effectiveness of the QA program. The selected underlying data and methods are independently evaluated by expert-reviewers of GHG inventories, government's focal points, universities' representatives with outstanding knowledge, and others.

Specifically for the LULUCF sector, it should be noted that a complementary strategy to the established standard QA was previously adopted, due to the complex process of generation of activity data for this sector (i.e., land-use conversion and land-cover matrices) and given the size and regional specificities of the national territory. To this end, a Scientific Validation Committee was set up, made up of experts from each biome. The committee's work ranged from validating the land-use and land-cover maps drawn up in previous inventories to selecting satellite images, providing technical support during the preparation of the updated map for 2016 and validating and analyzing the accuracy of the map drawn up as part of the inventory prepared in the Fourth National Communication (BRASIL, 2020). The involvement of experts in the mapping of each Brazilian biome contributed to better representing the dynamics of national land use and land cover.

Once completed, the NIR 2024 was submitted to a review by sectoral experts with proven experience in the international review of GHG emissions inventories. This stage took place in August 2024 and consisted of a workshop that allowed for an in-depth assessment of the inventory documentation, which had previously been made available as a preparatory activity for the workshop. In the run-up to the workshop, video-conferences were held to clarify the process, and the experts also had the opportunity to send preliminary questions

about the inventory to the technical team, as well as to make initial comments about the evaluation of the NIR documentation.

During the QA workshop, the experts were able to delve deeper into the evaluation of the documentation, as well as assess its methodologies, parameters and results together with the inventory team. At the end, they indicated points for improvement to the NIR 2024 and to subsequent inventories, which could be incorporated into the improvement plan.

The considerations received in this process were duly analyzed by the technical team, and improvements were incorporated where appropriate. Finally, the consolidated version of the NIR underwent a process of validation and approval by the Federal Government's technical focal points, who, in turn forwarded the document to the CIM for approval.

QA/QC Checklist

As mentioned above, the NIR 2024 QA/QC process was carried out with the support of a checklist, which includes different stages and targets, as shown in Dataframe 2.2. This document supported the development and approval of the document by the Brazilian government.

The stages of defining the calculation bases, preparing the data, calculating emissions and preparing the NIR were carried out with the involvement of the Inventory's technical team and the experts consulted in the QA stage. In turn, the approval of the document, complementing the QA stage, first took place at the level of the Federal Government's technical focal points, and finally the document was approved at a high level by the CIM.

Different stages have been adopted in the QA/QC process. Initially, the bases for calculating the inventory were defined, so that the data on activities and emission factors could be collected and prepared based on them, allowing the emissions to be calculated on the inventory spreadsheets. Once the NIR 2024 was completed, it underwent a QA process carried out by experts and a validation process carried out by the government's focal points.

In terms of processes, the level I targets include the objective or ideal condition to be met, according to the IPCC (2006). Any deviations refer to the level II targets, which are also in line with the NIR's QA/QC good practice guidance. In this respect, the document was able to meet practically all of the level I targets, but exceptional cases of data processing (level II) that had to be adopted to ensure the completeness of the time series should be noted.

Dataframe 2.2. QC/QA checklist of the Brazilian GHG emissions inventory.

PROCESS LEVEL	PROCESS NAME	TARGET (LEVEL I)	TARGET (LEVEL II)
1. DEFINITION OF CALCULATION BASES			
1.1	Review of methods	The calculation method is in line with the analysis of key categories.	NA
1.1	Review of methods	The calculation method complies with the decision tree in the IPCC Good Practice Guidance.	Deviations from the decision tree were duly explained according to logical and relevant expert criteria and were properly documented.
1.1	Review of methods	The calculation method was selected according to the requirements of the inventory plan.	Deviations from the inventory plan were duly explained according to logical and relevant criteria and were properly documented.

PROCESS LEVEL	PROCESS NAME	TARGET (LEVEL I)	TARGET (LEVEL II)
1.1	Review of methods	The calculation method selected is applicable to the entire inventory time series or is already being applied consistently.	In the event of changes to the calculation methodology applied to the time series, recalculations followed IPCC (2006) and were duly documented.
1.1	Review of methods	Deviations from the previously mentioned targets (level I) followed logical and relevant criteria and were duly documented.	NA
1.2	Review of data sources	New data sources used have been documented.	NA
1.2	Review of data sources	The data source(s) is/are/will be available for preparing the inventory on a biennial basis.	NA
1.2	Review of data sources	The complete time series required by the inventory is available in the data source(s).	Gaps in the data series were explained and duly documented.
1.2	Review of data sources	The complete time series required by the inventory is available in the data source(s).	An appropriate procedure (interpolation/extrapolation) was chosen to deal with the data gaps, in accordance with the IPCC Good Practice Guidance (chap. 7.3.2.2).
1.2	Review of data sources	The complete time series required by the inventory is available in the data source(s).	Once the data gaps had been identified, the time series was recalculated as necessary, and was duly documented and substantiated.
1.2	Review of data sources	The data source covers the entire emitting category.	The partial coverage was solved using an extrapolation technique and it was taken into account when calculating the uncertainties. All the stages were documented and justified clearly and logically.
1.2	Review of data sources	Information on the uncertainty of the data collected has been made available by the data provider.	NA
1.2	Review of data sources	The Activity Data (AD) and the Emission Factor (EF) are aligned with the specificities of the emitting category.	In the event of discrepancies, it was possible to establish the consistency between the two values through other data sources. Alternatively, the discrepancy was taken into account in an extrapolation and in the calculation of uncertainties, and the whole process was documented in an appropriate and logical manner.
1.2	Review of data sources	The procedures for calculating input data/parameters were clearly described.	NA

PROCESS LEVEL	PROCESS NAME	TARGET (LEVEL I)	TARGET (LEVEL II)
1.2	Review of data sources	The data source(s) were selected according to the requirements of the inventory plan.	All discrepancies were justified and documented clearly and logically.
1.2	Review of data sources	The assumptions and criteria considered in the selection of data were documented in a clear and logical manner.	NA
1.2	Review of data sources	The data provider carried out routine quality checks on the data source(s) and documented them.	NA
1.2	Review of data sources	When the IPCC default EF was used, the way in which the EF was adopted was based on Brazil's national circumstances and was duly documented in the Inventory.	For the default EF values adopted that were not in accordance with the national circumstances, the discrepancies were taken into account when calculating the uncertainties and were duly documented.
1.2	Review of data sources	In the cases where an EF other than the IPCC default value was used, the use was justified and substantiated in a clear and logical manner.	NA
1.2	Review of data sources	The activity data used was compared with other data sources and any discrepancies and selection criteria were duly documented.	NA
2. DATA COLLECTION			
2.1	Definition of requirements	The data requirements reflect the information and indications of the inventory plan and of the inventory's previous QA/QC assessments, including inputs from public searches.	NA
2.2	Data requests to the data provider	The QC requirements and data formats were forwarded to the data providers or contracted partners, and this has been duly documented.	The data provider (for example, an association) carries out its own quality controls, and the results have been duly documented.
2.3	Receipt of data	The data provider or contracting entity carried out the required quality controls and duly recorded this action.	The data provider carries out its own quality controls, and the results have been duly documented.
2.3	Receipt of data	The data received is complete, i.e., it covers all the required parameters and has no incompleteness.	All data gaps in the time series were filled in, in accordance with the IPCC Good Practice Guidance, by means of extrapolation/interpolation (chap. 7.3.2.2) which were duly documented and justified.
2.3	Receipt of data	The data received is consistent with previously adopted values and was adequately described.	Any discrepancies in terms of data were resolved and the procedures adopted were documented.

PROCESS LEVEL	PROCESS NAME	TARGET (LEVEL I)	TARGET (LEVEL II)
2.3	Receipt of data	The order of magnitude of the data received is compatible with other sources.	The reasons for any data discrepancies were duly identified and documented.
2.3	Receipt of data	The methods and assumptions on which the data uncertainty levels are based have been clearly and logically documented.	When it was not possible to adopt assumptions, an expert evaluation was carried out, and the relevant expert's quantification was documented in a clear and logical manner.
3. DATA PREPARATION, EMISSIONS CALCULATION, NIR PREPARATION AND APPROVAL			
3.1	Data input	All EFs were clearly identified in the Inventory spreadsheets.	NA
3.1	Data input	The documentation on the data sources of the EFs is complete and in accordance with the Inventory plan.	NA
3.1	Data input	The development and application of EFs in the time series was explained in a plausible manner and, in the case of unusual effects (such as changes in the order of magnitude), it was explained and documented in a clear and logical manner.	Non-plausible effects of EFs were duly corrected.
3.1	Data input	All AD was clearly identified in the Inventory spreadsheets.	NA
3.1	Data input	The documentation on the data sources of the AD is complete and in accordance with the Inventory plan.	NA
3.1	Data input	The development and application of AD in the time series was explained in a plausible manner and, in the case of unusual effects (such as changes in the order of magnitude), it was explained and documented in a clear and logical manner.	Non-plausible effects of AD were duly corrected.
3.1	Data input	Once all the data had been entered into the inventory spreadsheets, all the values, units and conversion factors entered were checked for accuracy and were confirmed.	NA
3.1	Data input	All uncertainties were entered into the spreadsheets and documented in accordance with the requirements of the Inventory plan.	NA

PROCESS LEVEL	PROCESS NAME	TARGET (LEVEL I)	TARGET (LEVEL II)
3.2	Data preparation	The description of the inventory includes an adequate explanation of the relevant models, with regard to organization, structure, calculation procedures, equations, assumptions, etc.	NA
3.3	Calculation of emissions	The calculations of the current inventory were compared with those of previous editions.	When significant changes or deviations from an expected trend occurred, the equations and data used in the calculation were reviewed, and any discrepancies were explained in an adequate, clear and logical manner and duly documented.
3.3	Calculation of emissions	The results of the emissions calculation for the current/previous reports were checked against other data sources in Brazil, and were considered to be comparable.	In cases where there was no comparability, or where no comparison was made, the relevant reasons were explained in an appropriate, clear and logical manner.
3.3	Calculation of emissions	The national implicit EFs are comparable with the EFs of other countries in order of magnitude.	Implicit EFs were explained adequately, clearly and logically, and duly documented, or a reference was made to an existing explanation.
3.4	Preparation of the NIR	The description of the emitting categories was reported logically in the NIR, covering General aspects with Results, Methodology, Activity data, Emission factors and Other parameters.	NA
3.5	Review and approval of the NIR by experts and federal government's focal points	The values for AD, EFs, emission estimates and uncertainties reported in the NIR are compatible with the values calculated in the Inventory spreadsheets.	NA
3.5	Review and approval of the NIR by experts and federal government's focal points	The documentation of the data sources, AD and EFs in the NIR is consistent with the values adopted in the NIR spreadsheets.	The incompleteness was explained adequately, clearly and logically, and was duly corrected and documented.

Note: NA — not applicable.

Planning and prioritizing of improvements

Inventory improvements can stem from a variety of external and internal sources. After compiling the activity data and preparing the preliminary estimates of GHG emissions and removals, the expert analysts provide feedback and recommendations on any methodological or procedural issues encountered. These recommendations generally refer to instances in which the inventory's compliance with the guiding principles of transparency, consistency, comparability, completeness and accuracy could be improved.

In addition to the improvements identified, members of the technical team are also encouraged to use their knowledge and experience in the development of inventory estimates to identify areas for improvement in the future, based on evolving science, innovative modeling approaches and new sources of activity data. Brazil identifies, monitors, plans and prioritizes improvements in both the emissions estimates (including the underlying activity data, EFs and methodologies) and the components of the national inventory arrangements (including the QA/QC plan, infrastructure and data management, archiving processes, uncertainty analysis and evaluation of key categories).

Improvements are prioritized by the respective teams based on the results of QA/QC and verification activities (as described in the QA/QC plan), analyses of key categories and uncertainty, availability of resources and assessment of potential impacts.

Additional information on improvement actions proposed by the NIR 2024 technical team can be found in the "Improvement Plan" sections at the end of the chapter for each sector inventoried (Chapters 4 to 8).

2.6 General assessment of uncertainty

The estimates of anthropogenic GHG emissions and removals presented in this Inventory are subject to uncertainties due to various causes, ranging from the inaccuracy of basic data to incomplete knowledge of the processes that give rise to GHG emissions or removals. According to the IPCC's "Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories – GPG 2000 (IPCC, 2000), it is recognized that the uncertainty of estimates cannot be completely eliminated. However, the main objective should be to produce accurate estimates, which are neither underestimated nor overestimated, and increasingly accurate, as far as possible.

According to the IPCC (2006),[11] uncertainty analysis should help prioritize national efforts to reduce uncertainty in future inventories, and guide decisions on methodological choices.

The Inventory's uncertainty is associated with each one of the activity data and emission factors and other parameters used in the estimates. Quantifying the uncertainty of each piece of information is as difficult, if not more so, to evaluate than the desired information itself.

For this Inventory, the accuracy of the estimates varied depending on the characteristics of each sector, the data available and the resources applied in determining the emission factors best suited to the Brazilian circumstances.

In order to calculate the uncertainties of the activity data and emission factors, the error propagation method (Approach 1) was used at national level for all sectors, with the exception of the Waste sector, which used the Monte Carlo method (Approach 2), given the possibility of detailing the various parameters involved in this estimate.

The total uncertainty of the Inventory was obtained by analyzing the uncertainties of all the estimated gases and not just of the three most relevant ones – CO_2, CH_4 and N_2O -, which made up 99.5% of the total emissions in kt CO_2 eq in 2022. The uncertainty of total net emissions in 2022 is 20.3%, and the uncertainty entered in the trend of total net emissions has been assessed at 9.8%. For further details, see Appendix II.

[11] Uncertainties (IPCC, 2006, chap. 3).

The uncertainty regarding the emission estimates is higher for Agriculture and LULUCF, thus reflecting the inherently high uncertainty due to the very nature of the biological processes involved, which determined higher values for this parameter on the activity data and emission factors. On the other hand, the estimated uncertainties tend to be low for carbon dioxide from energy consumption, as well as for some emissions from industrial processes. The uncertainty regarding estimates of these sources is generally between 1% and 3%. The calculated ranges are consistent with the typical ranges of uncertainty expected for each sector, as identified in IPCC (2006).

2.7 Overall assessment of completeness

The NIR 2024 presents a comprehensive assessment of anthropogenic GHG emissions and removals from 1990 to 2022 in Brazil. In general, this is a complete GHG inventory required by the MPGs, as follows: CO_2, CH_4, N_2O, HFCs, PFCs and SF_6, as well as the precursor gases CO, NO_x and NMVOC.

However, the emissions from some categories and of NF_3 were not estimated or were included in other categories due to the following reasons:

- Emissions that do not occur in the country;
- Unavailability of data, such as for NF_3 emissions from the production of photovoltaics, and
- Methodological issues specific to the national circumstances.

Overall, the NIR 2024 provides a comprehensive assessment of anthropogenic greenhouse gas (GHG) emissions and removals in Brazil. However, the emissions from some categories were not estimated (NE – not estimated) or their values were assigned to other categories (IE – included elsewhere), due to the reasons described in Dataframe 2.3 and Dataframe 2.4, respectively.

As part of the inventory improvement process, ongoing efforts are being made to identify suitable or improved data sources and methodologies to provide estimates for the NE categories.

More details on the completeness of the inventory can be found in the individual sectors' chapters, specifically Sections 4.2, 5.2, 6.2, 7.2 and 8.2 of the Energy, IPPU, Agriculture, LULUCF and Waste sectors' chapters, respectively.

Dataframe 2.3. GHG emissions and removals not estimated (NE) in the NIR 2024.[12]

GHG	SECTOR	IPCC SUBSECTOR/CATEGORY	JUSTIFICATION/PROPOSED IMPROVEMENT
C_2F_6	Industrial Processes and Product Use	2.E. Electronics Industry / 2.E.3. Photovoltaics	Emissions were not estimated due to the lack of activity data because of the incipiency of production activity in the country. The possibility of establishing partnerships to allow access to data with a view to accounting for these emissions in future editions of the inventory will be assessed.
CF_4	Industrial Processes and Product Use	2.E. Electronics Industry / 2.E.3. Photovoltaics	Emissions were not estimated due to the lack of activity data because of the incipiency of production activity in the country. The possibility of establishing partnerships to allow access to data with a view to accounting for these emissions in future editions of the inventory will be assessed.
C_6F_{14}	Industrial Processes and Product Use	2.E. Electronics Industry / 2.E.4. Heat Transfer Fluid	Emissions were not estimated due to the lack of activity data because of the incipiency of production activity in the country. The possibility of establishing partnerships to allow access to data with a view to accounting for these emissions in future editions of the inventory will be assessed.
CH_4	Energy	1.B. Fugitive Emissions from Fuels / 1.B.1.a Coal mining and handling (1.B.1.a.i.3. Abandoned underground mines)	There is not enough information to characterize abandoned mines in the country, therefore, it is not possible to estimate emissions after they have been closed down. The possibility of establishing partnerships to encourage the production of and access to data with a view to accounting for these emissions in future editions of the inventory will be assessed.
CH_4	Energy	1.B. Fugitive Emissions from Fuels / 1.B.2.a Oil (1.B.2.a.i. Exploration)	There is no data at national level to estimate emissions in this subcategory. The possibility of establishing partnerships to encourage the production of and access to data with a view to accounting for these emissions in future editions of the inventory will be assessed.
CH_4	Energy	1.B. Fugitive Emissions from Fuels / 1.B.2.b Natural Gas (1.B.2.b.i. Exploration)	There is no data at national level to estimate emissions in this subcategory. The possibility of establishing partnerships to encourage the production of and access to data with a view to accounting for these emissions in future editions of the inventory will be assessed.

[12] The reporting structure presented in this NIR is consistent with the CRT: Table 9 Completeness – Information on Notation Keys.

GHG	SECTOR	IPCC SUBSECTOR/CATEGORY	JUSTIFICATION/PROPOSED IMPROVEMENT
CH_4 , CO_2, N_2O	Land Use, Land-Use Change and Forestry	4.A. Forest Land / 4.B. Cropland / 4.C. Grassland / 4.F. Other Land	Emissions from fires in which there is no conversion of land-use and land-cover class have not yet been accounted for in the National GHG Inventories. Monitoring the dynamics of fires and vegetation regeneration over the inventoried years is not simple, as it requires access to satellite images on a more regular basis, as well as specific scientific data on vegetation growth rates. Furthermore, differentiating between natural fires and those caused by anthropogenic factors is not easy. The possibility of encouraging studies and methodologies that will enable these emissions to be accounted for in the future will be considered..
CO_2	Energy	1.B. Fugitive Emissions from Fuels / 1.B.2.a Oil (1.B.2.a.v. Distribution of oil products)	There is no data at national level to estimate emissions in this subcategory. The possibility of establishing partnerships to encourage the production of and access to data with a view to accounting for these emissions in future editions of the inventory will be assessed.
CO_2	Energy	1.B. Fugitive Emissions from Fuels / 1.B.2.b Natural Gas (1.B.2.b.v. Distribution)	There is no data at national level to estimate emissions in this subcategory. The possibility of establishing partnerships to encourage the production of and access to data with a view to accounting for these emissions in future editions of the inventory will be assessed.
CO_2	Agriculture	3.E. Prescribed Burning of Savannahs	Emissions were not estimated because differentiating the burning of savannahs due to anthropogenic or natural causes, as well as monitoring the dynamics of these fires over the years in the national territory, requires the development of a methodology to ensure that fires are properly linked with their respective causes. The possibility of encouraging the conduct of studies and the development of methodologies that will make it possible, in the future, to differentiate between the causes of fires, in order to account for these emissions, will be assessed.
CO_2	Land Use, Land-Use Change and Forestry	4.B. Cropland / 4.B.1. Cropland Remaining Cropland	CO_2 emissions and removals from Cropland Remaining Cropland (4.B.1) were not accounted for due to the unavailability of specialized data by type of crop for the periods prior to 2022. The possibility of establishing partnerships to encourage the production of and access to data with a view to accounting for these emissions in future editions of the inventory will be assessed.
HFC/PFC	Industrial Processes and Product Use	2.F. Product Uses as Substitutes for Ozone Depleting Substances/ 2.F.5. Solvents	No data could be obtained due to the large number of variations in this area and other uses for the same substances. Methodologies that deal with the disaggregation of imports of HFCs and PFCs by type of solvent, which could allow emissions to be accounted for, will be assessed.

GHG	SECTOR	IPCC SUBSECTOR/CATEGORY	JUSTIFICATION/PROPOSED IMPROVEMENT
NF_3	Industrial Processes and Product Use	2.E. Electronics Industry / 2.E.3. Photovoltaics	Emissions were not estimated due to the lack of activity data because of the incipiency of production activity in the country. The possibility of establishing partnerships to allow access to data with a view to accounting for these emissions in future editions of the inventory will be assessed.
N_2O	Industrial Processes and Product Use	2.G. Other Product Manufacture and Use / 2.G.3 N_2O from Product Uses	Emissions were not estimated due to the lack of activity data in the country. In future editions of the inventory, partnerships will be sought with institutions in the sector to collect this data.
N_2O	Waste	5.D. Wastewater treatment and discharge / 5.D.2 Industrial Wastewater Treatment	There are no specific IPCC emission factors to estimate N_2O emissions from the treatment and discharged of industrial effluents. The possibility of establishing Technical Cooperation Agreements or partnerships for the production of specific EFs will be assessed with a view to accounting for this gas in the Inventory in the future.

Note: Not estimated (NE) includes sources and sinks that are considered in the 2006 IPCC Guidelines (IPCC, 2006), but are not considered in this inventory.

Dataframe 2.4. GHG emissions and removals with values assigned to other categories (IE) in NIR 2024.[13]

GHG	IPCC SUBSECTOR/CATEGORY	IPCC (2006) ALLOCATION	ALLOCATION ADOPTED IN THE INVENTORY	JUSTIFICATION
CF_4	2.E. Electronics Industry / 2.E.1. Integrated Circuit or Semiconductor	2.E.1. Integrated Circuit or Semiconductor	2.E.5. Other	The activity data that is available does not allow disaggregation by the IPCC (2006) category.
CF_4	2.E. Electronics Industry / 2.E.2. TFT Flat Panel Display	2.E.2. TFT Flat Panel Display	2.E.5. Other	The activity data that is available does not allow disaggregation by the IPCC (2006) category.
CH_4	1.A. Fuel Combustion Activities (Sectoral approach) / 1.A.1. Energy Industries	1.A.1.a.i. Electricity Generation	1.A.1.a. Public Electricity and Heat Production	Only aggregate data was available.
CH_4	1.A. Fuel Combustion Activities (Sectoral approach) / 1.A.1. Energy Industries	1.A.1.a.ii. Combined Heat and Power Generation (CHP)	1.A.2. Manufacturing Industries and Construction	Only aggregate data was available.
CH_4	1.A. Fuel Combustion Activities (Sectoral approach) / 1.A.1. Energy Industries	1.A.1.a.iii. Heat Plants	1.A.1.a. Public Electricity and Heat Production	Only aggregate data was available.
CH_4	1.A. Fuel Combustion Activities (Sectoral approach) / 1.A.2. Manufacturing Industries and Construction	1.A.2.g.iv. Wood and Wood Products	1.A.2.d. Pulp, Paper and Print	The activity data that is available does not allow disaggregation by the IPCC (2006) category.
CH_4	1.A. Fuel Combustion Activities (Sectoral approach) / 1.A.2. Manufacturing Industries and Construction	1.A.2.g.vii. Off-road vehicles and other machinery	1.A.2.g.ii. Manufacturing of Transport Equipment	The activity data that is available does not allow disaggregation by the IPCC (2006) category.

[13] The reporting structure presented here is consistent with the Common Reporting Tables (CRT): Table 9 Completeness – Information on Notation Keys.

GHG	IPCC SUBSECTOR/CATEGORY	IPCC (2006) ALLOCATION	ALLOCATION ADOPTED IN THE INVENTORY	JUSTIFICATION
CH_4	1.B. Fugitive Emissions from Fuels / 1.B.2. Oil and Natural Gas	1.B.2.b. Production (Natural Gas)	1.B.2.b.ii. Production and Gathering	The available data allows for a greater disaggregation of emissions than the one proposed in IPCC (2006).
CH_4	4.B. Cropland / 4.B.1. Cropland Remaining Cropland	4.B.1. Cropland Remaining Cropland	3.F. Field Burning of Agricultural Residues / 3.F.1. Sugar cane	Phytophysiognomy in which emissions of non-CO_2 gases are related to field burning of agricultural residues, as is the case with sugar cane.
CH_4	5.B. Biological Treatment of Solid Waste / 5.B.2 Anaerobic Digestion at Biogas Facilities	5.B.2. Anaerobic Digestion at Biogas Facilities	1.A.4.c. Agriculture, forestry and fishing	Biogas is produced and consumed in Brazil in the agricultural sectors.
CO_2	1.A. Fuel Combustion Activities (Sectoral approach) / 1.A.2. Manufacturing Industries and Construction	1.A.2.g.v. Construction	1.A.2.g.ii. Manufacturing of Transport Equipment	The activity data that is available does not allow disaggregation by the IPCC (2006) category.
CO_2	1.A. Fuel Combustion Activities (Sectoral approach) / 1.A.1. Energy Industries	1.A.1.a.i. Electricity Generation	1.A.1.a. Public Electricity and Heat Production	Only aggregate data was available.
CO_2	1.A. Fuel Combustion Activities (Sectoral approach) / 1.A.1. Energy Industries	1.A.1.a.ii. Combined Heat and Power Generation (CHP)	1.A.2. Manufacturing Industries and Construction	Only aggregate data was available.
CO_2	1.A. Fuel Combustion Activities (Sectoral approach) / 1.A.1. Energy Industries	1.A.1.a.iii. Heat Plants	1.A.1.a. Public Electricity and Heat Production	Only aggregate data was available.
CO_2	1.A. Fuel Combustion Activities (Sectoral approach) / 1.A.2. Manufacturing Industries and Construction	1.A.2.g.i. Manufacturing of Machinery	1.A.2.g.ii. Manufacturing of Transport Equipment	The activity data that is available does not allow disaggregation by the IPCC (2006) category.

GHG	IPCC SUBSECTOR/CATEGORY	IPCC (2006) ALLOCATION	ALLOCATION ADOPTED IN THE INVENTORY	JUSTIFICATION
CO_2	1.A. Fuel Combustion Activities (Sectoral approach) / 1.A.2. Manufacturing Industries and Construction	1.A.2.g.iv. Wood and Wood Products	1.A.2.d. Pulp, Paper and Print	The activity data that is available does not allow disaggregation by the IPCC (2006) category.
CO_2	1.A. Fuel Combustion Activities (Sectoral approach) / 1.A.2. Manufacturing Industries and Construction	1.A.2.g.v. Construction	1.A.2.g.ii. Manufacturing of Transport Equipment	The activity data that is available does not allow disaggregation by the IPCC (2006) category.
CO_2	1.A. Fuel Combustion Activities (Sectoral approach) / 1.A.2. Manufacturing Industries and Construction	1.A.2.g.vii. Off-road vehicles and other machinery	1.A.2.g.ii. Manufacturing of Transport Equipment	The activity data that is available does not allow disaggregation by the IPCC (2006) category.
CO_2	1.B. Fugitive Emissions from Fuels / 1.B.2. Oil and Natural Gas	1.B.2.b. Production (Natural Gas)	1.B.2.b.ii. Production and Gathering	The available data allows for a greater disaggregation of emissions than the one proposed by IPCC (2006).
CO_2	2.C. Metal Industry / 2.C.5 Lead Production	2.C.5. Lead Production	2.C.7. Other (non-ferrous metals, except aluminum and magnesium)	The data was obtained in aggregate form, thus not allowing the reporting by the IPCC (2006) category.
CO_2	2.D. Non-Energy Products from Fuels and Solvent Use / 2.D.2 Paraffin Wax Use	2.D.2. Paraffin Wax Use	2.D.3. Other	The data was obtained in aggregate form, thus not allowing the reporting by the IPCC (2006) category.
HFC	2.E. Electronics Industry / 2.E.1. Integrated Circuit or Semiconductor	2.E.1. Integrated Circuit or Semiconductor	2.E.5. Other	The activity data that is available does not allow disaggregation by the IPCC (2006) category.
HFC	2.E. Electronics Industry / 2.E.2. TFT Flat Panel Display	2.E.2. TFT Flat Panel Display	2.E.5. Other	The activity data that is available does not allow disaggregation by the IPCC (2006) category.
N_2O	1.A. Fuel Combustion Activities (Sectoral approach) / 1.A.1. Energy Industries	1.A.1.a.i. Electricity Generation	1.A.1.a. Public Electricity and Heat Production	Only aggregate data was available.

GHG	IPCC SUBSECTOR/CATEGORY	IPCC (2006) ALLOCATION	ALLOCATION ADOPTED IN THE INVENTORY	JUSTIFICATION
N_2O	1.A. Fuel Combustion Activities (Sectoral approach) / 1.A.1. Energy Industries	1.A.1.a.ii. Combined Heat and Power Generation (CHP)	1.A.2. Manufacturing Industries and Construction	Only aggregate data was available.
N_2O	1.A. Fuel Combustion Activities (Sectoral approach) / 1.A.1. Energy Industries	1.A.1.a.iii. Heat Plants	1.A.1.a. Public Electricity and Heat Production	Only aggregate data was available.
N_2O	1.A. Fuel Combustion Activities (Sectoral approach) / 1.A.2. Manufacturing Industries and Construction	1.A.2.g.iv. Wood and Wood Products	1.A.2.d. Pulp, Paper and Print	The activity data that is available does not allow disaggregation by the IPCC (2006) category.
N_2O	1.A. Fuel Combustion Activities (Sectoral approach) / 1.A.2. Manufacturing Industries and Construction	1.A.2.g.v. Construction	1.A.2.g.ii. Manufacturing of Transport Equipment	The activity data that is available does not allow disaggregation by the IPCC (2006) category.
N_2O	1.A. Fuel Combustion Activities (Sectoral approach) / 1.A.2. Manufacturing Industries and Construction	1.A.2.g.vii. Off-road vehicles and other machinery	1.A.2.g.ii. Manufacturing of Transport Equipment	The activity data that is available does not allow disaggregation by the IPCC (2006) category.
N_2O	3.C. Rice Cultivation / 3.C.1. Irrigated	3.C.1. Irrigated	3.D.1. Direct N2O Emissions from Managed Soils	According to IPCC (2006), N_2O emissions generated from the anaerobic digestion of irrigated rice cultivation should be allocated to the Agricultural Soils category.
N_2O	4.B. Cropland / 4.B.1. Cropland Remaining Cropland	4.B.1. Cropland Remaining Cropland	3.F. Field Burning of Agricultural Residues / 3.F.1. Sugar cane	Phytophysiognomy in which emissions of non-CO_2 gases are related to field burning of agricultural residues, as is the case with sugar cane.

Note: Emissions with values assigned to other categories "IE" includes sources and sinks in this Inventory that are allocated to a sector other than that indicated by the 2006 IPCC Guidelines (IPCC, 2006).

2.8 Information on the metrics used

In accordance with Decision 18/CMA.1, all analyses and results presented in kt CO_2 eq in this NIR 2024 used the Global Warming Potential (GWP) metric for a 100-year time-horizon from the IPCC Fifth Assessment Report (GWP AR5) (IPCC, 2014).

GWP is a measure of the capacity of a greenhouse gas to trap heat in the atmosphere, in relation to the same amount of CO_2, over a given time horizon. It is expressed as a factor which, multiplied by the mass of the gas, results in an equivalent mass of CO_2 (CO_2 eq).

The results of Brazil's previous inventories were presented in CO_2-equivalent units, taking into account the GWP values for a 100-year time horizon published in the IPCC's Second Assessment Report (SAR) (IPCC, 1995), in accordance with Decision 17/CP.8.

The IPCC Fifth Assessment Report (IPCC, 2014) presented the values for the Global Temperature Change Potential (GTP), which Brazil also considers relevant. According to the IPCC, the GTP is characterized by being a metric based on temperature change, i.e., it is related to the variation in the average temperature of the global surface, over a selected time horizon, in response to a GHG emission pulse.

According to the IPCC (2014), "the most appropriate metric and time horizon will depend on which aspects of climate change are considered to be the most important for a particular use. No metric is capable of accurately comparing all the consequences of different emissions and they all have limitations and uncertainties." The IPCC also states that the GTP metric is the most suitable one for policies based on global warming containment targets, while GWP is not directly related to a temperature threshold. In view of this, the GTP metric would be the most consistent one for monitoring measures aimed at containing the increase in the average global temperature to below 2 °C compared to pre-industrial levels.

Table 2.1 shows the values of the coefficients per gas associated with the different metrics. For additional information purposes, Table 2.2 shows the NIR 2024 results according to the GWP (SAR and AR5) and GTP (AR5) metrics.

Table 2.1. Factors or coefficients per gas for GWP (100 years) and GTP (100 years).

GAS	GWP 100 years (SAR-1995)	GWP 100 years (AR5-2014)	GWP 100 years (AR5-2014)
CO_2	1	1	1
CH_4	21	28	4
N_2O	310	265	234
HFC-23	11,700	12,400	12,700
HFC-32	650	677	94
HFC-125	2,800	3,170	967
HFC-134a	1,300	1,300	201
HFC-143a	3,800	4,800	2,500
HFC-152a	140	138	19
HFC-227ea	3,220	3,350	1,460
HFC-365mfc	794	804	114
CF_4	6,500	6,630	8,040
C_2F_6	9,200	11,100	13,500
SF_6	23,900	23,500	28,200

Table 2.2. NIR 2024 results, in kt CO_2 eq, by sector and according to GWP (AR5 and SAR) and GTP (AR5) metrics.

GWP (AR5)	1990	2000	2010	2020	2022	Variation 2020-2022 %
	kt CO_2 eq					
1. Energy	196,119	291,613	377,678	390,210	418,451	+7.2%
2. Industrial Processes and Product Use	56,870	77,809	87,353	96,992	102,317	+5.5%
3. Agriculture	394,743	440,797	538,559	583,740	622,014	+6.6%
4. Land Use, Land-Use Change and Forestry	908,066	1,184,464	277,144	665,084	805,694	+21.1%
5. Waste	32,596	54,006	72,073	88,735	90,761	+2.3%
TOTAL	**1,588,395**	**2,048,689**	**1,352,807**	**1,824,760**	**2,039,236**	+11.8%
GWP (SAR)	**1990**	**2000**	**2010**	**2020**	**2022**	**Variation 2020-2022 %**
	kt CO_2 eq					
1. Energy	192,811	288,791	374,531	387,257	415,301	+7.2%
2. Industrial Processes and Product Use	56,920	78,418	87,101	96,690	101,985	+5.5%
3. Agriculture	329,613	370,335	458,343	505,318	537,110	+6.3%
4. Land Use, Land-Use Change and Forestry	899,560	1,172,613	271,319	657,591	797,319	+21.2%
5. Waste	25,159	41,523	55,325	67,790	69,252	+2.2%
TOTAL	**1,504,063**	**1,951,680**	**1,246,619**	**1,714,646**	**1,920,966**	+12.0%
GTP (AR5)	**1990**	**2000**	**2010**	**2020**	**2022**	**Variation 2020-2022**
	kt CO_2 eq					
1. Energy	182,644	279,136	362,151	374,757	402,201	+7.3%
2. Industrial Processes and Product Use	56,060	76,070	84,057	89,684	94,201	+5.0%
3. Agriculture	119,622	137,463	178,593	213,252	226,441	+6.2%
4. Land Use, Land-Use Change and Forestry	870,113	1,131,765	251,117	631,719	768,349	+21.6%
5. Waste	6,135	9,896	13,016	15,089	15,259	+1.1%
TOTAL	**1,234,573**	**1,634,330**	**888,934**	**1,324,500**	**1,506,451**	**+13.7%**

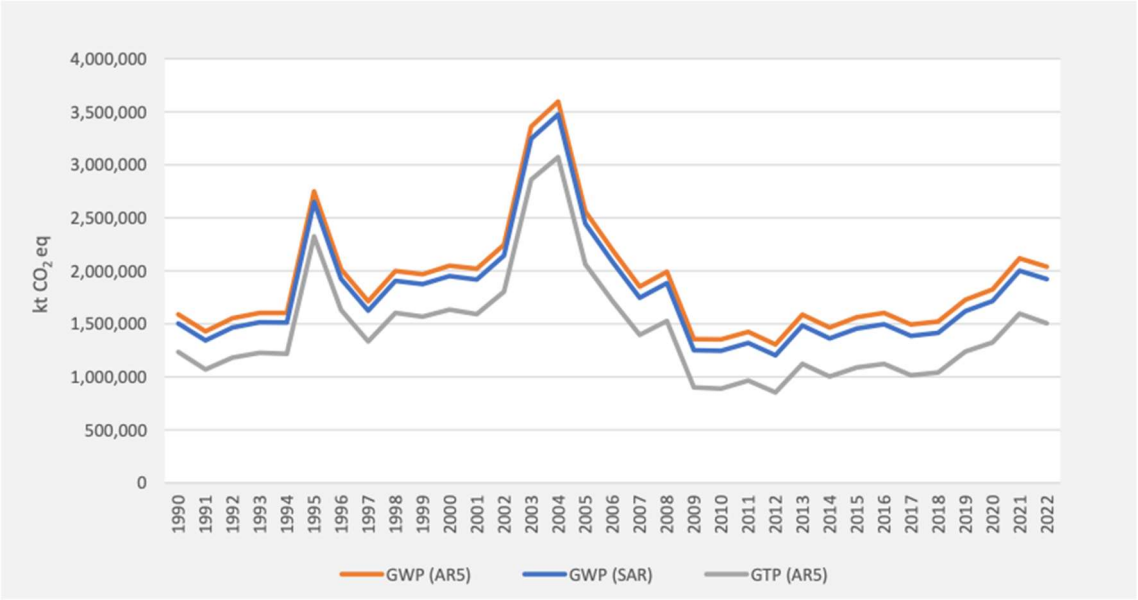


Figure 2.9. Evolution of emissions in kt CO_2 eq by GWP-AR5, GWP-SAR and GTP-AR5 metrics, from 1990 to 2022.

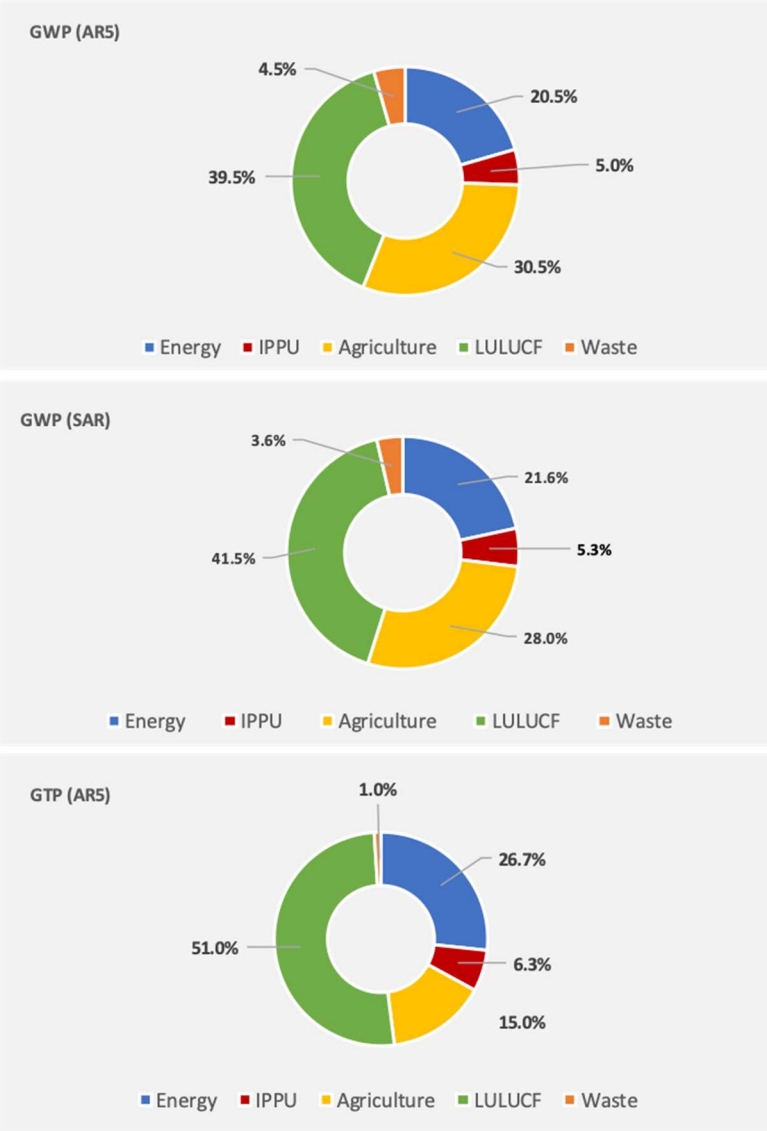


Figure 2.10. Share of the sectors' emissions in 2022 by GWP-AR5, GWP-SAR and GTP-AR5 metric.

2.9 Information on the provisions regarding flexibility

In order to promote universal participation, the ETF and its MPGs include an inherent flexibility that takes into account the different capacities of the Parties and is based on the collective experience of developed and developing countries. The MPGs specify the flexibility provisions available to Parties that are developing countries and that need it, in light of their capacities, as provided for in Article 13, paragraph 2.

The application of the flexibility provided for in the provisions of the MPGs for Parties that are developing countries should be self-determined, i.e., the country will determine when the flexibility can be applied in light of its capacity constraint(s) and always in relation to a specific reporting requirement to which such flexibility can be applied.

In doing so, developing countries should clearly indicate the provision to which flexibility is applied, concisely explain the capacity constraints, noting that some constraints may be

relevant to several provisions, and provide estimated and self-determined time frames for improvements in relation to these capacity constraints.

Dataframe 2.5 provides an overview of the flexibility provisions that are specific to Brazil, considering the NIR 2024.

Dataframe 2.5. Flexibility provision used by Brazil to prepare the National Inventory.

MPG Reference (Annex to Decision 18/ CMA.1)	MPGs Provisions	Indication of the flexibility provision used by Brazil, in light of its capacities
Paragraph 25 *Key category analysis*	Parties should implement the key category analysis consistently with the IPCC guidelines (i.e., apply the 95% threshold defined in the IPCC Guidelines).	**Flexibility not used by the country.** The 95% threshold was used to identify the categories, in accordance with the IPCC Guidelines.
Paragraph 29 *Assessment of Uncertainty*	Parties should quantitatively estimate and qualitatively discuss the uncertainty of emission and removal estimates for all categories, including the inventory totals, for at least the first and the last reporting year of the inventory time series, and should also estimate the trend uncertainty for these same categories/inventory totals for the entire time series.	**Flexibility not used by the country.** Brazil estimated the uncertainties of the Inventory for all categories for the first year (1990) and for the last year of the time series (2022).
Paragraph 32 *Use of the acronym "NE" (not estimated)*	A category should only be considered insignificant if the likely level of emissions is less than 0.05% of total national greenhouse gas emissions, excluding LULUCF, or 500 kt of CO_2 equivalent, whichever is lower. The aggregate national total of estimated emissions for all gases in categories considered insignificant must remain below 0.1% of the total national GHG emissions, excluding LULUCF.	**Flexibility not used by the country.** Brazil did not use the flexibility for the non-estimation of categories considered to be insignificant. Emissions were estimated and accounted for in the inventory for all the categories for which there were available data, without considering their degree of significance. For all the categories indicated by the country as not estimated, according to Section 2.7, Brazil will make efforts to improve the estimates in subsequent inventories.
Paragraph 34 *Quality assurance / Quality control*	Parties must draw up a quality assurance and inventory quality control plan in accordance with IPCC guidelines, including information on the inventory agency responsible for implementing these controls.	**Flexibility not used by the country.** Brazil has a quality assurance and inventory quality control plan. The Ministry of Science, Technology and Innovation (MCTI) is responsible for implementing this plan.

MPG Reference (Annex to Decision 18/ CMA.1)	MPGs Provisions	Indication of the flexibility provision used by Brazil, in light of its capacities
Paragraph 35 *Quality assurance / Quality control*	Parties should implement and provide information on general inventory quality control procedures in accordance with the quality assurance/quality control plan and the IPCC Guidelines.	**Flexibility not used by the country.** Brazil implements the quality assurance and inventory quality control plan.
Paragraph 48 *Gases*	The Parties should report seven gases: CO_2, CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3.	**Flexibility not used by the country.** All the gases included in Brazil's NDC were reported, in accordance with Article 4 of the Paris Agreement. However, emissions of NF_3 were not estimated due to the lack of activity data because of the incipiency of the production activity in the country. The action plan includes liaising with the institutions responsible for the sources that emit NF_3, with the aim of collecting the necessary data over the next two years. This data will, then, be analyzed and the results presented in 2028.
Paragraph 57 *Time series*	Parties should report a consistent annual time series beginning in 1990.	**Flexibility not used by the country.** The annual time series begins in 1990.
Paragraph 58 *Reporting year*	The last reporting year should not be more than two years before the submission of the national inventory report.	**Flexibility not used by the country.** The last reporting year (2022) is not more than two years before the submission of the report (2024).

3 TRENDS IN GHG EMISSIONS AND REMOVALS

3.1 Aggregate trends in GHG emissions and removals

Total Brazilian net emissions were 2,039,236 kt CO_2 eq in 2022, 11.8% more than estimated for 2020 (1,824,760 kt CO_2 eq). These total emissions, shown in Table 3.1, fell by 20.4% (or -522,009 kt CO_2 eq) compared to 2005. In relation to the levels seen in that year, there was a significant reduction in emissions from the LULUCF sector, mainly related to the reduction in deforestation, which was due above all to the adoption of Action Plans for the Prevention and Control of Deforestation and Fires.

Table 3.1. Brazil's net emissions by sector with LULUCF, in kt CO_2 eq, selected years.

SECTOR/CATEGORIES	1990	2005	2016	2020	2022
	NET EMISSIONS (kt CO_2 eq)				
TOTAL	**1,588,395**	**2,561,246**	**1,603,968**	**1,824,760**	**2,039,236**
1. ENERGY	**196,119**	**318,363**	**424,610**	**390,210**	**418,451**
1.A. Fuel combustion	187,161	299,732	403,235	369,462	395,626
1.A.1. Energy industries	25,308	48,620	78,925	68,134	56,565
1.A.2. Manufacturing industries and construction	37,633	65,396	71,952	62,697	69,116
1.A.3. Transport	85,195	139,226	204,239	187,220	217,378
1.A.4. and 1.A.5. Other sectors and Other (Not specified elsewhere)	39,025	46,489	48,119	51,411	52,567
1.B. Fugitive emissions	8,959	18,630	21,375	20,748	22,824
2. IPPU	**56,870**	**83,335**	**93,931**	**96,992**	**102,317**
2.A. Mineral industry	15,170	20,444	29,715	32,070	32,993
2.B. Chemical industry	8,379	13,195	8,470	7,155	7,021
2.C. Metal Industry	32,673	47,614	48,925	48,739	52,226
2.D. Non-Energy Products from Fuels and Solvent Use	520	661	763	820	843
2.E. Electronics industry	0	0	0	3	1
2.F. Product Uses as Substitutes for Ozone Depleting Substances (ODS)[1]	0	1,234	5,768	7,879	8,891
2.G. Other Product Manufacture and Use	128	187	290	325	343
3. AGRICULTURE	**394,743**	**520,260**	**567,146**	**583,740**	**622,014**
3.A. Enteric fermentation	284,981	370,824	376,932	376,720	404,062
3.B. Manure Management	17,801	21,951	27,716	27,713	29,012
3.C. Rice cultivation	9,271	10,796	11,159	11,779	11,901
3.D. Agricultural soils	71,071	104,417	131,056	141,045	145,078
3.F. Field burning of agricultural residues	1,848	2,296	551	473	477
3.G. Liming	9,141	8,097	15,844	21,593	27,087
3.H. Urea Application	631	1,878	3,888	4,417	4,397
4. LULUCF	**908,066**	**1,573,714**	**436,546**	**665,084**	**805,694**
4.A. Forest Land	-43,666	-269,055	-345,479	-326,825	-312,125
4.B. Cropland	79,305	196,422	138,607	157,403	184,499
4.C. Grassland	876,829	1,673,983	658,720	855,213	959,862
4.D. Wetlands	6,412	12,326	8,745	10,601	11,675
4.E. Settlements	6,896	7,067	5,154	5,008	5,670

SECTOR/CATEGORIES	1990	2005	2016	2020	2022
	NET EMISSIONS (kt CO_2 eq)				
4.F. Other land	1,275	5,021	8,998	11,740	12,620
4.G. Harvested wood products	-18,984	-52,050	-38,198	-48,056	-56,507
5. WASTE	**32,596**	**65,574**	**81,735**	**88,735**	**90,761**
5.A. Solid waste disposal	13,186	35,658	45,798	49,824	53,421
5.B. Biological treatment of solid waste	18	49	56	63	61
5.C. Incineration and open burning of waste	1,151	2,014	1,272	1,326	1,224
5.D. Wastewater treatment and discharge	18,241	27,854	34,608	37,522	36,056

Notes: ODS – Ozone Depleting Substances.

Brazil's net emissions peaked at 3,596,053 kt CO_2 eq in 2004, progressively reducing the volume emitted until 2012 (1,305,805 kt CO_2 eq). Especially from 2018 onwards, the emissions have increased, reaching a total volume of 2,039,236 kt CO_2 eq in 2022 (Figure 3.1), with an increase of 11.8% in 2022 compared to 2020.

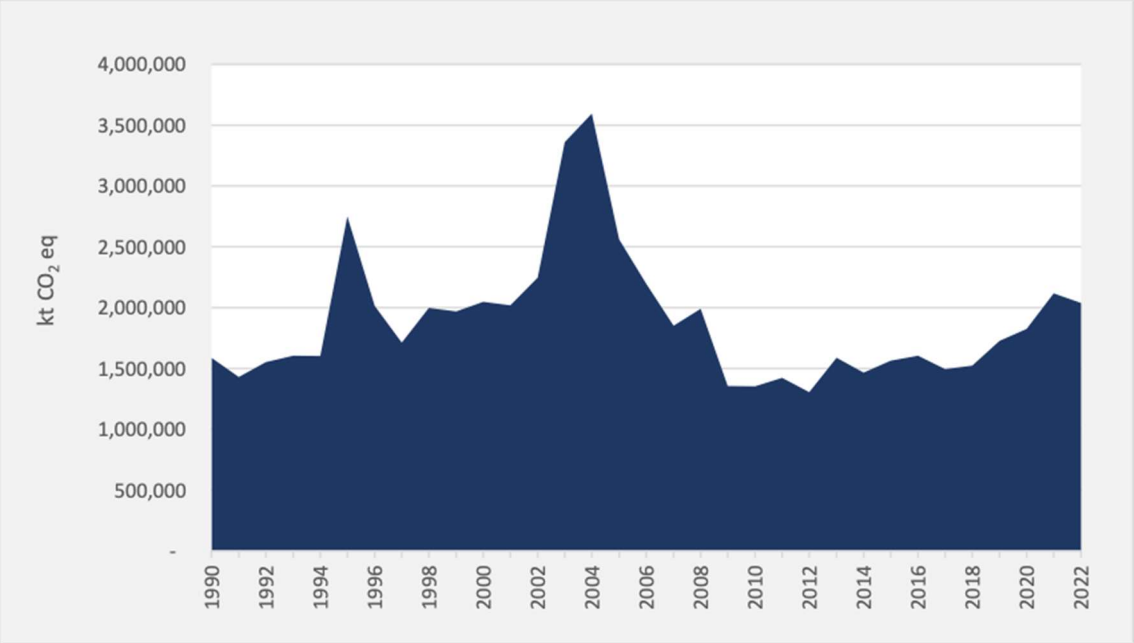


Figure 3.1. Brazil's total annual net emissions, in kt CO_2 eq.

The main elements that explain the increase in emissions between 2020 and 2022 are:

- Reduced consumption of biofuels and increased use of gasoline and mineral Diesel in transportation compared to COVID-19 pre-pandemic levels;
- Increased kerosene consumption in domestic aviation after a 43% reduction between 2019-2020;
- Recovery of the level of productive activity after the COVID-19 pandemic in the Mineral Industry and Metal Industry subsectors, which accounted for 83% of IPPU emissions in 2022;

- Growth in the cattle population and agricultural production, which impacts the emissions from enteric fermentation, manure and soil management, and the application of inorganic N fertilizers and liming;
- Total deforested area in the Amazon and Cerrado increased from 18.8 thousand km^2 to 22.3 thousand km^2 between 2020 and 2022; and
- An increase in the disposal of solid waste in sanitary and controlled landfills due to the closure of garbage dumps, as well as an increase in the population served with waste collection.

The biggest increase, according to the emissions categories, occurred in Transport, driven by an increase in the proportion of individual motorized transport (motorcycles and cars) in the vehicle fleet, to the detriment of a reduction in the use of public transport. This effect was more intense in the 2009-2014 period, decreasing in the following years due to the reduction in the consumption of Diesel and mineral gasoline, together with the subsequent increases in the consumption of biodiesel and anhydrous[14] and hydrous ethanol. After emissions peaked in 2012, the Domestic Aviation category stabilized its emissions in the following years, partly as a result of the stabilization of the number of domestic passengers transported, with a greater impact in 2020, with the greater incidence of restrictive measures in the face of the COVID-19 pandemic.

Despite the increase in emissions in 2022 compared to 2020, in the case of Energy Industries, emissions fell by 17%, driven by the Public electricity and heat production subcategory, which fell by 30%. This was due to the expansion of wind (43%) and solar (100%) generation in the period. As a result, the Brazilian electricity matrix reached 88% renewability in 2022, compared to 85% in 2020 (EPE, 2023).

3.1.1 Evolution of the time series with LULUCF

When analyzing the time series of national emissions, a different pattern can be seen when compared to developed countries, with 70% of the estimated value in 2022 occurring in the LULUCF and Agriculture sectors, 25% in Energy and IPPU sector, and 5% in the Waste sector.

[14] When blended with mineral gasoline.

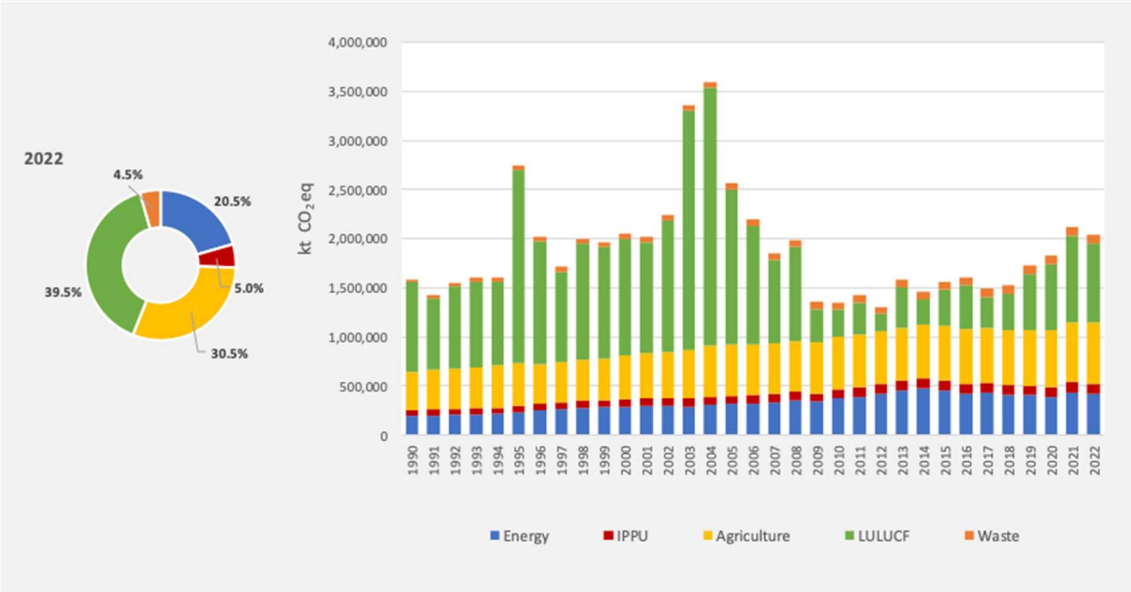


Figure 3.2. Net emissions by sector with LULUCF, in kt CO_2 eq.

After peaking in 2004 (2,624,326 kt CO_2 eq), atmospheric emissions from the LULUCF sector (CRT 4) fell by 93% by 2012 (172,897 kt CO_2 eq). Since then, the sector's emissions have increased again, reaching 805,694 kt CO_2 eq in 2022. The other sectors showed stable trends, especially the Agriculture sector (CRT 3), despite the increase in the cattle population.

3.1.2 Evolution of the time series excluding LULUCF

Excluding the LULUCF sector, there was a continuous increase in the sectoral emissions until 2014 (1,205,750 kt CO_2 eq), with a consistent reduction until 2020 (1,159,677 kt CO_2 eq), a year impacted by the restrictive measures of the COVID-19 pandemic.

From 2020 onwards, emissions from the selected sectors increased again, reaching 1,233,542 kt CO_2 eq in 2022. During this post-pandemic period, the highest increases were seen in the Energy and Agriculture sectors, with 7.2% and 6.6%, respectively.

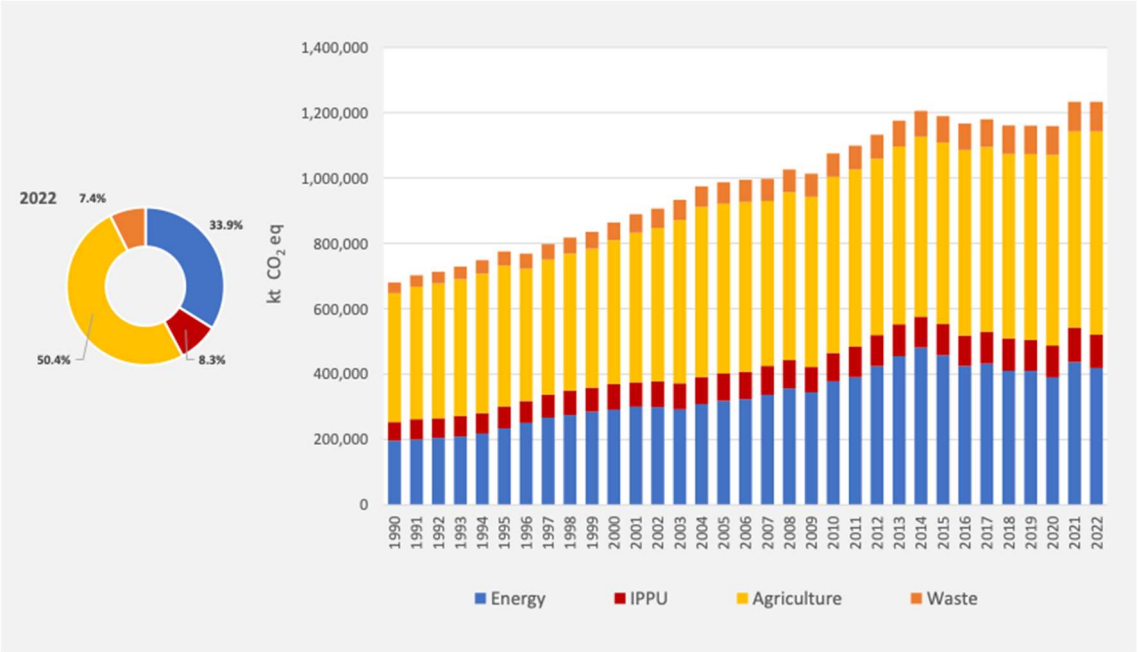


Figure 3.3. Net CO_2 eq emissions by sector, excluding LULUCF, in kt CO_2 eq.

When disregarding the most relevant sector in terms of emissions in the time series (LULUCF), the Agriculture sector accounted for the largest share of the total Brazilian emissions, with 50.4% (622,014 kt CO_2 eq) in 2022. The Energy sector comes next, accounting for 33.9% of the total (418,451 kt CO_2 eq). The IPPU and Waste sectors accounted for 8.3% (102,317 kt CO_2 eq) and 7.4% (90,761 kt CO_2 eq), respectively.

The most important subsector for Agriculture emissions is Enteric Fermentation, responsible for 69% of Brazil's total CH_4 emissions in 2022. In this key category in particular, progress has been made in terms of the efficiency and sustainability of its production systems, which has been reflected in productivity gains. Between 1990 and 2022, there was an 11% reduction in the emission of enteric methane per head of cattle.

3.2 Trends in GHG emissions and removals by gases and sectors

3.2.1 Evolution of the time series by gases and sectors

CO_2 emissions resulted from activities mainly related to the energy use of fossil fuels and to the changes in land use and land cover. Other sources that make up CO_2 emissions are the industrial processes for the production of pig iron and steel, cement, lime, soda ash, ammonia and aluminum, as well as the use of fertilizers in agriculture and the incineration or burning of solid waste.

In turn, removals by sinks are identified in the LULUCF sector.

Figure 3.4 shows the historical evolution of Brazil's gross emissions and total removals from 1990 to 2022, considering CO_2 gas. On the other hand, Figure 3.5 shows net emissions by sector over the same period.

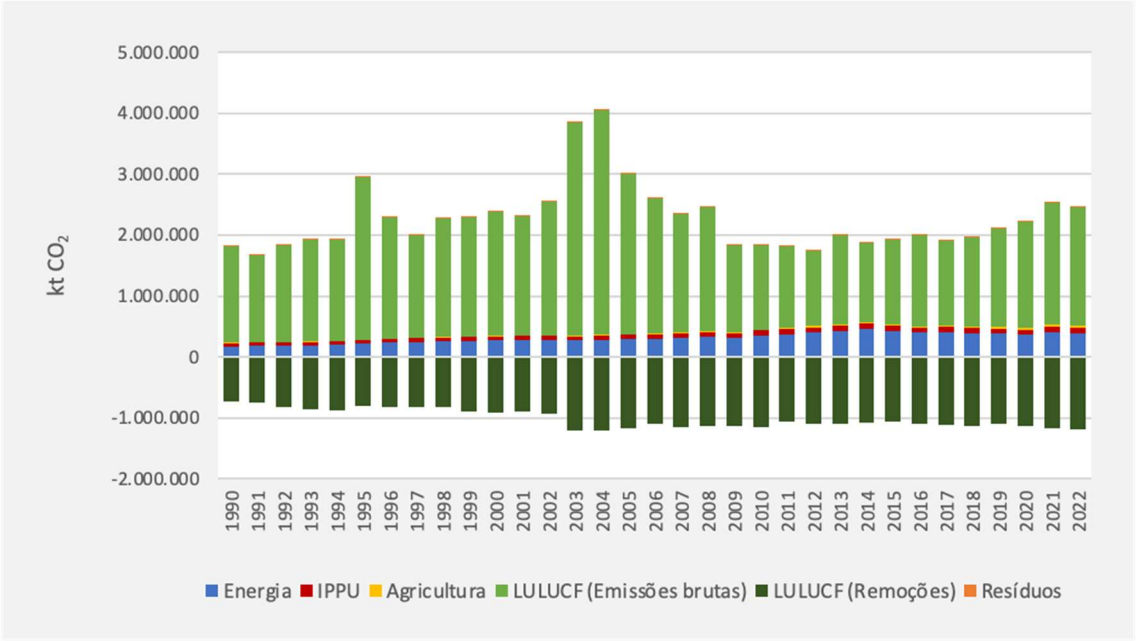


Figure 3.4. CO_2 emissions and removals by sector, in kt.

In total, gross emissions and removals amounted to 2,453,845 kt CO_2 and 1,187,714 kt CO_2 in 2022, respectively, thus resulting in net emissions reaching 1,266,131 kt CO_2, a result which was 15.7% higher than that estimated for 2020 (1,094,677 kt CO_2). With regard to net emissions. the LULUCF sector accounted for 59.4% of total CO_2 emissions (751,467 kt CO_2). The Energy sector, then, accounted for 30.9% of emissions (391,193 kt CO_2), while IPPU accounted for 7.2% (91,483 kt CO_2). The Agriculture sector, the second largest in terms of CO_2-equivalent emissions (31%), accounted for 2.5% of CO_2 emissions. Waste, in turn, accounted for 0.04% of the volume of CO_2 emitted.

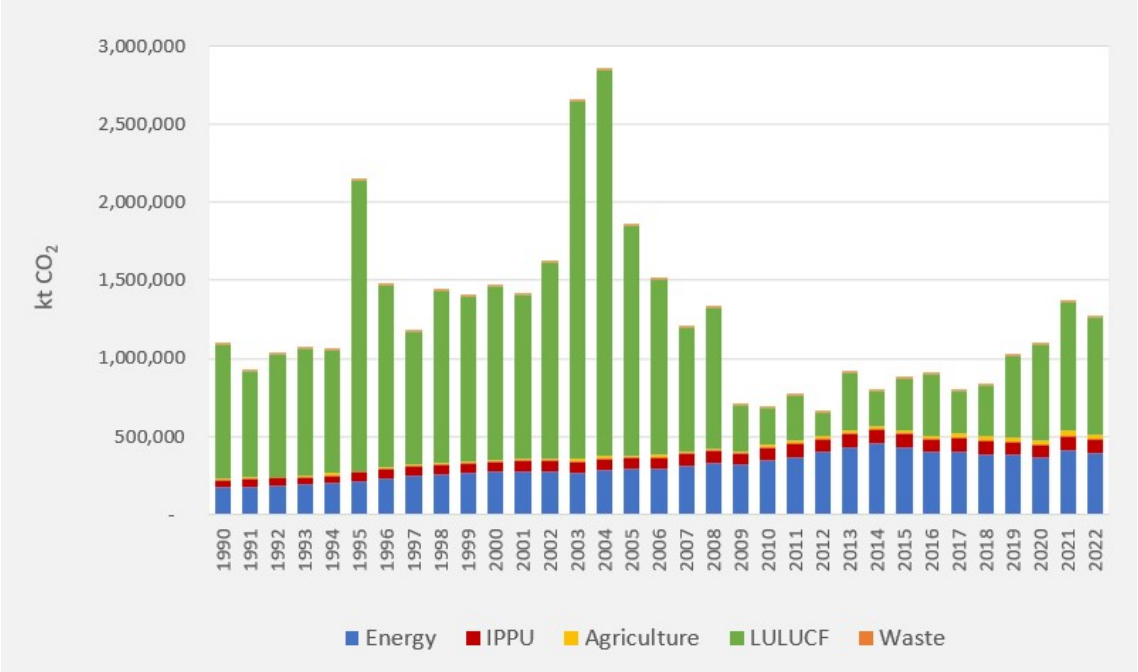


Figure 3.5. CO_2 emissions by sector, in kt.

From 2005 onwards, there was a significant reduction in emissions from the LULUCF sector, mainly related to a reduction in deforestation, which contributed to an increase in the Energy sector's relative share in the total CO_2 emissions until 2017. Between 2018 and 2021, CO_2 emissions in the LULUCF sector increased their share, due to the increase in deforestation rates in the Amazon and Cerrado biomes, a trend that was reversed from 2022 onwards.

Table 3.2 summarizes the results of CO_2 emissions by sector.

Table 3.2. Results of CO_2 emissions, by sector.

Sector	1990	1995	2000	2005	2010	2016	2020	2022	2022 /2020
	kt CO_2								%
Energy	177,047	216,612	272,800	293,505	352,767	399,958	364,226	391,193	7.4%
IPPU	48,558	57,189	69,165	72,795	82,049	86,285	87,215	91,483	4.9%
Agriculture	9,771	6,765	10,645	9,975	13,698	19,732	26,010	31,484	21.0%
LULUCF	852,933	1,865,092	1,108,079	1,474,209	239,301	398,371	616,678	751,467	21.9%
Waste	535	587	926	1.108	1,154	507	548	504	-8.0%
Total net emission	**1,088,844**	**2,146,245**	**1,461,615**	**1,851,592**	**688,969**	**904,853**	**1,094,677**	**1,266,131**	**15.7%**

National emissions of CH_4 come from agricultural activities, changes in land use and land cover, waste treatment, some industrial processes and from the extraction and refining of oil and natural gas.

In the Energy sector, CH_4 emissions occur due to incomplete combustion of fuels and leakage of CH_4 during the production and transportation processes of natural gas and coal mining. In the IPPU sector, CH_4 emissions occur during the production of petrochemicals. CH_4 emissions from the Agriculture sector are associated with enteric fermentation (eructation) in the country's livestock, as well as with manure management and rice cultivation. In the LULUCF sector, CH_4 emissions are caused by biomass burning associated with the dynamics of land use and land cover, while in the Waste sector they are mainly caused by solid waste disposal.

Brazil's total emissions of CH_4 are shown in Figure 3.6. In total, Brazilian emissions in 2022 reached 21,063 kt CH_4, 6.6% more than estimated for 2020 (19,758 kt CH_4). The Agriculture sector accounted for the largest share of total CH_4 emissions (74.8% in 2022 or 15,754 kt CH_4). This is followed by the Waste sector, which accounted for 14.9% of CH_4 emissions (3,134 kt CH_4). The LULUCF sector accounted for 7.1% (1,496 kt CH_4), while the Energy and IPPU sectors accounted for 3% (632 kt CH_4) and 0.2% (36 kt CH_4), respectively.

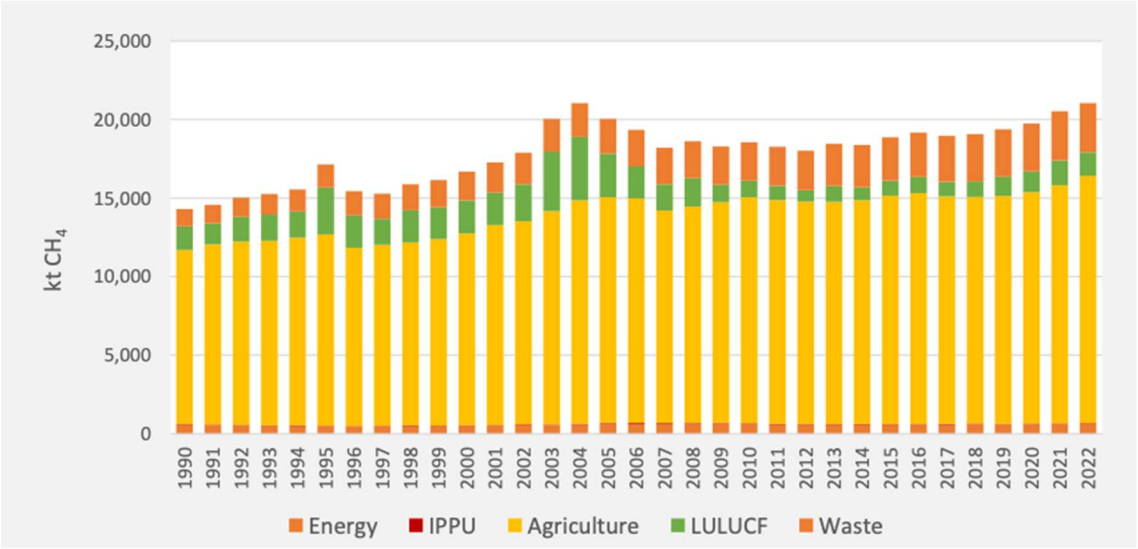


Figure 3.6. CH_4 emissions by sector, in kt.

In terms of CH_4 emissions trend, there was an increase in the share of the LULUCF sector in relation to the other sectors until 2004, with a decrease from 2005 to 2017 due to a decrease in the rates of deforestation. The Agriculture sector is the main emitter of this gas, but it has had a relatively constant share of total emissions between 2005 and 2022, despite the 15% growth in the cattle population over that period, which reflects gains in production efficiency, such as the expansion of high-production dairy cattle systems and cattle feedlots.

Table 3.3 summarizes the results of CH_4 emissions, by sector.

Table 3.3. Results of CH_4 emissions, by sector.

Sector	1990	1995	2000	2005	2010	2016	2020	2022	2022 /2020
	kt CH_4								%
Energy	543	464	497	660	610	558	600	643	7.2%
IPPU	43	38	41	51	42	35	36	36	-0.2%
Agriculture	11,102	12,180	12,208	14,353	14,407	14,712	14,729	15,754	7.0%
LULUCF	1,520	2,996	2,112	2,752	1,042	1,052	1,337	1,496	11.9%
Waste	1,096	1,474	1,829	2,227	2,449	2,812	3,056	3,134	2.5%
Total net emission	**14,304**	**17,151**	**16,687**	**20,043**	**18,550**	**19,168**	**19,758**	**21,063**	**6.6%**

National emissions of N_2O resulted from the application of inorganic N fertilizers and organic N fertilizers to the soil, as well as from the treatment of domestic wastewater, the burning of fossil fuels and biomass, industrial processes and changes in land use and land cover.

The Agriculture sector accounted for 85.9% (564 kt N_2O) of total N_2O emissions. The LULUCF sector accounted for 7.1% (47 kt N_2O) and the Energy sector accounted for 5.3% of the total (35 kt N_2O). The Waste and IPPU sectors accounted for 1.4% (9.5 kt N_2O) and 0.2% (1.2 kt N_2O), respectively.

In the Energy sector, the total emission of this gas in 2022 was mostly due to incomplete combustion of fuels.

In the IPPU sector, N_2O emissions occur during nitric acid and adipic acid production - which are much reduced in both cases due to the Clean Development Mechanism (CDM) projects which have been implemented since 2007 to reduce emissions - and during the production of metals. Together, these activities accounted for 1.4% of total N_2O emissions in 2022 (9.5 kt N_2O).

N_2O emissions from the Agriculture sector corresponded to 567 kt N_2O in 2022, representing 85.9% of the country's emissions of this gas. In this sector, direct emissions from the management of agricultural soils accounted for 74.8%, and indirect emissions accounted for 22.2%, while emissions from manure management and from field burning of agricultural residues accounted for 2.8% and 0.2% of the total, respectively.

In the LULUCF sector, N_2O emissions are caused by biomass burning associated with the dynamics of land use and land cover. These emissions represented 7.1% of total N_2O emissions in 2022 (47 kt N_2O).

In the Waste sector, N_2O emissions are mostly due to the presence of nitrogen in the protein consumed by humans, which ends up in the soil or in bodies of water. A smaller fraction comes from waste incineration. Waste accounted for 1.4% (9.5 kt N_2O) of emissions of this gas in 2022.

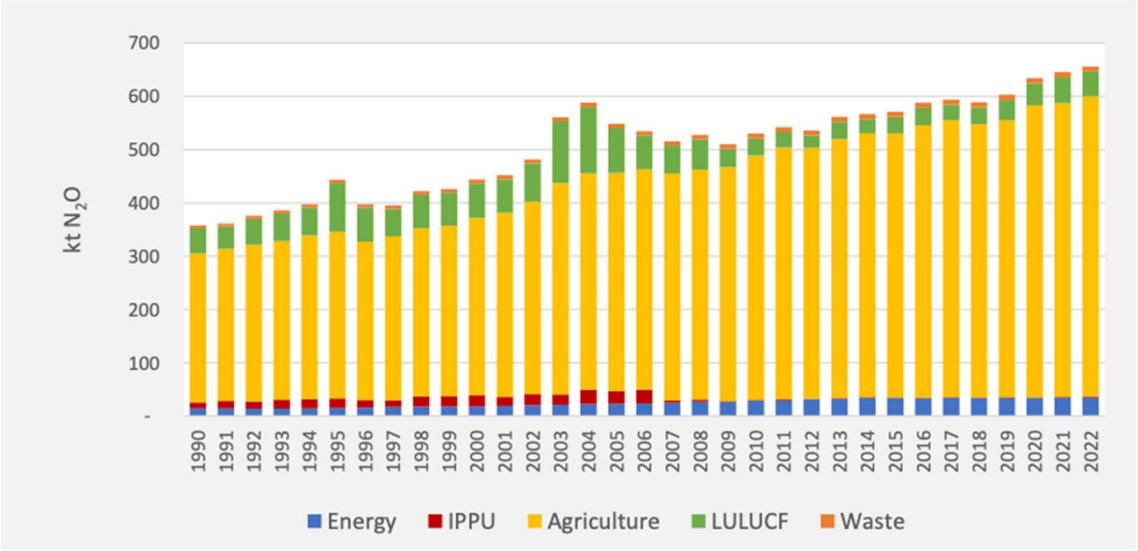


Figure 3.7. N_2O emissions by sector, in kt.

As previously mentioned, the majority of N_2O emissions come from the Agriculture sector, although the LULUCF sector's share increased until 2004 and from 2018 onwards, as a result of the burning of biomass following deforestation to convert Forest Land into Grassland and Cropland.

Table 3.4 summarizes the results of N_2O emissions by sector.

Table 3.4. Results of N_2O emissions, by sector.

Sector	1990	1995	2000	2005	2010	2016	2020	2022	2022 /2020
	kt N_2O								%
Energy	14	15	18	23	29	33	34	35	4.0%
IPPU	12	18	21	24	2	1	1	1	0.7%
Agriculture	280	313	333	409	458	511	548	564	2.8%
LULUCF	47	91	65	85	33	33	41	47	12.4%
Waste	5	6	7	8	9	9	10	9	-4.2%
Total net emission	**358**	**444**	**444**	**549**	**530**	**588**	**635**	**656**	**3.4%**

HFCs, PFCs and SF_6 gases do not originally exist in nature, but are synthesized by human activities. Emissions of HFCs are mainly due to the use of air conditioning and refrigeration activities. PFC emissions occur during the primary aluminum production process. On the other hand, SF_6 emissions were estimated for gas leaks in high-voltage electrical equipment.

Figure 3.8 shows the emissions trajectory for the emissions of HFCs, PFCs and SF_6. All the activities involving the emissions of these gases are from the IPPU sector.

Between 2020 and 2022, HFC emissions increased by 12.8%, reaching 8,892 kt CO_2 eq, showing uninterrupted growth since 2002. During the same period, emissions of PFCs increased by 11.3% (278 kt CO_2 eq), while the emitted volume of SF_6 increased by 5.4%, reaching 343 kt CO_2 eq.

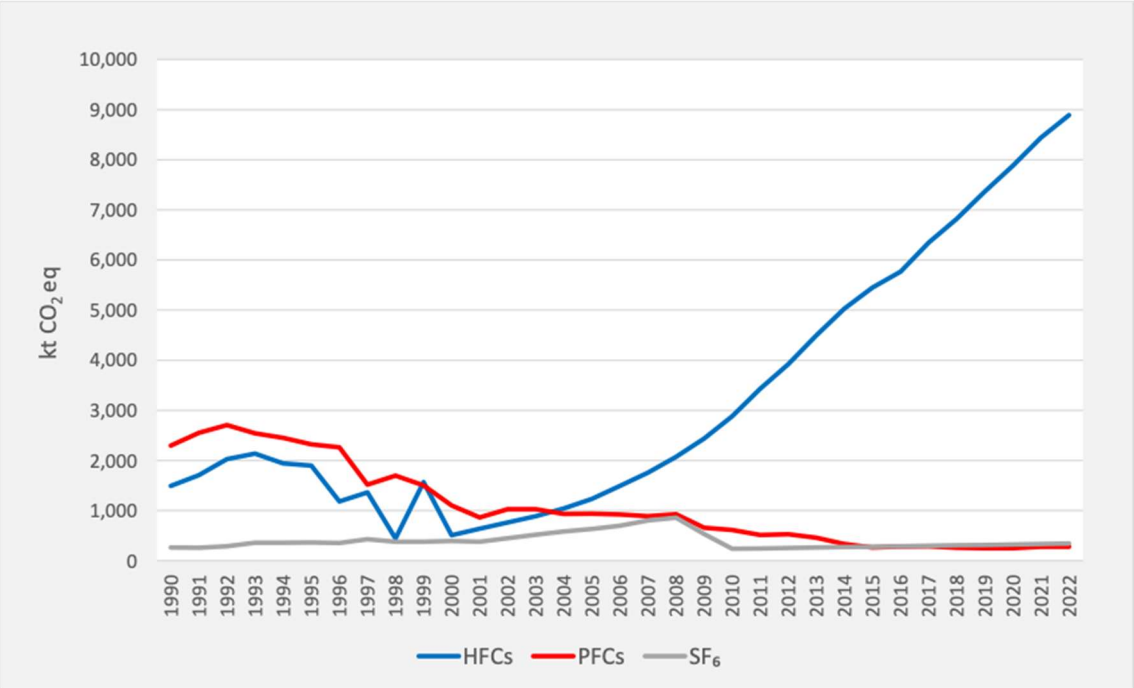


Figure 3.8. Emissions of HFCs, PFCs and SF_6 by sector, in kt CO_2 eq.

From 2000 to 2022, HFC emissions increased consistently due to the replacement of ozone-depleting CFC gases, a trend similar to that observed in the rest of the world. The main contribution from this family of gases came from the use of HFC-134a in the air-

conditioning and refrigeration category, which is particularly explained by the average refrigerant charge and the growth in the fraction of the vehicle fleet with an on-board air-conditioning system.

3.2.2 Last year inventoried by gases and sectors

As previously mentioned, Brazil's emissions in 2022 reached 2,039,236 kt CO_2 eq, 11.8% higher than estimated for 2020. CO_2 was the predominant gas in Brazil's emissions, with a 62% share in 2022. In 2020, the share of this gas was 60%. To a large extent, the increase in its share is due to the changes of Forest Land converted to Grassland and to Cropland in the LULUCF sector.

Figure 3.9 shows the trajectory of Brazil's net GHG emissions.

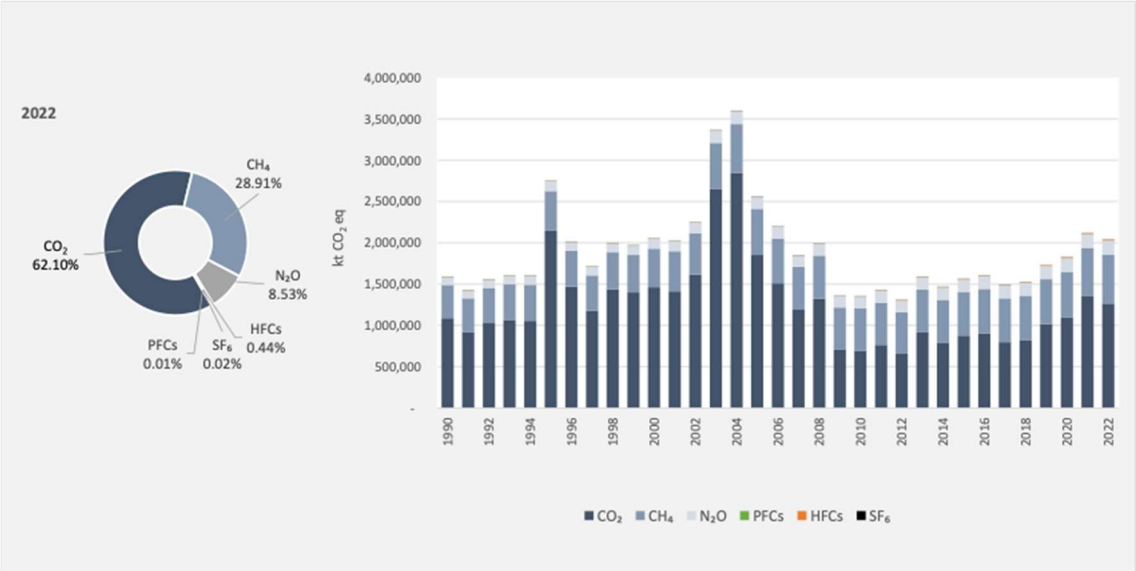


Figure 3.9. Brazil's net GHG emissions. in kt CO_2 eq.

Also in 2022, CH_4 and N_2O gases accounted for 29% and 8.5%, respectively, while SF_6, HFCs and PFCs combined accounted for 0.47% of the total. Compared to 2020, the share of CH_4 and N_2O gases fell by 1.4% and 0.7%.

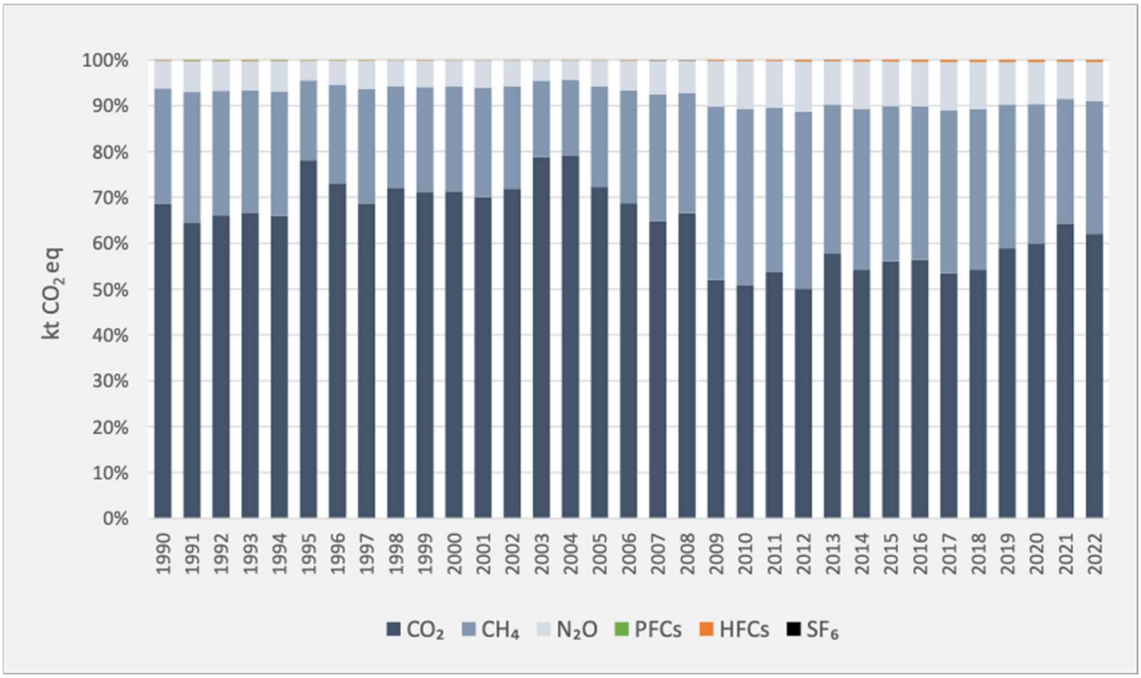


Figure 3.10. Share of each GHG inventoried in Brazil's total emissions.

The LULUCF sector accounted for 39.5% of total emissions in 2022 (805,694 kt CO_2 eq), being the most representative in the country (Table 3.5). Of this amount, CO_2 accounted for 93%, while CH_4 and N_2O accounted for 5% and 2%. Next, the Agriculture sector accounted for 30.5% of Brazil's total emissions. In this case, CH_4 gas accounted for 71% of emissions in 2022, mostly from Enteric Fermentation (3.A). N_2O and CO_2 gases accounted for 24% and 5%, respectively.

The third highest emitting sector is the Energy sector, with 418,451 kt CO_2 eq (20.5% in 2022). CO_2 accounted for 94% of this sector's emissions, while CH_4 and N_2O accounted for 4% and 2%. The IPPU sector accounted for 5% of Brazil's total emissions, with CO_2 accounting for 89% of the total. Finally, the Waste sector accounted for 4.5% of the total emitted in the country. Similarly to the Agriculture sector, CH_4 gas predominates among the GHGs emitted (with a share of 97%). This results mainly from Solid Waste Disposal (5.A) and Wastewater Treatment and Discharge (5.D) activities.

Table 3.5. Results of greenhouse gas emissions in 2022, by sector, in kt CO_2 eq.

Sector	Total emissions	Sector Contribution	CO_2	CH_4	N_2O	PFCs	HFCs	SF_6
Energy	418,451	20.5%	391,193	17,994	9,265	-	-	-
IPPU	102,316	5%	91,483	1,013	308	278	8,892	343
Agriculture	622,014	30.5%	31,484	441,109	149,420	-	-	-
LULUCF	805,694	39.5%	751,467	41,885	12,342	-	-	-
Waste	90,761	4,5%	504	87,743	2,514	-	-	-

3.3 Trends in precursor greenhouse gas emissions

Precursor GHGs contribute to the formation of tropospheric ozone, which, in turn, is a greenhouse gas. They have not been accounted for in CO_2 eq, given the lack of a metrics associated with them by the IPCC.

The precursor GHGs inventoried were CO, NO_x and NMVOC. Emissions of CO and NO_x are mainly caused by incomplete combustion of fuels. For CO, the main sources were biomass burning in the LULUCF sector and burning of fossil fuels in the Energy sector. In the case of NO_x emissions, the position of these two sectors is reversed.

Figure 3.11 shows CO emissions by sector.

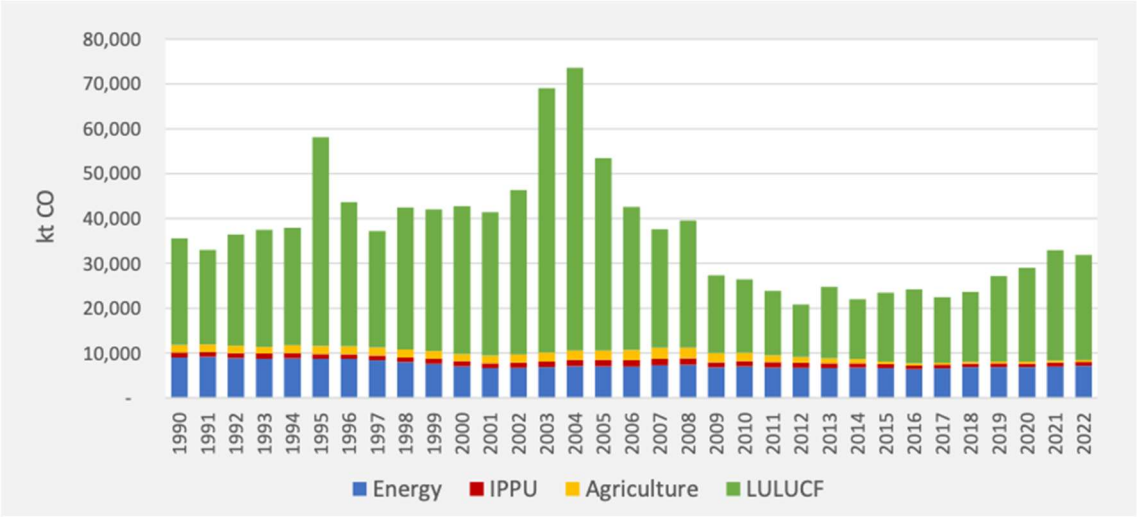


Figure 3.11. CO emissions by sector.

The volume of CO emitted in Brazil in 2022 reached 31,879 kt CO, 10% higher than estimated in 2020 (28,991 kt). The LULUCF sector predominated as the largest emitter with 73.5% (23,418 kt) of total CO emissions. The Energy sector accounted for 22.4% of the total (7,149 kt CO). The IPPU and Agriculture sectors accounted for 2.8% (880 kt CO) and 1.4% (432 kt CO), respectively. CO emissions were not accounted for the Waste sector.

The emissions of this precursor GHG are explained throughout the time series, above all, by the behavior of biomass burning in the LULUCF sector. Moreover, in the case of the dynamics of land-use change in Brazil, they are associated with the levels of deforestation activity and the burning of the remaining residues for conversion into cropland and grassland.

Table 3.6 summarizes the results of CO emissions by sector.

Table 3.6. Results of CO emissions by sector.

Sector	1990	1995	2000	2005	2010	2016	2020	2022	2022 /2020
	kt CO								%
Energy	9,001	8,692	7,052	7,057	7,029	6,424	6,843	7,149	4.5%
IPPU	1,096	1,106	1,155	1,430	1,200	801	835	880	5.3%
Agriculture	1,682	1,806	1,596	2,078	1,832	498	428	432	0.9%
LULUCF	23,819	46,525	32,928	42,877	16,364	16,500	20,885	23,418	12.1%
Waste	-	-	-	-	-	-	-	-	-
Total net emission	**35,599**	**58,129**	**42,731**	**53,443**	**26,425**	**24,222**	**28,991**	**31,879**	**10.0%**

The volume of NO_x emitted in Brazil in 2022 reached 2,667 kt NO_x, which is 3.7% higher than the volume in 2020 (2,571 kt). The Energy sector accounted for the largest share of emissions of this gas, with 82.1% (2,188 kt NO_x). The LULUCF sector, then, accounted for 15.5% (413 kt NO_x) of the total volume emitted by the country. The IPPU and Agriculture sectors accounted for 1.9% (50 kt NO_x) and 0.6% (16 kt NO_x), respectively. As in the case of CO, NO_x emissions were not accounted for the Waste sector.

In this case, emissions are related to the Transport and Energy Industries categories. In the former case, there is a downward trend due to the progress of the phases of the Program for the Control of Air Pollution from Motor Vehicles (PROCONVE, Programa de Controle da Poluição do Ar por Veículos Automotores), especially for light duty vehicles, even considering the continuous growth of the vehicle fleet. However, until 2014, there was an increase in aggregate emissions from the Energy sector due to the increase in natural gas consumption at Public Service Power Plants (SP, Centrais Elétricas de Serviço Público). Between 2015 and 2022, there was a reduction in the volume emitted as a result of the reduction in economic activity, combined with the expansion of wind and solar power generation and the maintenance of the downward trend in road transport.

Figure 3.12 and Table 3.7 shows NO_x emissions by sector.

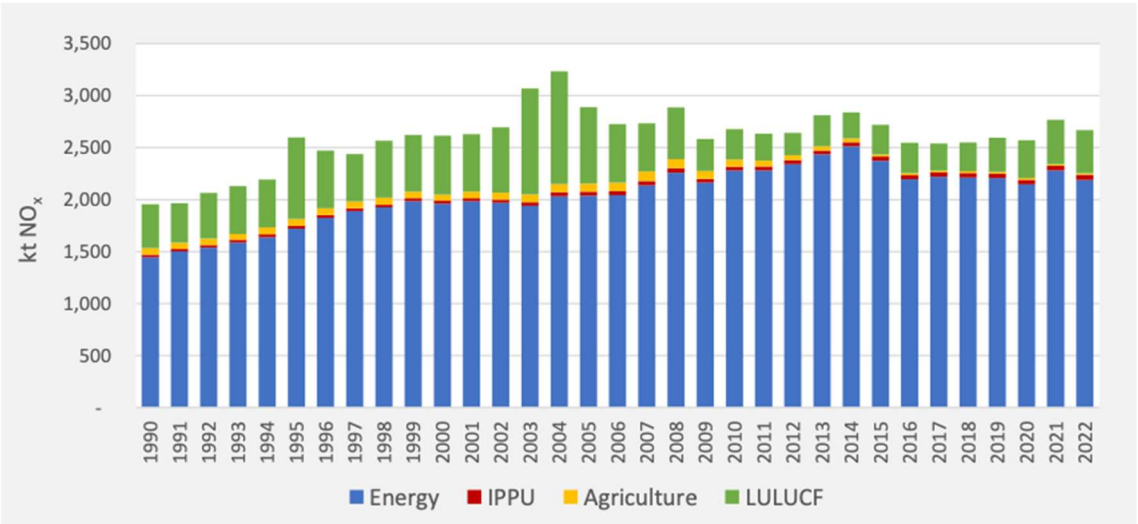


Figure 3.12. NO_x emissions by sector.

Table 3.7. Results of NO_x emissions, by sector.

Sector	1990	1995	2000	2005	2010	2016	2020	2022	2022 /2020
	kt NO_x								%
Energy	1,445	1,721	1,959	2,037	2,279	2,196	2,147	2,188	1.9%
IPPU	27	27	29	39	39	39	44	50	13.4%
Agriculture	61	67	59	77	68	18	16	16	0.9%
LULUCF	422	784	568	736	293	294	364	413	13.3%
Waste	-	-	-	-	-	-	-	-	NA
Total net emission	**1,954**	**2,598**	**2,616**	**2,889**	**2,679**	**2,547**	**2,571**	**2,667**	**3.7%**

Figure 3.13 shows NMVOC emissions by sector. In this case, only the Energy and IPPU sectors recorded the volume of emissions. Total emissions reached 4,074 kt NMVOC in 2022, which is 4.2% higher than in 2020 (3,912 kt NMVOC). The Energy sector accounted for 22.2% (906 kt NMVOC) of the total volume, while IPPU accounted for 77.8% (3,168 kt NMVOC) in the last year inventoried in the NIR 2024.

Regarding the Energy sector, there was a continuous decrease in emissions until 2015, due to the progress of the PROCONVE phases in the vehicle fleet, as well as the reduction in firewood consumption in the vegetable charcoal production and use activities (charcoal factories and households). There has been a stabilization since 2016, which can be explained by the aging of light and heavy weight vehicles in the vehicle fleet, due to the decrease in new vehicle sales, reducing the effect of PROCONVE's progress, as well as the growth in household firewood consumption, combined with the stabilization of sugarcane bagasse consumption in the ethanol production chain and of wet natural gas in oil exploration activities.

In the IPPU sector, the trend is explained by changes in tar consumption in the Non-Energy Products from Fuels and Solvent Use (2.D), as reported in the National Energy Balance (BEN, Balanço Energético Nacional).

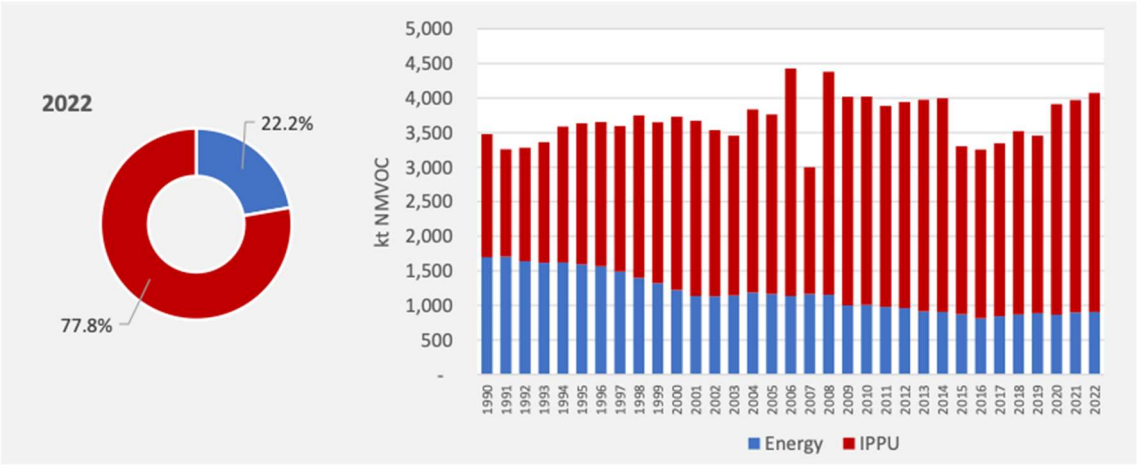


Figure 3.13. NMVOC emissions by sector.

Table 3.8 summarizes the results of NMVOC emissions by sector.

Table 3.8. Results of NMVOC emissions by sector.

Sector	1990	1995	2000	2005	2010	2016	2020	2022	2022 /2020
	kt NMVOC								%
Energy	1,696	1,596	1,222	1,164	1,008	812	866	906	4.6%
IPPU	1,783	2,040	2,508	2,597	3,015	2,442	3,046	3,168	4.0%
Agriculture	-	-	-	-	-	-	-	-	-
LULUCF	-	-	-	-	-	-	-	-	-
Waste	-	-	-	-	-	-	-	-	-
Total net emission	**3,479**	**3,635**	**3,730**	**3,761**	**4,023**	**3,254**	**3,912**	**4,074**	**4.2%**

4 ENERGY (CRT 1)

4.1 Sector overview

The Energy sector takes into account all GHG emissions from the extraction and processing of primary energy sources (energy resources obtained directly from nature, such as oil, natural gas, coal, etc.); their transformation into usable forms of energy in refineries, processing centers, electricity generation plants, etc.; the transmission and distribution of energy; and the consumption of fuels in installations and equipment.

The Energy sector accounts for direct GHG emissions, such as CO_2, CH_4, N_2O, as well as for precursor gases, such as CO, NO_x and NMVOC. Its main subsectors are: Fuel Combustion activities (1.A) and Fugitive Emissions (1.B). Within the scope of this NIR 2024, the CO_2 Transport and Storage segment (1.C) was disregarded, and the approach used in the Fourth National Inventory (BRASIL, 2021) was followed, given the absence of recorded national CO_2 storage activities, despite the use of CO_2 in Enhanced Oil Recovery (EOR) operations.

Fuel combustion activities are categorized according to their origin, specifically: Energy Industries (1.A.1), Manufacturing Industries and Construction (1.A.2), Transport (1.A.3), Other Sectors (1.A.4) and Other (Not specified elsewhere)[15] (1.A.5). Fugitive emissions (leaks and flares) are divided into Solid Fuels (1.B.1), Oil and Natural Gas (1.B.2) and Other Emissions from Energy Production (1.B.3).

Emissions in the Energy sector reached 418,451 kt CO_2 eq in 2022, which represented a 7% increase compared to 2020. The Fuel Combustion subsector (1.A) was responsible for 94.5% of these emissions, while the Fugitive Emissions subsector (1.B) accounted for the remaining 5.5%. In 2022, 93.5% of emissions were of CO_2, with 4.3% and 2.2% coming from CH_4 and N_2O, respectively (Figure 4.1).

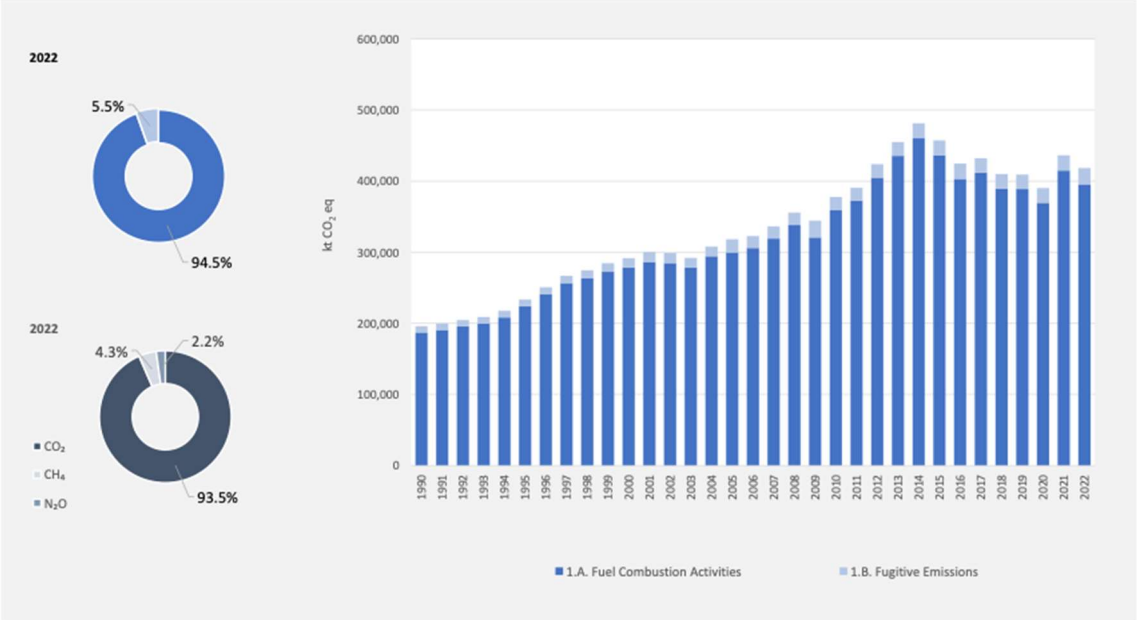


Figure 4.1. Total emissions from the Energy sector, in kt CO_2 eq, by subsector, from 1990 to 2022.

[15] Stationary and mobile combustions and multilateral operations not specified elsewhere.

The Transport category (1.A.3) was the most representative, accounting for 52% of the Energy sector's total emissions, followed by Manufacturing Industries and Construction (1.A.2) and Energy Industries (1.A.1), with 17% and 14%, respectively.

The emission pattern differs between subsectors when the gas is specified. In 2022, CH_4 emissions were higher in the Other Sectors categories (1.A.4), pertaining to the Fuel Combustion subsector (1.A), with a 51% share, and Oil and Gas (1.B.2), pertaining to the Fugitive Emissions subsector (1.B), with a 24% share. The categories that emitted the most N_2O in 2022 are the same as those that reflect emissions of kt CO_2 eq. Thus, the Transport category was the most representative (1.A.3) (53%), followed by Manufacturing Industries and Construction (1.A.2) (18%) and Energy Industries (1.A.1) (14%).

CO_2 emissions resulting from the consumption of biomass fuels are calculated and reported separately, according to the IPCC (2006) methodology.[16] Therefore, they are not accounted for in the total amount of emissions from the sector.

4.2 Methodological aspects

The methodology for calculating emissions followed the IPCC (2006). Due to the usually incomplete nature of combustion in engines, whether it is in motion or stationary, a variety of gases is produced. These gases may or may not be converted into less harmful substances before being released into the atmosphere, for example through catalytic converters. In this inventory, the gases released are categorized as CO_2 and non-CO_2. This second category includes the CH_4, N_2O, CO, NO_x and NMVOC gases.

The methodological approaches used in this NIR 2024 were based on the Reference Reports of the Inventory submitted in the Fourth National Communication (BRASIL, 2021), as well as on the 6th edition of the Annual Estimates (BRASIL, 2022), covering the years from 2017 to 2020. This edition of the inventory has, therefore, revised the activity or energy consumption data for the entire historical period (1990 to 2020), and estimated the emissions for 2021 and 2022.

The information on consumption in commercial units and the conversion factors to fuel energy units was taken from the Open Matrices (1990-2022), adjusting data from the National Energy Balance (BEN, Balanço Energético Nacional), made available annually by the Energy Research Office (EPE, Empresa de Pesquisa Energética) (EPE, 2023). The 1983, 1993 and 2004 editions of the Useful Energy Balance (BEU, Balanço de Energia Útil)[17] (MME - Ministry of Mines and Energy [Ministério de Minas e Energia]), 2005) were adopted in the energy end-use allocation process, which is necessary for estimating the emission of non-CO_2 gases from different subsectors and categories.

The emission of CO_2 is directly related to the carbon content of each type of fuel, which makes it possible to estimate the emissions of this gas based on the energy consumption of a technology or of the total energy consumed by the sector, using approaches that vary in terms of details. Therefore, the estimate of CO_2 emissions was based on the product between the energy consumed and the associated CO_2 emission factor, which takes into account the local energy density (toe/m^3 or toe/ton), available in BEN's time series. On the

[16] Energy (IPCC, 2006, v. 2).
[17] For the remaining years, interpolation and extrapolation techniques were applied to the existing data.

other hand, the volume of non-CO_2 gases emitted depends not only on the type of fuel, but also on the technology and operating conditions, requiring more detailed approaches.

Emissions from the Domestic Aviation category (1.A.3.a) between 2005 and 2018 refer to the bottom-up modeling (Tier 3a) described in the National Inventory of Atmospheric Emissions from Civil Aviation, by the National Civil Aviation Agency (ANAC, Agência Nacional de Aviação Civil, 2020). In domestic aviation, the Tier 3 approaches are based on real flight movement data. In the Tier 3a approach, origin-destination data and aircraft type are used, with emissions being calculated by flight phase classified into: LTO (Landing and Take-off) cycle, Cruise, and Auxiliary Power Unit (APU). The methodology uses more detailed information, adding complete flight movements with aircraft and engine data, among others. In addition, the top-down reference approach is used to compare and adjust results.

Along these lines, the bottom-up model was used to obtain the division between domestic and international consumption/bunker of aviation kerosene (QAv). Such division was not necessary in the case of aviation gasoline (GAv), since it is a source conventionally used by small aircraft operating on domestic routes. Emissions from 1990 to 2004 were calculated using information on domestic consumption and bunker from BEN, adjusted using the overlap technique to maintain the time consistency of the time series, multiplying the result by the implicit emission factors[18] estimated for 2005 (from the aforementioned *bottom-up* modeling). This protocol was also applied for the years from 2019 to 2022; however, using the updated implicit emission factors from the last year modeled using the bottom-up approach (BRASIL, 2020).

In the Road Transportation subcategory (1.A.3.b), the sectoral, bottom-up approach is adopted to calculate GHG emissions from the mobile sources present in the national vehicle fleet. As in the case of domestic aviation, the top-down reference approach is used to compare and adjust results. Both approaches are based on the IPCC (2006) methodological guidelines for mobile combustion. The blends of biofuels used over the time horizon were identified based on the volumes (m^3) in the BEN's time series (EPE, 2023).[19]

The estimate of fugitive emissions from Coal Mining and Handling (1.B.1.a) considered ROM (Run-of-Mine) production data, based on the yearbooks of the Santa Catarina State Coal Extraction Industry Union (SIECESC, Sindicato da Indústria de Extração de Carvão do Estado de Santa Catarina) and the Brazilian Mineral Coal Association (ABCM, Associação Brasileira do Carvão Mineral) (SIECESC, 2023). ABCM integrates the entire national coal production chain, including coal companies in the states of Paraná, Santa Catarina and Rio Grande do Sul.

Emissions from Oil and Natural Gas (1.B.2), also under the Fugitive Emissions subsector (1.B), were calculated using implicit emission factors derived from data collected on production, transportation and refining, published in the inventory of the Fourth National Communication (up to 2016). The projections between 2017 and 2022 took into account data on national refining and production of oil and Natural Gas Liquids (NGL) obtained from the ANP – National Agency of Petroleum, Natural Gas and Biofuels (Agência Nacional do

[18] Average emission factor per fuel (kg/TJ), obtained by dividing the total emission of a given gas (kg) by the amount representing the energy consumed in the process (TJ).
[19] Type A gasoline-anhydrous ethanol and diesel-biodiesel.

Petróleo, Gás Natural e Biocombustíveis) (2023). Production data from Petrobras was used to separate the total volume processed in relation to third-party companies.

Dataframe 4.1 summarizes the methodological levels applied by gas and references in the Energy sector.

Part of the Tier 1 and 2 emission factors applied to the Energy Industries (1.A.1), Manufacturing Industries and Construction (1.A.2), Transport (1.A.3), Other Sectors (1.A.4) and Other (Not specified elsewhere) (1.A.5) categories were obtained from the 2013 and 2016 editions of the Air Pollutant Emission Inventory Guidebook[20] (EMEP (European Monitoring and Evaluation Programme)/EEA (European Environment Agency), 2013; 2017). The documents were drawn up by the Co-Operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe (EMEP[21]) together with the European Environment Agency (EEA[22]). In the absence of disaggregated data, the factors available in the Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) were used.

The data on emission factors for the LTO cycle in Domestic Aviation (1.A.3.a) were taken from the Engine Emissions Data Bank (EEDb) of the International Civil Aviation Organization (ICAO). In the ANAC – National Civil Aviation Agency (Agência Nacional de Aviação Civil) study (2020), version 24 of the EEDb/ICAO spreadsheet, which includes the database, was used. In the Road Transportation category (1.A.3.b), the CH_4, N_2O, CO, NO_x and NMVOC factors, by technology or energy source, were obtained from the series of Vehicle Emissions Reports in the State of São Paulo (CETESB – State of São Paulo Environmental Company (Companhia Ambiental do Estado de São Paulo), 2022), as well as from the MMA – Ministry of the Environment (Ministério do Meio Ambiente) (2014) and IBTS – Brazilian Institute for Sustainable Transportation (Instituto Brasileiro de Transporte Sustentável) (2019) studies. As in the case of the amended procedure in the Domestic Aviation category (1.A.3.a.ii), the implicit emission factors for non-CO_2 gases were taken into account, multiplying them by the fuel consumption[23] associated with freight and passenger transport activities.

Considering the Fugitive Emissions subsector (1.B), the emission factors for underground and surface mines (Coal Mining and Handling category – 1.B.1.a) were taken from IPCC (2006), and adapted based on the local methane content. Emissions from Oil and Natural Gas (1.B.2) for the years 2017 to 2022 were calculated using implicit emission factors derived from data collected on production, transportation and refining, published in the Inventory submitted in the Fourth National Communication (up to 2016).

[20] Air Pollutant Emission Inventory Guidebook.
[21] EMEP is the cooperative program for monitoring and evaluation of the long-range transmission of air pollutants in Europe.
[22] European Environment Agency.
[23] Diesel, type A gasoline, hydrous ethanol, anhydrous ethanol and dry natural gas.

Dataframe 4.1. Methodological levels applied by gas and Energy sector references.

			ESTIMATED GASES AND METHODOLOGIES						REFERENCES	
Subsector	Category	Subcategory	CO_2	CH_4	N_2O	CO	NO_x	NMVOC	Activity data	Emission factors
1.A. FUEL COMBUSTION ACTIVITIES	1.A.1. Energy Industries	1.A.1.a. Public electricity and heat production	T2	T2	T2	T2	T2	T2	National Energy Balance – BEN (EPE, 2023); Useful Energy Balance – BEU (1983, 1993 and 2004) (MME, 2005).	IPCC (2006, v. 2, chap. 2); Volume 2 (IPCC, 1997); EMEP/EEA Air Pollutant Emission Inventory Guidebook (EMEP/EEA, 2013 and 2017); specific for firewood and vegetable charcoal for CH_4 and N_2O (BRASIL, 2020). EMEP/EEA Air Pollutant Emission Inventory Guidebook (EMEP/EEA, 2013 and 2017) for CO, NO_x e NMVOC.
		1.A.1.b. Petroleum Refining	T2	T2	T2	T2	T2	T2		
		1.A.1.c. Manufacture of Solid Fuels and Other Energy Industries	T2	T2	T2	T2	T2	T2		
	1.A.2. Manufacturing Industries and Construction	1.A.2.a. Iron and Steel	T2	T2	T2	T2	T2	T2		
		1.A.2.b. Non-ferrous metals	T2	T2	T2	T2	T2	T2		
		1.A.2.c. Chemicals	T2	T2	T2	T2	T2	T2		
		1.A.2.d. Pulp, Paper and Print	T2	T2	T2	T2	T2	T2		
		1.A.2.e. Food Processing, Beverages and Tobacco	T2	T2	T2	T2	T2	T2		
		1.A.2.f. Non-metallic Minerals	T2	T2	T2	T2	T2	T2		
		1.A.2.g.ii. Manufacturing of transport equipment	T2	T2	T2	T2	T2	T2		
		1.A.2.g.iii. Mining (excluding fuels) and Quarrying	T2	T2	T2	T2	T2	T2		
		1.A.2.g.vi. Textile and Leather	T2	T2	T2	T2	T2	T2		
	1.A.3. Transport	1.A.3.a. Domestic Aviation	T3a	T3a	T3a	T3a	T3a	T3a	Air Traffic Movement Database (BIMTRA, Banco de Informações de Movimento de Tráfego Aéreo); average times for each stage of the LTO cycle (ICAO, 2011; FOI (Swedish Defence Research Agency), 2013); average APU standard operating times for aircraft (ACRP (Airport Cooperative Research Program), 2012); National Energy Balance – BEN (EPE, 2023).	IPCC (2006, v. 2, chap. 3); ANAC (2020).
		1.A.3.b. Road transportation	T2	T3	T3	T3	T3	T3	Vehicle fleet: vehicle sales and scrapping curve (ANFAVEA – National Association of Automotive Vehicle Manufacturers (Associação Nacional dos Fabricantes de	IPCC (2006, v.2, chap. 3); Brasil (2014); CETESB (2022).

Subsector	Category	Subcategory	ESTIMATED GASES AND METHODOLOGIES						REFERENCES	
			CO_2	CH_4	N_2O	CO	NO_x	NMVOC	Activity data	Emission factors
									Veículos Automotores), 2022; ABRACICLO – Brazilian Association of Motorcycle, Moped, Scooter, Bicycle and Similar Manufacturers (Associação Brasileira dos Fabricantes de Motocicletas, Ciclomotores, Motonetas, Bicicletas e Similares), 2023; BRASIL, 2020; IBTS, 2019); Energy efficiency (BRASIL, 2014; IBTS, 2019; CETESB – State of São Paulo Environmental Company (Companhia Ambiental do Estado de São Paulo), 2022); Vehicle kilometers traveled (VKT) (BRASIL, 2020; BRASIL, 2014); Activity (BRIAND *et al.*, 2023)	
	1.A.4. Other sectors	1.A.3.c. Railways	T2	T1	T1	T1	T1	T1	National Energy Balance – BEN (EPE, 2023); Useful Energy Balance – BEU (1983, 1993 and 2004) (MME, 2005).	IPCC (2006, v. 2, chap. 2); IPCC (1997, v. 2); EMEP/EEA Air Pollutant Emission Inventory Guidebook (EMEP/EEA, 2013 and 2017); specific for firewood and vegetable charcoal for CH_4 and N_2O (BRASIL, 2020). EMEP/EEA Air Pollutant Emission Inventory Guidebook (EMEP/EEA, 2013 and 2017) for CO, NOx e NMVOC.
		1.A.3.d. Domestic navigation	T2	T1	T1	T1	T1	T1		
		1.A.3.e. Other Transportation	T2	T2	T2	T2	T2	T2		
		1.A.4.a. Commercial/Institutional	T2	T2	T2	T2	T2	T2		
		1.A.4.b. Residential	T2	T2	T2	T2	T2	T2		
		1.A.4.c. Agriculture/Forestry/Fishing	T2	T2	T2	T2	T2	T2		
	1.A.5. Other (Not specified elsewhere)	1.A.5.a. Stationary	T2	T2	T2	T2	T2	T2		
		1.A.5.b. Mobile	T2	T2	T2	T2	T2	T2		
		1.A.5.c. Multilateral operations	NO	NO	NO	NO	NO	NO		
1.B. FUGITIVE EMISSIONS FROM FUELS	1.B.1. Solid Fuels	1.B.1.a. Coal Mining and Handling	NO	T1	NA	NA	NA	NA	Coal production data from the Brazilian Mineral Coal Association and the Santa Catarina State Coal Extraction Industry Union (SIECESC, 2023).	IPCC (2006, v. 2, chap. 4).
		1.B.1.b. Fuel Transformation	NO	NO	NO	NO	NO	NO		

			ESTIMATED GASES AND METHODOLOGIES						REFERENCES	
Subsector	Category	Subcategory	CO_2	CH_4	N_2O	CO	NO_x	NMVOC	Activity data	Emission factors
		1.B.1.c. Spontaneous Combustion and Landfills for Burning Coal	NO	NO	NO	NO	NO	NO		
	1.B.2. Oil and Natural Gas	1.B.2.a. Oil	T2/T3	T2/T3	T2/T3	NE	NE	NE	GHG emissions results from Petrobras; Production and refining data from the National Petroleum, Natural Gas and Biofuels Agency (ANP, 2023); Volume of cargo processed from the National Energy Balance (EPE, 2023).	Industry protocols and emission sources for the categories.
		1.B.2.b. Natural Gas	T2/T3	T2/T3	T2/T3	NE	NE	NE		
1.C. CO_2 TRANSPORT AND STORAGE	1.C.1. Transport of CO_2		NO							
	1.C.2. Injection and Storage		NO							
	1.C.3. Other		NO							

Note: Methodological levels (IPCC, 2006) – T1: Tier 1; T2: Tier 2; T3: Tier 3; T3a: Tier 3a.
Notations: NA (Not applicable) – Activity in a given source/sink category that occurs in the country, but did not result in emissions or removals of a specific gas; IE (Included elsewhere) – Included in another location/category of emissions or removals; NO (Not occurring) – Categories and processes that do not occur in the country; NE (Not estimated) – Activity data and/or emissions by sources and removals by sinks of GHG that have not been estimated, but for which a corresponding activity may occur in the country.

Some of the activity data and emissions results could not be disaggregated in the Inventory. Instead, they were collected and reported in aggregated form. Dataframe 4.2 shows the distributions of emissions from subcategories that could not be disaggregated within the Energy sector.

Dataframe 4.2. Categories with values assigned in other categories (IE) in the Energy sector.

IPCC CODES	REALOCATED CATEGORIES	REALLOCATION DESTINATION
1.A.1.a.i	Electricity Generation	1.A.1.a. Public electricity and heat production
1.A.1.a.ii	Combined heat and power generation (CHP)	1.A.2. Manufacturing Industries and Construction
1.A.1.a.iii	Heat plants	1.A.1.a. Public electricity and heat production
1.A.2.g.i	Manufacturing of machinery	1.A.2.g.ii. Manufacturing of transport equipment
1.A.2.g.iv	Wood and wood products	1.A.2.d. Pulp, paper and print
1.A.2.g.v	Construction	1.A.2.g.ii. Manufacturing of transport equipment
1.A.2.g.vii	Off-road vehicles and other machinery	1.A.2.g.ii. Manufacturing of transport equipment
1.B.2.b	Production (Natural Gas)	1.B.2.b.ii. Production and gathering

For some subcategories, it was not possible to calculate emissions, mainly due to lack of information. Dataframe 4.3 lists the subcategories for which GHGs have not been estimated.

Dataframe 4.3. Non-estimated (NE) subcategories for the Energy sector.

IPCC CODES	NON-ESTIMATED CATEGORIES	NOTES
1.B.1.a.i.3	Abandoned underground mines (number of mines)	There is not enough information to characterize abandoned mines in the country, therefore, it is not possible to estimate emissions after their closure.
1.B.2.a.i	Exploration	There is no data to estimate emissions from these subcategories.
1.B.2.a.v	Distribution of oil products	
1.B.2.b.i	Exploration	
1.B.2.b.v	Distribution of oil products	

4.3 Comparison between Reference Approach and Sectoral Approach

The calculation of CO_2 emissions for burning of fossil fuels should be based on two approaches, according to the IPCC (2006): Reference Approach (top-down methodology) and Sectoral Approach (bottom-up Tier 1 methodology). The emissions accounted for in the national inventories are those that are calculated using the Sectoral Approach.

The Reference Approach, which is more aggregated, consists on the calculation based on aggregated data on fuel supply. To that end, the concept of apparent consumption is adopted: the production of primary fuels and the import of primary and secondary fuels are added together; and the export of primary and secondary fuels, of bunkers and the stock

variation (which can be positive or negative) are subtracted. Based on this result, CO_2 emissions are estimated based on the carbon content of the fuels.

Na Abordagem Setorial são empregadas informações sobre o consumo de combustíveis por setor energético, sendo multiplicado pelos fatores de emissão correspondentes. As estimativas das emissões de CO_2 por meio de ambas as abordagens convencionalmente retornam valores levemente distintos, sendo um mecanismo de controle de qualidade dos resultados do setor. De acordo com o IPCC (2006), diferenças acima de 5% são consideradas significativas e devem ser investigadas e explicadas.

For this inventory, an average percentage variation of 1.44% was observed between the Reference Approach and the Sectoral Approach, for the time series from 1990 to 2022, with an absolute maximum of 3,30% in 1998. In 2022, the difference between the two approaches was of 0.18% (Table A.III.1, Appendix III).

Figure 4.2 shows the evolution of the average difference in GHG emissions between the approaches.

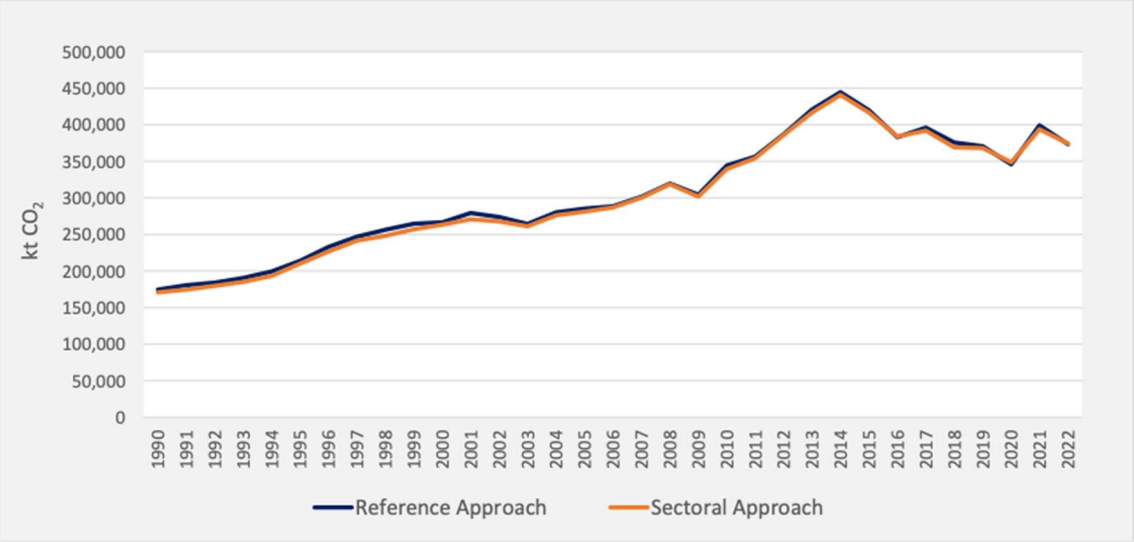


Figure 4.2. Estimates of CO_2 emissions between the Reference and Sectoral approaches, in kt CO_2, from 1990 to 2022.

4.4 International Fuels (bunkers)

The IPCC (2006) instructs that emissions from fuel combustion in international activities (bunker), for which there is not yet a criterion for the allocation of responsibilities, should not be accounted for in national inventories, but should be reported for the purposes of composing the global data. These emissions are associated with air and sea travel and river transport across national borders.

The subcategories covering emissions from bunkers are: 1.A.3.a.i. International Aviation; and 1.A.3.d.i. International Navigation. Figure 4.3 shows the evolution of emissions in kt CO_2 eq for international navigation and aviation.

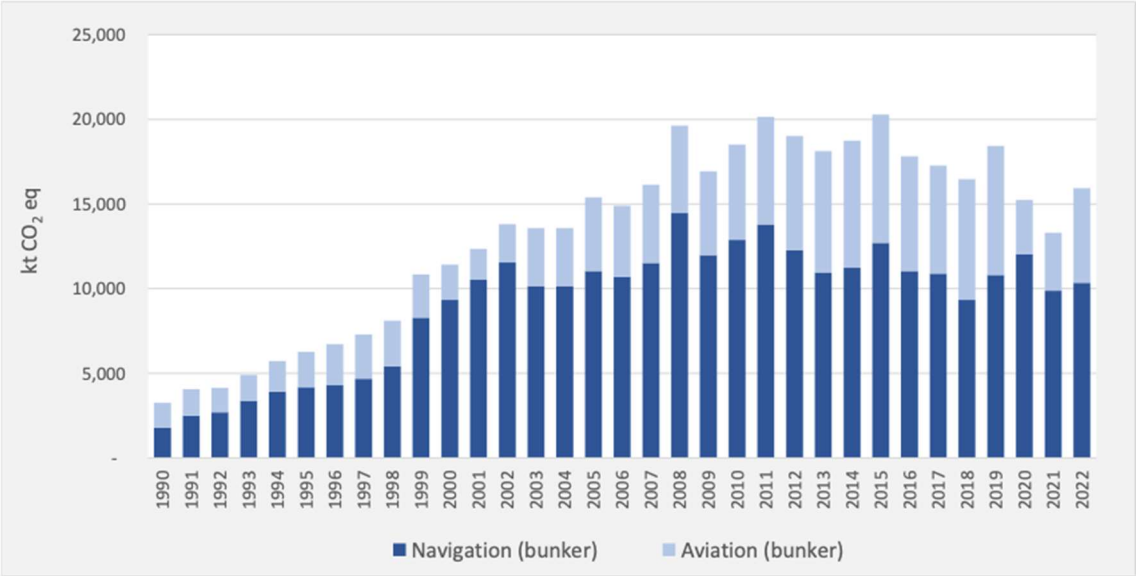


Figure 4.3. International fuel emissions (bunkers), in kt CO_2 eq, from 1990 to 2022.

International Aviation

Between 2005 and 2018, the estimates of bunker emissions took into account the aviation kerosene consumption data from the bottom-up modeling in Tier 3a detailed in the ANAC report (2020). Then, based on the implicit emission factors per type of fuel and gas, GHG emissions from the consumption of aviation kerosene that were made available in BEN's open matrices were projected for the 2019-2022 period (EPE, 2023).

As with the domestic estimates, there was no need to separate aviation gasoline consumption into domestic and bunker, since it is normally consumed by small aircraft operating on domestic routes. Emissions between 1990 and 2004 used bunker consumption data from BEN, which were adjusted using the overlap technique to ensure the time consistency of the time series. In addition, the implicit emission factors for 2005, derived from the bottom-up modeling in Tier 3a (ANAC, 2020), were taken into account.

Figure 4.4 shows the evolution of emissions in kt CO_2 eq for domestic aviation and bunker.

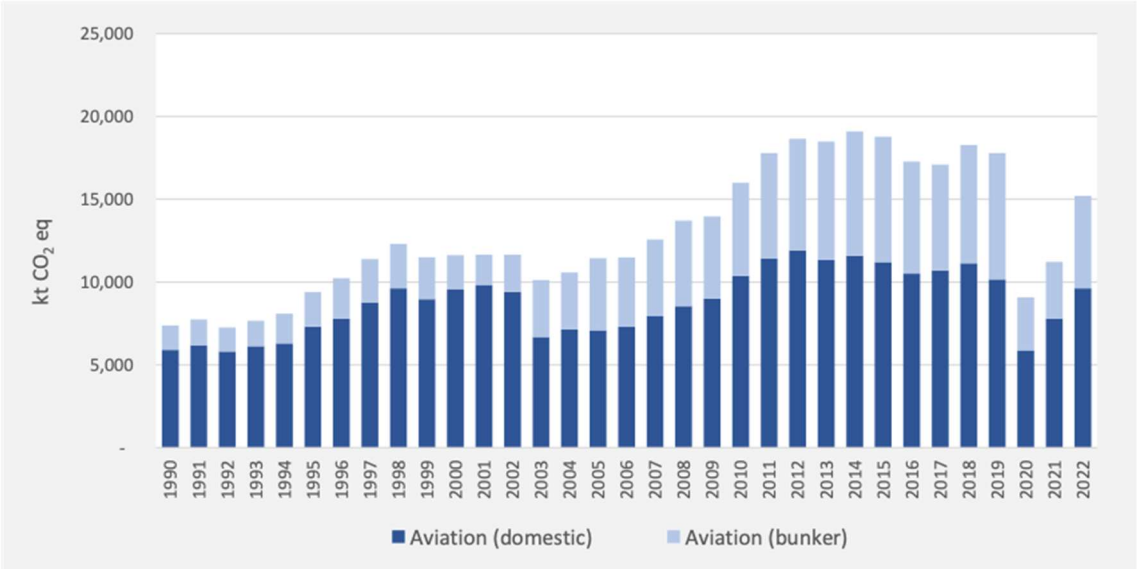


Figure 4.4. Emissions from domestic and international aviation, in kt CO_2 eq, from 1990 to 2022.

The results show that between 2020 and 2022 domestic and international emissions increased by 64% and 74%, respectively. This result stems, mainly, from the impact of measures resulting from the COVID-19 pandemic that affected passenger travel in this transport mode in 2020, and it is not strongly related to route optimization or SAF (Sustainable Aviation Fuel) penetration. Despite the increase in recent activity, domestic emissions in 2022 were 5% below 2019 levels (pre-pandemic), while international emissions are 27% lower.

International Navigation

Emissions related to international navigation for the entire history took into account the consumption of fuel oil and diesel oil indicated in BEN. Tier 1 emission factors, available in IPCC (2006), were, then, applied.

Figure 4.5 shows the evolution of emissions in kt CO_2 eq for domestic navigation and bunker.

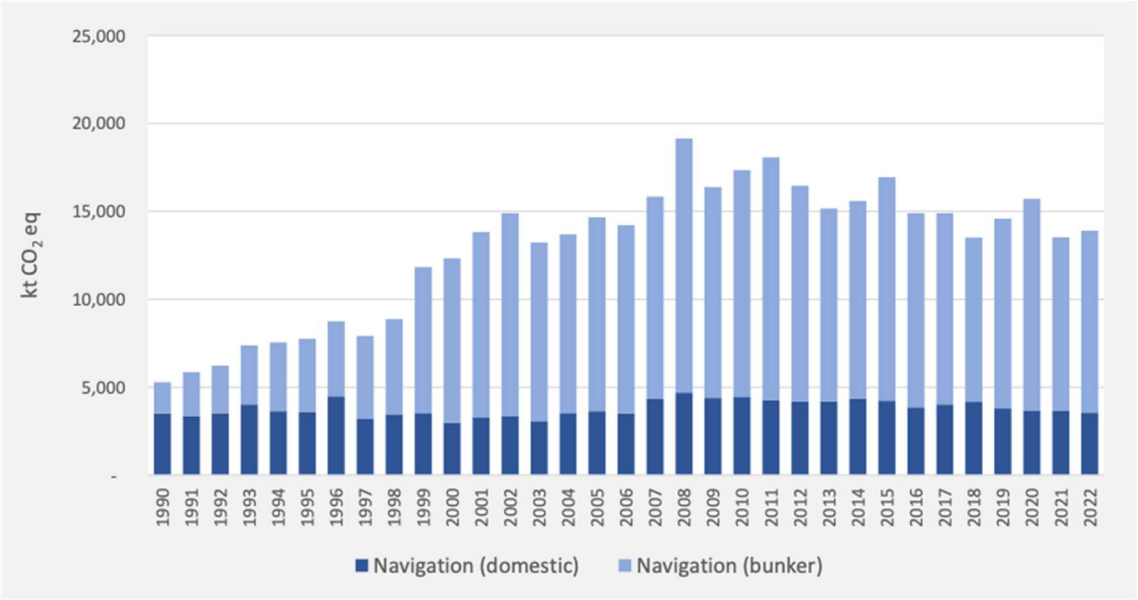


Figure 4.5. Emissions from domestic and international navigation, in kt CO_2 eq, from 1990 to 2022.

The results of international navigation do not point to significant impacts of the pandemic on the waterway mode. In 2022, kt CO_2 eq emissions were 14% lower than 2020 levels. On the other hand, emissions from domestic navigation (cabotage and inland waterways) fell by 4% in that period, following the historical rate of annual decline in these modes of transport since their peak in 2008 (-2% p.a.).

4.5 Feedstocks and non-energy uses of fuels

In order to avoid double counting, the emissions resulting from the non-energy use of fuels are not taken into account in the context of the Energy sector. Instead, they are assigned to the Industrial Processes and Product Use (IPPU) category, as explained below:

- Metal Industry: fuels used as reducers in the pig iron and steel, ferroalloys and non-ferrous industries. Petroleum coke, bituminous coal, mineral coal coke and charcoal values, whose end uses are in direct heating, are considered as reducers, according to the Useful Energy Balance (BEU, Balanço de Energia Útil).
- Non-Energy Products from Fuels and Solvent Use: fuels such as tarmac, lubricants, solvents, natural gas and other non-energy oil products specified in BEN.
- Chemical Industry: all fuels accounted for as "non-energy end use" in BEN, with the exception of those included in the above item.

4.6 Fuel combustion activities (CRT 1.A)

The Fuel Combustion Activities subsector (1.A) shows emissions from carbon oxidation that occurs in fuels during their end use. The gases considered in this segment are CO_2, CH_4 and N_2O, as well greenhouse gas precursors (CO, NOx and NMVOC).

In 2022, total emissions from this subsector reached 395,626 kt CO_2 eq. As mentioned above, the Transport category (1.A.3) was responsible for the largest share of emissions (54.9%), followed by the Manufacturing Industries and Construction (1.A.2), the Energy Industries (1.A.1) and Other Sectors (1.A.4), with 17.5%, 14.3% and 13.0%, respectively. Considering the total level of emissions in 2020, the volume emitted in 2022 was 7% higher.

Figure 4.6 shows emissions from the Fuel Combustion subsector by category.

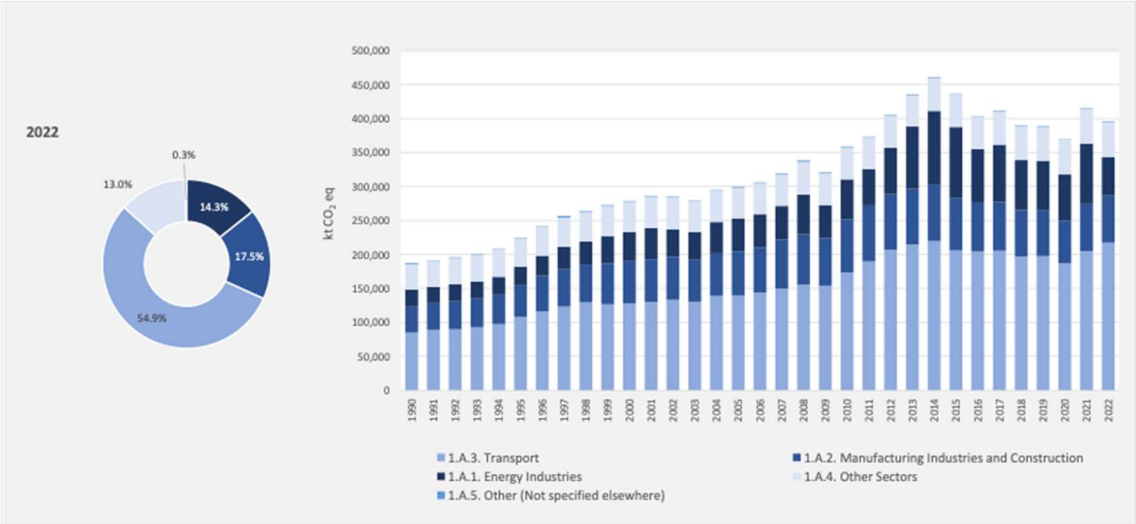


Figure 4.6. Emissions from Fuel Combustion Activities, in kt CO_2 eq by category, from 1990 to 2022.

In the Energy Industries (1.A.1), the majority of the emissions were from fuel combustion for electricity generation, accounting for 42% of the category, followed by the manufacture of solid fuels (34%) and petroleum refining (24%). In the Manufacturing Industries and Construction category (1.A.2), energy consumption in the non-metallic minerals industry led the emissions, with a 25% share. In second place, the chemical industry contributed 18%, followed by the iron and steel industry (12%).

In the Transport category (1.A.3), the pattern of intensive use of road transport was maintained, with a 92% share of GHG emissions. Despite representing less than 4% of the vehicle fleet, trucks[24] and buses[25] accounted for 57% of GHG emissions. Cars, then, accounted for 34% of the category's emissions. Air, water (cabotage and inland waterways) and railway transport contributed 4%, 1.6% and 1.5%, respectively.

Considering the Other Sectors segment (1.A.4), the residential category emerged as the main contributor, accounting for 51% of emissions. This was mainly due to the use of LPG (Liquefied Petroleum Gas). Emissions associated with the Other (Not specified elsewhere) segment (1.A.5) were concentrated in aviation. This result is due to fuel consumption by helicopters, small aircraft and military aircraft that are not included in the Transport category (1.A.3).

[24] Semi-light to heavy duty.
[25] Micro, urban and road.

4.6.1 Methodological aspects

This approach details the equations considered for categories 1.A.1, 1.A.2, 1.A.3.a, 1.A.3.c, 1.A.3.d, 1.A.3.e, 1.A.4, 1.A.5. This method follows the guidelines outlined in the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (IPCC, 2006), specifically in Chapters 2 and 3 of Volume 2.

The estimates adopt the IPCC's Sectoral approach, which consists in obtaining "Fuel Consumption" from statistical data on energy use, expressed in units of mass or volume and converted into terajoules (TJ). The Energy sector covers mainly the following activities: Exploration of primary energy sources; Conversion of primary energy sources into more usable forms;[26] Transmission and distribution of fuels; and Use of fuels in facilities and equipment.

The Sectoral approach adopted for the CO_2 estimates, as described in the equations in Dataframe 4.4, follows the following steps:

- Identification of energy consumption by sector or subsector of the National Energy Balance, considering their original units of measurement, which are then converted to tons of oil equivalent (toe).
- Standardization into a common energy unit (TJ).
- Multiplication by the carbon dioxide emission factor (CO_2).

On the other hand, the Sectoral approach used for the estimates of non-CO_2 gases comprises the following procedures:

- Identification of fuels consumption by sector or subsector of the National Energy Balance, using their original units of measurement, which are then converted to tons of oil equivalent (toe).
- Standardization into a common energy unit (TJ).
- Multiplication by the percentage of the fuel end use per category of the Useful Energy Balance.[27]
- Multiplication by the specific emission factor for methane (CH_4), nitrous oxide (N_2O), carbon monoxide (CO), nitrogen oxides (NO_x) and non-methane volatile organic compounds (NMVOC).

Dataframe 4.4. Equations for estimating emissions of inventoried gases for the categories in the Fuel Combustion subsector.

Equations	GHG	Categories	Central equation	IPCC Reference (2006)
Equation 4.1	CO_2	1.A.1 1.A.2 1.A.3d 1.A.3e 1.A.4 1.A.5	$E_{GHG,comb} = EF_{GHG,comb} * Cons_{comb}$	IPCC (2006, v. 2, p. 2.11)
Equation 4.2	non-CO_2		$E_{GHG,comb,technol,sector} = EF_{GHG} * Cons_{comb,sector}$	IPCC (2006, v. 2, p. 2.12)

[26] Carried out in transformation facilities, such as refineries, electricity generation plants, among others.
[27] Such as motive power, process heat, direct heating, refrigeration, lighting, electrochemistry and others.

In which:

E = Emission, expressed in kg of GHG by fuel type;
EF = Gas emission factor (kg GHG/TJ) by fuel type; and
Cons = Amount of fuel consumed (TJ).

4.6.2 Energy Industries

The Energy Industries category (1.A.1) covers emissions from fuel combustion by the fuel extraction or power generation industries. The Energy Industries category (1.A.1) covers emissions from fuel combustion by the fuel extraction or power generation industries. This category groups together emissions from Public Electricity and Heat Production (1.A.1.a) and subdivisions,[28] as well as Petroleum Refining (1.A.1.b) and Manufacture of Solid Fuels and Other Energy Industries (1.A.1.c).

Figure 4.7 summarizes the kt CO_2 eq emissions from Energy Industries.

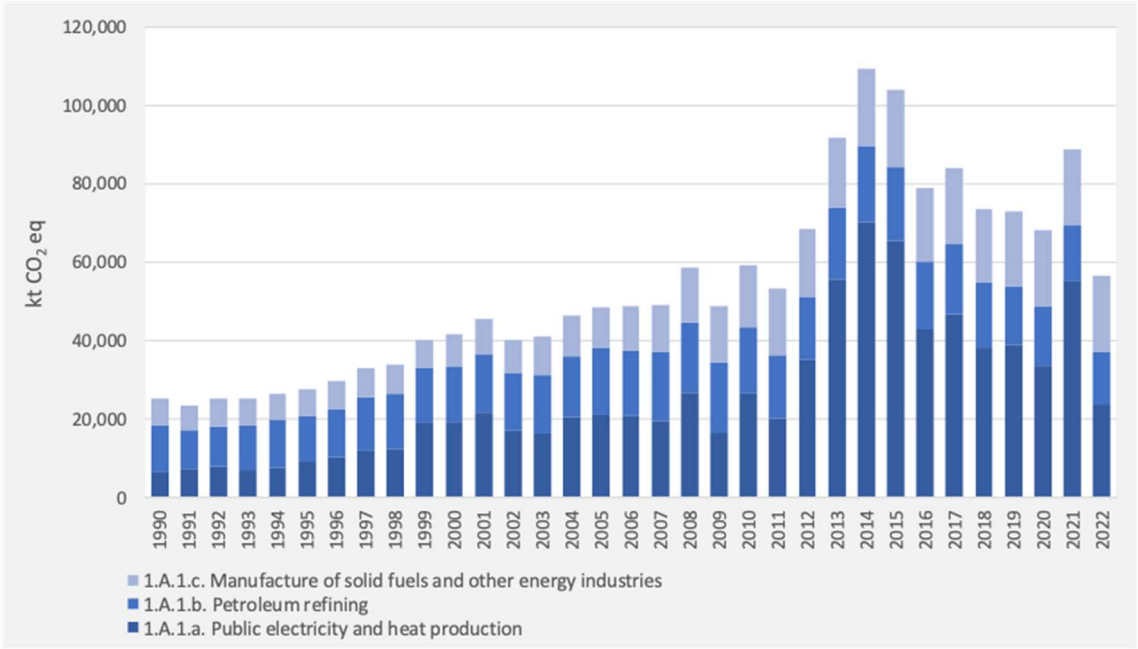


Figure 4.7. Emissions from Energy Industries, in kt CO_2 eq by category, from 1990 to 2022.

Between 2020 and 2022, emissions in this category fell by 17%, driven by the Public Electricity and Heat Production subcategory (1.A.1.a), which fell by 30%. This was due to the expansion of wind (43%) and solar (100%) generation during this period. Along these lines, the Brazilian electricity matrix reached 88% renewability,[29] compared to 85% in 2020 (EPE, 2023). It should be noted that in 2021 there was a one-off growth of 65% in emissions from Public Service Power Plants, driven by the increase in the consumption of dry natural gas, steam coal and fuel oil.

[28] Electricity generation (1.A.1.a.i), Combined heat and power generation (1.A.1.a.ii) and Heat plants (1.A.1.a.iii).
[29] Including isolated systems and self-production not injected into the grid.

Still considering the 2020-2022 period, the Petroleum Refining subcategory fell by 11%, driven by the decrease in dry natural gas consumption, while the Manufacture of Solid Fuels and Other Energy Industries subcategory remained stable.

4.6.3 Manufacturing Industries and Construction

This subsector covers emissions resulting from fuel combustion in industry, including combustion for electricity and heat generation for its own use. It should be noted that emissions from fuel combustion in coke ovens within the iron and steel industry are reported in 1.A.1.c., Manufacture of solid fuels and other energy industries, and not in the manufacturing industry. In addition, the energy consumed for transport by the industry is not reported in this subsector, but under Transport (1.A.3).

Figure 4.8 shows the estimated emissions from the Manufacturing Industries and Construction sector (1.A.2).

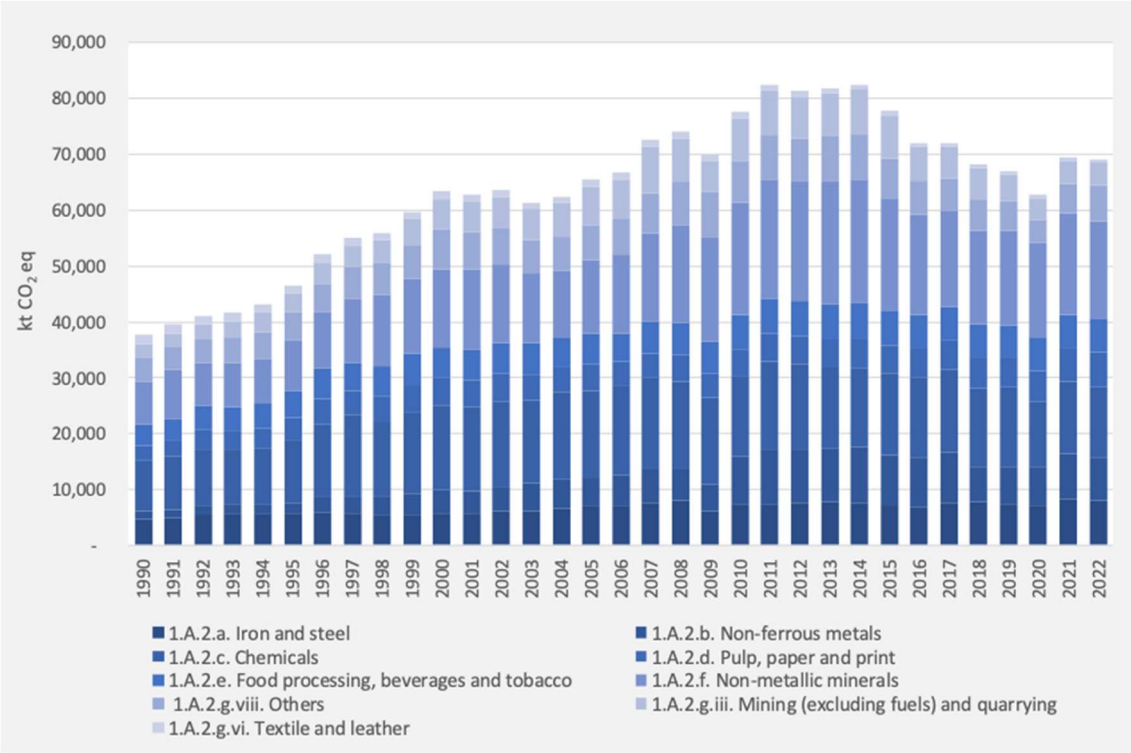


Figure 4.8. Emissions from Manufacturing Industries and Construction, in kt CO_2 eq by category, from 1990 to 2022.

Emissions from this subsector increased by 10% between 2020 and 2022. The subcategories that reduced their volume of kt CO_2 eq emitted were 1.A.2.e., Food processing, beverages and tobacco (-2%), due to increased use of firewood, and 1.A.2.g.vi. Textile and leather (-7%), with lower consumption of fuel oil and LPG. In the case of the Non-Metallic Minerals subcategory (1.A.2.f), the volume emitted increased by 3%, driven by the consumption of natural gas in ceramics production.

4.6.4 Transport

The Transport category (1.A.3) includes emissions resulting from the combustion and evaporation of fuel for all transport activities (with the exception of military transport), regardless of the sector. In line with IPCC (2006), emissions from international transport were reported separately. Thus, emissions from fuels sold to any aircraft or maritime vessel used in an international route were excluded from the totals and subtotals of this category.

Figure 4.9 shows the evolution of kt CO_2 eq emissions from this category, involving road, waterway (cabotage and inland waterway), domestic aviation and railways transport modes. The category's total emissions increased by 16% compared to 2020. Between 2020 and 2022, there was a decrease in emissions from waterway transportation (-4%) in the Other Transportation subcategory (1.A.3.e). The latter refers to combustion emissions from all other transport activities, including pipeline transport, land-based activities at airports and ports, and off-road activities that are not reported under Agriculture (1.A.4.c) and Manufacturing Industries and Construction (1.A.2).

It should be noted that emissions from the railways are mainly due to freight transport, since passenger railway transport is virtually[30] dependent on electricity, reported in its end use as zero-emission.

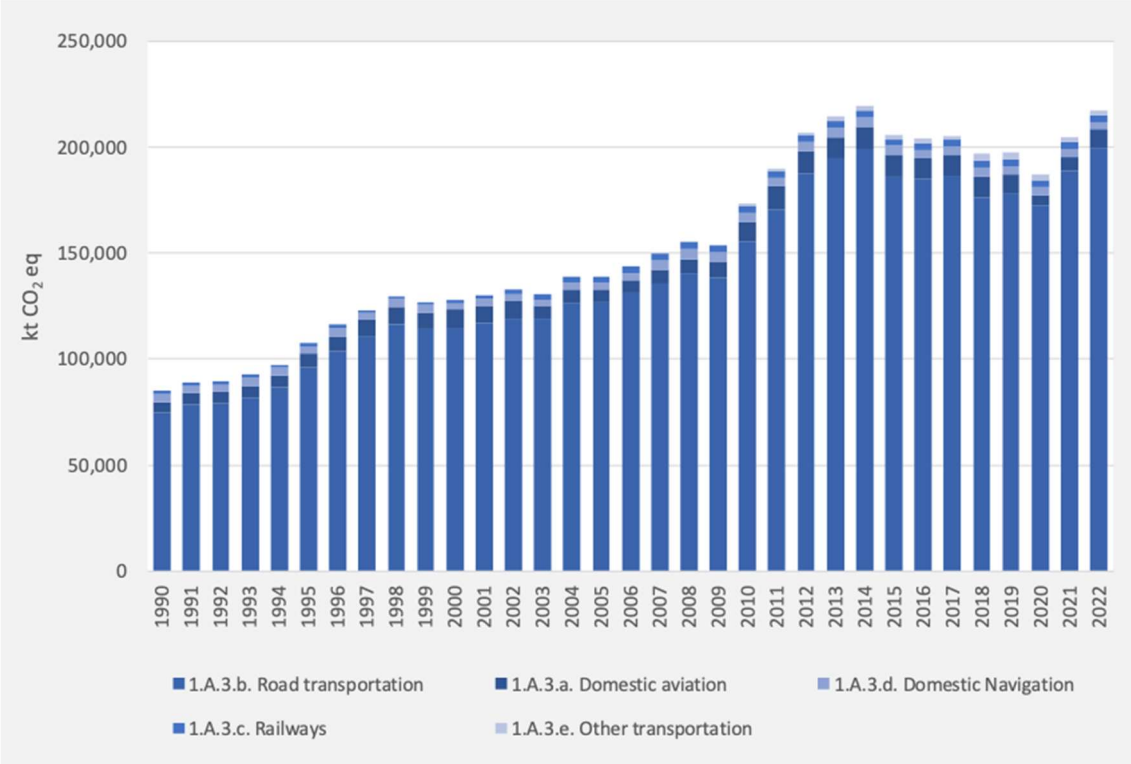


Figure 4.9. Emission from Transport, in kt CO_2 eq by category, from 1990 to 2022.

In the Road Transportation subcategory (1.A.3.b), heavy duty passenger and freight vehicles (buses and trucks) accounted for 57% of emissions, while cars, light duty trucks and motorcycles accounted for 34%, 6% and 3%, respectively (Figure 4.10). Between 2020 and

[30] There are some cases of diesel-powered LRT (Light Rail Transit) in capital cities and small towns (for example, Fortaleza and Sobral-CE (State of Ceará).

2022, emissions from motorcycles increased the most (20%), followed by emissions from cars, showing an increase in individual motorized transport to the detriment of other modes.

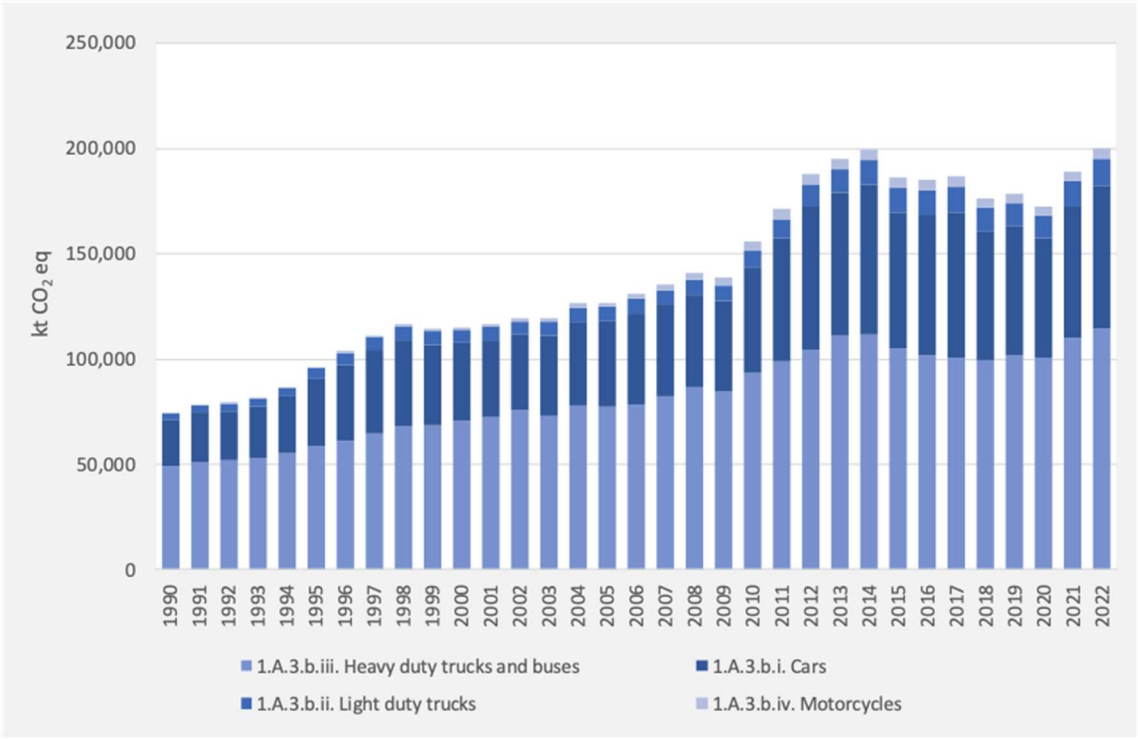


Figure 4.10. Emissions from Road Transportation, in kt CO_2 eq by vehicle subcategories, from 1990 to 2022.

4.6.4.1 Methodological aspects

4.6.4.1.1 Road Transportation

While emissions from railways and maritime transport were estimated based on energy consumption (top-down), as presented in section 4.6.1, the model used to estimate GHG emissions from the Road Transportation category (1.A.3.b) is derived from the procedures used in the 2nd National Inventory of Atmospheric Emissions from Road Motor Vehicles (BRASIL, 2014), in the IBTS study (2019) and the Inventory of the Fourth National Communication (BRASIL, 2020). A bottom-up approach is adopted, which estimates GHG emissions and air pollutants through the sectoral disaggregation of energy end use. This makes it possible to identify where and how emissions occur for each inventoried category of vehicle. At the same time, the emissions calculated using the bottom-up approach are adjusted using a top-down approach, which uses aggregated data on fuel supply.

The modeled fleet takes into account variations in the type of vehicle (motorcycles, trucks, among others); size (semi-light, light duty, heavy duty, etc.); and engine, including variations in the propulsion system (Otto cycle, diesel). Dataframe 4.5 describes the categories modeled in the road transportation mode.

Dataframe 4.5. Vehicle categories with emissions modeled in the NIR 2024.

Category	Description	Engine/Propulsion system
Motorcycles	Two-wheeled motor vehicle, with or without sidecar, driven in a mounted position.	Otto / Gasoline Otto / Flexible-fuel
Cars	Motor vehicle intended for the transportation of passengers, with capacity for up to eight people, excluding the driver	Otto / Gasoline Otto / Ethanol Otto / Flexible-fuel Otto / CNG Hybrid
Light duty commercial vehicles	Motor vehicle intended for transporting people or cargo, with a total gross weight of up to 3,500 kg	Otto / Gasoline Otto / Ethanol Otto / Flexible-fuel Otto / CNG Diesel
Minibuses	Motor vehicle for public transport	Diesel
Urban buses		Diesel
Coaches		Diesel
Semi-light duty trucks (TGW > 3.5 t < 6 t)	Motor vehicle intended for the transportation of cargo, with bodywork, and Total Gross Weight (TGW) exceeding 3,500 kg	Diesel
Light duty trucks (TGW ≥ 6t < 10 t)		Diesel
Medium-sized trucks (TGW ≥ 10 t < 15 t)		Diesel
Semi-heavy duty trucks (TGW ≥ 15 t; TGCW (Total Gross Combined Weight) < 40 t)		Diesel
Heavy duty trucks (TGW ≥ 15 t; TGCW ≥ 40 t)		Diesel

A bottom-up Tier 3 (IPCC, 2006) approach is used for non-CO_2 gases, in which emission factors vary according to vehicle technology. In addition, a bottom-up Tier 2 approach is used to estimate CO_2 emissions. Therefore, the protocol for calculating the emissions inventory is structured based on five pieces of information:

- Vehicle fleet: obtained based on the history of new vehicle sales; scrapping curves; fraction of flexible-fuel vehicles and conversion of vehicles for the use of CNG;
- Emission factor: obtained based on technical reports from national institutions. The increase in emissions for non-CO_2 gases as a result of vehicle deterioration due to wear and tear is taken into account;
- Vehicle kilometers travelled (VKT): obtained from the reference intensity of use and the correction factor, calibrated by vehicle category by comparing observed annual energy consumption (BEN) and estimated energy consumption (bottom-up);
- Transport activity: calibrated according to the IBTS (2019) and Briand *et al*. (2023) studies; and
- Energy consumption: obtained from the energy efficiency (km/l) and VKT of each vehicle category, technology and year of manufacture.

The equations shown in Dataframe 4.6 are used to calculate emissions of CO_2 and non-CO_2 gases.

Dataframe 4.6. Equations for estimating emissions of inventoried gases from Road transportation.

Equations	GHG	Category	Central equations	Reference
Equation 4.3	CO_2	1.A.3.b	$E = \sum_{a,b} (C_{a,b} * EF_{a,b})$	Equation 3.2.1 (IPCC, 2006, v. 2, chap. 3)
Equation 4.4	Non-CO_2	1.A.3.b	$E = \sum_{a,b} (VKT_{a,b} * EF_{a,b})$	Equation 3.2.5 (IPCC, 2006, v. 2, chap. 3)

In which:

E = annual emission rate of the gas in question (g/year);
F = fuel consumed (l);
EF = emission factor of the GHG in question, expressed in terms of the mass of pollutants emitted per km traveled (g/km) or per volume of fuel consumed (kg/l or kg/m^3);
VKT = vehicle kilometers traveled for vehicles of the model year in question (km/year);
a = type of fuel used; and
b = model year of the vehicle in question.

In the case of vehicles converted to CNG use, a top-down approach is used to estimate GHG emissions. In this case, emissions are estimated based on observed annual CNG consumption (m^3), available in the National Energy Balance (BEN), multiplying it by an average emission factor for each gas, with non-CO_2 gases in units of grams per cubic meter (g/m^3), and CO_2 in kilograms per cubic meter (kg/m^3). Therefore, in order to correctly estimate the vehicle fleet, the portion of vehicles that have been converted to use CNG is deducted from the original fleet.

It should be noted that the estimates of the bottom-up approach are calibrated with the results of the top-down approach, resulting in the same absolute value of energy consumption and emissions (of CO_2) for both approaches. In this case, the energy consumption adjustment process is carried out by vehicle model year, taking into account reference values for occupancy and average capacity of motor vehicles.

For non-CO_2 gases, the emissions are estimated based on the total mileage traveled per vehicle model year and specific emission factors. Therefore, the emissions of these gases using a bottom-up approach are different from those obtained using a top-down approach. For the road transportation inventory, the bottom-up approach is considered to be the estimates made from the combination of the vehicle fleet, intensity of use and energy efficiency.

The vehicle fleet is calculated by deducting the estimated number of vehicles that have ceased to circulate over time (scrapped) from accumulated sales, using Equation 4.6 for the Otto cycle, and Equation 4.7 for the Diesel cycle (Dataframe 4.7).

Dataframe 4.7. Equations for estimating the vehicle fleet.

Equations	Description	Notes	Central equations	Reference
Equation 4.5	Vehicle fleet	Adjusted with DPVAT[31]	$Fr_{a,V_{md,k}} = (1 - S_{a,V_{md,k}})$	IPCC (2006, v. 2, p. 3.28)
Equation 4.6	Scrapping function	Otto cycle vehicles	$S_{a,V_{md,k}} = \exp\{-\exp[a + (b * t)]\}$	IPCC (2006, v. 2, p. 3.28)
Equation 4.7	Scrapping function	Diesel cycle vehicles	$S_{a,V_{md,k}} = \frac{1}{\{1+\exp[a(t-t_0)]\}} + \frac{1}{\{1+\exp[a(t+t_0)]\}}$	IPCC (2006, v. 2, p. 3.28)

In which:

$Fr_{a,V_{m,k}}$ = estimated vehicle fleet, in terms of the number of vehicles for the year (a), relating to the vehicle (V_{md}) and to the fuel (k);
$V_{md,k}$ = number of vehicles sold of the type (v), model year (md) and fuel (k); and
$S_{a,V_{md,k}}$ = fraction of scrapped vehicles V_{md} (model year), which use fuel (k) and no longer make up the vehicle fleet in the year (a).

The fleet converted to use CNG is estimated based on information obtained from the National Traffic Office (SENATRAN, Secretaria Nacional de Trânsito, 2023), considering the month of December of each year. Based on this figure, the quantity (converted vehicles/year) is scrapped and deducted from the estimated vehicle fleet for the originally manufactured vehicle. It is, therefore, possible to estimate the vehicle fleet disaggregated by vehicle category, obtaining the average age of each type of vehicle.

The variables and coefficients of equations 4.5 and 4.6 are:

- $S_{a,V_{md,k}}$ = fraction of vehicles scrapped at age t;
- t = vehicle age;
- t_0 = calibration variable (Diesel cycle vehicles);
- a = calibration variable (Otto cycle vehicles); and
- b = calibration variable (Otto cycle vehicles).

The parameters established for the calibration coefficients *a* and *b* are: 1.798 and -0.096 for cars and vehicles converted to use CNG; 1.618 and -0.141 for light duty commercial vehicles; 0.15 and -0.175 for motorcycles of up to four years of use; and 0.8 and -0.0931 for motorcycles of over four years of use.

For light duty commercial vehicles with diesel cycle engines, buses and trucks, the values for the calibration coefficients *a* and t_0 are adopted: 0.17 and 17 for light duty commercial vehicles; 0.08 and 19.1 for trucks; and 0.16 and 19.1 for buses.

The non-CO_2 GHG emission factors are obtained from the reports of the State of São Paulo Environmental Company (Companhia Ambiental do Estado de São Paulo) (CETESB, 2022) and Brasil (2014). In the case of the CO_2 emission factor, the original unit in tC/TJ is used, converting it to the unit of mass of CO_2 per volume of fuel based on Equation 4.8 (Dataframe 4.8).

[31] Compulsory Insurance for the Protection of Victims of Traffic Accidents (Seguro Obrigatório para Proteção de Vítimas de Acidentes de Trânsito).

The energy factors (toe/m^3) per fuel type are corrected annually based on BEN's historical matrices (2023).

Dataframe 4.8. CO_2 emission factor conversion equation.

Equations	Description	Central equation	IPCC Reference (2006)
Equation 4.8	Emission factor for CO_2	$\frac{kgCO_2}{l} = \frac{tC}{TJ} * \frac{TJ}{toe} * \frac{toe}{m^3} * \frac{44}{12}$	Equation 3.2.2 (IPCC 2006, v. 2, chap. 3)

In which:

kg CO_2/l = emission factor calculated in kg of carbon dioxide per liter of fuel;
tC/TJ = emission factor in tons of carbon per terajoule;
TJ/toe = energy units conversion factor, from terajoule to tons of oil equivalent (toe); and
toe/m^3 = energy density in toe/m^3.

The energy densities applied by fuel and by year are shown in Table 4.1. In turn, Table 4.2 shows the emission factor in tons of carbon per terajoule.

Table 4.1. Energy density in toe/m^3 by fuel consumed in road transportation.

Year	Gasoline	Hydrous ethanol	Anhydrous ethanol	Mineral diesel	Biodiesel	CNG
1990	0.7867	0.5097	0.5339	0.8750	NO	0.8796
1991	0.7867	0.5097	0.5339	0.8707	NO	0.8796
1992	0.7867	0.5097	0.5339	0.8707	NO	0.8796
1993	0.7867	0.5097	0.5339	0.8707	NO	0.8796
1994	0.7867	0.5097	0.5339	0.8707	NO	0.8796
1995	0.7867	0.5097	0.5339	0.8707	NO	0.8796
1996	0.7867	0.5097	0.5339	0.8707	NO	0.8796
1997	0.7867	0.5097	0.5339	0.8707	NO	0.8796
1998	0.7807	0.5097	0.5339	0.8621	NO	0.8796
1999	0.7770	0.5097	0.5339	0.8568	NO	0.8796
2000	0.7733	0.5097	0.5339	0.8509	NO	0.8796
2001	0.7696	0.5097	0.5339	0.8484	NO	0.8796
2002	0.7700	0.5100	0.5340	0.8480	NO	0.8800
2003	0.7700	0.5100	0.5340	0.8480	NO	0.8800
2004	0.7700	0.5100	0.5340	0.8480	NO	0.8800
2005-2022	0.7700	0.5100	0.5340	0.8480	0.7920	0.8800

Note: NO – no biodiesel was produced in Brazil in the years indicated.

Table 4.2. Emission factor in tons of carbon per terajoule for road transportation.

Year	Gasoline	Hydrous ethanol	Anhydrous ethanol	Mineral diesel	Biodiesel	CNG
1990-2022	18.9	19.3	19.3	20.2	19.3	15.3

Evaporative emissions take into account the factors for the cycles: diurnal, hotsoak and running losses (CETESB, 2023). In addition, the emission factors for the three cycles were

converted from g/trip to g/km by dividing by a factor of 8 (km), as applied in the Brasil (2014) and ANTP – National Association of Public Transport (Associação Nacional de Transportes Públicos) (2008) studies. It is important to note that the emission factors for motorcycles, set out in CETESB (2023), are stratified by the following cylinder capacity ranges: less than or equal to 150 cc, from 151 to 500 cc and greater than or equal to 501 cc (for vehicles manufactured up to 2009) and less than or equal to 150 cc and greater than 150 cc (from 2010 onwards).

This makes it impossible to adopt a single factor for each vehicle category and model year. We, therefore, decided to calculate the weighted average of the emission factors based on the share of sales of each fleet profile, as shown in recent reports of the Brazilian Association of Manufacturers of Motorcycles, Mopeds, Scooters, Bicycles, and Similar Products (Associação Brasileira dos Fabricantes de Motocicletas, Ciclomotores, Motonetas, Bicicletas e Similares) (ABRACICLO, 2023).

The durability tests established by the Program for the Control of Air Pollution from Motor Vehicles (PROCONVE, Programa de Controle da Poluição do Ar por Veículos) check whether the established emission limits are respected for at least 80,000 km or five years of use (average of 16,000 km/year). Therefore, since the durability tests established by PROCONVE do not include CO_2, N_2O and CH_4, only precursor gases will be considered in the deterioration.

As proposed in Brasil (2014), indirect GHG emission factors (except NO_x) for vehicles not equipped with catalytic converters, mostly before 1994, deteriorate linearly by 20% in relation to the emission factor of a new vehicle, until the vehicle reaches 160,000 km of use. From then onwards, the emission factor remains constant until the end of the vehicle's useful life.

Energy efficiency data by vehicle category was obtained from the Brasil (2014), IBTS (2019) and CETESB (2023) studies. For vehicles of the flexible-fuel type, it is necessary to infer the number of vehicles that use hydrous ethanol and type C Gasoline (flex curve). The fractions of users opting for each type of liquid fuel should, therefore, be disaggregated from the fleet of flexible-fuel vehicles, using the data from the Brasil (2014) study as parameters up to 2012; while for the following years, the fraction is adjusted based on the proportion between the final price of hydrous ethanol and the price of type C Gasoline (ANP, 2024). In addition, the consistency with the evolution of the proportion of consumption of both fuels is checked (EPE, 2023).

Dataframe 4.9 shows the equation for calculating the energy consumption of each vehicle category (model year).

Dataframe 4.9. Equations for calculating and adjusting energy consumption.

Equations	Road transportation	Central equation	IPCC Reference (2006)
Equation 4.9	Energy consumption	$C_i = Fl_i . \frac{VKTi}{Ql_i}$	IPCC (2006, v. 2, p. 3.26)
Equation 4.10	Comparison with the top-down approach	$Tc = \sum_i C_i$	IPCC (2006, v. 2, p. 3.26)
Equation 4.11	Adjusted VKT	$VKT_{i,adjusted} = VKT_i . \frac{T_{c\ observed}}{T_c}$	IPCC (2006, v. 2, p. 3.25)
Equation 4.12	Adjusted energy consumption	$C_{i,adjusted} = Fl_i . \frac{VKT_{i,adjusted}}{Ql_i}$	IPCC (2006, v. 2, p. 3.25)

In which:

Ci = annual fuel consumption of vehicle type i (l/year);
Tc = total annual consumption of a fuel type (l/year);
Fli = vehicle fleet of vehicle type i (unit/year);
Iui = reference VKT of vehicle type i (km/year);
Qli = energy efficiency of vehicle type i (km/l).
Iui, adjusted = adjusted annual VKT of the vehicle type (km/year);
Tc observed = aggregated annual consumption of a fuel type (l/year); and
Ci, adjusted = adjusted annual fuel consumption of vehicle type i (l/year).

If the estimated consumption of the vehicle type *i* differs from that observed using the top-down approach, its VKT is adjusted, as the road transportation variable is the one with the greatest associated uncertainty. It is important to emphasize that the observed consumption should be the basis for the estimated consumption (bottom-up), as the amount of uncertainties of the disaggregated method is greater.

Based on the sum of the energy consumption of each vehicle category and model year, the total consumption by fuel type can be estimated. Therefore, consumption by vehicle type (i) is adjusted by the new intensity (VKT, adjusted) based on Equation 4.11. Afterwards, the value is adjusted based on Equation 4.12. The implicit emission factors per GHG modeled in the Road Transportation category (1.A.3.b) are presented in Tables A.IV.1 a A.IV.8 (Appendix IV). The implicit factors for the years 2017 to 2022 repeated the 2016 results.

4.6.4.1.2 Domestic Aviation

Equation 4.13 follows the approach used to calculate emissions from Domestic Aviation activities (1.A.3.a). In air transport, there is a discrepancy in fuel consumption values between data from the National Energy Balance (BEN) and the bottom-up approach modeled by the National Civil Aviation Agency (ANAC, Agência Nacional de Aviação Civil). This discrepancy arises due to the bunker concept used by BEN, which includes fuels consumed by foreign companies, while the bottom-up modeling considers fuels consumed in international routes, regardless of the nationality of the aircraft.

The distribution between domestic emissions and bunker follows the criteria established by the bottom-up modeling. In addition, the difference between the total (domestic and bunker) BEN and the modeling was attributed to category 1.A.5.b (Other – Not specified elsewhere, mobile, aviation component), under the premise that the bottom-up approach does not include values related to helicopters, small aircrafts and military aircrafts.

Annual adjustments between the 1990-2004 periods were made using the overlap method, by applying correction factors to the observed energy consumption (BEN). The correction factors were calculated based on the results of the Tier 3a approach for the 2005-2016 period. The 2017-2022 period was calculated based on the implicit emission factors obtained in 2016.

Dataframe 4.10. Equations for estimating emissions of inventoried gases from Domestic Aviation.

Equations	GHG	Categories	Central equation	IPCC Reference (2006)
Equation 4.13	CO_2 and non-CO_2	1.A.3a	**LTO cycle:** $E_{g,a,f,p} = nE_a * Ff_{a,f} * T_{a,f,p} * EF_{g,a,f}$ **Cruise cycle:** $E_{g,a,f,p} = M_{a,d,g} * Y1_{a,g} + (Y2_{a,g} - Y1_{a,g}) * \frac{(d - X_1)}{(X_2 - X_1)}$ **APU:** $E_{g,a,f} = Ff_{a,f} * T_{a,f,o} * EF_{g,a,f}$	Tier 3a (EMEP/EEA, 2017)

In which:

E = Emission, expressed in kg, of gas "*g"* by aircraft "*a"* in flight phase "*f"* at aerodrome "*p"*;
nE = Number of engines of aircraft "*a*";
Ff = Fuel flow, in kg/s, from each engine of aircraft "*a*" in phase "*f*";
t = Time, in seconds, that aircraft "*a*" remains in flight phase "f" at aerodrome p;
EF = Gas emission factor, in kg/kg, of aircraft "*a*" in phase "*f*".
M = Mass expressed in kg of fuel consumed or gas emitted "g" on the flight of distance "*d*" covered by aircraft "*a*";
d = Calculated flight distance in km between the origin and destination aerodromes;
X1 = Tabulated distance immediately below distance "*d"*;
X2 = Tabulated distance immediately above distance "*d"*;
Y1 = Mass of fuel consumed or mass of gas "*g*" emitted tabulated for aircraft "*a*" for distance X1; and
Y2 = Mass of fuel consumed or mass of gas "*g*" emitted tabulated for aircraft "*a*" for distance X2.

4.6.5 Other sectors and Other (Not specified elsewhere)

The Other Sectors category (1.A.4) covers combustion emissions from commercial, residential, agriculture, forestry, and fishing activities. The Other (Not specified elsewhere) category (1.A.5) covers all other transportation activities, including pipeline transportation, land-based activities at airports and ports, and off-road activities not reported under 1.A.4.c Agriculture, or 1.A.2 Manufacturing Industries and Construction.

Figure 4.11 summarizes emissions from the Other Sectors category (1.A.4).

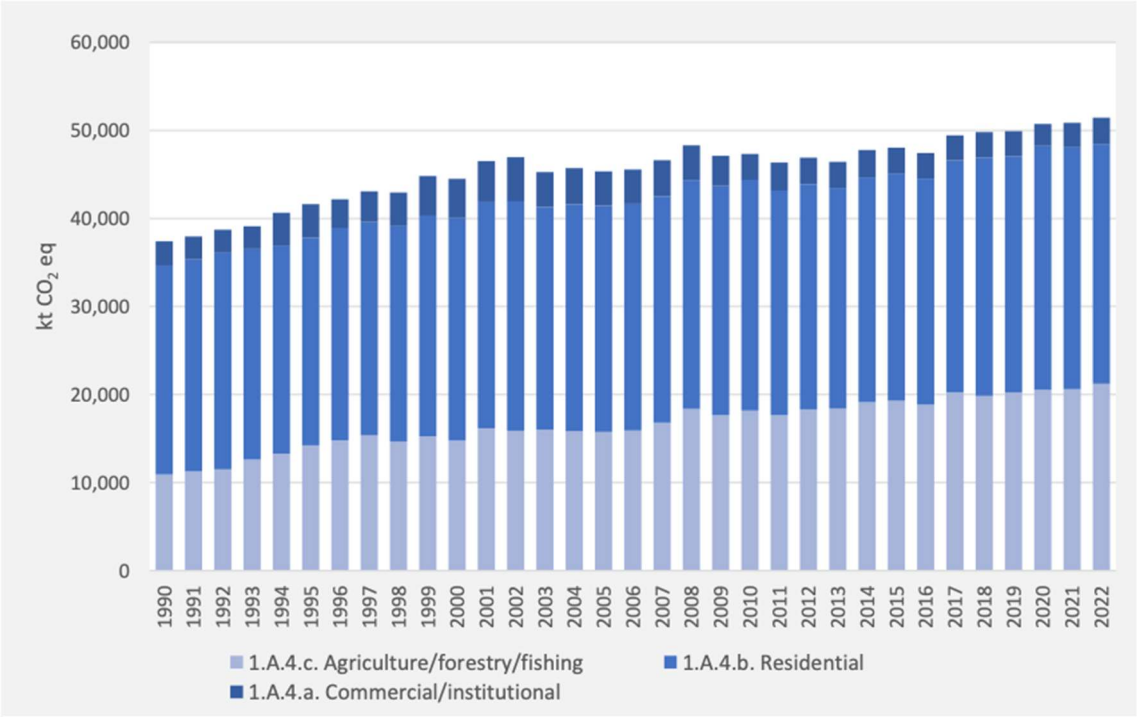


Figure 4.11. Emissions from Other Sectors, in kt CO_2 eq by category, from 1990 to 2022.

The amount emitted increased by 1% in the last two years of the time series. The largest emitting subcategory, Residential (1.A.4.b), fell by 2%. This result can be explained by the greater penetration of electricity from solar power, along with greater consumption of firewood and a decrease in the use of LPG.

Emissions in the Commercial and Institutional category increased by 20%, driven by growth in the consumption of dry natural gas and LPG. Lastly, the Agriculture, forestry and fishing category had a slight increase of 3%, due to marginal growth in Diesel consumption.

With regard to the Other (Not specified elsewhere) subcategory (1.A.5), in 2022 emissions were concentrated in the Mobile subcategory (1.A.5.b), specifically in the aviation component. The results point to an increase of 61%, due to the loss of activity resulting from the restrictive measures of the COVID-19 pandemic.

Figure 4.12 summarizes the emissions from the Other (Not specified elsewhere) category (1.A.5).

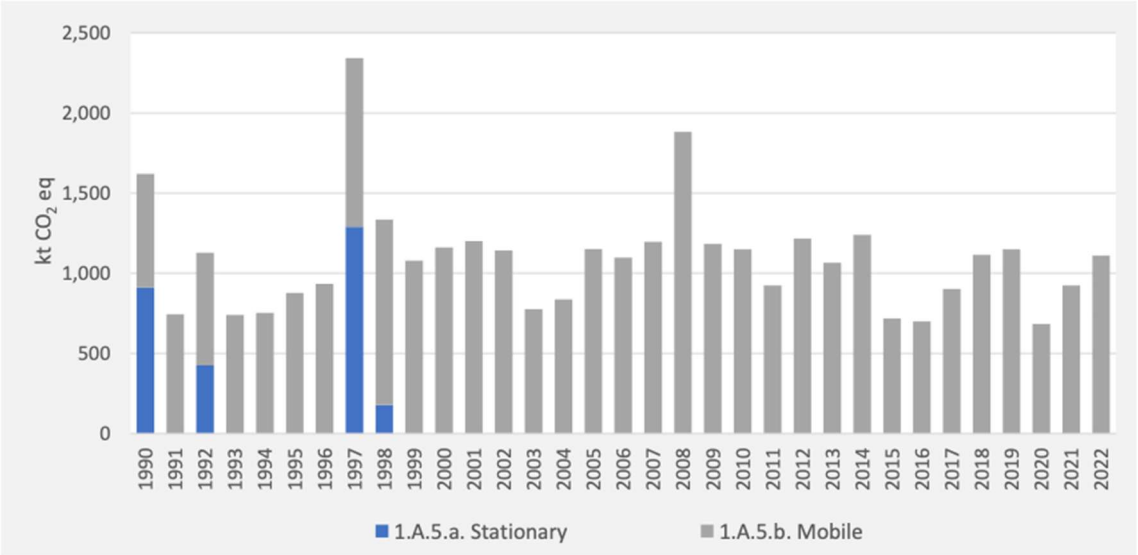


Figure 4.12. Emissions from the Other (Not specified elsewhere) category, in kt CO_2 eq, from 1990 to 2022.

4.6.6 Quality assurance and quality control

The quality assurance/quality control (QA/QC) procedures for the Fuel Combustion subsector (1.A) were applied in accordance with the QA/QC plan described in section 2.5 of this NIR, and are in line with Volume 1, Chapter 6, of the 2006 IPCC Guidelines.

In addition, in the 2024 NIR for the Energy sector, the energy results of the key Transport category (1.A.3), responsible in 2022 for 52% of kt CO_2 eq emissions, were compared with passenger (pass-km) and freight (t-km) transport activity data for each mode of transport. Energy intensity values (KJ/pass-km and KJ/t-km) were, therefore, obtained in order to check whether the fluctuations in emissions presented in Section 4.6.4 are in line with data from activities from sources other than those adopted in this inventory. The division between types of activity (passengers and freight) was made on the basis of energy use by mode, when exclusive to a particular type, as well as by means of the BRIAND et al. (2023) and BRIAND *et al*. (2024) studies. Further details on the data sources can be found in Dataframe A.IV.1 of Appendix IV.

Figure 4.13 and Figure 4.14 illustrate the energy intensity for the transport category, separated by type of activity (passengers and freight).

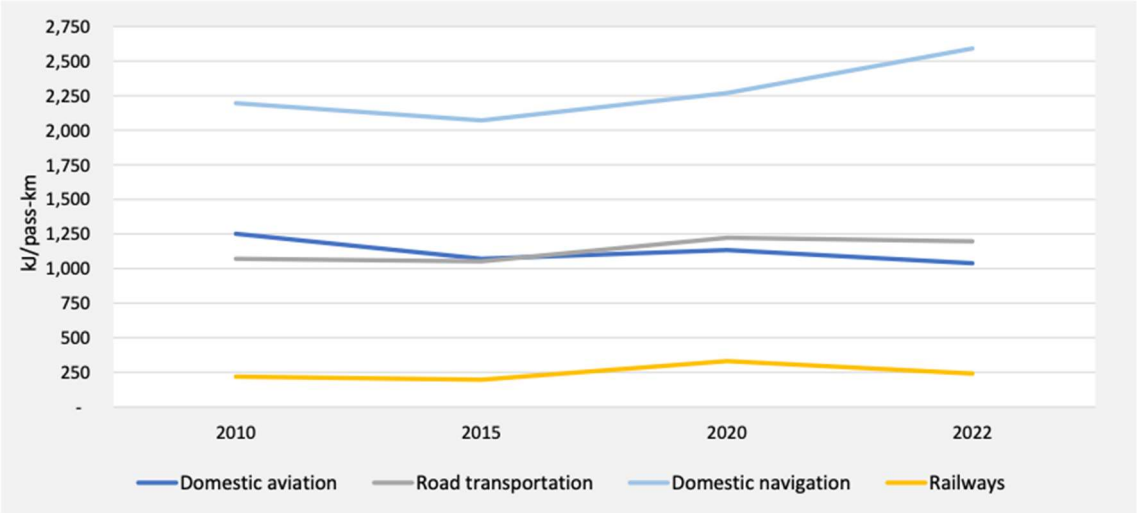


Figure 4.13. Energy intensity by mode for passenger transport.

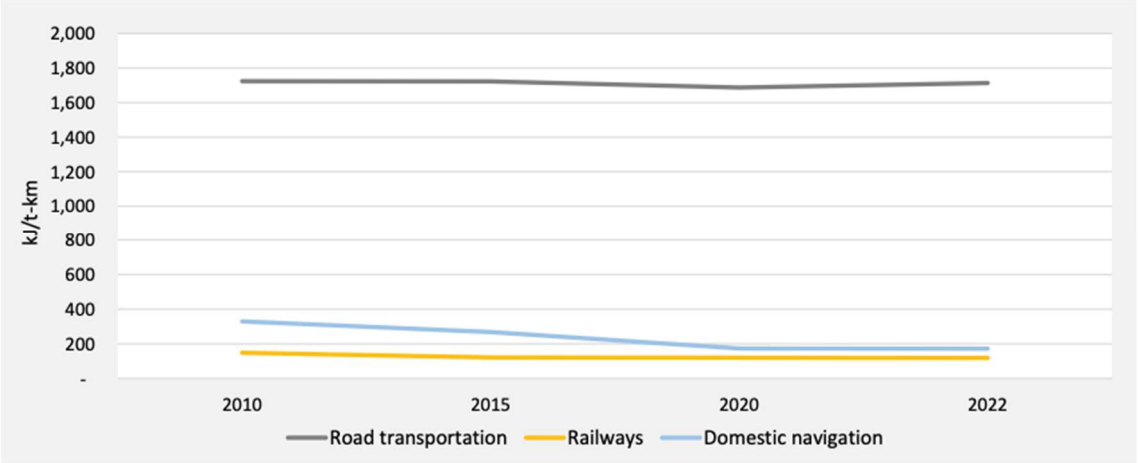


Figure 4.14. Energy intensity by mode for freight transport.

According to Figure 4.13, in 2020, energy intensity increased slightly in all modes of passenger transport compared to 2019. This reflects the greater impact that the activity has had in the face of restrictive measures to mitigate the effects of the COVID-19 pandemic, by reducing the average occupancy of the modes. This effect was accentuated in public transport services by bus, subway, Light Rail Vehicles (LRVs) and metropolitan trains, given the need to maintain a stable supply even in the face of restricted demand.

In the following years, part of the increase in energy intensity was recovered, with the exception of water transport (ferries). This mode is intensive in the states of Rio de Janeiro and Amazonas, and there has been a continuous increase in the reduction of occupancy, while maintaining the supply pattern (BRIAND *et al*., 2023).

On the other hand, freight transport was not significantly impacted in the first year of the pandemic (2020), since there was a need to maintain the continuous flow of various supplies. Unlike the case of passenger transport by ferry, cabotage and inland waterway

transport have become more energy efficient,[32] partly explaining the continuous decrease in GHG emissions from these modes.

Therefore, the QC analysis for the Transport category (1.A.3), when comparing freight (t-km) and passenger (pass-km) activity data with the respective energy consumption, corroborates the fluctuations in emissions shown in the previous sections of NIR 2024. Thus, the estimated data on energy use and GHG emissions is supported by information on activity obtained from multiple sources.

Dataframe A.IV.1 of Appendix IV summarizes the data sources considered in the QC.

4.6.7 Assessment of uncertainty, consistency and recalculations of the time series

An uncertainty analysis was carried out using the random sampling methods and techniques described in the 2006 IPCC Guidelines. The national inventory updating process included a review of the time series of energy consumption, activity and emission factors. For the most part, this process resulted in adjustments, albeit small ones, to the historical matrices of the National Energy Balance (BEN, 2023). In summary, the main adjustments stem from:

Fossil emissions:

- *Coking plants (1998-2009):* review of petroleum coke consumption in coking plants;
- *Self-generating power plants + Consumption in generation for self-generation (2012-2020):* Increased consumption of wet natural gas and diesel;
- *Self-generating power plants – Energy sector (Oil – Exploration) (2012-2020):* Increased consumption of wet natural gas and diesel;
- *Consumption in the Energy Sector (Oil – Exploration) (2012-2020):* Reduction in diesel consumption and slight increase in fuel oil consumption;
- *Mineral coal (1996-2022)*: shifting of consumption of piped gas (RJ) from the electricity sector (line 120) to 'mineral coal and others' (line 121 of BEN);
- *Waterway transport (2019)*: reduction in diesel and fuel oil consumption;
- *Waterway transport (2020)*: reduction in diesel consumption and increase in fuel oil consumption; and
- *Cement (2020)*: reduction in the consumption of CE 6000 charcoal.

Emissions from renewable sources:

- *Charcoal factories (2013-2020)*: increased consumption of firewood;
- *Cement (2020)*: increased consumption of "Other renewables" (Biomass); and
- *Ferroalloys (2013-2016)*: increase in charcoal consumption.

[32] Comparing port handling data from the National Agency for Waterway Transportation (ANTAQ, Agência Nacional de Transportes Aquaviários, 2023) with fuel oil consumption in waterway transport (EPE, 2023).

In addition to the variation in energy consumption over the time series, the uncertainty associated with the sector's main key category (Transport – 1.A.3) stems from the division of diesel and biodiesel energy consumption between passenger (buses) and freight (light duty commercial vehicles and trucks) transport. To that end, activity data (t-km and pass-km), as well as energy intensity data (kJ/t-km, kJ/pass-km) were used to divide energy consumption between types of activity, allowing for greater accuracy in the calculation of emissions.[33] Other modes of transport and categories of the Energy inventory have a clearer division of consumption between fuels, making it easier to calculate disaggregated factors. More details on the data sources used in this division can be found in Appendix IV.

Comparing the consolidated results of the previous Inventory with the one carried out for this NIR 2024, the average adjustment was 0.01%, which demonstrates the consistency of the sector's time series (Figure 4.15).

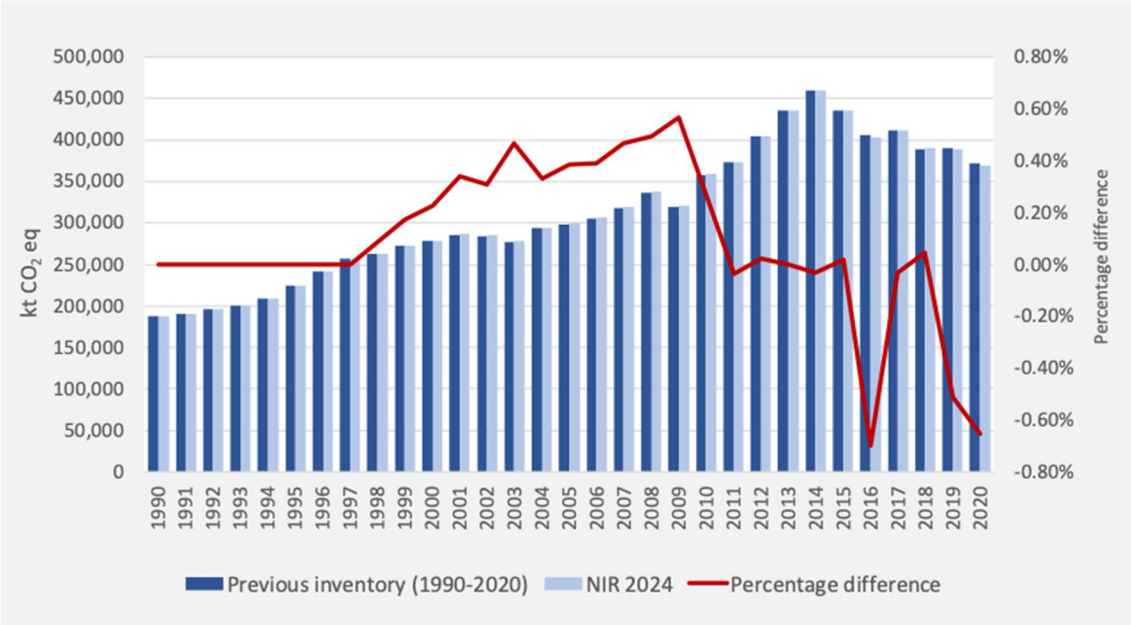


Figure 4.15. Comparison of estimated emissions from the Fuel Combustion Activities subsector (1.A) between inventories.

4.6.8 Improvement plan

The experience gained in the periodic preparation of national GHG inventories has led to the proposal of a series of measures to improve the consistency and greater detailing of the inventory's results. Therefore, Dataframe 4.11 summarizes the potential improvements for possible implementation in future editions.

[33] In view of the fact that each model year of vehicle emits non-CO_2 gases at quite different intensities.

Dataframe 4.11. Potential improvements applicable to improving the emissions inventory of the Fuel Combustion Activities subsector (1.A).

Subsector	Category	Improvement
1.A. FUEL COMBUSTION	General (all categories)	▪ Establish partnerships with a view to promoting the updating of the Useful Energy Balance; ▪ Establish Technical Cooperation Agreements or partnerships to promote the collection and continuous supply of fuel's CO_2 emission factors; ▪ Establish Technical Cooperation Agreements or partnerships to promote the collection and continuous supply of non-CO_2 emission factors, taking into account stationary combustion for energy sources.
	1.A.3.b. Road Transportation	▪ Establish partnerships with motor vehicle manufacturers' associations, with a view to having a continuous breakdown of data on the sales of electrified vehicles, separating them into BEV (Battery Electric Vehicles), PHEV (Plug-in Hybrid Electric Vehicles) and HEV (Hybrid Electric Vehicles); ▪ Establish partnerships with entities in the transport sector, seeking to align the continuous format of data on fleets of cars and light-duty commercial vehicles converted to use CNG; ▪ Establish partnerships with motor vehicle manufacturers' associations to assess the feasibility of expanding data systematization for the Otto Cycle cars and light-duty commercial vehicles categories, breaking them down by size or engine.
	1.A.3.a. Domestic aviation 1.A.3.d. Domestic navigation	▪ Establish Technical Cooperation Agreements or partnerships to promote the standardization of data on the classification of bunker and domestic energy by sector's entities

4.7 Fugitive Emissions from Fuels (CRT 1.B)

GHG emitted accidentally or intentionally during the extraction, processing, storage and transportation of fossil fuels until their end use are referred to as fugitive emissions. Thus, the Fugitive Emissions category (1.B), is related to fugitive emissions from fuel production systems.

In Brazil, these emissions refer to the process of mineral coal mining and processing (1.B.1.a., Coal Mining and Handling), as well as those associated with the process of extracting, transporting and processing oil and natural gas (1.B.2. Oil and Natural Gas). Given the national characteristics, only CH_4 was estimated for Coal Mining and Handling (1.B.1.a), while for the Oil and Natural Gas category (1.B.2), CO_2, CH_4 and N_2O gases were considered.

Between 2020 and 2022, fugitive emissions increased by 10%, maintaining the historical rate of 5% p.a. throughout the inventoried time series (1990-2022). In this two-year period, emissions from the oil and natural gas chain increased by 9%, while those from solid fuel extraction increased by 26%. In total, category 1.B.1, Solid Fuels, accounted for only 7%, while category 1.B.2, Oil and Natural Gas, accounted for 93% of fugitive emissions. Of the gases estimated in this subsector (1.B), CO_2 accounted for 73.9% of emissions in 2022, followed by CH_4 and N_2O, with 25.8% and 0.3%, respectively.

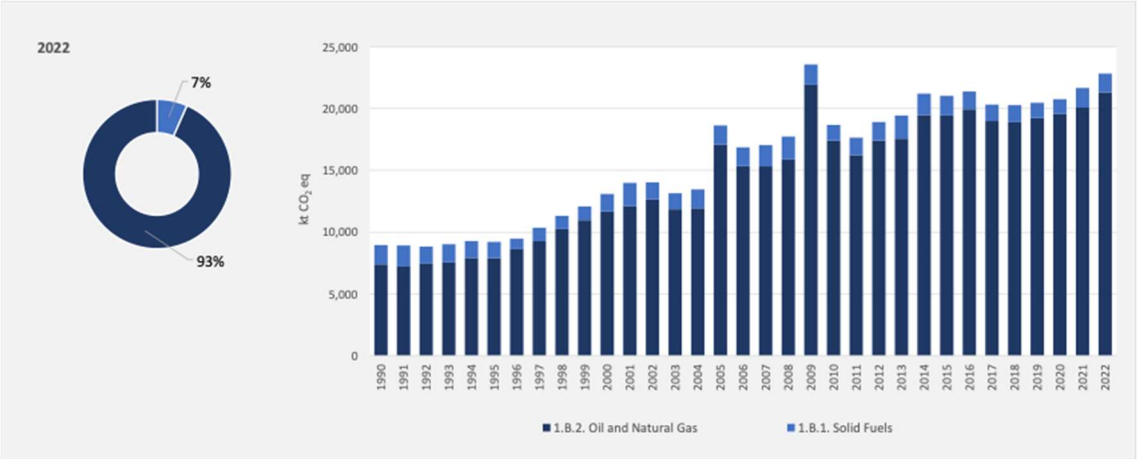


Figure 4.16. Emissions from the Fugitive Emissions from Fuels subsector, in kt CO_2 eq by category, from 1990 to 2022.

The increase in the Solid Fuels category (1.B.1) stems from the increase in ROM (*Run-of-Mine*)[34] coal production activity in 2021 (32%), despite the 4% decrease in the following year.

Considering the category that emits the most (1.B.2. Oil and Natural Gas and Other Emissions from Energy Production), 93% of emissions in 2022 come from the oil production, transportation and refining chain. Oil production had sharp increases of 8% in 2019, and 6% in 2020, stabilizing in 2021 (-1%), and increasing again, by 4%, in 2022 (ANP, 2024). The remaining emissions from the Oil and Natural Gas category (1.B.2) correspond to the portion emitted in natural gas tailings (venting and flaring). Figure 4.17 shows this stratification.

Emissions from the Oil and Natural Gas category (1.B.2) include fugitive emissions of CH_4 during the extraction of oil and natural gas, its transportation and distribution in pipelines and ships, and its processing in refineries. In addition, emissions of CO_2, CH_4 and N_2O from gas flaring (flare) at oil and natural gas extraction platforms and refinery units are also taken into account. CO_2 emissions from gas flaring, or non-useful combustion, are included as fugitive emissions, even though they are the result of combustion, but they are associated with the loss and not with the useful consumption of fuel. The use of oil and natural gas, or their derivatives, to provide energy for internal use in energy production and transportation is considered as combustion and is, therefore, covered in the Fuel Combustion Activities subsector (1.A).

[34] Raw ore, obtained directly from the mine, without undergoing any kind of processing.

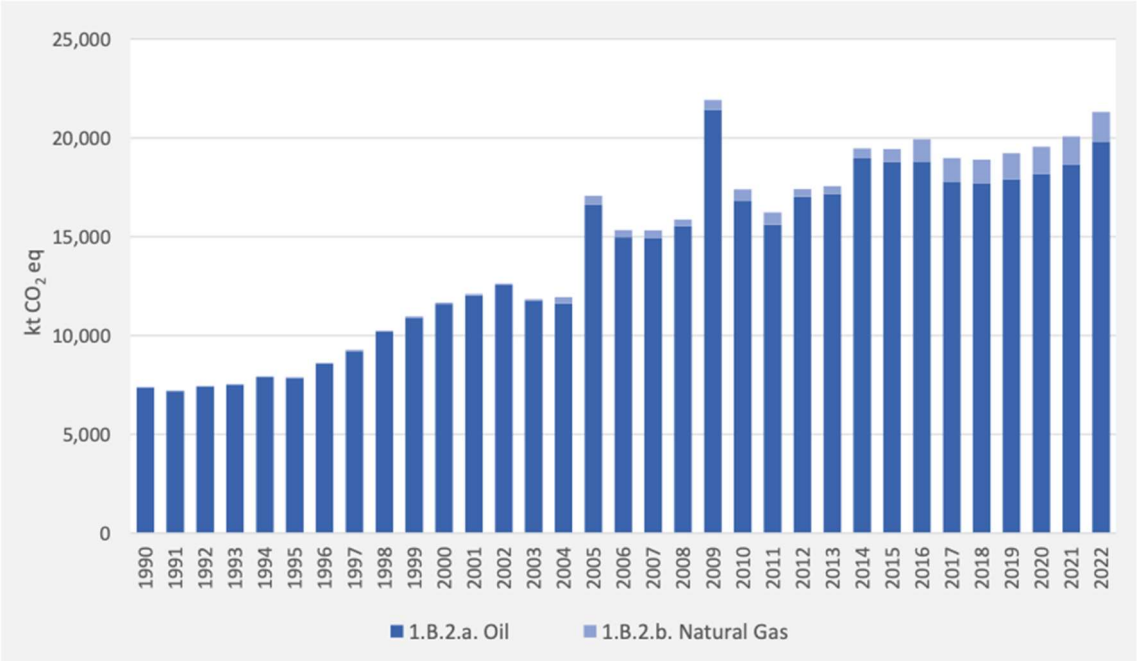


Figure 4.17. Emissions from Oil, Natural Gas and Other Emissions from Energy Production in kt CO_2 eq, from 1990 to 2022.

When detailing the emissions from the Flaring, Venting and Other subcategory,[35] we have the results shown in Figure 4.18.

[35] Fugitive emissions from petroleum systems (except venting and flaring) not considered in the above categories. Includes fugitive emissions from spills and other accidental leaks, waste oil treatment facilities and oilfield waste disposal facilities.

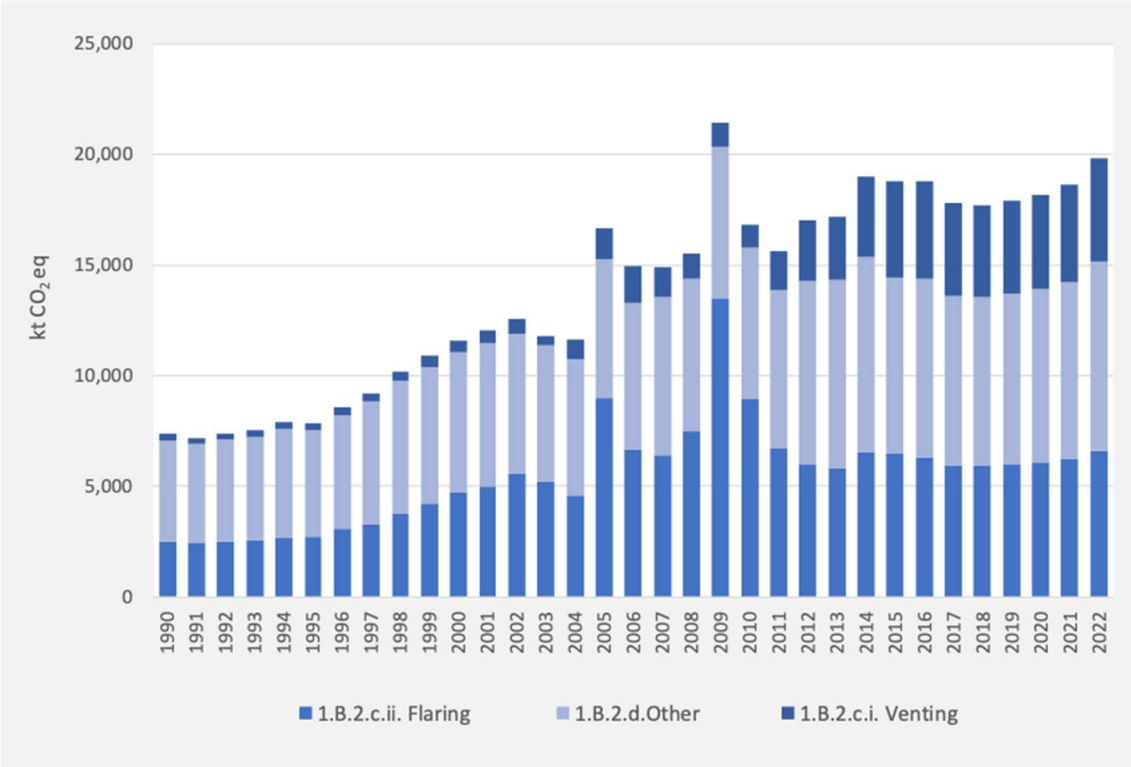


Figure 4.18. Emissions from Oil, Natural Gas and Other Emissions from Energy Production in kt CO_2 eq by subcategory, from 1990 to 2022.

4.7.1 Methodological aspects

4.7.1.1 Coal Mining and Handling

Potential categories of fugitive emissions sources for active underground coal mines include emissions from gases present in cracks, released into the atmosphere through coal mines ventilation and degassing systems, and post-mining activities. Low-temperature oxidation and uncontrolled combustion are also considered as significant sources of emissions. After closure, coal mines that released CH_4 during their operations continue to emit methane, unless they are flooded, which would stop these emissions. Even after closure, CH_4 can still be released due to the natural migration of the gas or through artificial ducts, such as old channels, ventilation pipes, cracks and fissures in the overlying strata. These emissions decrease rapidly until they reach an almost constant rate, which can be maintained over a long period of time.

In the case of surface mines, the categories of potential sources that were considered include CH_4 and CO_2 emitted during mining from the extraction of coal and associated strata, as well as other leaks, post-mining activities, low-temperature oxidation and uncontrolled combustion at disposal sites. Although the emission of these gases is generally lower than in deeper coal seams in underground mines, such emissions should not be ignored. As in the case of underground mines, after closure, abandoned or decommissioned surface mines can continue to release methane through gas leaks from coal seams that were ruptured or deteriorated during mining.

Dataframe 4.12 shows the equations used to estimate emissions from Coal Mining and Handling (1.B.1.a) using the Tier 1 method.

Dataframe 4.12. Equations for calculating emissions from mining and post-mining activities.

Equations	Mining	GHG	Central equation	Reference
Equation 4.14	Underground mining	CH_4	$E_{CH4} = EF_{CH4} * Prod_{und} * FC$	Equation 4.1.3 (IPCC, 2006, v. 2, chap. 4)
Equation 4.15	Underground post-mining		$E_{CH4} = EF_{CH4} * Prod_{und} * FC$	Equation 4.1.4 IPCC, 2006, v.2, chap. 4)
Equation 4.16	Surface mining		$E_{CH4} = EF_{CH4} * Prod_{sur} * FC$	Equation 4.1.7 IPCC, 2006, v.2, chap. 4)
Equation 4.17	Surface post-mining		$E_{CH4} = EF_{CH4} * Prod_{sur} * FC$	Equation 4.1.8 IPCC, 2006, v. 2, chap. 4)

In which:

E_{CH4} = methane emissions (Gg/year);
EF_{CH4} = methane emission factor (m^3/t);
$Prod_{und}$= underground coal production (t/year); and
$Prod_{sur}$= surface coal production (t/year).

With regard to Euqnations 4.14 and 4.15, in the process of selecting the emission factor, specific variables, such as the depth of the main coal seams, were taken into account to determine the appropriate emission factor. According to the IPCC (2006), as the gas content generally increases with depth, the lower end of the range should be applied for average mining depths of less than 200 meters; for depths of more than 400 meters, the higher value of the emission factor would be appropriate. For intermediate depths, average values can be used.

In Brazil, an analysis was carried out based on data provided by ABCM – Brazilian Mineral Coal Association (Associação Brasileira do Carvão Mineral) to define the average depth range of Brazilian underground mines, supporting the study of the Inventory submitted in the Fourth National Communication. It was possible to obtain this information for 47% of ROM-type underground mines, for both active and inactive ones. The average depth of these mines was calculated, resulting in approximately 125 meters. As a result, the minimum emission factor of CH_4 (10 m^3/t) was chosen, which, according to the IPCC, should be applied to underground mines with a depth of up to 200 meters. To calculate post-mining activities in underground mines, equation 4.1.4 of the IPCC (2006) was used, maintaining the previous logic. For the emission factor, the lowest value was also selected (0.9 m^3/t).

In the case of Equations 4.16 and 4.17, for choosing the emission factor in the Tier 1 approach, it is considered good practice to use the lower end of the specific emission range for mines with average overburden depths of less than 25 meters and the higher end for overburden depths of more than 50 meters. For intermediate depths, average values can be used for the emission factors. In the absence of data on the thickness of the overburden, it is considered good practice to use the average emission factor, i.e., 1.2 m^3/ton. To calculate post-mining activities in surface mines, equation 4.1.8 of the IPCC 2006 was used, following the same logic as above. To choose the emission factor, the average factor of 0.1 m^3/t was considered, in line with the logic used to select the emission factor for mining.

Table 4.3 shows the emission factors by type of mine and activity in the Coal Mining and Handling category (1.B.1.a).

Table 4.3. Emission factors by type of mine and activity in the Coal Mining and Handling category (1.B.1.a).

Types of mine	Mining	Post-mining	Mining	Post-mining
	m^3 CH_4/t_{coal}		kt CH_4/t_{coal}	
Underground	10	0.9	0.0000067	0.000000603
Surface	1.2	0.1	0.000000804	0.000000067

4.7.1.2 Oil and Natural Gas

The oil and natural gas system covers all the infrastructure needed to produce, collect, process or refine, and deliver natural gas and oil products to the market. This system starts at the well or the source of the oil and gas, and extends to the final point of sale to the consumer. In Brazil, the activities for which GHG emissions are estimated for the oil and natural gas system are: Oil and natural gas production; Petroleum refining and natural gas processing; and Oil and natural gas transportation.

Oil and natural gas are extracted from underground formations through onshore and offshore wells. In Brazil, both fuels are usually extracted simultaneously from the same geological formation and are, then, separated. As CH_4 is the main component of natural gas, leaks or venting that occur in the extraction system and in the primary processing stages of oil and gas result in methane emissions (CH_4), in addition to CO_2, CH_4 and N_2O emissions from gas flaring.

During the refining process, refineries transform oil into a variety of hydrocarbon products, such as gasoline, diesel and kerosene. This activity encompasses separation, conversion and treatment processes, as well as the storage of basic fractions and end products. Due to the diversity of processing units, storage and fluid lines (gas or liquid), there are several potential sources of leaks, venting and gas flaring, in addition to emissions from Hydrogen Generation Units (HGU) and Fluid Catalytic Cracking Units (FCCU).

During Natural Gas Processing, while still in the production phase, the gas undergoes an initial treatment, known as natural gas conditioning, which involves processes such as dehydration and the removal of acidic compounds. This treatment aims to guarantee the safe and continuous transfer of gas from the production fields to the Natural Gas Processing Units (NGPUs) via pipelines. In the NGPUs, the gas is separated from the liquid phase (water and liquid hydrocarbons), dehydrated to remove residual water, cooled and fractionated into specific products for distribution to the end consumer. The streams produced by NGPUs include methane and ethane, which make up natural gas for sale, propane and butane for LPG (liquefied petroleum gas) or domestic use, and natural gasoline or C5+, which consists of hydrocarbons with more than 5 carbons. The C5+ stream, generally without a specific defined application, is often reinjected into oil streams in various NGPUs.

The extracted oil is transported to refineries via ships and pipelines, where it is stored in tanks for a set period of time. In Brazil, the gas produced is transported exclusively through pipelines. With regard to fugitive greenhouse gas (GHG) emissions in transportation, leaks and venting that occur in gas transportation lines are taken into account, as well as emissions from flaring of the torches installed along the gas pipeline network. The main activities related to the transport and distribution of natural gas include gas pipelines and distribution systems.

In summary, the NIR 2024 covers specific areas with sources of fugitive emissions, including Exploration and Production (E&P), Refining and Transport. The following processes and equipment were, therefore, considered as emission sources:

- E&P: Torches (flares); gas venting; methane flash in tanks; glycol dehydration process; process of removing CO_2 from gas (MEA/DEA); passage of PIG in lines; leaks in line components (flanges, connectors, valves, pump and compressor seals, drains and others); drilling activities; oil spills in ducts; atmospheric ventilation tank; depressurization; and tank and vessel cleaning.
- Refining: UFCC (Fluid Catalytic Cracking Unit) regenerator; Hydrogen Generation Units (HGU; leaks in line components (flanges, connectors, valves, pump and compressor seals, drains and others); gas flaring (flares); gas venting; glycol dehydration process; and PIG passage in lines.
- Transport: Decompression; leaks in line components (flanges, connectors, valves, pump and compressor seals, drains and others); gas venting; gas flaring (flares); gas pipelines; methane flash in tanks; PIG passage in lines; and Truck/Wagon Load E&P.

The method used for the estimates presented in this inventory follows the guidelines established in the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories, as detailed in volume 2, chapter 4 (IPCC, 2006).

To estimate emissions from the E&P sector between 1990 and 2002, an implicit emission factor was used for the subsequent period from 2003 to 2008, excluding 2005 due to atypical results. This average factor was applied to domestic production, which occurred exclusively at Petrobras during this period, in order to estimate fugitive emissions from the E&P sector as a whole, as Petrobras began to inventory its emissions from 2003 onwards. The choice of the period from 2003 to 2008 as the basis for calculating the implicit factor, used to estimate emissions between 1990 and 2002, was made to maintain a similar pattern of gas flaring, a significant emission source in E&P, especially in earlier periods. The gas flaring pattern has changed in recent years, especially since 2010, due to Petrobras' efforts to increase the use of the gas produced.

For the emissions of the other companies in the E&P sector, excluding Petrobras, between 2003 and 2016, annual implicit emission factors (EF) were applied. This was done on the basis of Petrobras' emission data (by type of gas) and production data (in barrels per day). Petrobras' annual implicit EF for each year between 2003 and 2016 was, then, applied to the annual volume produced by the other companies in Brazil.

An implicit emission factor was also used to estimate national emission data for the Refining area between 1990 and 2002. This factor was calculated as the ratio between the average emissions between 2003 and 2008 and the load processed in the refineries during the same period. By multiplying this factor by the processed load for each year, emissions estimates were obtained for the period from 1990 to 2002. The choice of this time period was motivated mainly by the increase in the pattern of emissions per unit of fuel produced in the national refineries, especially accentuated from 2009 onwards. This increase is related to the improvement in fuel quality in Brazil, which has led to greater complexity in the refining park, resulting in greater energy consumption and an increase in demand for hydrogen, produced from the steam reforming of natural gas in Hydrogen Generation Units (HGUs), generating CO_2 as a by-product of the reaction.

To estimate the emissions related to other companies in the Refining sector between 2003 and 2016, Petrobras' emission data (by type of gas) and processing data (in barrels per day) were also used. Petrobras' annual implicit factors for each year between 2003 and 2016 were, then, applied to the annual volume processed by the other companies in Brazil.

In transport, the emissions inventoried by Petrobras are recorded for the years from 2003 to 2016. In order to estimate the emissions of Transportadora Brasileira Gasoduto Bolívia-Brasil (TBG) from 2000 to 2003, it was necessary to make an extrapolation. An average percentage of TBG emissions was calculated in relation to the sum of E&P and Refining during the period from 2004 to 2006. This average percentage was, then, applied to the fugitive emissions values of E&P and Refining of other companies between 2000 and 2003. Therefore, national emissions related to Transport from 2000 to 2003 consist of the sum of Petrobras' emissions and TBG's estimated emissions during this period. The extrapolation only considered CH_4 emissions for TBG during this time period.

To estimate emissions from Petrobras' Transport sector between 1990 and 2002, a ratio was established between emissions from this area, calculated between 2003 and 2006, and the sum of emissions from Petrobras' E&P and Refining sectors during this same period. This calculation determined the average percentage share of the Transport sector in relation to the sum of Petrobras' E&P and Refining emissions between 2003 and 2006, multiplied by the sum of E&P and Refining emissions between 1990 and 2002. The period up to 2006 was chosen because from 2007 and 2008 onwards, the sector's emissions profile changed due to TBG's and Transpetro's activity in Petrobras' inventory. Petrobras' emissions related to the Transport sector between 1990 and 1999 will be considered on the basis of the national emissions from this sector in that period.

For the three categories, considering the 2017-2022 period, implicit emission factors from 2016 were used, derived from information on production, transport and refining provided by Petrobras. The projections then took into account refining data and national oil and Natural Gas Liquids (NGL) production obtained from ANP (2023). As in previous years, Petrobras' production data was used to distinguish the total volume processed in relation to outsourced companies.

4.7.2 Quality assurance and quality control

The quality assurance/quality control (QA/QC) procedures for the Fugitive Emissions from Fuels subsector (1.B) were applied in accordance with the QA/QC plan described in section 2.5 of this NIR, and are in line with Volume 1, Chapter 6, of the 2006 IPCC Guidelines.

4.7.3 Assessment of uncertainty, consistency and recalculations of the time series

An uncertainty analysis was carried out using the random sampling methods and techniques described in the 2006 IPCC Guidelines. As in the case of the Fuel Combustion Activities subsector (1.A), the Oil Production data (m^3) between 2016 and 2022 for the Fugitive Emissions from Fuels subsector (1.B) has been revised. For this reason, a slight difference of 0.15% in emissions of kt CO_2 eq was seen in this period. In previous years (1990-2015), there was no difference between the estimates. Figure 4.19 shows the comparison between the NIR 2024 and the previous inventory.

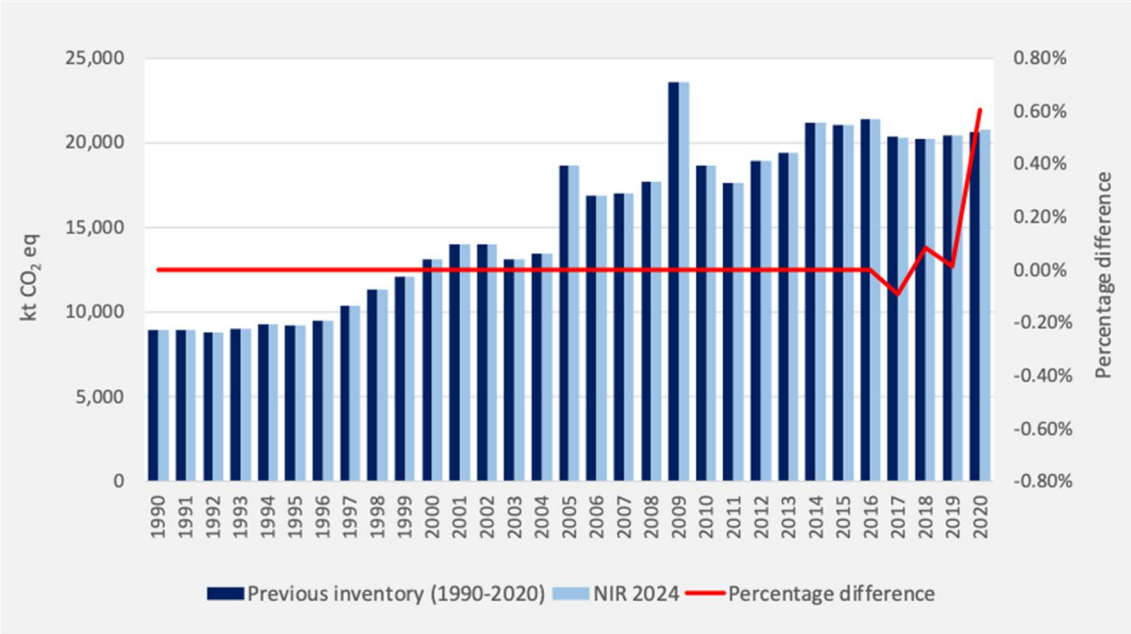


Figure 4.19. Comparison of estimated emissions from the Fugitive Emissions from Fuels subsector (1.B) between inventories.

4.7.4 Improvement plan

The improvements identified for future editions of the national inventory derive above all from the expansion of direct channels for collecting information from institutions that provide primary data. The result of the survey of these and other points for improvement is shown in Dataframe 4.13.

Dataframe 4.13. Potential improvements applicable to improving the emissions inventory for the Fugitive Emissions from Fuels subsector (1.B).

Subsector	Category	Improvement
	1.B.1. Solid fuels	▪ Establish Technical Cooperation Agreements or partnerships with the sector's entities with a view to promoting a continuous supply of data on ROM (Run-of-Mine) coal by mine, Federal Unit, and type (surface and underground);
1.B. FUGITIVE EMISSIONS FROM FUELS	1.B.2. Oil and Natural Gas and other emissions from energy production	▪ Establish Technical Cooperation Agreements or partnerships with the sector's companies, with a view to promoting a continuous supply of data on production, transportation and refining from companies operating in Brazil; ▪ Establish Technical Cooperation Agreements or partnerships with the sector's companies with a view to assessing the possibility of estimating emission factors for production, refining and transportation specific to the companies operating in the country.

5 INDUSTRIAL PROCESSES AND PRODUCT USE (CRT 2)

5.1 Sector overview

Emissions related to activities in the Industrial Processes and Product Use (IPPU) sector result from production processes in industries, including the non-energy consumption of fuels as feedstocks. Fuel combustion for energy purposes is reported in the Energy sector inventory (CRT 1).

In the NIR 2024, which covers IPPU emissions from 1990 to 2022, the following subsectors were considered in this Inventory: Mineral Industry (2.A), Chemical Industry (2.B), Metal Industry (2.C), Non-Energy Products from Fuels and Solvent Use (2.D), Electronics Industry (2.E), Product Uses as Substitutes for Ozone Depleting Substances (2.F), Other Product Manufacture and Use (2.G), and Other (2.H).

The gases inventoried in this sector were: CO_2, CH_4, N_2O and SF_6; those belonging to the HFC (hydrofluorocarbons) family – HFC-23, HFC-32, HFC-125, HFC-134a, HFC-143a, HFC-152a, HFC-227ea and HFC-365mfc; and PFCs (perfluorocarbons) – CF_4 and C_2F_6. In addition, it should be noted that the use of NF_3 (nitrogen trifluoride) in the country has not been identified.

Estimates of emissions from the IPPU sector totaled 102,317 kt CO_2 eq in 2022, which indicated an increase of 5% compared to 2020, as shown in Figure 5.1. The Metal Industry (2.C) contributed the largest share of emissions, accounting for 51% of the sector's emissions in kt CO_2 eq in 2022. In turn, the Mineral Industry (2.A) subsector was the second most representative, with 32%.

In 2022, CO_2 emissions represented 89% of total IPPU (in kt CO_2 eq), with the Metal Industry (2.C) and Mineral Industry (2.A) contributing 56% and 36%, respectively.

After CO_2, F-gases accounted for 9% of the sector, with Product Uses as Substitutes for Ozone Depleting Substances (2.F) accounting for almost 100% of them.

CH_4 had a 1% share of the sector's GHG emissions in 2022, with 72% coming from the Metal Industry subsector (2.C) and 28% from the Chemical Industry subsector (2.B).

N_2O accounted for 0.3% of emissions in 2022, divided between the Chemical Industry (2.B), with 57%, and the Metal Industry (2.C), with 43%.

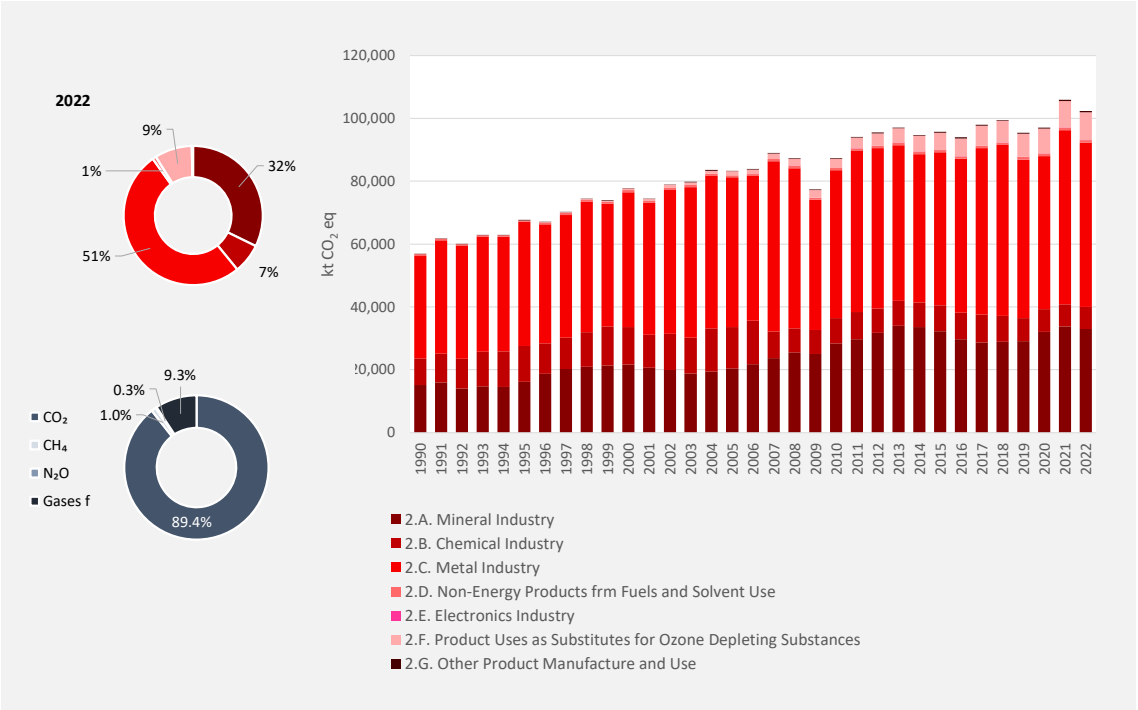


Figure 5.1. Emissions from the Industrial Processes and Product Use sector, in kt CO_2 eq, by subsector, from 1990 to 2022.

The share of emissions from PFCs and SF_6 was the same, 0.3% each, with the former being emitted almost entirely from aluminum production and the latter from Other Product Manufacture and Use (2.G), more specifically in electrical equipment.

5.2 Methodological aspects

The methodology for calculating emissions was the one indicated in the IPCC (2006).[36] For precursor greenhouse gases emission factors, calculated by Tier 1, the 1996 IPCC reference was used.[37] Whenever possible, and particularly considering key categories, parameters or emission factors available in the national literature were adopted, for example in ceramics production, or used in industry, such as in iron and steel production, cement production and in the chemical industry, in order to portray the reality of the country and avoid using the IPCC default values. The data obtained from official sources was supplemented by information from the production sector, through trade associations.

Access to activities data and other parameters in the IPPU sector presented specific challenges, as it often involved the confidentiality of companies' information, particularly with regard to technological processes and the quantity of their production. For some subsectors, such as cement, aluminum and iron and steel production, the quantities produced, imported and exported were available in official publications, such as in the IBGE's – Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística) – SIDRA Automatic Recovery System (Sistema IBGE de Recuperação Automática) (IBGE, 2024a), COMEX STAT (foreign trade statistics) (MDIC – Ministry of Development, Industry, Trade and Services (Ministério do Desenvolvimento, Indústria,

[36] Industrial Processes and Product Use (IPCC, 2006, v. 3).
[37] The Workbook (Volume 2) (IPCC, 1997, v. 2).

Comércio e Serviços), IBGE) and BEN (EPE, 2023), as well as Statistical Yearbooks for the Metal Sector (MME – Ministry of Mines and Energy (Ministério de Minas e Energia)), 2022a), the Non-Metallic Transformation Sector (MME, 2022b), the Steel Sector (IABR – Brazil Steel Institute (Instituto Aço Brasil)), 2023) and the Cement Sector (SNIC – National Cement Industry Union (Sindicato Nacional da Indústria do Cimento), 2024). In order to supplement the information related to certain parameters and emission factors in these subsectors, industry associations were important, either through access to their publications, or through direct contact with the institutions' representatives.

For the Cement Production (2.A.1) and Aluminum Production (2.C.3) subsectors, aggregated information was obtained from industry associations regarding the most accurate estimates (Tier 3) for specific years, from member companies. In the absence of these values, extrapolations were made with the available data. For the Iron and Steel Production subsector (2.C.1), data collected by Instituto Aço Brasil (IABr) (Brazil Steel Institute) from its members enabled a general carbon balance to be calculated for CO_2 (Tier 2).

In the Chemical Industry (2.B), for Nitric Acid Production (2.B.2) and Adipic Acid Production (2.B.3), the existence of Clean Development Mechanism (CDM) projects allowed access to detailed company data, based on published reports on monitoring of GHG reduction operations (UNFCCC, 2024).

Dataframe 5.1 details the methodologies, parameters, emission factors and sources of information used in each category of the IPPU sector.

Dataframe 5.1. Methodological levels applied by gas and IPPU sector references.

		ESTIMATED GASES AND METHODOLOGIES									REFERENCES	
Subsector	Category	CO_2	CH_4	N_2O	CO	NO_x	NMVOC	HFCs	PFCs	SF_6	Activity data	Emission factors
2.A. MINERAL INDUSTRY	2.A.1. Cement Production	T3	NA	NA	NA	NA	NA	NA	NA	NA	Total clinker and cement production (SNIC, 2024).	Data from SNIC (2013), with emission factors last calculated in 2010. For the period from 2011 to 2021, the implicit factor was informed by SNIC, and in 2022 the 2021 value was adopted.
	2.A.2. Lime Production	T2	NA	NA	NA	NA	NA	NA	NA	NA	Production of quicklime and hydrated lime (ABPC – Brazilian Lime Producers Association (Associação Brasileira dos Produtores de Cal), 2014; MME, 2022b). Due to the lack of data, 2021 production was maintained in 2022. Average composition of lime according to the variation allowed by Brazilian standards.	IPCC (2006, v. 3, chap. 2).
	2.A.3. Glass Production	T3	NA	NA	NA	NA	NA	NA	NA	NA	Glass production from the Statistical Yearbook – Non-Metallic Transformation Sector (MME, 2006; 2007; 2009; 2013; 2020; 2022b).	Stoichiometry of chemical processes, based on the average composition of the feedstock of the glass, according to the Yearbook, with emission factors from IPCC (2006, v. 3, chap. 2).
	2.A.4. Other Process Uses of Carbonates	T2	NA	NA	NA	NA	NA	NA	NA	NA	Ceramics: Production (IBGE, 2024b), distribution of national production by the Statistical Yearbook of the Non-Metallic Transformation Sector (MME, 2022); Soda ash: Production, import and export (ABIQUIM – Brazilian Chemical Industry Association (Associação Brasileira da Indústria Química), 2014), with extrapolation for 2015 to 2022; Magnesite: Data from Mineral Summary (ANM – National Mining Agency (Agência Nacional de	For the ceramics sector, publications that differentiated the parameters according to the characteristics of the various states and regions of the country were considered. Stoichiometry of chemical processes; (IPCC, 2006, v. 3, chap. 2).

Subsector	Category	ESTIMATED GASES AND METHODOLOGIES									REFERENCES	
		CO_2	CH_4	N_2O	CO	NO_x	NMVOC	HFCs	PFCs	SF_6	Activity data	Emission factors
											Mineração) 2016) and Mineral Sector Bulletin (MME, 2020b), with maintenance of the 2019 production for 2020 to 2022.	
2.B. CHEMICAL INDUSTRY	2.B.1. Ammonia Production	T3	NA	NA	NA	NA	NA	NA	NA	NA	Ammonia production (ABIQUIM, 2017; 2024); Urea (IBGE, 2017b; 2024b), combined with data from the yearbooks and personal contact with ABIQUIM for 1990 to 2024.	National specific factor, deducting CO_2 emissions from urea.
	2.B.2. Nitric Acid Production	NA	NA	T3/T1	NA	T1	NA	NA	NA	NA	Production up to 2007 (ABIQUIM, 2009). And after that, through the monitoring of CDM projects (UNFCCC, 2019).	Data from Abiquim (2009) and from CDM projects monitoring (UNFCCC, 2024). IPCC (1997) for precursor gases.
	2.B.3. Adipic acid Production	NA	NA	T3	T1	T1	NA	NA	NA	NA	Production up to 2010 (ABIQUIM, 2009; 2012). And after that, through the monitoring of CDM projects (UNFCCC, 2019).	Data from Abiquim (2012) and CDM projects monitoring (UNFCCC, 2019). IPCC (1997) for precursor gases.
	2.B.4. Caprolactam, Glyoxal and Glyoxylic Acid Production	NA	NA	T1/NO	NA	NA	NA	NA	NA	NA	Abiquim (2024).	IPCC (2006, v. 3, chap. 3).
	2.B.5. Carbide Production	T1	NA	NA	NA	NA	NA	NA	NA	NA	Plant-specific information up to 2007, with additions up to 2010 (ABIQUIM, 2012); repeated until 2022.	Plant-specific information until 2007; 2008 to 2010 Abiquim (2012); repeated until 2016.
	2.B.6. Titanium Dioxide Production	NA	NA	NA	NA	NA	NA	NA	NA	NA		
	2.B.7. Sodium Carbonate Production	NO	NO	NO	NO	NO	NO	NO	NO	NO		
	2.B.8. Petrochemical and Carbon Black Production	T1	T1	NA	NA	T1	T1	NA	NA	NA	Abiquim (2020; 2024).	IPCC (2006, v. 3, chap. 3). IPCC (1997) for precursor gases.

Subsector	Category	ESTIMATED GASES AND METHODOLOGIES									REFERENCES	
		CO_2	CH_4	N_2O	CO	NO_x	NMVOC	HFCs	PFCs	SF_6	Activity data	Emission factors
	2.B.9. Fluorochemical Production	NA	NA	NA	NA	NA	NA	T1	NA	NA	Prozon – Interministerial Executive Committee for the Protection of the Ozone Layer (Comitê Executivo Interministerial para Proteção da Camada de Ozônio) (1999).	IPCC (2006, v. 3, chap. 3).
	2.B.10. Other Chemicals	NA	NA	NA	NA	NA	T1	NA	NA	NA	Abiquim (2020;2024)	IPCC (2006, v. 3, chap. 3). IPCC (1997) for precursor gases.
2.C. METAL INDUSTRY	2.C.1. Iron and Steel Production	T2	T1	T1	T1	T1	T1	NA	NA	NA	Brazil Steel Institute (Instituto Aço Brasil) (IABR, 2017; 2020) for emissions up to 2016 and BEN (EPE, 2023) for energy, with emissions from 2017 to 2022 accounted for proportionally to crude steel production by IABr (2023).	CO_2: carbon balance (IABR, 2020); non-CO_2: IPCC (2006, v. 2, chap. 2). IPCC (1997) for precursor gases
	2.C.2. Ferroalloys Production	T1	T1	NA	NA	NA	NA	NA	NA	NA	National Energy Balance – BEN (EPE, 2023) and MME (2022a) for the sector's production.	IPCC (2006, v. 3, chap. 4).
	2.C.3. Aluminum Production	T1/T2 /T3	NA	NA	T1	T1	NA	NA	T1/T2 /T3	NA	ABAL – Brazilian Aluminum Association (Associação Brasileira do Alumínio) (2019), ALBRAS – Alumínio Brasileiro S.A. (2022), CBA – Companhia Brasileira de Alumínio (2022) and IBGE (2024b).	CO_2 and PFCs: ABAL (2019); non-CO_2: IPCC (1997).
	2.C.4. Magnesium Production	T1	NA	NA	NA	NA	NA	NA	NA	T1	CDM project monitoring (UNFCCC, 2024), with extrapolation to 2022.	IPCC (2006, v. 3, chap. 4).
	2.C.5. Lead Production	IE	NA	NA	NA	NA	NA	NA	NA	NA	Considered in category 2.C.7.	
	2.C.6. Zinc Production	NA	NA	NA	NA	NA	NA	NA	NA	NA	National Energy Balance – BEN (EPE, 2019; 2023) and BEU (EPE, 2005).	
	2.C.7. Other (non-ferrous metals, except aluminum and magnesium)	T1	NA	NA	NA	NA	NA	NA	NA	NA	National Energy Balance – BEN (EPE, 2019; 2023) and BEU (EPE, 2005).	IPCC (2006, v. 3, chap. 4).

		ESTIMATED GASES AND METHODOLOGIES									REFERENCES	
Subsector	Category	CO_2	CH_4	N_2O	CO	NO_x	NMVOC	HFCs	PFCs	SF_6	Activity data	Emission factors
2.D. NON-ENERGY PRODUCTS FROM FUELS AND SOLVENT USE	2.D.1. Lubricant Use	T1	NA	NA	NA	NA	NA	NA	NA	NA	National Energy Balance – BEN (EPE, 2023).	IPCC (2006, v. 3, chap. 5).
	2.D.2. Paraffin Wax Use	IE	NA	NA	NA	NA	NA	NA	NA	NA	Considered in category 2.D.3.	
	2.D.3. Other	T1	NA	NA	NA	NA	T1	NA	NA	NA	National Energy Balance – BEN (EPE, 2023).	IPCC (1997) for precursor gases
2.E. ELECTRONICS INDUSTRY	2.E.1. Integrated Circuit or Semiconductor	NA	NA	NA	NA	NA	NA	IE	IE	NA	Considered in category 2.E.5.	
	2.E.2. TFT Flat Panel Display	NA	NA	NA	NA	NA	NA	IE	IE	NA	Considered in category 2.E.5.	
	2.E.3. Photovoltaics	NA	NA	NA	NA	NA	NA	NE	NE	NA		
	2.E.4. Heat Transfer Fluid	NA	NA	NA	NA	NA	NA	NE	NE	NA		
	2.E.5. Other	NA	NA	NA	NA	NA	NA	T2a	T2a	NA	Foreign trade statistics – Comex Stat (MDIC, 2024).	IPCC (2006, v. 3, chap. 6).
2.F. PRODUCT USES AS SUBSTITUTES FOR OZONE DEPLETING SUBSTANCES DE OZÔNIO	2.F.1. Refrigeration and Air Conditioning	NA	NA	NA	NA	NA	NA	T2a	NA	NA	Foreign trade statistics – Comex Stat (MDIC, 2024), IBGE (2024b), ELETROS (2019); ABRAVA (2022).	IPCC (2006, v. 3, chap. 7).
	2.F.2. Foam Blowing Agents	NA	NA	NA	NA	NA	NA	T2a	NA	NA	Foreign trade statistics – Comex Stat (MDIC, 2024).	IPCC (2006, v. 3, chap. 7).
	2.F.3. Fire Protection	NA	NA	NA	NA	NA	NA	T2a	NA	NA	Foreign trade statistics – Comex Stat (MDIC, 2024).	IPCC (2006, v. 3, chap. 7).

		ESTIMATED GASES AND METHODOLOGIES									REFERENCES	
Subsector	**Category**	**CO_2**	**CH_4**	**N_2O**	**CO**	**NO_x**	**NMVOC**	**HFCs**	**PFCs**	**SF_6**	**Activity data**	**Emission factors**
	2.F.4. Aerosols	NA	NA	NA	NA	NA	NA	T2a	NA	NA	Foreign trade statistics – Comex Stat (MDIC, 2024).	IPCC (2006, v. 3, chap. 7).
	2.F.5. Solvents	NA	NA	NA	NA	NA	NA	NE	NE	NA		
	2.F.6. Other applications	NA	NA	NA	NA	NA	NA	NO	NO	NA		
2.G. OTHER PRODUCT MANUFACTURE AND USE	2.G.1. Electrical Equipment	NA	NA	NA	NA	NA	NA	NA	NO	T1	MCT – Ministry of Science and Technology (Ministério da Ciência e Tecnologia) national survey (2009).	IPCC (2006, v. 3, chap. 8).
	2.G.2. SF_6 and PFCs from Other Product Uses	NA	NA	NA	NA	NA	NA	NA	NO	NO		
	2.G.3. N_2O from Product Uses	NA	NA	NE	NA	NA	NA	NA	NA	NA		
	2.G.4. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO		
2.H. OTHER	2.H.1. Pulp and Paper Industry	NA	NA	NA	T1	T1	T1	NA	NA	NA	IBA – Brazilian Tree Industry (Indústria Brasileira de Árvores) (2019; 2021; 2023).	IPCC (1997) for precursor gases
	2.H.2. Food and Beverage Industry	NA	NA	NA	NA	NA	T1	NA	NA	NA	Food in general and beer: IBGE (2024b); Sugar: UNICA – Brazilian Sugarcane Industry Association (União da Indústria de Cana-de-Açúcar) (2019; 2024); Wines: IBRAVIN – Brazilian Wine Institute (Instituto Brasileiro do Vinho) (2023), after 2004 (IBGE, 2024b). Bread and flour: ABITRIGO – Brazilian Wheat Industry Association (Associação Brasileira da Indústria do Trigo) (2024) and ABIP – Brazilian Bakery and	IPCC (1997) for precursor gases

Subsector	Category	ESTIMATED GASES AND METHODOLOGIES									REFERENCES	
		CO_2	CH_4	N_2O	CO	NO_x	NMVOC	HFCs	PFCs	SF_6	Activity data	Emission factors
											Confectionery Industry Association (Associação Brasileira da Indústria de Panificação e Confeitaria) (2024).	
	2.H.3. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA		

Note: Methodological levels (IPCC, 2006) – T1: Tier 1; T2: Tier 2; T3: Tier 3.
Notations: NA (Not applicable) – Activity in a given source/sink category that occurs in the country, but did not result in emissions or removals of a specific gas; IE (Included elsewhere) – Included in another location/category of emissions or removals; NO (Not occurring) – Categories and processes that do not occur in the country; NE (Not estimated) – Activity data and/or emissions by sources and removals by sinks of GHG that have not been estimated, but for which a corresponding activity may occur in the country.

Some activity data and emissions results could not be disaggregated in the NIR 2024, thus, this information was obtained in aggregated form and has been reported as such. Dataframe 5.2 shows the emissions allocations of the categories that could not be disaggregated, in the IPPU Sector.

Dataframe 5.2. Categories with values allocated in other categories (IE) in the IPPU Sector.

IPCC CODES	REALLOCATED CATEGORIES	REALLOCATION DESTINATION
2.C.5	Lead Production	2.C.7. Other (Non-Ferrous Metals, Except Aluminum and Magnesium)
2.D.2	Paraffin Wax Use	2.D.3. Other
2.E.1	Integrated Circuit or Semiconductor	2.E.5. Other
2.E.2	TFT Flat Panel Display	2.E.5. Other

For some categories, it was not possible to calculate emissions, mainly because of the lack of information due to incipient production. In Dataframe 5.3, the subcategories for which GHGs were not estimated in the IPPU sector have been compiled.

Dataframe 5.3. Categories not estimated (NE) in the Inventory for the IPPU Sector.

IPCC CODES	CATEGORIES NOT ESTIMATED	NOTES
2.E.3	Photovoltaics	Production is still considered to be in its infancy in the country.
2.E.4	Heat Transfer Fluid	Production is still considered to be in its infancy in the country.
2.F.5	Solvents	No data could be obtained due to the large number of variations of HFCs and PFCs and other uses for the same substances.
2.G.3	N_2O from Product Uses	There is no data available in the country on anesthetic products.

5.3 Mineral Industry (CRT 2.A)

The Mineral Industry subsector (2.A) includes CO_2 emissions from Cement Production (2.A.1), Lime Production (2.A.2), Glass Production (2.A.3), and Other Process Uses of Carbonates (2.A.4) processes.

In 2022, the Mineral Industry emitted 32,993 kt CO_2 eq, which corresponded to 32% of IPPU emissions (Figure 5.2). Most emissions were related to the Cement Production category (2.A.1), which emitted 24,625 kt CO_2 eq and contributed with 75% of the subsector's emissions. This was followed by Lime Production (2.A.2), which emitted 5,924 kt CO_2 eq, accounting for 18% of emissions. Emissions from the Mineral Industry were 11% higher in 2022 than estimated in 2016. However, there was a 3% decrease in the emissions from this sector compared to 2020.

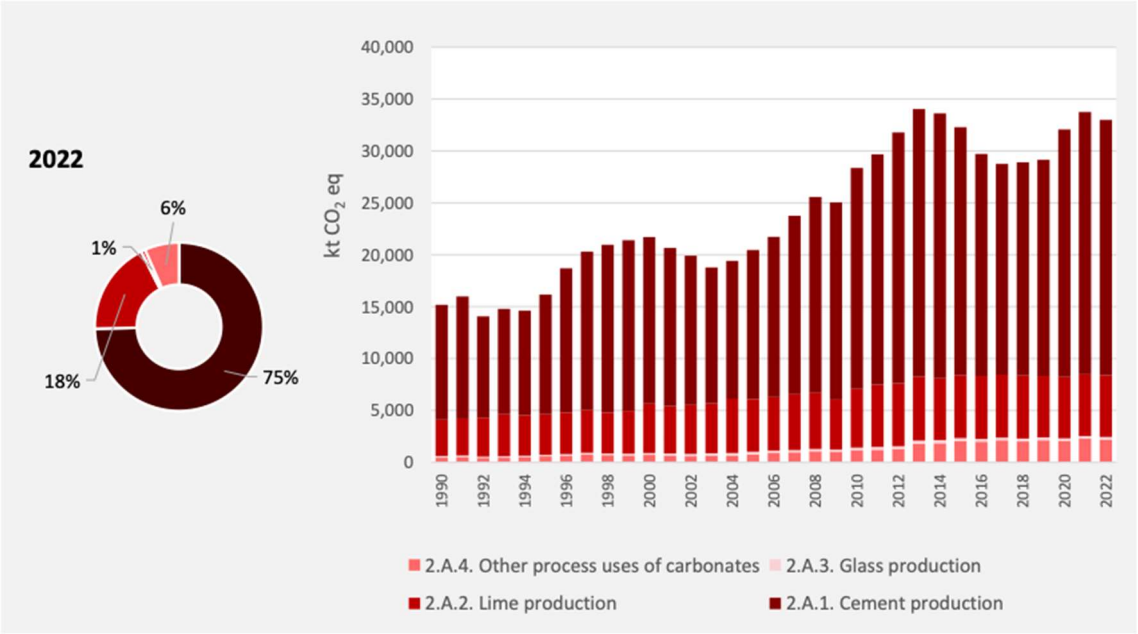


Figure 5.2. Emissions from the Mineral Industry (2.A), in kt CO_2 eq by category, from 1990 to 2022.

5.3.1 Methodological aspects

5.3.1.1 Cement Production

The Brazilian cement sector has been striving to obtain the detailed information needed to apply the sectoral methodology of the Cement Sustainability Initiative (CSI), an initiative from the world's largest cement groups linked to the World Business Council for Sustainable Development (WBCSD), with the aim of developing a series of environmental actions, including the control and monitoring of GHG emissions. This information is compatible with the IPCC 2006 Tier 3 approach (IPCC, 2006), which takes into account the composition of the feedstocks (carbonates) used, corrects the emissions by MgO content and includes other specific parameters, such as the correction of Cement Kiln Dust – CKD, which is considered a system loss, and the carbon of the organic matter contained in the feedstocks.

In order to obtain the most accurate estimates possible, it was decided to use the Tier 3 methodology defined in IPCC 2006 (IPCC, 2006), modified on the basis of the information available from the application of the CSI methodology. In order to justify this choice, a comparative analysis of the approaches is provided below.

In IPCC (2006) – Tier 3, CO_2 emissions are basically calculated taking into account the composition of the carbonates consumed during the limestone decarbonation process in the clinker calcination kiln. In the CSI approach, emissions are based on the contents of CaO and MgO present in the clinker.

In both methodologies, a correction is made for the portion of dust emitted from the kilns (CKD) and not calcined, and any relevant amounts of CaO and MgO in the clinker generated by non-carbonaceous sources are corrected, i.e., which did not originate in the decarbonization in the clinker kiln – therefore without associated emissions in the process, for example, calcium silicates or fly ashes used in the kiln, as chemical correctives for the

feedstock. However, this is not a common practice in the Brazilian cement industry and only a few plants do it.

Tier 3 – IPCC (2006)

Equation 5.1, presented in IPCC (2006) Tier 3 is used to calculate emissions based on data from the feedstocks consumed in clinker production, deducting emissions from non-calcined CKD (system losses) and taking into account emissions from non-energy feedstocks that contain carbon.

Dataframe 5.4. Equation for calculating emissions from cement production (Tier 3 methodology).

Equations	GHG	Categories	Central equation	Reference
Equation 5.1	CO_2	2.A.1	$CO_2\ Emissions = \underbrace{\sum_i (EFi \times M_i \times F_i)}_{Carbonate\ Emissions} - \underbrace{M_d \times C_d \times (1 - F_d) \times EF_d}_{Emissions\ of\ CKD\ that\ is\ not\ calcined\ and\ is\ not\ reinjected\ in\ the\ kiln} + \underbrace{\sum_k (M_k \times X_k \times EF_k)}_{Emissions\ from\ non-energy\ feedstocks\ that\ contain\ carbon}$	Equation 2.3 (IPCC, 2006, v. 3, chap. 2)

- First part – carbonate emissions

For each carbonate, the following will be needed: the corresponding mass (Mi), the respective emission factor (EFi) and the calcination fraction (Fi) achieved by each substance. According to the IPCC (2006), the degree of calcination reached by all materials is 100% (Fi = 1), or very close to this value, due to the high temperature and time of these materials in the kiln.

- Second part – CKD correction

The mass of dust (CKD) not recycled in the kiln (Md), the fraction of carbonates in this mass (Cd), its calcination fraction (Fd) and the respective emission factor (EFd) are required. If all the dust has been calcined, or if all the dust is recycled in the kiln, this term cancels out. The part of the CKD that is not calcined and is not reinjected can be considered a source of false CO_2 counting, as it would have been counted together with the total of the calcined feedstocks, and should, therefore, be deducted accordingly. According to GPG 2000, only a correction of 1.5% to 2% in the emissions calculated for clinker in modern plants is suggested.

- Third part – emissions from non-energy feedstocks in addition to carbon-containing carbonates

The mass of this non-energy, carbon-containing feedstock (Mk), the carbon fraction (Xk) and the respective emission factor (EFk) are required. This means a CO_2 emission in addition to that resulting from the decarbonization process.

According to the IPCC (2006), CO_2 emissions relating to this term can be ignored, if the contribution of this carbon is less than 5% of the total heat from fuels.

CSI Methodology

- Emissions from Carbonates

Based on the knowledge of the CaO and MgO fractions of the clinker, obtained through chemical analysis in each plant, the emission factor related to the decarbonation process is obtained, corresponding to the term "Emissions from Carbonates" in Equation 5.1 mentioned above, and can be calculated as the sum of the two emission factors related to the oxides:

Dataframe 5.5. Equations for estimating the emission factors of clinker, CaO and MgO, using the CSI methodology.

Equations	GHG	Categories	Central equation	Reference
Equation 5.2	CO_2	2.A.1	$EF_{clinker} = EF_{CaO} + EF_{MgO}$	WBCSD (2011)
Equation 5.3	CO_2	2.A.1	$EF_{CaO} = \underbrace{CaO\ content}_{of\ the\ chemical\ analyses} \times \underbrace{\left(\frac{44.0 g/mol\ CO_2}{56.1 g/mol\ CaO}\right)}_{0.7843}$	WBCSD (2011))
Equation 5.4	CO_2	2.A.1	$EF_{MgO} = \underbrace{MgO\ content}_{of\ the\ chemical\ analyses} \times \underbrace{\left(\frac{44.0 g/mol\ CO_2}{40.3 g/mol\ MgO}\right)}_{1.0918}$	WBCSD (2011)

The CaO and MgO contents are presented as a dimensionless fraction.

Basically, the two approaches (CSI and IPCC 2006 Tier 3) converge on the same emissions values, as they are based on the stoichiometry of the process.

In the case of plants that did not have specific data on the CaO and MgO content in the clinker, the default EF recommended by the CSI methodology of 0.525 t CO_2/t clinker was applied. This factor is already corrected for the MgO content, suggested by both the CSI (around 2%) and the IPCC (2006 (between 1% and 2%)). This value is similar to the reference EF used by GPG 2000 of 0.51 t CO_2/t clinker, if the correction for MgO content is added to it (2% x 1.0918 = 0.022 t CO_2/t clinker). In both cases, there is no correction for CKD.

- Cement Kiln Dust (CKD) emissions

Cement Kiln Dust (CKD) varies from uncalcined to calcined. Such CKD can be partially or totally recycled when reinjected into the calcining kiln. The portion of the calcined CKD that is not reinjected can be considered a source of additional CO_2 emissions, as it is not accounted for by the chemical analysis of the clinker.

- Emissions from the organic carbon contained in the feedstocks

In addition to carbonates, the feedstocks used in clinker production usually contain a small fraction of organic carbon, most of which is converted into CO_2 during burning. The total organic carbon content (TOC) in feedstocks can vary substantially due to differences in location and feedstocks used.

Data compiled by CSI indicate typical values of organic carbon in raw meal of between 0.1% and 0.3%. The emissions of CO_2 from organic carbon in raw meal can be quantified and recorded by the mill. However, since its contribution to total emissions is small, the

standard of 11 kg CO_2/t clinker is suggested, based on the multiplication of the following parameters from Equation 5.5 below:

Dataframe 5.6. Equação para estimar o fator de emissão do carbono orgânico no clínquer.

Equations	GHG	Categories	Central equation	Reference
Equation 5.5	CO_2	2.A.1	$EF_{organic\ matter} = Factor_{default\ clinker\ raw\ meal}\ X\ TOC\ X\ CO2/C$	WBCSD (2011)

In which:

Clinker raw meal factor = 1.55 t raw meal/t clinker;
TOC = Total Organic carbon content in raw meal of 2 kg TOC/t raw meal;
Ratio of the molecular weights of CO_2/C: 3.664 kg CO_2/kg C.

This multiplication assumes that all organic carbon is converted into CO_2.

Conclusion of the comparison between the CSI methodology and IPCC 2006

Under the CSI methodology, CO_2 emissions from the carbon contained in feedstocks are calculated using information from the plants themselves, or the default value of 11 kg CO_2/t clinker is applied, as shown in Equation 5.5 (Dataframe 5.6).

Based on the above, it was found that the emissions estimates calculated using both methodologies are compatible with each other, and a decision was made to use the default value recommended by the IPCC (2006) methodology, modified using the data available from the application of the CSI method. However, when no data was obtained for its application, the emission factor of 0.536 tCO_2/t clinker was used, considering the organic carbon contained in the feedstocks.

Activity data and other parameters

Data was obtained from the specific time series of plants in Brasil (2010; 2015a; 2021b), for the period from 2017 to 2022 from extrapolations of previous editions of the inventory. The estimated data comprised:

- The CaO and MgO contents that make up clinker production per plant, per year;
- The amount of clinker produced, purchased and sold per plant, per year;
- The amount of cement produced per type; and
- The amounts of mineral compounds, such as plaster, limestone, slag, fly ash, pozzolan and CKD used to produce cement.

According to the survey carried out in previous inventories, the vast majority of Brazilian plants reinject the CKD back into the clinker kiln, meaning that there are no system losses and, therefore, no CKD correction is necessary. A few plants send the previously calcined CKD to be mixed with cement to make a special cement with a low alkali content, a practice that is not very common in Brazil. In these cases, however, the CKD emission factor was taken into account when calculating national emissions, reaching an average percentage

between 0.4% and 1.1% of clinker production emissions, according to the information provided by the plants that carry out this measurement.

Data was collected by consulting SNIC and its members. For reasons of industrial secrecy, only consolidated data on clinker and cement production and the respective clinker content in cement at national level will be presented in this section (Table 5.1).

In order to integrate the data collected by SNIC with the rest of the national production, the amounts produced by non-member companies were estimated and the same implicit annual emission factor was applied to the CO_2 emissions of their members. Given the lack of data on clinker content in cement for 2021 and 2022, the values observed in 2020 were maintained.

Table 5.1. National cement and clinker production and clinker content in cement.

Year	Product		Clinker content in cement
	Clinker	Cement	
	kt		t clinker / t cement
1990	20,161	25,848	0.780
1991	21,458	27,490	0.781
1992	17,748	23,903	0.742
1993	18,407	24,843	0.741
1994	18,412	25,230	0.730
1995	21,071	28,256	0.746
1996	25,346	34,597	0.733
1997	27,971	38,096	0.734
1998	29,684	39,942	0.743
1999	29,941	40,234	0.744
2000	29,227	39,901	0.732
2001	27,791	39,454	0.704
2002	26,178	38,927	0.672
2003	23,681	35,122	0.674
2004	23,945	35,983	0.665
2005	26,307	38,706	0.680
2006	28,468	41,896	0.679
2007	31,768	46,551	0.682
2008	34,482	51,970	0.664
2009	34,737	51,747	0.671
2010	38,053	59,117	0.644
2011	40,780	64,093	0.636
2012	44,300	68,809	0.644
2013	46,890	70,161	0.668
2014	47,000	72,503	0.648
2015	43,500	66,489	0.654
2016	38,600	58,160	0.664
2017	36,500	54,004	0.676
2018	37,000	53,602	0.690
2019	38,000	56,611	0.671

Year	Product		Clinker content in cement
	Clinker	Cement	
	kt		t clinker / t cement
2020	42,200	61,052	0.691
2021	44,210	65,884	0.671
2022	43,050	63,546	0.677

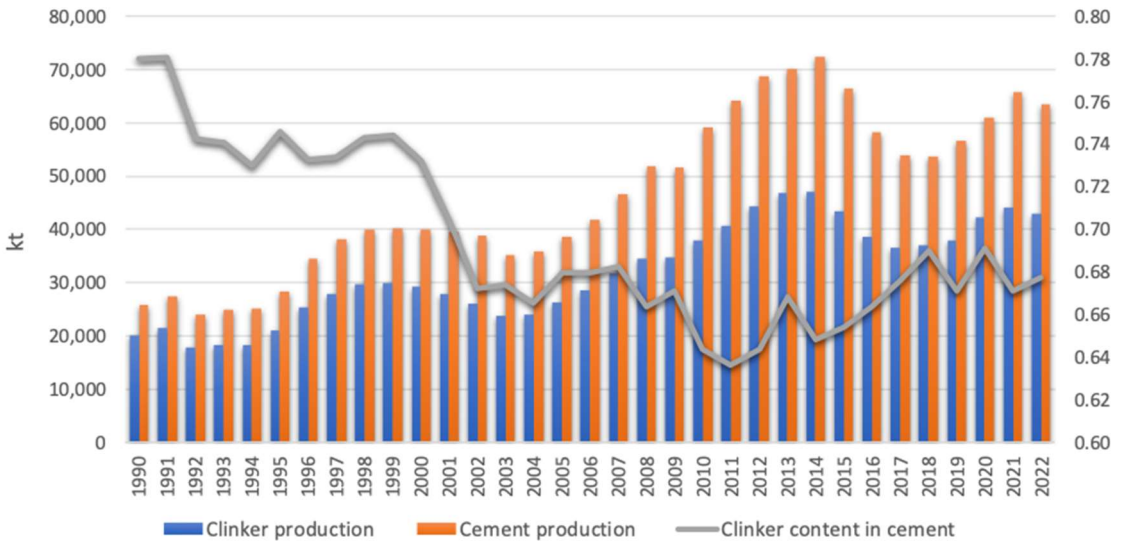


Figure 5.3. Cement and clinker production, and clinker content in cement.

Table 5.2 shows the molecular weights of the chemical substances involved in the decarbonation process.

Table 5.2. Molecular masses of substances related to the decarbonation process.

Molecular masses	g/mol
Calcium carbonate – $CaCO_3$	100.1
Magnesium carbonate – $MgCO_3$	84.3
Calcium oxide – CaO	56.1
Magnesium oxide – MgO	40.3
Carbon dioxide – CO_2	44.0

Source: Prepared based on WBCSD, 2011.

5.3.1.2 Lime Production

The term "lime" is used in Brazilian literature and in the standards of the Brazilian Association of Technical Norms (Associação Brasileira de Normas Técnicas, ABNT) to designate the product made of calcium oxide (CaO) and calcium and magnesium oxide

(CaOMgO), resulting from the calcination of limestones, magnesian limestones and dolomites.

The mass of CO_2 produced per unit of manufactured lime can be estimated by the molecular weights and the lime content of the products. Based on the calcination reaction, one mole of CO_2 is formed for every mole of quicklime produced by the calcination of calcium carbonate. In cases where dolomite is calcined, the emission factor is based on the proportion of calcium and magnesium oxides.

In order to measure lime emissions, the CO_2 emission factors are presented according to Table 2.4 of the IPCC (2006, v. 3, chap. 3), as described in Dataframe 5.7. In both cases, the formulas assume pure lime, but in some cases, the purity can vary from 85% to 95%. The value of 95% for lime purity has been adopted in this Inventory.

Dataframe 5.7. Emission factors for quicklime and dolomitic lime.

Categorias	Produto	Fatores de emissão	Referência
2.A.2	Quicklime	$0.785 \frac{tCO2}{t\ quicklime}$	Table 2.4 (IPCC, 2006, v. 3, chap. 2)
2.A.2	Dolomitic lime	$0.913 \frac{tCO2}{t\ dolomitic\ lime}$	Table 2.4 (IPCC, 2006, v. 3, chap. 2)

In practice, as there is a mixture of limestones, magnesian and dolomitic limestones, the resulting limes have varying CaO and CaO.MgO contents. In Brazil, the following classification is adopted:

Table 5.3. Lime classification.

Classification	% of total CaO
Calcitic	90 – 100
Magnesian	65 – 90
Dolomitic	58.2 – 65

Source: Own preparation, according to ABNT.

Using the stoichiometric ratios, the percentage of total CaO can be correlated with the composition of the lime, considering a variable share between CaO and CaO.MgO:

Table 5.4. Ratio between the total percentage of CaO in lime and its composition.

% of total CaO	CaO	CaO.MgO
58.2	0.0%	100.0%
65.0	16.3%	83.7%
90.0	76.1%	23.9%

In the absence of a complete characterization of lime in the country, the average values for the percentage of total CaO have been adopted for this report, resulting in the proportions of CaO and CaO.MgO shown in Table 5.5. In order to obtain the final emission factors, the purity of 95% of the lime produced is also taken into account.

Table 5.5. Emission factors according to lime classification.

Lime classification	Average CaO	Average CaO.MgO	EF (t CO_2/t lime)
Calcitic	88.0%	12.0%	0.760
Magnesian	46.2%	53.8%	0.811
Dolomitic	8.2%	91.8%	0.857

Another important piece of information for the purposes of this Inventory is the composition of the lime produced in the country. According to information from the ABPC – Brazilian Lime Producers Association (Associação Brasileira dos Produtores de Cal), quicklime is, basically, calcitic. Hydrated lime is divided into calcitic, 20%, and dolomitic, 80%. This 80% percentage of dolomitic lime can be further subdivided into actual dolomitic lime, 30%, and magnesian lime, 50%.

Activity data and other parameters

The Brazilian Lime Producers Association (ABPC) was the main source of information on the sector's figures until 2014, and was also the basis for the Mineral Summary of the National Department of Mineral Production (DNPM, Departamento Nacional de Produção Mineral), and, subsequently, for the Statistical Yearbook of the Non-Metallic Transformation Sector (MME, 2020a; 2020b; 2022b), in the period covered by the NIR 2024.

Data on quicklime and hydrated lime production was obtained from the ABPC, which reports information from the member companies, captive market companies, and evaluates non-member companies (Table 5.6). Captive market companies are those that supply their needs with their own production, basically the large steel companies, which have lime as a strategic input of great importance, to the point of justifying the maintenance of their own production facilities. In 2009, member companies were responsible for 51% of national production, the captive market had 22%, and non-member companies had an estimated share of 27%. From 2010 onwards, when some steel furnaces started selling to the open market, ABPC changed the mode of the information, indicating only the captive market and the open market, with shares of 13% and 87%, respectively. As of 2015, only total production is available in the Statistical Yearbook of the Non-Metallic Transformation Sector (MME, 2020a; 2022b), with the breakdown between types based on 2014. Due to the lack of production data for 2021 and 2022, the production cited in MME (2022b) for 2020 was maintained.

Table 5.6. Lime production in Brazil.

Year	Quicklime – Informed production				Hydrated lime – informed production			Grand Total
	Member producers QL_1	Non-members QL^3	Captive production QL^2	Total of quicklime	Member producers HL^1	Non-members HL^3	Total of hydrated lime	
1990	1,335	646	1,048	**3,029**	978	893	1,871	**4,900**
1991	1,359	658	1,008	**3,025**	1,067	908	1,975	**5,000**
1992	1,351	689	1,236	**3,276**	1,013	951	1,964	**5,240**
1993	1,327	790	1,375	**3,492**	1,052	1,090	2,142	**5,634**
1994	1,498	599	1,378	**3,475**	1,122	828	1,950	**5,425**
1995	1,444	546	1,427	**3,417**	1,273	754	2,027	**5,444**
1996	1,465	546	1,466	**3,477**	1,416	754	2,170	**5,647**
1997	1,527	560	1,549	**3,636**	1,343	771	2,114	**5,750**
1998	1,418	512	1,523	**3,453**	1,306	734	2,040	**5,493**
1999	1,354	935	1,470	**3,759**	1,225	765	1,990	**5,749**
2000	1,595	1,491	1,546	**4,632**	1,244	682	1,926	**6,558**
2001	1,592	1,421	1,392	**4,405**	1,221	682	1,903	**6,308**
2002	1,696	1,380	1,558	**4,634**	1,240	607	1,847	**6,481**
2003	1,783	1,388	1,589	**4,760**	1,270	587	1,857	**6,617**
2004	2,145	1,366	1,589	**5,100**	1,278	830	2,108	**7,208**
2005	2,189	1,521	1,392	**5,102**	1,165	720	1,885	**6,987**
2006	2,420	1,162	1,570	**5,152**	1,157	748	1,905	**7,057**
2007	2,474	1,246	1,670	**5,390**	1,228	775	2,003	**7,393**
2008	2,536	1,238	1,635	**5,409**	1,201	815	2,016	**7,425**
2009	2,167	920	1,490	**4,577**	1,203	865	2,068	**6,645**
2010	4,677		995	**5,672**	2,089		2,089	**7,761**
2011	5,243		963	**6,206**	2,029		2,029	**8,235**
2012	5,346		962	**6,308**	2,005		2,005	**8,313**
2013	5,219		1,184	**6,403**	2,016		2,016	**8,419**
2014	4,932		1,253	**6,185**	1,967		1,967	**8,152**
2015	5,022		1,276	**6,297**	2,003		2,003	**8,300**
2016	5,022		1,276	**6,297**	2,003		2,003	**8,300**
2017	5,022		1,276	**6,297**	2,003		2,003	**8,300**
2018	5,022		1,276	**6,297**	2,003		2,003	**8,300**
2019	4,901		1,245	**6,146**	1,954		1,954	**8,100**
2020	4,901		1,245	**6,146**	1,954		1,954	**8,100**
2021	4,901		1,245	**6,146**	1,954		1,954	**8,100**
2022	4,901		1,245	**6,146**	1,954		1,954	**8,100**

Unit: Thousand tons. Note: [1] Production reported to ABPC by member companies up to 2009; from 2010 onwards, included in the open market. [2] Own production reported to ABPC by CSN, Cosipa, Açominas, Usiminas, CST, White Martins e Cia. Nacional de Álcalis, until 2009. [3] Estimated values. As of 2010, the value is included in the open market.

In the case of hydrated lime, it was also necessary to identify the portion relating to water, so that it could be subtracted from the total production, and, thus, obtain the corresponding

dry production (quicklime). Each ton of quicklime produces 1.27 tons of hydrated lime,[38] which means that 21.3% of the weight of hydrated lime is made up of water.

In view of that, and with the information obtained previously, the types of lime and their respective production quantities, minus water, can be seen in Table 5.7.

Table 5.7. Types of lime produced, without water.

Year	Calcitic lime equivalent (without water)	Magnesian lime equivalent (without water)	Dolomitic lime equivalent (without water)
	thousand t		
1990	3,324	736	442
1991	3,336	778	467
1992	3,585	773	464
1993	3,829	843	506
1994	3,782	768	461
1995	3,736	798	479
1996	3,819	854	513
1997	3,969	832	499
1998	3,774	803	482
1999	4,072	783	470
2000	4,935	758	455
2001	4,705	749	450
2002	4,925	727	436
2003	5,052	731	439
2004	5,432	830	498
2005	5,399	742	445
2006	5,452	750	450
2007	5,705	789	473
2008	5,726	794	476
2009	4,903	814	489
2010	6,001	822	493
2011	6,526	799	479
2012	6,624	789	474
2013	6,720	794	476
2014	6,495	774	465
2015	6,613	788	473
2016	6,613	788	473
2017	6,613	788	473
2018	6,613	788	473
2019	6,453	769	462
2020	6,453	769	462
2021	6,453	769	462
2022	6,453	769	462

[38] This information is obtained from previous editions of the National Inventory and is compatible with the value of 1.3 in the Statistical Yearbook of the Non-Metallic Transformation Sector (MME, 2020a).

5.3.1.3 Glass Production

Similar to the cement and lime production processes, there are other uses where limestone ($CaCO_3$) and dolomite ($CaCO_3.MgCO_3$) are subjected to high temperatures and where CO_2 is released, while the lime that is also produced has various other reactions. Similarly, there is the use of soda ash (Na_2CO_3), which also undergoes the same decomposition in the glassmaking process.

The amount of CO_2 emitted by the calcination of limestone and dolomite for glass production can be estimated from the consumption and purity of the feedstocks, by means of the stoichiometry of the chemical processes. Based on the calcination reaction, one mole of CO_2 is formed for each mole of limestone. Thus, the CO_2 emission factors for the use of limestone, dolomite and soda ash were estimated as shown in Dataframe 5.8.

Dataframe 5.8. Emission factors for limestone, dolomite and soda ash.

Categories	Product	Emission factors	Reference
2.A.3	Limestone	$(0.440\ X\ f)\frac{tCO2}{t\ limestone}$	Table 2.1 (IPCC, 2006, v.3, chap. 2)
2.A.3	Dolomite	$(0.477\ X\ f)\frac{tCO2}{t\ dolomite}$	Table 2.1 (IPCC, 2006, v.3, chap. 2)
2.A.3	Soda ash	$(0.415\ X\ f)\frac{tCO2}{t\ soda\ ash}$	Table 2.1 (IPCC, 2006, v.3, chap. 2)

In which:

f is the fraction indicating the purity of the limestone (t in tons of $CaCO_3$/t ore), and is considered equal to 1, if the purity is not known.

Activity data and other parameters

Disaggregated data on glass production was obtained from the Statistical Yearbook – Non-Metallic Transformation Sector (MME, 2019; 2022b). The production estimates were presented according to the following typologies:

- Glass packaging, used in the beverage sector, in jars and bottles, mainly for beer, in the food sector and, lastly, in the packaging of non-food products (pharmaceuticals and cosmetics);
- Special (technical) glass, including glass wool and fibers (for insulation and the textile industry), glass bricks and blocks, glass electrical insulators, ampoules for thermal bottles, light bulbs, glass for imaging tubes and pharmaceutical vials for medicines;
- Flat glass, made into sheets, used mainly by the construction industry, followed by the automobile industry, the furniture industry and interior design, mainly mirrors; and
- Household glasses, those used in utensils, such as tableware, glassware, cups, and decorative objects, such as vases.

As the data series are interposed in these three publications, the most up-to-date numbers, which are considered to be revised, have always been used. Thus, for annual production data, the following were considered: a) 1997-2001 (MME, 2006); b) 2002-2003 (MME, 2007); c) 2004-2007 (MME, 2009); and d) 2008-2011 (MME, 2012). In this calculation, production from 2002 to 2008 was estimated at 95% of installed capacity for packaging, and 70% for other types.

For the previous years, from 1991 to 1996, the sector's evolution data was used, according to the IBGE-Sidra system (Table 5.8); for 1990, in the absence of other data, the year of 1991 was repeated.

Table 5.8. Percentage change by type compared to the previous year.

IBGE-Sidra	1992	1993	1994	1995	1996	1997
Packaging – % over previous year	67.22	123.95	92.09	131.94	92.92	100.40
Remaining – % over previous year	86.80	129.93	101.34	114.58	113.35	118.02

For glass production from 2012 to 2022 – including glass packaging, technical glass, flat glass and household glass – data from IBGE (2024b) was also used, which shows the variation in the manufacture of glass and glass products (Table 5.9).

Table 5.9. Percentage change by type compared to the previous year.

IBGE-Sidra	2012	2013	2014	2015	2016	2017
% over previous year	-6.7	16.6	-5.6	-4.2	-6.0	3.1
IBGE-Sidra	**2018**	**2019**	**2020**	**2021**	**2022**	
% over previous year	3.7	-1.5	-15.1	15.0	-1.8	

Since the glass production shown includes some recycled glass, this needs to be deducted from the total to arrive at the amount of virgin glass responsible for CO_2 emissions from the calcination of limestone and dolomite. The Yearbooks show packaging recycling percentages for all the years since 1991, and accurate figures for the quantities of packaging recycled in 2005 and 2006: 457,000 t and 448,000 t, respectively. Considering the sector's estimate for these two years in order to extrapolate recycling in the other years, given that recycling is unknown for all types and recognizing that packaging recycling is the largest part, the amount of packaging recycled was taken and divided by the total production. Following the same logic, the recycling percentage was calculated for all the other years, keeping the recycled percentage constant from 2011 onwards. The consolidation of the data can be seen in Table 5.10.

Table 5.10. Production and recycling in the glass industry from 1990 to 2022.

Year	Glass packaging (t)	Packaging recycling	National production (t)	Average glass recycling	Virgin glass production (t)
1990	942,352	15%	1,397,871	10.7%	1,248,299
1991	942,352	15%	1,397,871	10.7%	1,248,299
1992	633,449	18%	1,028,840	11.7%	908,466
1993	785,160	25%	1,298,891	16.0%	1,091,069
1994	723,054	33%	1,243,669	20.3%	991,204
1995	953,997	35%	1,550,518	22.8%	1,197,000
1996	886,454	37%	1,562,611	22.2%	1,215,711
1997	890,000	39%	1,688,000	21.8%	1,320,016
1998	833,000	40%	1,673,000	21.1%	1,319,997
1999	869,000	40%	1,875,000	19.7%	1,505,625
2000	911,000	41%	2,067,000	19.2%	1,670,136
2001	883,000	42%	2,071,000	19.0%	1,677,510
2002	1,039,000	44%	2,412,000	20.1%	1,927,188
2003	970,000	45%	2,389,000	19.4%	1,925,534
2004	958,000	45%	2,571,000	17.8%	2,113,362
2005	969,000	45%	2,623,000	17.6%	2,161,352
2006	973,000	46%	2,318,000	20.5%	1,842,810
2007	1,042,000	47%	2,363,000	22.0%	1,843,140
2008	904,000	47%	2,351,000	19.2%	1,899,608
2009	913,000	47%	2,375,000	19.2%	1,919,000
2010	982,000	47%	2,611,000	18.7%	2,122,743
2011	1,090,000	47%	3,000,000	18.1%	2,457,000
2012	1,016,970	47%	2,799,000	18.1%	2,292,381
2013	1,185,787	47%	3,263,634	18.1%	2,672,916
2014	1,119,383	47%	3,080,870	18.1%	2,523,233
2015	1,072,369	47%	2,951,474	18.1%	2,417,257
2016	1,008,027	47%	2,774,385	18.1%	2,272,222
2017	1,039,276	47%	2,860,391	18.1%	2,342,661
2018	1,077,729	47%	2,966,226	18.1%	2,429,339
2019	1,061,563	47%	2,921,733	18.1%	2,392,899
2020	901,267	47%	2,480,551	18.1%	2,031,571
2021	1,036,457	47%	2,852,634	18.1%	2,336,307
2022	1,017,801	47%	2,801,286	18.1%	2,294,253

According to the Yearbooks, among the components of virgin glass, limestone accounts for 10%, dolomite 2%, and soda ash 15%, on average. Considering these shares, it was possible to calculate the amount of limestone and dolomite used, and the CO_2 emissions related to the calcination of these materials.

Table 5.11. Use of limestone, soda ash and dolomite in the glass industry, from 1990 to 2022.

Year	Use of limestone (t)	Use of dolomite (t)	Use of soda ash (t)
1990	124,830	24,966	187,245
1991	124,830	24,966	187,245
1992	90,847	18,169	136,270
1993	109,107	21,821	163,660
1994	99,120	19,824	148,681
1995	119,700	23,940	179,550
1996	121,571	24,314	182,357
1997	132,002	26,400	198,002
1998	132,000	26,400	198,000
1999	150,563	30,113	225,844
2000	167,014	33,403	250,520
2001	167,751	33,550	251,627
2002	192,719	38,544	289,078
2003	192,553	38,511	288,830
2004	211,336	42,267	317,004
2005	216,135	43,227	324,203
2006	184,281	36,856	276,422
2007	184,314	36,863	276,471
2008	189,961	37,992	284,941
2009	191,900	38,380	287,850
2010	212,274	42,455	318,411
2011	245,700	49,140	368,550
2012	229,238	45,848	343,857
2013	267,292	53,458	400,937
2014	252,323	50,465	378,485
2015	241,726	48,345	362,589
2016	227,222	45,444	340,833
2017	234,266	46,853	351,399
2018	242,934	48,587	364,401
2019	239,290	47,858	358,935
2020	203,157	40,631	304,736
2021	233,631	46,726	350,446
2022	229,425	45,885	344,138

5.3.1.4 Other process uses of carbonates

5.3.1.4.1 Ceramics

Emissions related to the ceramics process result from the calcination of carbonates in clay, as well as the addition of additives. Similar to the cement and lime production processes, carbonates are heated at high temperatures in a kiln, producing oxides and CO_2.

The Tier 1 methodology applies a single composition to the mass of carbonates present in the clay. In this NIR 2024, information was collected on the proportion of calcium (CaO) and magnesium (MgO) oxides, which constitutes Tier 2 methodology, according to Equation 5.6, shown in Dataframe 5.9.

Dataframe 5.9. Equation for estimating CO_2 emissions from calcium carbonate.

Equations	GHG	Categories	Central equation	Reference
Equation 5.6	CO_2	2.A.4	$CO2\ Emissions = (EF_{CaCO3}\ X\ M_{CaCO3}) + (EF_{MgCO3}\ X\ M_{MgCO3})$	Equation 2.15 (IPCC, 2006, v. 3, chap. 2)

In which:

EF$CaCO_3$ is the CO_2 emission factor of calcium carbonate;
M$CaCO_3$ is the mass of calcium carbonate, calculated from the amount of CaO; EF$MgCO_3$ is the CO_2 emission factor of magnesium carbonate; and
M$MgCO_3$ is the mass of magnesium carbonate, calculated from the amount of MgO.

The IPCC (2006) presents a default value of 10% of carbonate content. However, for this Inventory we searched for publications that presented the chemical composition of the clays used in the country. The oxides CaO and MgO are presented in percentages. They originate from limestone and magnesium carbonates, respectively. These carbonates, once calcined, emit CO_2, which is part of the percentage of the so-called "loss on ignition". Based on the percentages of CaO and MgO, the percentages of $CaCO_3$ and $MgCO_3$ are obtained using the atomic weights shown in Table 5.12. The $CaCO_3$/CaO ratio will be obtained by multiplying the percentage of CaO in the sample by 1.785 and the $MgCO_3$/MgO ratio by 2.092.

Table 5.12. Atomic weights of lime and carbonates.

Substance	Atomic weight
CaO	56.08
MgO	40.31
$CaCO_3$	100.09
$MgCO_3$	84.32

Activity data and other parameters

In order to obtain the production of ceramics in Brazil, IBGE data was used (IBGE, 2016). Initially, the information available was from 2005 to 2013.[39] In order to convert to a single unit of mass, the following factors were taken into account:

- NCM – Mercosur Common Nomenclature (Nomenclatura Comum do Mercosul]) code[40] 2342.2030: Glazed ceramic floor or wall tiles (with side greater than or

[39] Table 5809. Production and sales of industrial products and/or services, according to activity classes and products – CNAE National Classification of Economic Activities (Classificação Nacional das Atividades Econômicas) 2222 to 2822 – Prodlist Indústria (Industry Products List) 2013. Link: https://sidra.ibge.gov.br/tabela/5809.
[40] Mercosur Common Nomenclature.

equal to 7 cm) ➔ 16.8 kg/^{2} or 0.0168 t/m^2;

- NCM code 2342.2040 Unglazed ceramic floor or wall tiles (with side greater than or equal to 7 cm) ➔ 16.8 kg/m^2 or 0.0168 t/m^2;
- NCM code 2342.2045 Ceramic mosaic tiles, cubes and similar ceramic products, for mosaics, whether or not glazed (with side less than 7 cm) ➔ 16.8 kg/m^2 or 0.0168 t/m^2;
- NCM code 2342.2050 Ceramic roof tiles ➔ 2.0 kg/unit or 2.0 t/thousand units;
- NCM code 2342.2065 Perforated bricks, beam covers and other ceramic building bricks, except refractory bricks ➔ 2.0 kg/unit or 2.0 t/thousand units; and
- NCM code 2349.2110 Ceramic or porcelain sinks, baths, bidets and similar sanitary ware ➔ 13.0 kg/unit or 13.0 t/thousand units.

As NCM codes 2349.2070 and NCM 2349.2075 were discontinued by the IBGE from 2014 and represent little in relation to the other items, they were disregarded for this Inventory. To complete the series for NCM codes 2342.2010, NCM 2342.2080, NCM 2349.2010, NCM 2349.2045 and NCM 2349.2100, interpolations were made when data was missing for the years of 2006 to 2012; when data was missing for 2005, the same number from 2006 was taken as a reference.

Production as of 2014[41] was also obtained from SIDRA/IBGE, and to complete the series for NCM code 2349.2100, interpolation was made between 2013 (from the previous series) and 2015. Production from 2005 to 2022 is shown in Table 5.13 and Table 5.14. The production in 2022 was an exception, which, due to the unavailability of data, was estimated by extrapolating the production trend observed between 2014-2021.

In order to extrapolate this series to previous years up to 1990, the initial year of the Inventory, a correlation was made between ceramics production and the energy used by the ceramics sector between 2005 and 2022, according to the National Energy Balance (Table A.V.1 and Table A.V.2, Appendix V). In order to cover the continuous improvement of efficiency in the consumption of energy inputs in the sector, an exponential correlation model was chosen (Figure A.V.1, Appendix V). Using this correlation, we were able to obtain the total ceramics production from 1990 to 2004, and to break it down into the 17 categories for the years prior to 2005, we used the average share from 2005 to 2022, referring to production, in terms of mass, as shown in Table A.V.3, of Appendix V. The 17 categories obtained from IBGE/SIDRA were, then, grouped into just four categories, as shown in Dataframe A.V.1 (Appendix V).

Thus, the annual production for the four subcategories was obtained, which can be seen in Table 5.15.

[41] Table 6705 – Production and sales of industrial products and/or services, according to activity classes and products - Prodlist Indústria. Link https://sidra.ibge.gov.br/tabela/6705.

Table 5.13. Total ceramics production table by NCM, in tons, from 2005 to 2013.

NCM code	2005	2006	2007	2008	2009	2010	2011	2012	2013
2341.2025	8,578	11,205	38,460	36,461	36,111	15,200	14,078	14,271	29,009
2341.2040	332,545	771,620	885,454	1,137,516	632,375	855,875	1,038,425	448,605	452,169
2342.2010	898	898	1,764	1,290	816	1,092	492	714	935
2342.2030	8,968,013	9,785,001	10,011,188	11,296,512	10,984,223	12,621,184	14,009,544	14,589,073	14,637,828
2342.2040	100,987	74,725	189,347	171,102	358,327	266,666	271,493	296,532	242,867
2342.2045	314,770	313,909	488,282	311,893	452,796	590,437	546,478	325,321	253,475
2342.2050	3,272,646	4,569,920	4,024,140	4,438,102	4,625,378	4,833,174	5,241,092	4,859,466	5,075,088
2342.2065	6,374,466	7,764,682	8,026,712	9,353,462	8,959,064	10,144,398	10,609,710	11,937,622	13,853,984
2342.2080	49,228	47,041	49,448	56,298	63,149	12,049	15,484	6,718	5,331
2349.2010	742	1,193	6,780	3,267	3,025	2,783	16,371	20,990	18,225
2349.2030	32,165	31,913	44,068	22,214	18,210	26,856	38,993	32,601	51,586
2349.2045	123	8,895	846	3,691	2,294	2,313	2,313	2,332	460
2349.2050	13,633	16,746	19,243	47,641	44,468	37,544	31,132	37,256	41,579
2349.2080	2,721	2,859	3,376	1,097	1,078	1,026	1,111	1,557	5,039
2349.2090	34,459	36,171	32,811	32,065	30,232	42,482	39,569	23,529	18,596
2349.2100	1,979	1,979	981	859	852	845	3,955	4,079	4,204
2349.2110	307,970	347,568	332,059	282,503	276,055	314,535	342,238	415,961	455,234
Total	**19,815,923**	**23,786,326**	**24,154,959**	**27,195,973**	**26,488,453**	**29,768,460**	**32,222,478**	**33,016,625**	**35,145,611**

Table 5.14. Total ceramics production by NCM, in tons, from 2014 to 2022.

NCM code	2014	2015	2016	2017	2018	2019	2020	2021	2022
2341.2025	31,450	27,496	6,808	5,149	8,267	11,820	0	35,756	31,438
2341.2040	480,690	359,673	3,667,425	1,950,287	4,288,077	3,932,982	4,206,478	5,270,232	4,633,844
2342.2010	595	385	490	550	704	843	2,001	2,069	1,819
2342.2030	15,126,268	14,772,640	13,464,749	13,434,915	13,995,959	13,745,734	12,787,700	15,808,336	13,899,457
2342.2040	310,599	443,802	543,609	579,811	521,898	1,300,739	1,678,606	1,186,194	1,042,959
2342.2045	292,343	295,162	166,205	96,101	116,790	118,363	109,512	54,421	47,850
2342.2050	6,045,664	5,765,134	5,488,932	4,899,306	3,528,860	3,907,692	3,738,462	4,523,130	3,976,956
2342.2065	16,460,558	14,695,994	11,338,594	10,349,708	10,585,996	12,973,184	9,385,766	11,792,074	10,368,164
2342.2080	3,297	2,216	1,279	2,533	1,526	5,553	6,048	470,550	413,730
2349.2010	11,699	14,894	8,204	5,098	5,753	14,642	17,271	29,441	25,886
2349.2030	87,573	53,311	63,831	104,424	68,535	63,831	67,637	85.457	75,138
2349.2045	6,550	801	1,241	855	0	4,627	8,373	3,476	3,056
2349.2050	50,731	38,539	0	37,107	39,044	430,364	406,410	622,978	547,753
2349.2080	5,846	6,772	4,268	66,579	112,008	0	480,865	587,604	516,650
2349.2090	21,074	22,986	18,965	87,887	35,876	75,178	55,936	45,779	40,251
2349.2100	3,477	2,750	2,558	4,767	5,922	1,446	1,319	1,905	1,675
2349.2110	468,806	519,480	455,039	398,619	339,599	369,629	309,283	448,734	394,549
Total	**39,407,220**	**37,022,034**	**35,232,196**	**32,023,697**	**33,654,814**	**36,956,627**	**33,261,667**	**40,968,136**	**36,021,175**

Table 5.15. Total ceramics production by type, in thousand tons, from 1990 to 2022.

Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Red ceramics	5,146	5,125	5,290	5,909	6,193	6,339	6,996	7,631	8,013	8,259	8,777	8,777
Ceramic tiles	4,059	4,043	4,172	4,661	4,885	5,000	5,518	6,019	6,321	6,514	6,923	6,923
Tableware	98	98	101	113	118	121	134	146	153	158	168	168
Sanitary ware	111	110	114	127	133	136	151	164	172	178	189	189
Total	**9,414**	**9,376**	**9,677**	**10,811**	**11,330**	**11,596**	**12,798**	**13,960**	**14,660**	**15,109**	**16,057**	**16,057**
Type	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Red ceramics	9.220	9,678	10,212	10,039	13,167	13,033	15,026	14,320	15,865	16,936	17,288	19,435
Ceramic tiles	7,273	7,634	8,055	9,384	10,174	10,689	11,780	11,795	13,478	14,828	15,211	15,134
Tableware	176	185	195	85	99	101	108	97	111	117	101	121
Sanitary ware	198	208	220	308	348	332	283	276	315	342	416	455
Total	**16,868**	**17,706**	**18,683**	**19,816**	**23,786**	**24,155**	**27,196**	**26,488**	**29,768**	**32,222**	**33,017**	**35,146**
Type	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**			
Red ceramics	23,034	20,866	20,512	17,213	18,419	20,847	17,356	22,123	19,452			
Ceramic tiles	15,729	15,512	14,175	14,111	14,635	15,165	14,576	17,049	14,990			
Tableware	175	125	91	302	261	575	1,021	1,347	1,185			
Sanitary ware	469	519	455	399	340	370	309	449	395			
Total	**39,407**	**37,022**	**35,232**	**32,024**	**33,655**	**36,957**	**33,262**	**40,968**	**36,021**			

The emission factors follow the stoichiometric ratio shown in Table 5.16.

Table 5.16. Emission factors for carbonates.

Emission factor	unit
0.440	t CO_2/t $CaCO_3$
0.522	t CO_2/t $MgCO_3$

Thus, as long as you have the amounts of CaO and MgO oxides in the clay, you can calculate the CO_2 emitted in the manufacture of ceramics, in terms of t CO_2/t clay consumed. For the amounts of CaO and MgO oxides in clay, 20 studies were obtained, with 32 state references, as shown in Table A.V.4 (Appendix V).

For the sake of simplicity, we worked on an average per region, with the North region, with no identified works, being made the same as the Northeast region. The emission factors by state are in the right-hand column (Table A.V.4, Appendix V), with the 110% factor built in, and these are taken into account when calculating the sector's emissions.

Finally, as the goal was to obtain the total emission from the emissions by state, it was necessary to know the share of each state in the four categories summarized above. The distributions were obtained from the Statistical Yearbook of the Non-Metallic Transformation Sector (MME, 2022b).

5.3.1.4.2 Other uses of soda ash

Soda ash (neutral sodium carbonate, Na_2CO_3) is used as a consumable material in many industries, including in the manufacturing of glass, soaps and detergents, paper and pulp production and water treatment. CO_2 is emitted from the use of soda ash and can be emitted during its production, depending on the industrial process used to make it. Four different processes can be used commercially to produce soda ash. Three of them are referred to as natural processes and use trona as a basic consumable material. The fourth one, the Solvay process, is classified as a synthetic process.

Natural processes are the only ones known to produce CO_2 emissions during the manufacturing of soda ash. Brazilian production, which was discontinued from 2002 onwards, used the synthetic process and, therefore, no net emissions were produced from that year onwards.

In terms of the methodology for estimating emissions, the same steps listed in section 5.3.1.3 are followed.

Activity data and other parameters

In order to determine soda ash consumption, it is necessary to survey the production, import and export of the product. Abiquim's Yearbooks (1995, 1997, 2000, 2005, 2008, and 2012) were used as a source of information, with statistics up to 2014. From 2015 onwards, in the absence of updated data, imports were extrapolated based on data from 2010 to 2014, and exports in 2014 were considered constant until 2022.

Table 5.17 shows the production, import, export and consumption of soda ash considered in the emissions estimate. To avoid double counting, the amounts of soda ash consumed in glass production, already reported in Table 5.11, were deducted from the values in the consumption column, in order to calculate CO_2 emissions.

Table 5.17. Production, export, import and consumption of soda ash, 1990 to 2022.

Year	Production	Import	Export	Consumption
	t			
1990	195,893	242,788	0	438,681
1991	207,607	253,610	0	461,217
1992	220,596	179,785	0	400,381
1993	231,390	218,954	10	450,334
1994	219,471	231,827	255	451,043
1995	203,950	392,071	2	596,019
1996	211,043	306,932	9	517,966
1997	206,273	334,398	3	540,668
1998	201,866	358,459	4	560,321
1999	208,834	352,073	4	560,903
2000	190,616	393,845	4	584,457
2001	194,837	430,797	400	625,234
2002	-	424,780	609	424,170
2003	-	471,938	558	471,381
2004	-	473,063	1	473,062
2005	-	597,888	2	597,886
2006	-	742,140	2	742,139
2007	-	804,105	2,192	801,913
2008	-	861,195	20	861,175
2009	-	770,854	560	770,294
2010	-	954,675	47	954,629
2011	-	904,506	602	903,904
2012	-	1,062,560	704	1,061,856
2013	-	1,041,162	4,810	1,036,352
2014	-	1,237,081	1,302	1,235,779
2015	-	1,250,438	1,302	1,249,136
2016	-	1,320,585	1,302	1,319,283
2017	-	1,390,732	1,302	1,389,430
2018	-	1,460,879	1,302	1,459,577
2019	-	1,531,026	1,302	1,529,724
2020	-	1,601,173	1,302	1,599,871
2021	-	1,671,320	1,302	1,670,018
2022	-	1,741,467	1,302	1,740,165

5.3.1.4.3 Non-metallurgical magnesium production

Magnesium oxide (MgO), or magnesia, is produced by mining and calcining magnesite (magnesium carbonate, $MgCO_3$). It is also possible to obtain it from other minerals, notably dolomite, or directly from brines and seawater.

As an input, it is used: a) in refractory coatings; b) in agriculture, as a corrective, fertilizer and feed additive; c) in metallurgical plants, in aluminum alloys; d) in the chemical industry, to obtain magnesium compounds; and e) in civil construction, in sorel cement and in sheets to replace drywall, among dozens of other applications (MME, 2020a).

The steel industry is the main consumer of refractories, absorbing approximately 70% of refractory production in terms of volume. Other industries with a high aggregated consumption of refractories are iron and steel foundries, non-ferrous metallurgy, such as aluminum, cement and lime, glass, chemicals and others (MME, 2020a).

CO_2 emissions are calculated from the amount of calcined magnesite, with an emission factor of 0.52197 t CO_2/t magnesite, the IPCC (2006) default emission factor. Since there is no information on the purity of the ore, a reduction factor was not applied.

Activity data and other parameters

To obtain the amount of processed magnesite (apparent consumption in the country), the amount imported must be added to national magnesite production, and the amount exported must be subtracted.

From 1990 to 1998, data on the production, import and export of processed magnesite was obtained from the Brazilian Mineral Balance 2001 (BRASIL, 2001). From 1999 onwards, data was obtained from various editions of the Mineral Summary (MME, 2019). Given the lack of updated data, the figures presented in MME (2020b) in 2019 were considered constant for the period from 2020 to 2022.

Table 5.18. Production, exports, imports and consumption of processed magnesite, 1990 to 2022.

Year	Production	Import	Export	Apparent consumption
	t			
1990	345,415	1,873	92,408	254,880
1991	337,306	2,570	40,735	299,141
1992	284,357	4,618	107,837	181,138
1993	232,683	3,513	78,832	157,364
1994	279,489	16,580	93,041	203,028
1995	315,978	87,014	141,515	261,477
1996	316,697	133,561	94,181	356,077
1997	497,624	126,043	92,403	531,264
1998	342,485	121,967	88,092	376,360
1999	259,834	67,173	46,718	280,289
2000	279,876	79,930	7,590	352,216
2001	265,749	7,609	56,657	216,701

Year	Production	Import	Export	Apparent consumption
	t			
2002	302,230	7,443	67,727	241,946
2003	306,444	9,331	37,948	277,827
2004	366,174	8,013	98,440	275,747
2005	386,759	13,293	63,625	336,427
2006	382,718	15,247	88,168	309,797
2007	399,314	17,562	98,838	318,038
2008	421,333	19,871	124,031	317,173
2009	409,909	16,443	129,245	297,107
2010	483,882	52,147	148,649	387,380
2011	476,805	57,812	157,267	377,350
2012	479,304	52,643	159,794	372,153
2013	1,388,866	58,449	172,574	1,274,741
2014	1,423,211	83,837	485,527	1,021,521
2015	1,621,425	278,875	388,290	1,512,010
2016	1,652,424	148,435	428,211	1,372,648
2017	2,034,000	148,435	428,211	1,754,224
2018	1,700,000	148,435	428,211	1,420,224
2019	1,700,000	148,435	428,211	1,420,224
2020	1,700,000	148,435	428,211	1,420,224
2021	1,700,000	148,435	428,211	1,420,224
2022	1,700,000	148,435	428,211	1,420,224

5.3.2 Quality assurance and quality control

The QA/QC procedures adopted for the Metal Industry subsector (2.A) are described in section 2.5 of this document.

5.3.3 Assessment of uncertainty, consistency and recalculations of the time series

Uncertainty analysis was carried out using the random sampling methods and techniques described in the 2006 IPCC Guidelines. The uncertainty associated with CO_2 emissions from the Mineral Industry (2.A) is presented in Appendix II.

The process of updating the national inventory took into account the revision of the time series for activity data in light of the publication of updated documents covering production, exports and imports of products of the Mineral Industry subsector segments. In summary, the main adjustments stem from:

- *Cement (2019-2020):* revision of clinker and cement production;
- *Lime (2019-2020):* revision of lime production;
- *Glass (2018-2020):* revision of production by type of glass, as well as the associated use of limestone, soda ash and dolomite;

- *Ceramics (2017-2020):* revision of the production of different ceramic products, as well as energy consumption by the sector; and
- *Processed magnesite (2018-2019):* revision of production, imports and exports (BRASIL, 2022).

Comparing the consolidated results of the previous Inventory with the one carried out for this NIR 2024, the largest proportion of adjustments is seen in 2020, with a 1.5% difference between estimated emissions. In fact, in the previous edition of the Inventory (BRASIL, 2022), which covered emissions from 1990 to 2020, the unavailability of data in the SIDRA/IBGE database, the main reference for Mineral Industry activity data, required extrapolations, particularly for the 2019-2020 biennium. Between 2017 and 2020, the average adjustment in aggregate emissions was only 0.12%, and in the period from 1990 to 2020, it was 0.02%, which demonstrates the consistency of the sector's time series (Figure 5.4).

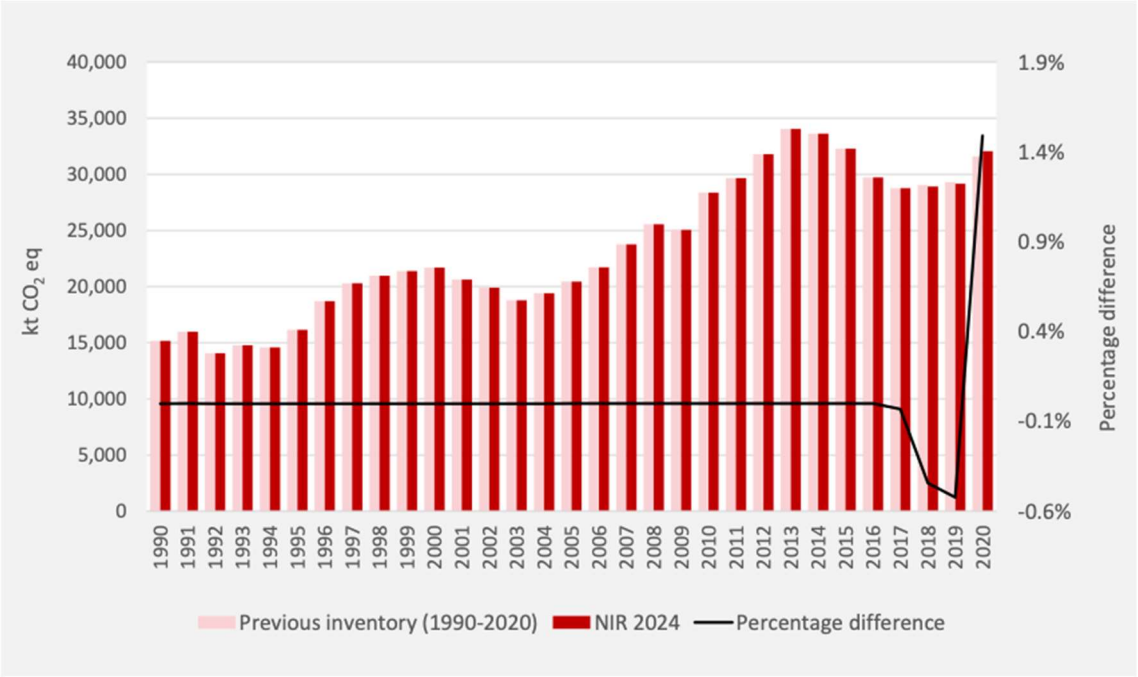


Figure 5.4. Comparison of estimated emissions from the Mineral Industry subsector (2.A) between inventories.

5.3.4 Improvement plan

The experience gained in the periodic preparation of national GHG inventories has led to the proposal of a series of measures to improve the consistency and greater detailing of the results of the Inventory, particularly in the Mineral Industry (2.A). Dataframe 5.10 summarizes the potential improvements for implementation in future editions of the inventory for this subsector.

Dataframe 5.10. Potential improvements applicable to improving the emissions inventory for the Mineral Industry subsector (2.A).

Subsector	Category	Improvement
2.A. MINERAL INDUSTRY	General (all categories)	▪ Establish Technical Cooperation Agreements or partnerships with Sectoral Associations with a view to promoting the systematic collection and gathering of activity data for the preparation of the Inventory on a biennial basis. ▪ Establish Technical Cooperation Agreements or partnerships with governmental entities in order to encourage the annual production of sectoral production statistics to be made available on the SIDRA database.
	2.A.1. Cement Production	▪ Deepen the studies to evaluate data on CaO and MgO contents that make up clinker production per plant, the amount of clinker produced per plant, the quantity of cement produced by type and mineral compounds, such as plaster, limestone, slag, fly ash, pozzolan and CKD used to produce cement.
	2.A.2. Lime production	▪ Establish Technical Cooperation Agreements or partnerships with a view to encouraging the annual production of sectoral production statistics to be made available nationally.
	2.A.3. Glass production	▪ Establish partnerships with a view to encouraging the systematic production of the Non-Metallic Transformation Sector Yearbooks. ▪ Evaluate studies on annual recycling data by type of glass.
	2.A.4. Other Process Uses of Carbonates	▪ Establish partnerships with a view to encouraging the systematic production of the Non-Metallic Transformation Sector Yearbooks. ▪ Evaluate the possibility of establishing partnerships with ceramics sector associations with a view to encouraging the updating of emission factors and shares by subcategory of production at sub-national level.

5.4 Chemical Industry (CRT 2.B)

In the Chemical Industry subsector (2.B), emissions result from its production processes. The categories estimated in the Inventory were: Ammonia Production (2.B.1); Nitric Acid Production (2.B.2); Adipic Acid Production (2.B.3); Caprolactam, Glyoxal and Glyoxylic Acid Production (2.B.4); Carbide Production (2.B.5); Petrochemical and Carbon Black Production (2.B.8); and Fluorochemical Production (2.B.9). Titanium Dioxide Production (2.B.6) does not emit GHG due to the technological route used in the country. For the Soda Ash Production category (2.B.7), there was no verified production activity during the inventory period.

In 2022, the Chemical Industry emitted 7,021 kt CO_2 eq, which corresponded to 9% of IPPU emissions, with a 2% reduction compared to 2020 (Figure 5.5). The Petrochemical and Carbon Black Production category (2.B.8) was the most representative and accounted for 95% of the subsector's total (2.B). Next, emissions from Ammonia Production (2.B.1), Nitric Acid Production (2.B.2) and Carbide Production (2.B.5) were the most representative, with 2%, 2% and 1%, respectively.

Between 2020 and 2022, among emissions from the Chemical Industry subsector (2.B), CO_2 fell by 2%, CH_4 by 4%, and NO_x by 8%. On the other hand, N_2O emissions increased by 1%, NMVOC by 2%, and CO by 15%.

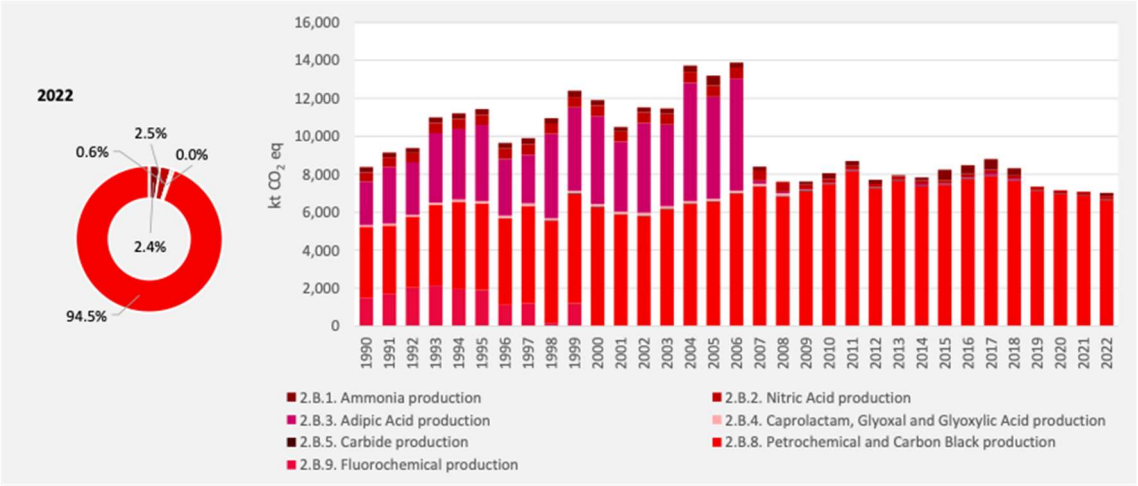


Figure 5.5. Emissions from the Chemical Industry (2.B), in kt CO_2 eq by category, from 1990 to 2022.

With regard to CO_2, the main emitting category throughout the period was Petrochemical and Carbon Black Production (2.B.8), which in 2022 accounted for 97% of emissions of this gas in this subsector. In this category, emissions from ethylene production stood out (77% of the category).

In the case of CH_4, the total emissions referred to the Petrochemical and Carbon Black Production category (2.B.8), with emphasis on ethylene production (92% of the category). N_2O emissions came from the Nitric Acid Production (2.B.2) and Adipic Acid Production (2.B.3) categories, which accounted for 99% and 1% in 2022, respectively.

With regard to CO, emissions were related to the Adipic Acid Production category (2.B.3). NO_x emissions came from Nitric Acid Production (2.B.2), Adipic Acid Production (2.B.3) and Petrochemical and Carbon Black Production (2.B.8), with 68%, 28% and 4%, respectively in 2022. Lastly, NMVOC emissions came from the Other Chemicals category (2.B.10), and Petrochemical and Carbon Black Production (2.B.8), with shares of 81% and 19%, respectively in 2022.

5.4.1 Methodological aspects

The methodologies applied to estimate CO_2, N_2O, and CH_4 emissions from chemical industrial processes followed the IPCC (2006). Emissions of CO, NO_x and NMVOC were estimated through the IPCC (1997).

Data on chemicals production was obtained from SIDRA/IBGE (IBGE, 2024b) and Abiquim Statistical Yearbooks (ABIQUIM, 1993; 1997; 2000; 2005; 2008; 2009; 2012; 2013; 2016; 2020), a publication coordinated by the Association that brings together chemicals manufacturers in the country. The data from 2017 to 2022 was obtained through direct contact with Abiquim (ABIQUIM, 2024), and the information received is kept confidential, which is a condition for its provision.

5.4.1.1 Ammonia production

Ammonia is one of the basic chemicals, produced in large quantities, used as a source of nitrogen. It is a feedstock for the manufacture of urea, the main nitrogen fertilizer, and for

nitric acid production, an intermediate in the production of ammonium nitrate fertilizer and explosive ammonium nitrate.

According to the IPCC (2006) methodology, CO_2 emissions from ammonia production should be deducted only from the part used to manufacture urea, which was accounted for under the use of this fertilizer in the Agriculture sector.

For CO_2 emissions, Tier 3 was applied, according to IPCC (2006), with the measurement of fuels used as feedstocks in the process by the companies themselves. Due to industrial secrecy, the factories have not disclosed this basic data, but can only indicate the average emission factors for three of the existing routes in the country:

- Asphalt waste: 2.0 t of CO_2/t of ammonia;
- Refinery gas: 1.3 t of CO_2/t of ammonia; and
- Natural gas: 1.2 t of CO_2/t of ammonia.

Considering the feedstocks used in Brazil and their respective emission factors shown above, an average value was obtained for the national emission factor of 1.46 t of CO_2/t of ammonia, which was applied to all years from 1990 to 2022 in the NIR 2024.

In order to deduct the CO_2 used for urea production, the same emission factor of 0.20 t C/t urea adopted in the Agriculture sector was used, according to the IPCC (2006) default value associated with the conversion of C to CO_2 with a factor of 44/12.

Activity data and other parameters

Ammonia production data was provided by Abiquim for the period from 1990 to 2022, and confidentiality was requested for data from 2017 to 2022. As for urea production, the SIDRA/IBGE database provides data from 2005 to 2022. For the previous years, an average correlation was made with the amount of ammonia produced between 2005 and 2007, and, then, applying it from 1990 to 2004. Table 5.19 shows the ammonia and urea production in the country.

Table 5.19. Ammonia and urea production, 1990 to 2022.

Year	*Ammonia production*	*Urea production*
	t	*t*
1990	1,152,563	1,904,707
1991	1,012,110	1,672,596
1992	1,038,436	1,716,102
1993	1,153,336	1,905,984
1994	1,156,830	1,911,758
1995	1,222,348	2,020,032
1996	1,201,047	1,984,831
1997	1,252,722	2,070,228
1998	1,176,431	1,944,151
1999	1,331,113	2,199,775
2000	1,139,109	1,882,473

Year	*Ammonia production*	*Urea production*
	t	*t*
2001	955,998	1,579,867
2002	1,073,161	1,773,488
2003	1,157,575	1,912,989
2004	1,324,479	2,188,812
2005	1,316,154	1,908,586
2006	1,347,748	2,331,134
2007	1,278,118	2,272,463
2008	1,240,527	2,659,423
2009	1,079,145	1,919,919
2010	1,191,042	1,967,508
2011	1,366,231	2,346,966
2012	1,204,377	2,111,578
2013	1,236,209	2,379,181
2014	1,107,156	1,979,452
2015	1,423,005	2,076,816
2016	1,327,214	2,020,461
2017	C	1.560.869
2018	C	2,081,138
2019	C	1,647,462
2020	C	1,094,523
2021	C	1,716,854
2022	C	1,417,773

Sources: Based on Abiquim (2017; 2024) and SIDRA/IBGE (2017; 2024b). Notation: C – Confidential.

5.4.1.2 Nitric Acid Production

Nitric acid (HNO_3) is an inorganic compound used mainly in the manufacture of Inorganic N Fertilizers. It is the most important compound as an input in the manufacture of adipic acid, as an intermediate in the production of concentrated nitric acid, as a nitrating agent for organic compounds and in the manufacture of explosives.

Different methods were used for N_2O emissions, depending on the plant and only for plants that emit N_2O.

For those plants that have carried out CDM projects,[42] it was possible to apply the most accurate method, Tier 3 of IPCC (2006). This method uses data from direct measurements that result in specific emission factors for each plant. For the others, the Tier 1 method was used, by applying the IPCC (2006) default emission factors.

The emission factors used in the estimates are open by type of technology and indicated as default or measured values:

- Low pressure plants: 4.89 kg N_2O /t HNO_3 – measured value.
- Medium pressure plants:

[42] Fosfertil's plants: PAN2 and PAN4, and Rhodia's plant: Paulínia (UNFCCC, 2024).

  - 8.14 kg of N_2O/t HNO_3 – measured value.
  - 6.01 kg N_2O/t HNO_3 – measured value.
  - 7.00 kg N_2O/t HNO_3 – default value (IPCC, 2006).
- Vacuum plants: 5 kg N_2O/t HNO_3 – default value (IPCC, 2006).

After July 2007, with the implementation of a CDM project in a medium pressure plant, the measured emission factor of this plant was reduced from 6.01 kg N_2O/t HNO_3 to 0.52 kg N_2O/t HNO_3, indicating a reduction in GHGs in this process.

For NO_x emissions, an emission factor of 1.75 kg NO_x /t HNO_3 was applied to the entire production of nitric acid. This value is below the default value adopted by the IPCC, which is 12 kg NO_x /t HNO_3 (1997), in view of the control of emissions of these gases in the country.

In the unit that uses high-pressure technology, integrated with ammonia production, nitrogen oxides, including N_2O, are destroyed in a system that uses fuel combustion.

Activity data and other parameters

The total production of nitric acid was provided by Abiquim for the period from 1990 to 2022, and confidentiality was requested for the data from 2017 to 2022. In the case of production that emits N_2O, data from Abiquim (2017) up to 2007 was used, and emissions from 2008 to 2022 were estimated based on CDM projects (UNFCCC, 2024).

Table 5.20. Nitric acid production, 1990 to 2022.

Year	Total nitric acid production	Nitric acid production that emits N_2O
	t	t
1990	389,426	295,824
1991	404,823	313,909
1992	398,608	310,526
1993	416,789	325,567
1994	554,265	326,489
1995	574,216	332,842
1996	612,031	335,850
1997	611,729	343,127
1998	532,949	332,560
1999	525,011	335,069
2000	540,087	336,025
2001	619,759	331,805
2002	641,626	346,225
2003	539,844	349,566
2004	559,918	357,524
2005	612,609	363,422
2006	601,618	355,706
2007	594,336	356,661
2008	580,386	390,832
2009	577,555	423,757
2010	558,078	360,083

Year	Total nitric acid production	Nitric acid production that emits N_2O
	t	t
2011	546,028	352,060
2012	492,408	311,591
2013	480,076	312,725
2014	522,626	308,731
2015	517,350	302,939
2016	505,675	305,910
2017	C	314,297
2018	C	315,323
2019	C	313,279
2020	C	312,504
2021	C	320,007
2022	C	320,007

Sources: Based on Abiquim (2017; 2024) and UNFCCC (2024). Notation: C – Confidential.

5.4.1.3 Adipic Acid Production

Adipic acid is a white crystalline solid that is used as an intermediate in the manufacture of synthetic fibers, plastics, polyurethanes, elastomers and synthetic lubricants. Commercially, it is the most important aliphatic dicarboxylic acid, used in the manufacture of polyester and nylon 6.6.

The only adipic acid plant in Brazil uses the two-stage production technology, with the second stage emitting nitrous oxide (N_2O). At the end of 2005, a CDM project for the destruction of N_2O from this plant was registered with the UNFCCC, which took place from 2007 onwards. An installation has been built dedicated to the high-temperature conversion of nitrous oxide into nitrogen, in the process of thermal decomposition of this GHG.

For N_2O emissions, the most accurate method was applied, Tier 3 from IPCC (2006). This method uses the plant's own production data and the emission factor is measured directly by periodic sampling. These measurements were taken for the CDM project, which requires measured data for its implementation. Thus, nitrous oxide emissions were measured for a certain period, which reflected the plant's usual operating pattern.

The emission factor measured corresponds to 0.270 t N_2O/t adipic acid and was applied to the period from 1990 to 2006. After implementing the CDM project, there was a significant reduction in emissions, and the implicit emission factor, also obtained by measurements, varied from 0.00640 t N_2O/t adipic acid to 0.00155 t N_2O/t adipic acid.

With regard to precursor GHGs, they were estimated using national emission factors, due to the control of emissions of these gases in the country. Carbon monoxide (CO) emissions were estimated using a factor of 16 kg CO/t adipic acid, and for NO_x emissions, the emission factor of 5 kg NO_x/t adipic acid was applied.

Activity data and other parameters

Table 5.21 provides a summary of the national production of adipic acid. The data comes from Abiquim up to 2007 and, from 2008 onwards, from the CDM reports (UNFCCC, 2024).

It should be noted that given the unavailability of monitoring reports for 2021 and 2022, the production verified in 2020 was applied to those years.

Table 5.21. Adipic acid production, 1990 to 2022.

Year	Adipic acid production
	t
1990	31,951
1991	41,676
1992	38,538
1993	51,264
1994	51,825
1995	55,864
1996	41,554
1997	35,767
1998	62,055
1999	61,572
2000	64,862
2001	51,486
2002	65,931
2003	59,979
2004	86,958
2005	75,147
2006	82,614
2007	88,808
2008	85,021
2009	87,196
2010	86,286
2011	85,813
2012	64,792
2013	63,337
2014	51,257
2015	46,643
2016	44,428
2017	65,582
2018	59,088
2019	59,265
2020	51,563
2021	51,563
2022	51,563

Sources: Based on Abiquim (2017; 2024) and UNFCCC (2024).

5.4.1.4 Caprolactam production

The primary industrial use of caprolactam is as a monomer in the production of nylon-6. This chemical is also used in the manufacture of plastics, bristles, films, coverings, carpets,

synthetic leather, plasticizers and automotive paints. One of its characteristics is that it is biodegradable and achieves up to 94% removal of chemical oxygen demand in activated sludge systems. Brazil had a plant dedicated to the production of these products, which closed down in 2009. Furthermore, the country does not produce glyoxal and glyoxylic acid.

Brazilian caprolactam production starts with the hydrogenation of benzene to cyclohexane, oxidation to cyclohexanol and cyclohexanone with nitric acid, a stage in which nitrous oxide is generated, followed by dehydrogenation of the cyclohexanol produced and subsequent reaction with sulphate.

For N_2O emissions, the IPCC 2006 Tier 3 method was applied. This method uses the N_2O measurements made by the plants (ABIQUIM, 2015). The average emission factor resulting from these measurements, applied to the entire period, was 6 kg N_2O/t caprolactam.

Activity data and other parameters

Table 5.22 shows the national production of caprolactam, and the null value from 2010 onwards is due to the closure of the plant.

Table 5.22. Caprolactam production, 1990 to 2022.

Year	Caprolactam production
	t
1990	42,059
1991	47,193
1992	41,699
1993	50,824
1994	50,838
1995	52,608
1996	54,712
1997	56,024
1998	42,973
1999	50,498
2000	56,005
2001	48,550
2002	57,519
2003	48,847
2004	50,472
2005	49,655
2006	44,906
2007	49,592
2008	55,395
2009	13,282
2010 - 2022	0

Sources: Based on Abiquim (2017).

5.4.1.5 Carbide Production

Calcium carbide (CaC_2) is produced by calcining limestone ($CaCO_3$) and subsequently reducing the lime (CaO) with petroleum coke or charcoal. These two types of reducing agents are used in Brazil.

Both the calcination and reduction processes emit CO_2. The use of feedstocks such as petroleum coke and charcoal in the production process of CaC_2 generates emissions of carbon monoxide (CO) and CO_2, but only emissions from the fossil reducer – petroleum coke – are considered in this Inventory, and emissions from the use of charcoal are considered to be renewable. In Brazil, CO gas is reused for energy purposes.

Around 67% of the carbon contained in petroleum coke is retained in the final product (CaC_2), but the applications of CaC_2 produced in Brazil end up resulting in more emissions. They are:

- Steelmaking applications: steel desulphurization in Brazil and abroad; and
- Acetylene production in Brazil and abroad.

Therefore, the carbon stored in CaC_2 ends up being emitted as CO_2 when used.

CO_2 emissions were estimated using the Tier 1 method (IPCC, 2006), with petroleum coke consumption data to estimate the emissions associated with calcium carbide production. For emissions related to carbide consumption (e.g., application in steelmaking and acetylene manufacturing), the quantity produced has been reduced by a small part that is exported, estimated at 15%, for all the years of the report. In both cases, the default emission factors are applied: 1.7 t CO_2/t coke consumed in the process and 1.10 t CO_2/t CaC_2 consumed.

Activity data and other parameters

Data on fuel production and use is confidential (WHITE MARTINS, 2010). Therefore, emissions from 2011 onwards were assumed to be in line with production in 2010, which was 53,604 t.

5.4.1.6 Petrochemical and Carbon Black Production

The petrochemical industry uses fossil fuels such as natural gas or refinery products like naphtha, for example, as feedstocks. The same occurs in the production process of carbon black, although it is not considered a petrochemical product.

Activity data and other parameters

The production data for petrochemical and carbon black production was provided by Abiquim, although confidentiality was requested.

5.4.1.6.1 Methanol

The main use of methanol is in the production of formaldehyde used in the production of resins for use in the furniture and plywood industry. It is also used in the production of biodiesel, although in this application methanol is recyclable.

Methanol production technologies need hydrogen (H), carbon monoxide (CO) and carbon dioxide (CO_2). In Brazil, the process used until 2016 was low- and high-pressure synthesis, for which the feedstocks are natural gas (CH_4) and carbon dioxide (CO_2). The plant was closed down in July 2016, so emissions from 1990 to 2016 are estimated.

The main GHGs emitted are CO_2 and CH_4. CO_2 emissions were estimated using the IPCC (2006) Tier 1 method. This method uses national methanol production data and applies the default emission factor of 0.267 t CO_2/t methanol, taking into account the process used in Brazil. CH_4 emissions also used the Tier 1 method, with an emission factor of 2.3 kg CH_4/t methanol.

5.4.1.6.2 Ethene (or Ethylene)

Ethylene is the primary hydrocarbon produced in the largest quantity in the country and one of the main ones in the petrochemical industry's value chain. It is used in the production process of plastics, including high- and low-density polyethylenes, polyvinyl chloride, and is also used as a feedstock for the manufacture of vinyl chloride, ethylene oxide, ethylbenzene and dichloroethane.

It is usually produced by cracking petrochemical feedstocks. The production of ethylene also generates propylene, butadiene and aromatic compounds as secondary substances. The technological route used in Brazil is the traditional naphtha cracking process, but in 2004 natural gas was introduced for the first time as a feedstock for the pyrolysis process.

Since 2010, the chemical industry has incorporated ethanol as a feedstock for the production of ethylene: ethanol, and, therefore, the product derived from ethanol ethylene, polyethylene, sequesters carbon, considering the life cycle approach.

The main gases emitted are carbon dioxide (CO_2) and methane (CH_4), as well as NMVOC.

CO_2 emissions were estimated using the IPCC (2006) Tier 1 method. This method uses national ethylene production data and applies the default emission factor of 1.73 kg CO_2/t ethylene. According to the methodology, the emissions calculated with this factor must be corrected, in the case of South America, by a factor of 1.1 to correct for the mix of production from the steam cracking process line, which includes, in addition to ethylene, propylene, butadiene, aromatics and other chemicals.

CH_4 emissions also used the Tier 1 method, with an emission factor of 3 kg CH_4/t ethylene, which was applied until 2005.

As of 2006, with the start of the operation of the plant that uses natural gas, the factors were calculated based on plant-specific measurements of the consumption of fossil feedstocks. For CO_2, the emission factors from 2006 onwards became 1.74 kg CO_2/t ethylene, while for CH_4 they were 3.54 kg CH_4/t ethylene between 2006 and 2009 and 3.25 kg CH_4/t ethylene from 2010 onwards.

For precursor greenhouse gases, the IPCC (1997) default emission factor of 1.4 kg NMVOC/t ethylene was used.

5.4.1.6.3 Dichloroethane and Vinyl Chloride (MVC)

Dichloroethane (1,2 dichloroethane) is a chlorinated hydrocarbon that appears as a light-colored oily liquid with a sweet chloroform smell. It is used as an intermediate in the

production of Vinyl Chloride (MVC), solvents, polychlorinated hydrocarbons, ethylene glycol and others. It is also used as a solvent for greases, oils and fats, industrial cleaning, a fuel additive and in solvent formulations, among other uses.

The production of MVC and dichloroethane in Brazil uses the technological route of direct chlorination and oxychlorination of ethylene, using the hydrogen chloride generated in the cracking of dichloroethane. The MVC and dichloroethane production plant can operate as a "balanced process" between the two products. As the process does not achieve 100% conversion of ethylene, a small percentage of the feedstock is not converted. The exhaust gases are, then, treated to eliminate the chlorinated compounds formed in secondary reactions. The unreacted ethylene is converted into CO_2 and the chlorinated compounds undergo a catalytic reduction process. The cleaned gases are sent into the atmosphere in compliance with the requirements of the environmental control agency.

The GHGs emitted are CO_2 and CH_4, as well as NMVOC.

For CO_2 and CH_4 emissions, we used Tier 1 from the IPCC 2006. The emission factor of 0.294 t CO_2/t MVC was used to estimate CO_2 emissions from integrated dichloroethane – vinyl chloride production. Similarly, the CH_4 emission factor was 0.0226 kg CH_4/t MVC and covers emissions from the integrated production of both compounds.

NMVOC emissions were estimated with the same emission factors used in the Initial Inventory (MCT, 2004) of 8.5 kg NMVOC/t MVC, and 2.2 kg NMVOC/t dichloroethane (IPCC, 1997).

5.4.1.6.4 Ethylene oxide

The main use of ethene (or ethylene) oxide in the world is in the production of ethylene glycol, commonly known for its use as an automotive coolant and antifreeze. This chemical is also used in the production of polyester polymers, as an intermediate in the production of ethers, higher alcohols and amines. In Brazil, its main use is in the production of glycols.

It can be produced through two technological routes. The first one begins with the reaction of chlorine on ethylene in the presence of water, followed by dehydrochlorination of the ethylene hydrochloride that is formed. The second one uses direct oxidation of ethylene by air. The latter is the process used to produce ethylene oxide in Brazil.

The GHGs emitted are carbon dioxide (CO_2) and methane (CH_4).

For CO_2 emissions, the IPCC 2006 Tier 2 method was used, when the mass balance of the total carbon of the feedstocks used in the production process is used. The emission factor, thus calculated, was 0.52 t CO_2/t ethylene oxide, mainly related to the selectivity and efficiency of the catalytic converter used in the production process and it was applied to all the years from 1990 to 2022. For CH_4 emissions, Tier 1 was used, with an emission factor of 1.79 kg CH_4/t ethylene oxide.

5.4.1.6.5 Acrylonitrile

Acrylonitrile is used in the manufacture of acrylic fibers, organic syntheses, fumigants, surfactants and dyes. The best-known compounds that use it are: a) NBR (butadiene-acrylonitrile) rubbers; b) ABS (acrylonitrile-butadiene-styrene) resins; and c) ABS/PA blends.

The production process installed in Brazil uses Sohio technology for the catalytic reaction of propylene, ammonia and air, used as feedstocks. The process produces acrylonitrile as the primary product and acetonitrile and hydrocyanic acid as secondary products. Ammoniation of propene does not yield 100% of acrylonitrile, therefore a small fraction of the propene is converted into CO_2 by direct oxidation or converted into other hydrocarbons by parallel reactions during the ammoniation process.

The gases emitted in these processes are carbon dioxide (CO_2) and methane (CH_4), as well as NMVOC.

For CO_2 emissions, the IPCC 2006 Tier 2 method was used, using the mass balance of the total carbon of the feedstocks used in the production process. The calculated emission factor was 0.2325 t CO_2/t acrylonitrile and it was applied to all the years from 1990 to 2022. For CH_4 emissions, the *Tier* 1 method was used, with a default emission factor of 0.18 kg CH_4/t acrylonitrile. Precursor greenhouse gas emissions were estimated according to IPCC 1997, with an emission factor of 1 kg NMVOC/t acrylonitrile.

5.4.1.6.6 Carbon black

The main use of carbon black is as an additive in rubber for the manufacture of tires. Another important use is as a pigment in the manufacture of paints.

Carbon black production processes are based on the partial oxidation of gaseous or liquid hydrocarbons. In Brazil, aromatic waste is the main feedstock associated with heavy fuel (naphthenic) oil in the carbon black generation stage. Natural gas or fuel oil is used as a secondary feedstock. During the production process, a purge gas is generated which contains carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4) and other volatile organic compounds. This purge gas is used as fuel for heat generation, when the last two substances are converted into CO_2.

The GHGs emitted are carbon dioxide (CO_2) and methane (CH_4).

For CO_2 emissions, the IPCC (2006) Tier 1 method was used, with a default value of 2.62 t CO_2/t carbon black. For CH_4 emissions, the Tier 1 method was also used, with a default emission factor of 0.06 kg CH_4/t carbon black. For precursor greenhouse gases, the estimates from the Initial Inventory (MCT, 2004) were maintained, when only NO_x emissions were considered, with an emission factor of 0.14 kg NO_x/t carbon black.

5.4.1.7 Fluorochemical production

In Brazil, there was no production of fluorinated gases between 1990 and 2022, with the exception of HCFC-22, which was produced in the country until 1999. Although this gas is also a greenhouse gas, it is not included in this Inventory because it is already controlled by the Montreal Protocol, which was created to reduce emissions from ozone-depleting gases. For this Inventory, the focus is on the gas production process, which generates another gaseous compound, HFC-23, a potent greenhouse gas.

HFC-23 emissions were estimated using the default emission factor of 4% of HCFC-22 production (IPCC, 2006).

Activity data and other parameters

The production of HCFC-22 is shown in Table 5.23.

Table 5.23. HCFC-22 production.

Year	HCFC-22 Production
	t
1990	3,006
1991	3,438
1992	4,090
1993	4,307
1994	3,915
1995	3,826
1996	2,226
1997	2,383
1998	326
1999	2,429
2000 – 2022	0

Source: Prepared based on Prozon (1999).

5.4.1.8 Other Chemicals

This category includes calcined petroleum coke, as well as other chemicals not listed in IPCC 2006, but whose production emits precursor GHGs, such as: ABS, phthalic anhydride, styrene butadiene rubber (SBR), styrene, ethylbenzene, formaldehyde, polyvinyl chloride - PVC, polystyrene, HDPE polyethylene, LDPE polyethylene, polyethylene, LLDPE, polypropylene and propylene. The corresponding emissions of NO_x, NMVOC and CO are covered only by IPCC 1997.

For CH4 emissions from petroleum coke production, the IPCC 1997 Tier 1 method was used, using the default factor of 0.5 kg CH_4/t coke produced.

For the other chemicals in this section, precursor GHG emissions were calculated with the emission factors used in the Initial Inventory (MCT, 2004), listed in Table 5.24

Table *5.24*. In general, these are IPCC 1997 default factors, but some have been derived from technologies suggested by Corinair (phthalic anhydride, polyvinyl chloride – PVC and polystyrene) or determined by the authors and by Abiquim (styrene butadiene rubber – SBR).

Table 5.24. NMVOC emission factors for other chemicals.

Chemical	(kg NMVOC/t chemical)
ABS	27.2
Phthalic anhydride	1.3

Chemical	(kg NMVOC/t chemical)
Styrene butadiene rubber (SBR)	5.8
Styrene	18
Ethylbenzene	2
Formaldehyde	5
Polyvinyl chloride (PVC)	1.5
Polystyrene	3.3
HDPE Polyethylene	6.4
LDPE Polyethylene	3
LLDPE Polyethylene	2
Polypropylene	12
Propylene	1.4

Activity data and other parameters

Table 5.25 provides a summary of the consumption of phosphate rocks – for the production of phosphoric acid – and the production of other chemical substances.

Table 5.25. Production data for other chemicals.

Year	ABS resins	Phthalic anhydride	Styrene butadiene rubber (SBR)	Styrene	Ethylbenzene	Formaldehyde	Polyvinyl chloride PVC (polyvinyl chloride)	Polystyrene	HDPE Polyethylene	LDPE Polyethylene	LLDPE Polyethylene	Polypropylene	Propylene
	kt												
1990	27	28	185	302	441	156	530	125	322	629	0	301	821
1991	26	77	189	280	314	179	484	145	162	551	0	180	779
1992	28	77	196	254	287	206	485	125	311	570	0	375	827
1993	32	76	192	223	238	245	422	143	430	609	104	478	975
1994	32	91	209	262	346	257	593	133	479	609	133	522	1,086
1995	33	75	221	273	407	276	581	149	495	595	150	558	1,077
1996	0	87	211	236	259	282	627	131	529	561	170	590	1,085
1997	0	86	239	232	250	292	632	133	644	664	177	636	1,219
1998	0	74	206	228	263	312	632	139	693	649	174	708	1,271
1999	0	90	244	227	240	368	658	165	764	659	266	787	1,264
2000	0	88	237	405	437	326	648	176	891	647	334	848	1,409
2001	0	91	205	403	439	287	538	239	819	636	270	832	1,340
2002	0	95	233	400	422	322	602	314	811	608	313	891	1,390
2003	0	98	246	388	428	467	604	292	811	672	359	1,012	1,559
2004	0	103	261	445	468	506	630	319	833	673	407	1,130	1,747
2005	0	85	212	405	395	477	640	317	812	682	442	1,212	1,731
2006	0	103	0	460	446	447	676	361	1,018	681	635	1,235	1,834
2007	0	113	0	430	446	473	686	376	1,022	691	685	1,293	1,876

Year	ABS resins	Phthalic anhydride	Styrene butadiene rubber (SBR)	Styrene	Ethylbenzene	Formaldehyde	Polyvinyl chloride PVC (polyvinyl chloride)	Polystyrene	HDPE Polyethylene	LDPE Polyethylene	LLDPE Polyethylene	Polypropylene	Propylene
	kt												
2008	0	97	0	324	303	528	699	345	925	590	606	1,262	1,698
2009	0	101	0	455	369	625	689	367	976	636	674	1,486	2,086
2010	0	106	0	440	399	488	725	396	985	652	743	1,586	2,192
2011	0	88	0	424	378	479	696	376	940	622	709	1,835	2,363
2012	0	102	0	442	280	493	759	380	1,010	669	762	1,647	2,151
2013	0	90	0	440	283	557	866	384	1,034	684	780	1,627	2,128
2014	0	85	0	467	250	617	874	378	964	638	727	1,592	2,183
2015	0	72	0	464	263	688	783	389	1,097	726	828	1,510	2,059
2016	0	67	0	485	284	689	854	400	1,121	742	845	1,592	2,070
2017	0	68	0	497	284	650	1,222	400	1,097	767	845	1,842	1,624
2018	0	66	0	550	284	674	1,182	400	1,101	748	845	1,772	1,556
2019	0	66	0	449	284	672	1,072	400	1,067	665	845	1,795	1,334
2020	0	66	0	462	284	771	1,213	400	1,102	763	845	1,727	1,093
2021	0	66	0	568	284	885	1,466	400	1,094	736	845	1,746	1,195
2022	0	66	0	521	284	864	1,387	400	1,091	722	845	1,705	964

Source: Based on Abiquim (2017; 2020; 2024); SIDRA/IBGE (2024b). Exceptions: From 2010, Abiquim only provided data on polyethylene production; from then onwards, the division into HDPE, LDPE or LLDPE was estimated according to the proportion between these types in 2010. In addition, no data was provided for phthalic anhydride, ethylbenzene, polystyrene and LLDPE from 2017 to 2022, which is why the production was considered to be constant from 2016 onwards.

5.4.2 Quality assurance and quality control

The quality assurance/quality control (QA/QC) procedures for the Chemical Industry subsector (2.B) were applied in accordance with the QA/QC plan described in section 2.5 of this NIR, and are in line with Volume 1, Chapter 6, of the 2006 IPCC Guidelines.

5.4.3 Assessment of uncertainty, consistency and recalculations of the time series

Uncertainty analysis was carried out using the random sampling methods and techniques described in the 2006 IPCC Guidelines. The uncertainty associated with CO_2, CH_4 and N_2O emissions from the Chemical Industry (2.B) is presented in Appendix II.

The updating of the inventory included revising the time series of the activity data in the light of access to data, particularly the data obtained from ABIQUIM, relating to production in the different segments of the Chemical Industry, as well as from SIDRA/IBGE (ABIQUIM, 2024; IBGE, 2024b). In summary, the main adjustments stem from:

- *Ammonia (2017-2020):* revision of production data previously extrapolated in BRASIL (2022) due to lack of information;
- *Urea (2017-2020):* revision of production data previously extrapolated in BRASIL (2022) due to lack of information;
- *Nitric acid (2017-2020):* revision of nitric acid production and nitric acid production that emits N_2O based on CDM projects;
- *Adipic acid (2019-2020):* revision of production based on CDM projects;
- *Petrochemicals and carbon black (2017-2020):* revision of production data previously extrapolated in Brasil (2022) due to lack of information; and
- *Other chemicals (2019-2020):* revision of production data previously extrapolated in Brasil (2022) due to lack of information.

Compared to the previous Inventory, the largest proportion of adjustments in this NIR is seen in 2019 and 2020, with -14% and -17% changes in emissions from the Chemical Industry (2.B), respectively. This difference stems from the fact that data was accessed directly from Abiquim in this Inventory, which was not possible in Brasil (2022), and extrapolations were used for the aforementioned biennium. Above all, the impact on emissions stems from the decrease in ammonia and ethylene production, and the lack of methanol production compared to the values estimated in Brasil (2022). Between 2017 and 2020, the average adjustment in aggregate emissions was 8%, and in the period from 1990 to 2020, it was only 1%, thus demonstrating the consistency of the sector's time series (Figure 5.6).

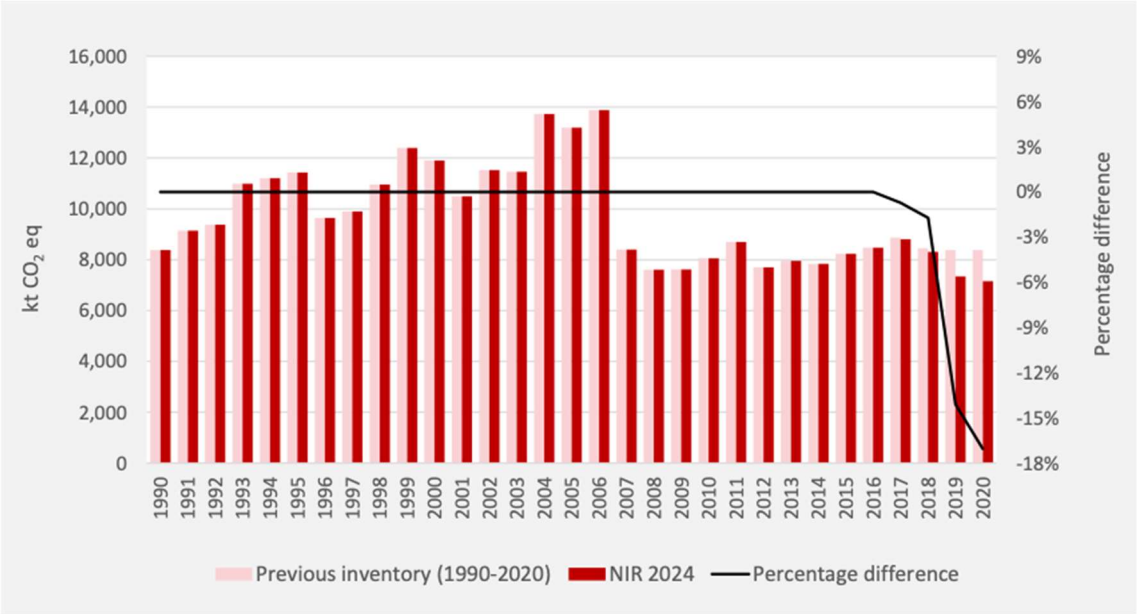


Figure 5.6. Comparison of estimated emissions from the Chemical Industry subsector (2.B) between inventories.

5.4.4 Improvement plan

The systematic preparation of national GHG inventories has allowed us to gain knowledge that enables us to propose measures aimed at improving the results of the Inventory, particularly in the Chemical Industry subsector (2.B). Dataframe 5.11 summarizes the potential improvements for implementation in future editions of the inventory for this subsector.

Dataframe 5.11. Potential improvements applicable to improving the emissions inventory for the Chemical Industry subsector (2.B).

Subsector	Category	Improvement
2.B. CHEMICAL INDUSTRY	General (all categories)	▪ Establish Technical Cooperation Agreements to promote the elaboration of annual production statistics to be made available nationally.
	2.B.2. Nitric acid production 2.B.3. Adipic acid production	▪ Establish a dialogue with companies that have CDM projects to assess the possibility of accessing the projects' removal data
	2.B.5. Carbide Production	▪ Establish Technical Cooperation Agreements to obtain recent carbide production data.
	2.B.8. Petrochemical and Carbon Black Production 2.B.10. Other Chemicals	▪ Establish Technical Cooperation Agreements with a view to facilitating the collection of annual production data for Petrochemical and Carbon Black Production, as well as Other Chemicals.

5.5 Metal Industry (CRT 2.C)

Emissions from the Metal Industry subsector (2.C) refer to the following categories: Iron and Steel Production (2.C.1); Ferroalloys production (2.C.2); Aluminum Production (2.C.3); Magnesium Production (2.C.4); Other (Non-Ferrous Metals, Except Aluminum and Magnesium) (2.C.7); the latter also includes emissions from Lead Production (2.C.5). There are no GHG emissions in the Zinc Production category (2.C.6), as no reducers are used in this process in Brazil.

In 2022, 52,226 kt CO_2 eq was emitted by this subsector,[43] which corresponded to 51% of IPPU emissions (Figure 5.7). From 2020 to 2022, emissions from the Metal Industry (2.C) increased by 7%. The subsector's most representative category was Iron and Steel Production (2.C.1), responsible for 92% of emissions. The Aluminum Production (2.C.3), Other (Non-Ferrous Metals, Except Aluminum and Magnesium) (2.C.7) and Ferroalloys Production (2.C.2) categories accounted for 3%, 3% and 1%, respectively, with the remaining emissions being allocated to the Magnesium Production category (2.C.4).

[43] According to the IPCC (2006) methodology, CO_2 emissions from the consumption of biomass fuels are reported, but are not included in the sector's total emissions.

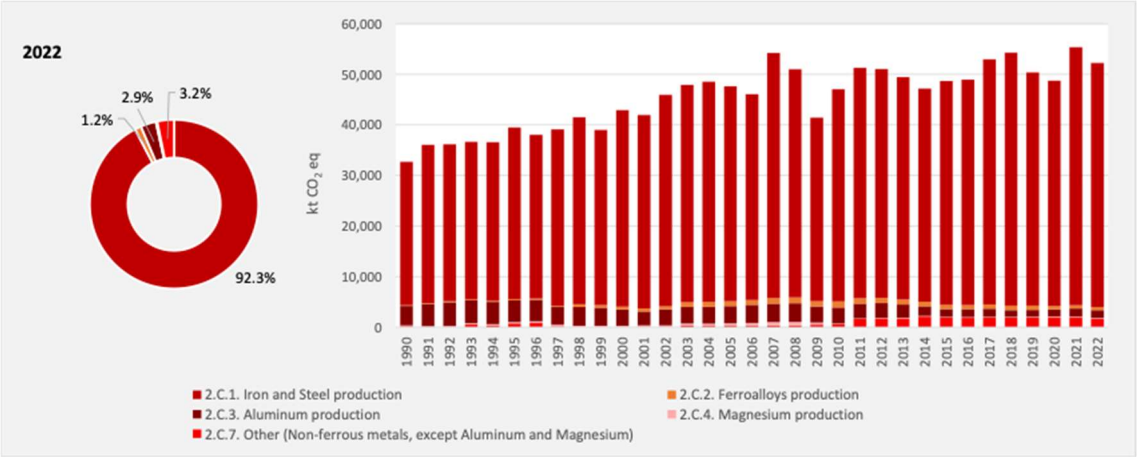


Figure 5.7. Emissions from the Metal Industry (2.C), in kt CO_2 eq by category, from 1990 to 2022.

With regard to CO_2, the main emitting category was Iron and Steel Production (2.C.1), with a share of 93% in 2022. Most of the CO_2 emissions from steelmaking occurred during the production of pig iron in the blast furnace, i.e., in the iron ore reduction stage. The Ferroalloys Production (2.C.2), Aluminum Production (2.C.3) and Other (Non-Ferrous Metals, Except Aluminum and Magnesium) (2.C.7) categories accounted for 1%, 2%, and 3%, respectively, either due to the reduction in feedstocks or the consumption of anodes.

Emissions of CH_4 and N_2O came from Iron and Steel Production (2.C.1), while CO and NO_x were related to Iron and Steel Production and Aluminum Production (2.C.3).

5.5.1 Methodological aspects

5.5.1.1 Iron and Steel Production

The steel industry uses carbon to generate energy and as a reducing agent for iron ore. A fraction of this carbon is incorporated into the products; the other portion, after combustion, is emitted in the form of carbon dioxide (CO_2), either directly in the steelmaking gases or after they have been burned.

Up to 75% of CO_2 emissions from steelmaking occur during the production of pig iron in the blast furnace, i.e., in the iron ore reduction stage. The remaining percentage comes from the transportation of feedstocks and the generation of electricity and heat. The emissions presented in this category only include the production process, excluding electricity generation and transportation, which are accounted for in the Energy sector (CRT 1).

In Brazil, the following technological routes are used for steelmaking:

- Integrated: blast furnace + LD steelworks;
- Direct reduction: direct reduction + electric arc furnace (EAF); and
- Semi-integrated: electric arc furnace (EAF).

5.5.1.1.1 Iron and steel production in integrated and semi-integrated steel plants

In Brazil, the production of pig iron and steel by integrated/semi-integrated steel plants uses petroleum coke, steam coal with a calorific value greater than or equal to 5,900 kcal/kg, metallurgical coal and coal coke as the main reducing fuels.

Due to the availability of detailed data, CO_2 emissions could be obtained by means of a general carbon balance, according to Equation 5.7:

Dataframe 5.12. Equation for estimating CO_2 emissions from integrated and semi-integrated pig iron and steel plants.

Equations	GHG	Categories	Central equation	Reference
Equation 5.7	CO_2	2.C.1	$E_{CO_2} = \left[\sum_i Q_Input_i * C_Input_i - \sum_j Q_Output_j * C_Output_j\right] * \frac{44}{12}/1000$	IABr (2020); Brasil (2021c)

In which:

ECO_2 = CO_2 emissions (Gg);
Q_Input_i = Quantity of input (feedstock) i, in tons;
C_Input_i = Quantity of carbon in input (feedstock) i, in t C / t feedstock;
Q_Output_i = quantity of output (product) j, in tons; and
C_Output_i = quantity of carbon in output (product) j, in t C / t product.

According to the IPCC (2006), lime production by integrated industries should be reported in the Lime Production category (2.A.2), which includes all lime production in the country. However, the carbon contained in limestone and dolomite, which is calcined inside the furnaces, must be taken into account.

The emissions of non-CO_2 gases from the iron and steel production of the integrated plants were calculated using the IPCC (2006) Tier 1 approach. For the production of sinter, CH_4 emissions are calculated, and in Brazil, according to the IABr (2020), only the production of sinter using anthracite as an input generates such emissions. With regard to the steelmaking and blast furnace gases consumed in production, emissions of CH_4 and N_2O were also calculated with default emission factors.

Activity data and other parameters

With regard to CO_2-emitting processes, detailed figures were obtained for the feedstocks used in the various processes, as well as the products of each one of them, in the steel production chain, from its initial stages (integrated steel plants), from 2007 to 2016 (IABR, 2017; 2020). For the period from 2017 to 2022, the balance was estimated in proportion to crude steel production, according to IABr (2023). These figures are not broken down by the various industries, but by the entire sector and divided between the following processes:

- Coking;
- Sintering;
- Blast furnace;
- BOF and EAF steelworks;
- Energy (production of electricity and steam);
- Lamination and finishing;
- Calcination (only the use of fuel);
- Other consumers;
- Flare;
- Thermal power plant.

Emissions from the following processes were accounted for in the Energy sector (CRT 1): Coking, Energy, Lamination and finishing, Other consumers, Flare, and Thermal power plant, except when the fuel used was blast furnace gas or steelmaking gas, both of which are fully considered in IPPU. The consumption of coke oven gas is only considered in the Energy sector, even if it is used in other processes. Emissions from Tar, LPG, Natural Gas, Light Oil and Heavy Oil fuels used in some of the above processes were only accounted for in the Energy sector (CRT 1).

For the years from 1990 to 2006, there was the data series provided by the IABr on the occasion of the Inventory submitted in the Second National Communication (MCT, 2010), involving Coking, Sintering and Blast Furnace/Steelworks processes. The inputs and outputs required for the carbon balance in this sector are shown in Table A.V.5, Table A.V.6, and Table A.V.7 (Appendix V).

It was noted, however, that some input and output processes or substances were not available in the first period (1990-2006), compared to the second one (2007-2017), which meant that the two periods had to be made compatible by estimating what was missing in the first period, as described below.

For the carbon balance, the following factors were used for each material used (Table 5.26), and for conversion into tons, the gas densities indicated in Table 5.27 were taken into account.

Table 5.26. Carbon content of the materials.

Material	Carbon in the material (t C/t)	Source
Crude steel	0.010	IPCC (2006), Table 4.3
Tar	0.924	WSA v. 7 ou ISO 14404-1
Anthracite	0.716	IPCC (2006), Table 4.3
Raw limestone	0.120	WSA v. 7 ou ISO 14404-1
EAF Coal	0.888	WSA v. 7 ou ISO 14404-1
Metallurgical coal	0.834	WSA v. 7 ou ISO 14404-1
PCI coal	0.806	WSA v. 7 ou ISO 14404-1
Coke	0.888	WSA v. 7 ou ISO 14404-1
Petroleum coke	0.870	IPCC (2006), Table 4.3
Coke breeze	0.888	WSA v. 7 ou ISO 14404-1
Raw dolomite	0.128	WSA v. 7 ou ISO 14404-1

Material	Carbon in the material (t C/t)	Source
Electrode	0.999	WSA v. 7 ou ISO 14404-1
Pig iron	0.047	WSA v. 7 ou ISO 14404-1
Steelmaking gas (BOFG / LDG)	0.350	IPCC (2006), Table 4.3
Blast furnace gas (BFG)	0.170	IPCC (2006), Table 4.3
Coke oven gas (COG)	0.470	IPCC (2006), Table 4.3
Natural gas	0.730	IPCC (2006), Table 4.3
LPG	0.814	WSA v.7 ou ISO 14404-1
Graphite	0.820	IPCC (2006), Table 4.3
BTX oil	0.804	IPCC (2006, Table 4.3
Light oil	0.860	IPCC (2006), Table 4.3
Heavy oil	0.852	IPCC (2006), Table 4.3
CDQ powder	0.888	WSA v. 7 ou ISO 14404-1
Steel scrap	0.010	IABr (2020)

Table 5.27. Density and calorific value of steelmaking gases.

Material	Density (t/dam3)	Source	NCV (GJ/t)	Source
Steelmaking Gas (BOFG)	1.190	IPCC & WSA	7.06	IPCC (2006), Table 1.2
Blast Furnace Gas (BFG)	1.336	IPCC & WSA	2.47	IPCC (2006), Table 1.2

After the appropriate conversions to tons of carbon, the inputs required for the carbon balance are shown in Table 5.28, for the Sintering, Blast Furnace, Steelmaking and Calcination processes (fuel consumption only), plus the carbon values for the consumption of steelmaking gas and blast furnace gas in the other processes of the integrated iron and steel industries.

As for the carbon balance input data from 1990 to 2006, presented in Table 5.29, the following materials are missing, compared to the subsequent period: Steelmaking gas, Blast furnace gas, graphite, pig iron (whether or not it is converted to steel) and CDQ (Coke Dry Quenching) powder. In addition, the quantities relating to blast furnace gas are much lower, because those used in other unreported processes are missing, which is why this series has been recalculated.

In order to eliminate the inconsistency between the two periods, the ratios between basic items in the second period and crude steel production were taken into account, so that an average could be applied to the first one. It was decided to consider the average of the ratios for the years from 2007 to 2011, i.e., of the five years closest to the incomplete series.

The following averages were obtained for the carbon input values:

- Consumption of pig iron ➔ 32.5876 t C/kt steel;
- Steelmaking gas ➔ 11.5715 t C/kt steel;
- Blast Furnace Gas ➔ 144.5887 t C/kt steel;
- Graphite ➔ 0.0880 t C/kt steel; and
- CDQ Powder ➔ 0.8419 t C/kt steel.

With crude steel production in Brazil, it was possible to complement the carbon series of the inputs from 1990 to 2006 (Table 5.30), and for carbon outputs, the data from 2007 to 2022 are shown in Table 5.31.

For the period from 1990 to 2006, the following averages were obtained for carbon output values:

- Pig iron not converted to steel ➔ 2.15% of total pig iron;
- Pig iron that goes to steelworks ➔ 97.85% of total pig iron;
- Steelmaking Gas ➔ 24.0967 t C/ kt steel; and
- Blast Furnace Gas ➔ 245.1713 t C/ kt steel.

By applying these values to the inputs of the products included in MCT (2010), it was possible to complement the carbon output series from 1990 to 2006, as shown in Table 5.32.

Table 5.28. Carbon inputs considered, compared to feedstock inputs from 2007 to 2022.

Inputs (feedstocks)	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Anthracite	545,419	395,700	273,590	373,420	334,889	303,220	261,023	295,558	330,677	257,423
Limestone	392,050	385,279	289,249	369,173	410,946	409,728	402,230	393,456	414,298	358,412
EAF coal consumed in electric steelworks	3,579	2,822	0	0	0	0	0	0	0	0
PCI coal consumed in blast furnaces	2,601,184	2,553,482	1,775,163	2,275,960	2,220,927	2,116,908	2,241,783	2,427,108	2,821,879	2,894,725
Consumption of pig iron	1,101,588	1,125,297	886,989	1,051,724	1,156,422	1,139,333	1,101,030	1,134,408	1,188,677	1,103,361
Petroleum coke	461,513	469,879	455,156	39,372	77,762	50,388	65,680	21,120	19,627	28,336
Metallurgical coke	7,582,445	8,091,333	6,489,881	7,962,114	8,983,741	8,745,085	8,258,602	8,100,969	8,333,663	8,110,331
Dolomite	85,950	102,547	108,772	145,610	150,747	195,261	217,894	237,789	205,586	198,980
Electrode	13,864	13,274	10,778	14,403	14,850	14,026	15,301	15,342	11,399	12,198
Steelmaking gas	881,509	423,317	363,824	494,463	581,519	555,166	524,400	550,750	537,198	723,606
Blast furnace gas	6,917,581	5,768,936	4,940,131	5,754,519	6,821,801	6,931,522	6,353,660	7,002,309	7,187,685	6,716,399
Graphite	4,173	3,638	1,960	2,276	2,423	2,413	8,289	3,571	3,404	13,908
Coke grinder	837,156	994,485	801,881	1,014,082	1,178,838	1,130,119	1,156,656	1,105,684	1,050,007	988,939
CDQ powder	7,539	11,785	10,972	52,044	59,067	44,419	25,512	12,876	12,077	10,549
Scrap	60,548	51,795	48,965	47,459	54,023	56,400	74,444	66,456	59,365	56,023
Total	**21,496,098**	**20,393,571**	**16,457,312**	**19,596,620**	**22,047,954**	**21,693,989**	**20,706,504**	**21,367,397**	**22,175,540**	**21,473,191**

Source: Based on IABr (2020) and Brasil (2021c). Unit: t C.

Continued. Carbon inputs considered, compared to feedstock inputs from 2007 to 2022.

Inputs (feedstocks)	2017	2018	2019	2020	2021	2022
Anthracite	296,288	301,647	277,469	267,637	307,304	290,418
Limestone	408,337	415,722	382,401	368,851	423,519	400,247
EAF coal consumed in electric steelworks	0	0	0	0	0	0
PCI coal consumed in blast furnaces	3,186,118	3,243,743	2,983,745	2,878,023	3,304,574	3,122,997
Consumption of pig iron	1,199,020	1,220,705	1,122,861	1,083,076	1,243,598	1,175,266
Petroleum coke	24,203	24,641	22,666	21,863	25,103	23,724
Metallurgical coke	8,708,408	8,865,910	8,155,275	7,866,313	9,032,175	8,535,883
Dolomite	241,583	245,953	226,239	218,222	250,565	236,797
Electrode	13,656	13,903	12,789	12,336	14,164	13,386
Steelmaking gas	727,963	741,129	681,725	657,570	755,028	713,541
Blast furnace gas	7,343,989	7,476,813	6,877,519	6,633,832	7,617,029	7,198,494
Graphite	14,162	14,418	13,263	12,793	14,689	13,882
Coke grinder	1,161,655	1,182,665	1,087,870	1,049,324	1,204,844	1,138,641
CDQ powder	0	0	0	0	0	0
Scrap	57,540	58,580	53,885	51,976	59,679	56,400
Total	**23,382,923**	**23,805,830**	**21,897,706**	**21,121,816**	**24,252,269**	**22,919,675**

Source: Based on IABr (2020) and Brasil (2021c). Unit: t C.

Table 5.29. Carbon inputs considered, compared to feedstock inputs from 1990 to 2006.

Inputs (feedstocks)	1990	1991	1992	1993	1994	1995	1996	1997	1998
Anthracite	169,680	172,487	180,438	221,346	238,965	246,076	249,222	288,966	291,968
Limestone	211,074	218,427	209,645	214,700	218,055	219,880	231,399	246,845	300,565
EAF coal consumed in electric steelworks	6,977	5,178	6,056	6,267	5,559	5,335	5,506	6,544	6,796
PCI coal consumed in blast furnaces	155,659	167,965	171,302	191,252	148,579	488,596	491,783	738,250	1,346,304
Petroleum coke	35,000	31,342	33,943	35,982	39,379	36,341	68,366	105,302	102,314
Metallurgical coke	6,343,938	6,952,656	7,097,033	7,106,397	7,229,430	7,546,495	7,044,262	7,248,197	7,254,700
Dolomite	108,258	118,213	130,963	133,160	136,794	134,680	136,668	145,126	186,197
Electrode	8,250	7,188	7,878	8,407	10,283	10,341	10,069	10,960	9,747
Coke grinder	830,110	846,103	865,140	794,949	817,962	840,482	860,437	873,151	775,946
Scrap	36,205	33,086	36,369	39,221	40,385	37,295	39,044	42,848	40,919
Total inputs	**7,905,151**	**8,552,644**	**8,738,766**	**8,751,681**	**8,885,391**	**9,565,519**	**9,136,756**	**9,706,189**	**10,315,456**

Source: Based on IABr (2020) and Brasil (2021c). Unit: t C.

Continued. Carbon inputs considered, compared to feedstock inputs from 1990 to 2006.

Inputs (feedstocks)	1999	2000	2001	2002	2003	2004	2005	2006
Anthracite	183,488	257,917	320,083	325,903	337,958	408,928	422,110	436,985
Limestone	289,759	324,477	300,537	288,300	339,243	326,988	294,268	339,785
EAF coal consumed in electric steelworks	7,946	9,802	11,345	10,040	9,043	10,652	10,836	8,845
PCI coal consumed in blast furnaces	1,447,613	2,097,614	2,024,181	2,165,102	2,485,672	2,661,850	2,512,579	2,375,955
Petroleum coke	278,187	320,669	365,316	413,663	424,578	314,268	438,808	449,821
Metallurgical coke	6,365,225	7,038,251	6,714,329	7,508,713	7,596,784	7,451,853	7,162,774	6,724,855
Dolomite	141,338	104,927	149,427	160,761	182,786	210,367	205,820	100,850
Electrode	11,780	12,081	12,183	12,404	14,133	14,689	14,036	13,748
Coke grinder	798,885	769,968	698,896	786,962	741,672	752,967	718,713	655,167
Scrap	48,875	48,688	52,491	54,338	60,016	63,167	61,303	59,871
Total inputs	9,573,095	10,984,394	10,648,788	11,726,186	12,191,886	12,215,728	11,841,247	11,165,881

Source: Based on IABr (2020) and Brasil (2021c). Unit: t C.

Table 5.30. Carbon inputs from 1990 to 2006, with the addition of the missing inputs.

Inputs (feedstocks)	1990	1991	1992	1993	1994	1995	1996	1997	1998
Anthracite	169,680	172,487	180,438	221,346	238,965	246,076	249,222	288,966	291,968
Limestone	211,074	218,427	209,645	214,700	218,055	219,880	231,399	246,845	300,565
EAF coal consumed in electric steelworks	6,977	5,178	6,056	6,267	5,559	5,335	5,506	6,544	6,796
PCI coal consumed in blast furnaces	155,659	167,965	171,302	191,252	148,579	488,596	491,783	738,250	1,346,304
Consumption of pig iron	662,842	718,047	756,667	794,939	806,989	797,456	803,093	831,927	811,337
Petroleum coke	35,000	31,342	33,943	35,982	39,379	36,341	68,366	105,302	102,314
Metallurgical coke	6,343,938	6,952,656	7,097,033	7,106,397	7,229,430	7,546,495	7,044,262	7,248,197	7,254,700
Dolomite	108,258	118,213	130,963	133,160	136,794	134,680	136,668	145,126	186,197
Electrode	8,250	7,188	7,878	8,407	10,283	10,341	10,069	10,960	9,747
Steelmaking gas	235,368	254,970	268,684	282,274	286,553	283,168	285,169	295,408	288,096
Blast furnace gas	2,940,975	3,185,918	3,357,268	3,527,081	3,580,545	3,538,250	3,563,257	3,691,191	3,599,836
Graphite	1,790	1,939	2,044	2,147	2,180	2,154	2,169	2,247	2,191
Coke grinder	830,110	846,103	865,140	794,949	817,962	840,482	860,437	873,151	775,946
CDQ powder	17,124	18,550	19,548	20,536	20,848	20,601	20,747	21,492	20,960
Scrap	36,205	33,086	36,369	39,221	40,385	37,295	39,044	42,848	40,919
Total inputs	**11,763,248**	**12,732,069**	**13,142,976**	**13,378,659**	**13,582,504**	**14,207,149**	**13,811,191**	**14,548,454**	**15,037,876**

Source: Based on IABr (2020) and Brasil (2021c). Unit: t C.

Continued. Carbon inputs from 1990 to 2006, with the addition of the missing inputs.

Inputs (feedstocks)	1999	2000	2001	2002	2003	2004	2005	2006
Anthracite	183,488	257,917	320,083	325,903	337,958	408,928	422,110	436,985
Limestone	289,759	324,477	300,537	288,300	339,243	326,988	294,268	339,785
EAF coal consumed in electric steelworks	7,946	9,802	11,345	10,040	9,043	10,652	10,836	8,845
PCI coal consumed in blast furnaces	1,447,613	2,097,614	2,024,181	2,165,102	2,485,672	2,661,850	2,512,579	2,375,955
Consumption of pig iron	834,863	917,277	885,334	972,868	1,018,252	1,050,445	1,011,025	976,638
Petroleum coke	278,187	320,669	365,316	413,663	424,578	314,268	438,808	449,821
Metallurgical coke	6,365,225	7,038,251	6,714,329	7,508,713	7,596,784	7,451,853	7,162,774	6,724,855
Dolomite	141,338	104,927	149,427	160,761	182,786	210,367	205,820	100,850
Electrode	11,780	12,081	12,183	12,404	14,133	14,689	14,036	13,748
Steelmaking gas	296,450	325,714	314,372	345,455	361,570	373,001	359,004	346,793
Blast furnace gas	3,704,219	4,069,882	3,928,155	4,316,539	4,517,900	4,660,742	4,485,837	4,333,265
Graphite	2,255	2,477	2,391	2,628	2,750	2,837	2,731	2,638
Coke grinder	798,885	769,968	698,896	786,962	741,672	752,967	718,713	655,167
CDQ powder	21,568	23,697	22,872	25,133	26,305	27,137	26,119	25,230
Scrap	48,875	48,688	52,491	54,338	60,016	63,167	61,303	59,871
Total inputs	**14,432,449**	**16,323,442**	**15,801,912**	**17,388,808**	**18,118,663**	**18,329,891**	**17,725,961**	**16,850,446**

Source: Based on IABr (2020) and Brasil (2021c). Unit: t C.

Table 5.31. Carbon outputs considered, from 2007 to 2022.

Outputs (products)	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Crude steel	340,276	337,745	268,728	330,483	356,744	347,895	341,054	339,734	334,286	311,136
Pig iron not converted to steel	20,640	39,228	17,840	25,840	26,749	32,159	34,970	46,217	24,346	31,905
Pig iron used in steelworks	1,208,021	1,236,808	972,559	1,180,592	1,271,869	1,248,338	1,223,376	1,267,611	1,294,923	1,218,541
Steelmaking gas	917,527	762,093	645,133	746,088	869,483	993,157	883,674	1,148,982	1,273,241	912,018
Blast furnace gas	8,224,221	8,388,857	6,673,267	7,945,040	8,813,381	8,969,228	8,526,547	8,896,742	8,975,778	8,432,214
Total outputs	**10,710,684**	**10,764,731**	**8,577,527**	**10,228,044**	**11,338,228**	**11,590,777**	**11,009,621**	**11,699,286**	**11,902,573**	**10,905,814**

Source: Based on IABr (2020) and Brasil (2021c). Unit: t C.

Continued. Carbon outputs considered, from 2007 to 2022.

Outputs (products)	2017	2018	2019	2020	2021	2022
Crude steel	341,326	347,499	319,645	308,320	354,016	334,563
Pig iron not converted to steel	38,317	39,010	35,883	34,611	39,741	37,557
Pig iron used in steelworks	1,334,474	1,358,610	1,249,712	1,205,432	1,384,088	1,308,036
Steelmaking gas	1,017,868	1,036,277	953,216	919,441	1,055,711	997,702
Blast furnace gas	9,031,243	9,194,583	8,457,604	8,157,930	9,367,012	8,852,321
Total outputs	**11,763,227**	**11,975,978**	**11,016,060**	**10,625,734**	**12,200,568**	**11,530,181**

Source: Based on IABr (2020) and Brasil (2021c). Unit: t C.

Table 5.32. Carbon outputs considered, from 1990 to 2006, with the addition of the missing outputs.

Outputs (products)	1990	1991	1992	1993	1994	1995	1996	1997	1998
Crude steel	208,142	224,720	237,048	248,895	253,360	249,752	251,686	261,114	253,717
Pig iron not converted to steel	16,064	18,289	19,136	19,544	20,067	20,397	20,043	20,677	20,607
Pig iron used in steelworks	730,625	831,800	870,339	888,872	912,648	927,687	911,591	940,426	937,206
Steelmaking gas	490,135	530,956	559,513	587,814	596,724	589,675	593,843	615,164	599,939
Blast furnace gas	4,986,855	5,402,192	5,692,741	5,980,684	6,071,340	5,999,622	6,042,026	6,258,957	6,104,050
Total outputs	6,431,820	7,007,957	7,378,777	7,725,808	7,854,138	7,787,133	7,819,189	8,096,338	7,915,518

Source: Based on IABr (2020) and Brasil (2021c). Unit: t C.

Continued. Carbon outputs considered, from 1990 to 2006, with the addition of the missing outputs.

Outputs (products)	1999	2000	2001	2002	2003	2004	2005	2006
Crude steel	261,415	286,579	276,340	304,047	318,443	329,569	316,502	306,085
Pig iron not converted to steel	19,596	22,050	21,349	23,397	24,420	25,179	24,379	23,242
Pig iron used in steelworks	891,264	1,002,879	970,962	1,064,136	1,110,630	1,145,168	1,108,791	1,057,053
Steelmaking gas	617,335	678,275	654,655	719,382	752,941	776,746	747,597	722,170
Blast furnace gas	6,281,046	6,901,083	6,660,764	7,319,325	7,660,764	7,902,972	7,606,395	7,347,687
Total outputs	8,070,656	8,890,866	8,584,070	9,430,288	9,867,197	10,179,634	9,803,664	9,456,237

Source: Based on IABr (2020) and Brasil (2021c). Unit: t C.

For non-CO_2 gases, the emission factors can be found in Table 5.33. In order to obtain the quantity of these gases in terms of energy, we used their carbon content by mass (t C/t), as shown in Table 5.26, and their energy densities (GJ/t) as provided by the IPCC (2006), according to Table 5.34, together with the consumption values for the feedstock inputs presented in Brasil (2021c) and BEN (EPE, 2023) (Table 5.28 and Table 5.30).

Table 5.33. Emission factors for non-CO_2 gases for the iron and steel production category.

Gas	CH_4	N_2O
	kg/TJ	
Steelmaking gas	1	0.1
Blast furnace gas	1	0.1

Source: IPCC (2006, v. 2, Table 2.3).

Table 5.34. Energy densities of steelmaking gases.

Fuel	Emission factor (GJ/t)
Steelmaking gas	7.06
Blast furnace gas	2.47

Source: IPCC (2006, v. 2, Table 1.2).

For the production of sinter, only for the one that uses anthracite, the emission factor of 0.07 kg CH_4/t sinter was used, according to the IPCC (2006, v. 3, chap. 4, Table 4.2). The values were provided by IABr for the years of 2007-2016. In order to complete the series, an extrapolation was made using the average proportion between this sinter production and crude steel production in Brazil, calculated as 55.4%, and applied to the crude steel production shown in Table 5.35.

Table 5.35. Crude steel production, consumption of steelmaking and blast furnace gas and production of sinter using anthracite, 1990-2022.

Year	Crude steel production	Steelmaking gas consumption	Blast furnace gas consumption	Production of sinter using anthracite
	kt	TJ	TJ	kt
1990	20,340	4,748	42,731	11,271
1991	22,034	5,143	46,290	12,210
1992	23,219	5,420	48,779	12,867
1993	24,394	5,694	51,246	13,517
1994	24,764	5,780	52,023	13,722
1995	24,471	5,712	51,409	13,560
1996	24,644	5,752	51,772	13,656
1997	25,529	5,959	53,631	14,146
1998	24,897	5,811	52,303	13,796

Year	Crude steel production	Steelmaking gas consumption	Blast furnace gas consumption	Production of sinter using anthracite
	kt	TJ	TJ	kt
1999	25,619	5,980	53,820	14,196
2000	28,148	6,570	59,133	15,598
2001	27,168	6,341	57,074	15,055
2002	29,854	6,968	62,717	16,543
2003	31,247	7,293	65,642	17,315
2004	32,234	7,524	67,718	17,862
2005	31,025	7,242	65,177	17,192
2006	29,970	6,995	62,960	16,607
2007	34,028	17,781	100,508	18,985
2008	33,774	8,539	83,819	20,347
2009	26,873	7,339	71,777	15,800
2010	33,048	9,974	83,610	19,278
2011	35,674	11,730	99,117	18,927
2012	34,789	11,198	100,711	16,558
2013	34,105	10,578	92,315	17,719
2014	33,973	11,109	101,739	17,609
2015	33,429	10,836	104,433	17,761
2016	31,114	14,596	97,585	19,727
2017	34,778	14,684	106,704	22,768
2018	35,407	14,950	108,634	23,180
2019	32,569	13,751	99,926	21,322
2020	31,415	13,264	96,386	20,567
2021	36,071	15,230	110,671	23,615
2022	34,089	14,393	104,590	22,317

As previously indicated, GHG emissions from coking plants are allocated to the Energy sector, more precisely to category 1.A.1.c. Manufacture of solid fuels and other energy industries (IPCC, 2006). It should be noted that emissions from coking plants were calculated based on the official information available in the National Energy Balance (BEN). However, since the coking plants are located inside steel plants, BEN is unable to present the disaggregated industrial gases (blast furnace and steelmaking gases). Therefore, for this Inventory, the difference in emissions between the calculation based on BEN data and the calculation based on IABr data (which includes industrial gases) was allocated to the IPPU sector.

5.5.1.1.2 Iron and steel production in dedicated plants

In Brazil, pig iron is also produced in plants dedicated exclusively to this product, either for foundry or for steelmaking. Foundry material is used by the auto parts industry in forgings, while steelmaking material is predominantly exported. To produce pig iron, approximately 1.68 tons of iron ore and around 3 m^3 of charcoal are consumed per ton of pig iron produced.

In Brazil, the production of pig iron by dedicated plants uses only charcoal, which is ideal for smaller furnaces compared to those used by integrated industries, and the initial process includes the same stages as the production of pig iron by the latter.

Emissions were calculated using only charcoal consumption and the application of emission factors for the various gases resulting from the reduction process. Consumption is shown directly in BEN (EPE, 2023), in the iron and steel subsector, where this fuel is only used in dedicated pig iron plants. The emission factors are shown in Table 5.36, and for CO_2, the amount corresponding to the carbon contained in the pig iron still needs to be deducted.

Table 5.36. Emission factors for pig iron production using charcoal.

Gas	EF
	kg/TJ
CO_2 biomass	106,519
CH_4	200
N_2O	4
CO	4,000
NO_x	100
NMVOC	100

Source: Based on IPCC (1996; 2006).

The consumption of charcoal was obtained from BEN (EPE, 2023), in thousand toe. For the conversion into terajoule, a factor of 41.868 TJ/thousand toe was used. The average carbon content for pig iron was 4% in terms of mass.

5.5.1.2 Ferroalloys Production

Ferroalloys is a term used to describe concentrated alloys of iron and one or more metals, such as silicon, manganese, chromium, molybdenum, vanadium and tungsten. Manganese-based ferroalloys are used in the manufacture of steel and cast iron. Ferrosilicon acts as a deoxidizer and is used in the production of common steels. Nickel and chromium alloys are mainly used in the manufacture of stainless steel. Special alloys, such as niobium alloy, are used in special steels for aeronautical, optoelectronic and superconducting applications.

Ferroalloys plants produce concentrated compounds that are shipped to steelworks to be incorporated into the various steel alloys. The production of ferroalloys involves the metallurgical process of reduction, which results in emissions of carbon dioxide (CO_2) and methane (CH_4).

During the melting of ferroalloys, the reduction reaction takes place at high temperature. The carbon reducers that are used are usually coal and coke, but charcoal is also commonly used as a primary or secondary carbon source, an emission that is accounted for in the Land Use, Land-Use Change and Forestry sector (CRT 4).

The methodology for calculating CO_2 and CH_4 emissions used the Tier 1 approach, based on the use of reducers, as per Equation 5.8. The emission factors applied are shown in Table 5.37.

Dataframe 5.13. Equation to measure CO_2 emissions from ferroalloys production.

Equations	GHG	Categories	Central equation	Reference
Equation 5.8	CO_2	2.C.2	$E_{CO_2} = \sum_i (\text{Reducing fuel}_i * EF_i)/10^3$	Equation 4.15 (IPCC, 2006, v. 3, chap. 4)

In which:

E_{CO2} = CO_2 emissions (Gg);
Reducing $fuel_i$ = consumption of type i reducing fuel reported in BEU for direct heating (TJ); and
EF_i = emission factor of type i reducer (kg CO_2 / TJ).

Table 5.37. CO_2 emission factors for the reducers used in ferroalloys production.

Furnaces (AD)	t CO_2/t reducer
Petroleum coke	3.5
Bituminous coal (CV6000)	3.1
Coal coke	3.3
Charcoal	3.5

Source: Based on IPCC (2006).

For CH_4 emissions, the Tier 1 approach was also used, based only on the quantity of silicon-based ferroalloys. The emission factor used was 1 kg CH_4/t FeSi (ferrosilicon).

Activity data and other parameters

To calculate CO_2 emissions, the fuel consumption reported in BEN (EPE, 2023) and in the Energy subsector were used. In addition, the production data listed in Table 5.38 was taken into account.

Table 5.38. Ferroalloys production, 1990 to 2022.

Year	Manganese-based ferroalloys	Silicon-based ferroalloys	Chrome-based ferroalloys	Nickel-based ferroalloys	Niobium-based ferroalloys	Special ferroalloys/ other	Total
	t						
1990	170,504	229,408	83,753	0	0	323,998	807,663
1991	169,103	190,864	82,225	0	0	387,086	829,278
1992	178,937	243,838	91,100	0	0	410,937	924,812
1993	201,518	238,864	83,892	0	0	405,509	929,783
1994	199,667	198,505	77,163	0	0	371,001	846,336
1995	130,207	243,824	95,840	0	0	286,754	756,625
1996	215,260	236,838	72,609	0	0	299,205	823,912
1997	152,530	212,183	67,429	0	0	274,058	706,200
1998	267,007	166,278	72,507	26,389	30,973	36,478	599,632

Year	Manganese-based ferroalloys	Silicon-based ferroalloys	Chrome-based ferroalloys	Nickel-based ferroalloys	Niobium-based ferroalloys	Special ferroalloys/ other	Total
	t						
1999	233,644	200,833	90,784	19,807	28,557	52,003	625,628
2000	292,581	189,935	142,352	19,315	27,359	65,080	736,622
2001	576,251	159,345	90,327	17,966	37,411	42,339	923,639
2002	339,166	145,910	133,697	19,874	36,450	50,952	726,049
2003	438,393	156,824	179,408	19,874	37,303	70,899	902,701
2004	465,600	177,245	188,836	20,338	35,863	114,887	1,002,769
2005	598,648	199,856	170,303	23,707	58,616	120,453	1,171,583
2006	573,426	220,214	166,547	28,865	65,886	107,824	1,162,762
2007	419,230	225,303	167,540	29,171	71,676	107,088	1,020,008
2008	388,010	182,790	199,324	26,694	81,591	105,262	983,671
2009	154,094	174,467	90,632	31,600	48,888	60,066	559,747
2010	305,808	247,306	172,794	8,465	77,246	97,758	909,377
2011	295,923	210,910	145,122	16,750	81,860	74,509	825,074
2012	330,419	203,881	181,425	31,342	80,187	87,587	914,841
2013	311,000	158,000	174,180	37,237	46,555	0	726,972
2014	303,000	127,000	188,682	34,501	51,737	0	704,920
2015	129,000	0	173,467	21,286	51,874	0	375,627
2016	124,000	0	150,240	44,538	44,390	0	363,168
2017	149,000	0	171,531	43,800	58,690	0	423,021
2018	168,000	0	175,061	42,310	55.726	0	441,097
2019	151,000	0	136,780	45,544	57,418	0	390,742
2020	147,133	0	146,850	53,382	59,110	0	406,476
2021	0	0	141,995	58,011	60,803	0	260,808
2022	0	0	137,140	62,639	62,495	0	262,274

Source: until 1997, The Brazilian Association of Ferroalloys & Silicon Metal Producers (Associação Brasileira dos Produtores de Ferroligas e de Silício Metálico, ABRAFE); after 1998, Statistical Yearbooks of the Metal Sector (MME, 2000; 2005; 2010; 2013; 2019; 2021; 2022a).

5.5.1.3 Aluminum Production

The Inventory presents estimates of CO_2 emissions from the consumption of anodes in the primary aluminum production process, as well as accounting for perfluorocarbon emissions (PFCs) from electrolytic reduction. The PFC gases accounted for include perfluormethane (CF_4) and perfluorethane (C_2F_6), whose emissions occur during the anode effect. It also considers CO and NO_x emissions from primary aluminum production.

The plants in operation during the period covered by this inventory adopted the Soberberg production route, with anode paste, and Prebaked Anode. The industry once had seven plants, but since 2016, it has reduced its industrial park to two plants.

CO_2 emissions were estimated using Tier 1, Tier 2 and Tier 3 approaches.

The Tier 1 CO_2 method uses only the broad classification of Prebaked Anode or Soderberg technology, using default emission factors applied to production, as shown in Equation 5.9.

In this case, the 2006 IPCC guidelines provide values of 1.6 t CO_2/t aluminum for Prebaked Anode and 1.7 t CO_2/t aluminum for Soderberg.

Dataframe 5.14. Equation for estimating CO_2 emissions in aluminum production (Tier 1).

Equations	GHG	Categories	Central equation	Reference
Equation 5.9	CO_2	2.C.3	$E_{CO2} = EF_P \bullet MP_P + EF_S \bullet MP_S$	Equation 4.20 (IPCC, 2006, v. 3, chap. 4)

In which:

E_{CO2} = CO_2 emissions from anode consumption and/or paste consumption (t CO_2);
EF_P = specific emission factor for the Prebaked Anode technology (t CO_2/t aluminum);
MP_P = quantity of aluminum produced from the Prebaked Anode process (t aluminum);
EF_S = Soderberg technology-specific emission factor (t CO_2/t aluminum); and
MP_S = quantity of aluminum produced from the Soderberg process (t aluminum).

In the Tier 2 method, the carbon content in the consumption of anode (Prebaked Anode technology) or paste (Soderberg technology) is considered to be fully converted into CO_2. Typical industry values for impurities are applied in both cases (Equation 5.10).

Dataframe 5.15. Equation for estimating CO_2 emissions from prebaked anode consumption.

Equations	GHG	Categories	Central equation	Reference
Equation 5.10	CO_2	2.C.3	$E_{CO2} = NAC \bullet MP \bullet \frac{100 - S_a - Ash_a}{100} \bullet \frac{44}{12}$	Equation 4.21 (IPCC, 2006, v. 3, chap. 4)

In which:

E_{CO2} = CO_2 emissions from the consumption of prebaked anode (t CO_2);
MP = quantity of aluminum produced by the Prebaked Anode process (t aluminum);
NAC = net prebaked anode consumption per ton of aluminum (t C / t aluminum);
S_a = sulphur content in baked anodes (%);
Ash_a = ash content in baked anodes (%); and
44/12 = ratio of CO_2/C molecular masses (dimensionless).

Emissions from the burning of fossil fuels used in the production of baked anodes were considered in the Energy Sector. However, two other sources of CO_2 emissions are associated with anode baking furnaces – the combustion of volatiles in pitch and the baking furnace packaging material (Equation 5.11 and Equation 5.12). The IPCC (2006) provides default values for the Prebaked Anode technology, according to Table 5.39.

Dataframe 5.16. Equation for estimating CO_2 emissions from the combustion of volatiles in pitch.

Equations	GHG	Categories	Central equation	Reference
Equation 5.11	CO_2	2.C.3	$E_{CO2} = (GA - H_w - BA - WT) \bullet \frac{44}{12}$	Equation 4.22 (IPCC, 2006, v. 3, chap. 4)

In which:

E_{CO2} = CO_2 emissions from the combustion of volatiles in pitch (t CO_2);
GA = original weight of the anodes before baking (t);
Hw = hydrogen content of the anodes before baking (t);
BA = baked anode production (t);
WT = tar waste collected (t); and
44/12 = ratio of CO_2/C molecular masses (dimensionless).

Dataframe 5.17. Equation for estimating CO_2 emissions from the combustion of packaging material in the baking furnace.

Equations	GHG	Categories	Central equation	Reference
Equation 5.12	CO_2	2.C.3	$E_{CO2} = PCC \bullet BA \bullet \frac{100 - S_{pc} - Ash_{pc}}{100} \bullet \frac{44}{12}$	Equation 4.23 (IPCC, 2006, v. 3, chap. 4)

In which:

E_{CO2} = CO_2 emissions from the combustion of packaging material in the baking furnace (t CO_2);
PCC = packaging material consumption (t/t BA);
BA = baked anode production (t);
Spc = sulphur content in the packaging material (%);
Ash_{pc} = ash content in the packaging material (%); and
44/12 = ratio of CO_2/C molecular masses (dimensionless).

Table 5.39. Default values for the parameters of the Prebaked Anode technology (Tier 2).

***Prebaked Anode* Technology**	
Factor (Tier *2*)	**CWPB/SWPB**
Sa = sulphur content in baked anodes (%)	2
Asha = ash content in baked anodes (%)	0.4
Hw = hydrogen content of anodes before baking (t)	0.005*GA[1]
WT = tar waste collected (t)	0.005*GA for Riedhammer furnaces; 0 for others
PCC = packaging material consumption (t/t BA)	0.015
Spc = sulphur content in the packaging material (%)	2
Ashpc = ash content in the packaging material (%)	2.5

Notes: [1] GA (green anodes) prebaked anodes.

Source: Based on IPCC (2006).

In the case of emissions related to the consumption of paste (Soderberg), emissions are calculated according to Equation 5.13, taking into account the IPCC (2006) parameters in Table 5.40.

Dataframe 5.18. Equation for estimating CO_2 emissions from paste consumption.

Equations	GHG	Categories	Central equation	Reference
Equation 5.13	CO_2	2.C.3	$E_{CO2} = (PC \bullet MP - \frac{CSM \bullet MP}{1000} - \frac{BC}{100} \bullet PC \bullet MP \bullet \frac{Sp+Ashp+Hp}{100} - \frac{100-BC}{100} \bullet PC \bullet MP \bullet \frac{Sc+Ashc}{100} - MP \bullet CD) \bullet \frac{44}{12}$	Equation 4.24 (IPCC, 2006, v. 3, chap. 4)

In which:

E_{CO2} = CO_2 emissions from paste consumption (t CO_2);
MP = quantity of aluminum produced in the Soderberg process (t aluminum);
PC = paste consumption per ton of aluminum (t C / t aluminum);
CSM = emissions from cyclohexane soluble matter per ton of aluminum (kg / t aluminum);
BC = binder content in the paste (%);
S_p = sulphur content in pitch (%);
Ash_p = ash content in pitch (%);
H_p = hydrogen content in pitch (%);
S_c = sulphur content in the paste's calcined coke (%);
Ash_c = ash content in the paste's calcined coke (%);
CD = carbon in the supernatant dust of the Soderberg vats (%); and
44/12 = ratio of CO_2/C molecular masses (dimensionless).

Table 5.40. Default values for the parameters of the Soderberg technology (Tier 2).

Factor (Tier 2)		
Parameters	**VSS**	**HSS**
CSM = emissions from cyclohexane soluble matter (kg / t aluminum)	0.5	4.0
BC = binder content in the paste (%) dry paste (wet)	24.0 (27.0)	24.0 (27.0)
Sp = sulphur content in pitch (%)	0.6	0.6
Ashp = ash content in pitch (%)	0.2	0.2
Hp = hydrogen content in pitch (%)	3.3	3.3
Sc = sulphur content in the calcined coke of the paste (%)	1.9	1.9
AshC = ash content in the calcined coke of the paste (%)	0.2	0.2

Source: Based on IPCC (2006).

In the Tier 3 method, the same reasoning is used as in Tier 2, only the values indicated in Table 5.39 are replaced by measured or specific parameters for each plant.

To estimate PFC emissions from primary aluminum production, in the case of CF_4 and C_2F_6, the Tier 1 method uses the subdivisions of the Prebaked Anode (CWPB or SWPB) and Soderberg (VSS or HSS) technologies, with default emission factors (Table 5.41) applied to production in each case, according to Equation 5.14 and Equation 5.15.

Table 5.41. Default emission factors for CF_4 and C_2F_6 in primary aluminum production.

Technology	$EFCF_4$	EFC_2F_6
	kg CF_4/t Al	kg C_2F_6 /t Al
Prebaked Anode – CWPB	0.4	0.04
Prebaked Anode – SWPB	1.6	0.4
Soderberg – VSS	0.8	0.04
Soderberg – HSS	0.4	0.03

Source: Based on IPCC (2006).

Dataframe 5.19. Equation to estimate CF_4 emissions from aluminum production.

Equations	GHG	Categories	Central equation	Reference
Equation 5.14	CF_4	2.C.3	$E_{CF4} = \sum_i (EF_{CF4,i} \bullet MP_i)$	Equation 4.25 (IPCC, 2006, v. 3, chap. 4)

In which:

E_{CF4} = CF_4 emissions from aluminum production (kg CF_4);
EF_{CF4} = default emission factor by technology type i for CF_4 (kg CF_4/ t aluminum); and
MP = quantity of aluminum produced by technology type (t aluminum).

Dataframe 5.20. Equation for estimating C_2F_6 emissions from aluminum production.

Equations	GHG	Categories	Central equation	Reference
Equation 5.15	C_2F_6	2.C.3	$E_{C2F6} = \sum_i (EF_{C2F6,i} \bullet MP_i)$	Equation 4.25 (IPCC, 2006, v. 3, chap. 4)

In which:

E_{C2F6} = C_2F_6 emissions from aluminum production (kg C_2F_6);
EF_{C2F6} = default emission factor by technology type i for C_2F_6 (kg C_2F_6/ t aluminum); and
MP = quantity of aluminum produced by cell technology type i (t aluminum).

There are two Tier 2 methods for calculating CF_4 emissions: the slope method, Equation 5.16, and the overvoltage method, each one with an associated formula. Estimates of C_2F_6 are calculated as a fraction of CF_4 emissions (Equation 5.17). These equations refer to the slope method, which was the only one applied to estimates of PFCs emissions from the Brazilian aluminum industry.

Dataframe 5.21. Equation for estimating CF_4 emissions from aluminum production.

Equations	GHG	Categories	Central equation	Reference
Equation 5.16	CF_4	2.C.3	$E_{CF4} = S_{CF4} \bullet AEM \bullet MP$	Equation 4.26 (IPCC, 2006, v. 3, chap. 4)

In which:

E_{CF4} = CF_4 emissions from aluminum production, kg CF_4;
S_{CF4} = slope coefficient for CF_4 (kg CF_4/t aluminum) / (AE-min/cell-day);
AEM = Anode effect minutes per cell-day, AE-min/cell-day; and
MP = quantity of aluminum produced (t aluminum).

Dataframe 5.22. Equation for estimating C_2F_6 emissions from aluminum production.

Equations	GHG	Categories	Central equation	Reference
Equation 5.17	CF_4 / C_2F_6	2.C.3	$E_{C2F6} = E_{CF4} \bullet F_{C2F6/CF4}$	Equation 4.26 (IPCC, 2006, v. 3, chap. 4)

In which:

E_{C2F6} = C_2F_6 emissions from aluminum production, kg C_2F_6;
E_{CF4} = CF_4 emissions from aluminum production, kg CF_4; and
$F_{C2F6/CF4}$ = weight fraction of C_2F_6/CF_4 (kg C_2F_6/kg CF_4).

On the other hand, Table 5.42 shows the default values for the slope coefficient and the C_2F_6/CF_4 ratio, by technology, in the Tier 2 approach.

In the Tier 3 method, the same reasoning is used as in Tier 2, only the values indicated in Table 5.42 are replaced by measured or specific parameters for each plant.

Table 5.42. Slope coefficients for calculating emissions for CF_4 and C_2F_6.

Technology	Slope coefficient	FC_2F_6/CF_4 = C_2F_6/CF_4 ratio
	(kg CF_4/t aluminum)/(AE-min/cell-day)	kg C_2F_6/kg CF_4
Prebaked Anode – CWPB	0.143	0.121
Prebaked Anode – SWPB	0.272	0.252
Soderberg – VSS	0.092	0.053
Soderberg – HSS	0.099	0.085

Source: Based on IPCC (2006).

To estimate CO and NO_x emissions, the Tier 1 methodology (IPCC, 1997) was followed, according to the emission factors in Table 5.43.

Table 5.43. Emission factors for CO and NO_x in primary aluminum production.

Emission source	CO	NO_x
Electrolytic process	135	2.15
Baking of anodes	400	NE

Source: Based on IPCC (2006). Unit: kg/t aluminum.

Lastly, it should be noted that the companies only provided detailed calculations of emission factors up to 2007 or 2008, which required the adoption of the following assumptions:

- For CO_2, the 2007 emission factors for each plant were maintained.
- For CF_4, the average of the last three emission factors for each plant was applied.
- For C_2F_6, the ratio of C_2F_6/CF_4 that existed in 2007 for each plant was considered.

Activity data and other parameters

Emissions of CO_2 and PFCs were estimated for the period from 1990 to 2022. The results reflect the consolidation of the measurements made by the companies in certain periods; and when it was not possible to use the measurement, the IPCC (2006) default values were applied.

Each plant used the best possible approach (Tier) to calculate the emissions from its processes according to Table 5.44.

Table 5.44. Approaches used to estimate CO_2 and PFC emissions by plant for the period from 1990 to 2007.

Technology route		Plant	CO_2	PFCs
Type	Subdivision			
Soderberg	VSS e HSS	Novelis (BA) (State of Bahia)	Tier 2	Tier 2
	HSS	Novelis (MG) (State of Minas Gerais)	Tier 2	Tier 2
	VSS	Alcoa (MG)	Tier 2	Tier 3
	VSS	CBA (SP) (State of São Paulo)	Tier 3	Tier 3
Prebaked Anode	CWPB	Albras (PA) (State of Pará)	Tier 1	Tier 1 (1990-1996) Tier 3 (1997-2007)
	CWPB	Alumar (MA) (State of Maranhão)	Tier 3	Tier 2
	CWPB	Valesul (RJ) (State of Rio de Janeiro)	Tier 2	Tier 1

The data collected for the PFCs emission estimates included:

- Annual aluminum production based on the records of the electrolytic vat rooms of the primary production companies themselves.
- Data on the duration and frequency of anode effects from the following

companies: Novelis, Alcoa, Votorantim Metais – CBA, Albras and Alumar. For Valesul, emissions estimates were made using Tier 1.

The data for the estimates of CO_2 emissions were:

- Annual aluminum production based on records from the companies' electrolytic vat rooms.
- The anode consumption data for each Novelis, Alcoa, VMetais – CBA and Alumar plant. Emissions from Albras were estimated using Tier 1.

Data was collected with the collaboration of the aluminum producing companies, for the period from 1990 to 2007/2008, for each plant. From 2008 onwards, the quantities of primary aluminum produced by technology and plant were obtained from ABAL– Brazilian Aluminum Association (Associação Brasileira do Alumínio) (2013; 2019), ALBRAS (2022) and CBA (2022) (Table 5.45).

Table 5.45. National production of primary aluminum, by type of technology, 1990-2022.

Detail	Brazilian aluminum production (tons)									
	Soderberg Technology					Prebaked Anode Technology				Total
Plant	Novelis	Novelis	Alcoa	CBA	Total	Albras	Alumar	Valesul	Total	
Tech type.	VSS+HSS	HSS	VSS	VSS	Soderberg	CWPB	CWPB	CWPB	Prebaked Anode	
Location	Aratu – BA	Ouro Preto – MG	Poços de Caldas – MG	Alumínio – SP		Barcarena – MG	São Luís - MA	Santa Cruz – RJ		
1990	56,382	50,896	88,512	174,013	**369,803**	193,997	264,324	92,749	**551,070**	**920,873**
1991	56,826	49,900	89,438	204,328	**400,492**	287,995	352,173	92,181	**732,349**	**1,132,841**
1992	56,533	50,615	89,646	216,431	**413,225**	335,192	357,386	93,014	**785,592**	**1,198,817**
1993	28,910	48,938	89,821	216,883	**384,552**	345,017	358,669	85,169	**788,855**	**1,173,407**
1994	29,890	42,580	90,401	221,804	**384,675**	347,419	362,630	90,696	**800,745**	**1,185,420**
1995	38,427	41,516	89,766	220,462	**390,171**	341,129	365,269	91,891	**798,289**	**1,188,460**
1996	49,033	44,369	88,761	220,007	**402,170**	339,661	363,579	91,581	**794,821**	**1,196,991**
1997	45,604	47,666	89,690	220,972	**403,932**	337,983	353,921	92,333	**784,237**	**1,188,170**
1998	53,648	48,869	90,922	221,047	**414,486**	344,697	355,296	92,859	**792,852**	**1,207,338**
1999	52,660	49,707	91,261	233,883	**427,511**	361,242	365,623	93,074	**819,939**	**1,247,449**
2000	56,631	50,302	91,733	240,078	**438,744**	369,209	369,059	92,572	**830,840**	**1,269,584**
2001	47,607	44,438	69,637	230,375	**392,056**	334,782	325,674	79,845	**740,301**	**1,132,357**
2002	52,210	49,575	87,220	246,435	**435,440**	416,140	370,520	92,883	**879,543**	**1,314,983**
2003	56,265	50,173	95,014	284,273	**485,725**	435,922	333,066	94,613	**863,601**	**1,349,326**
2004	57,823	50,950	90,693	345,365	**544,831**	440,458	377,084	95,361	**912,903**	**1,457,734**
2005	57,033	50,593	95,267	370,368	**573,261**	449,520	380,967	94,007	**924,494**	**1,497,755**
2006	58,442	51,439	96,120	404,922	**610,922**	459,886	437,596	95,845	**993,327**	**1,604,249**
2007	58,503	49,790	96,482	450,872	**655,647**	458,896	447,155	93,768	**999,819**	**1,655,466**
2008	58,704	44,778	97,203	465,743	**666,429**	459,289	451,628	85,724	**996,641**	**1,663,070**
2009	52,038	48,752	65,253	471,354	**637,397**	453,781	434,121	10,241	**898,143**	**1,535,540**
2010	40,870	48,168	88,327	472,018	**649,383**	451,117	433,203	0	**884,320**	**1,533,703**
2011	0	48,741	87,914	405,296	**541,951**	458,166	439,157	0	**897,323**	**1,439,274**
2012	0	46,500	85,900	454,893	**587,293**	446,669	402,400	0	**849,069**	**1,436,362**
2013	0	29,200	69,400	413,700	**512,300**	452,300	339,500	0	**791,800**	**1,304,100**
2014	0	18,000	17,500	318,500	**354,000**	441,000	167,000	0	**608,000**	**962,000**
2015	0	0	0	302,200	**302,200**	435,200	34,800	0	**470,000**	**772,200**
2016	0	0	0	343,900	**343,900**	446,100	0	0	**446,100**	**790,000**
2017	0	0	0	355,000	**355,000**	446,700	0	0	**446,700**	**801,700**
2018	0	0	0	351,500	**351,500**	307,500	0	0	**307,500**	**659,000**

Continued. National primary aluminum production, by type of technology, 1990-2022

Detail	Brazilian aluminum production (tons)									
	Soderberg Technology					*Prebaked Anode* Technology				
Factory	**Novelis**	**Novelis**	**Alcoa**	**CBA**	**Total**	**Albras**	**Alumar**	**Valesul**	**Total**	**Total**
Tech type.	VSS+HSS	HSS	VSS	VSS		CWPB	CWPB	CWPB		
Location	Aratu – BA	Ouro Preto – MG	Poços de Caldas – MG	Alumínio - S	**Soderberg**	Barcarena – MG	São Luís – MA -	Santa Cruz – RJ	**Prebaked Anode**	
2019	0	0	0	323,554	**323,554**	326,588	0	0	**326,588**	**650,142**
2020	0	0	0	306,192	**306,192**	378,918	0	0	**378,918**	**685,110**
2021	0	0	0	344,800	**344,800**	426,900	0	0	**426,900**	**771,700**
2022	0	0	0	347,000	**347,000**	405,000	0	0	**405,000**	**752,000**

5.5.1.4 Magnesium Production

SF_6 is used as a cover gas to prevent the oxidation of molten magnesium during the production and casting of magnesium metal products and normally escapes into the atmosphere. SF_6 is considered a non-reactive gas and is ideally suited to this type of protection, as a "cover" for molten magnesium (hence the term "cover gas"). The consumption of the gas used is, therefore, taken as an estimate of emissions. However, the production of magnesium by Rima Industrial, the only magnesium producer in Brazil, started using SO_2 instead of SF_6 due to a CDM project,[44] eliminating its use from the second half of 2009. The use of dolomite – the only feedstock used in the process – also generates CO_2 emissions.

SF_6 emissions are based on the amount of gas that was consumed before the CDM project, when 100% of the gas was emitted after use. According to IPCC (2006), CO_2 emissions from the calcination of dolomite ($CaCO_3.MgCO_3$) used should be reported in this category. The approach used was Tier 1, with an emission factor of 5.13 t CO_2/t magnesium produced (due to the calcination of dolomite).

Activity data and other parameters

The series reported for the inventory of the Third National Communication (BRASIL, 2016), which extended until 2011, was taken into account. For 2008, the same SF_6 emissions were considered as for 2007; and for 2009, half of them was considered, since the first monitoring report indicates that the CDM project actually began in the second half of 2009. For the years from 2010 to 2021, data was obtained from CDM project reports directly from the UNFCCC (2024). The value for 2022 was extrapolated from the trend of the previous five years.

The activity data is shown in Table 5.46.

Table 5.46. Magnesium production, 1990 to 2022.

Year	Magnesium production
	t
1990	5,731
1991	5,805
1992	6,945
1993	10,046
1994	9,833
1995	10,043
1996	9,706
1997	12,692
1998	10,025

[44] "Conversion of SF_6 to the alternative cover gas SO_2 at RIMA magnesium production". Available at: https://cdm.unfccc.int/Projects/projsearch.html.

Year	Magnesium production
	t
1999	9,753
2000	10,256
2001	9,291
2002	10,092
2003	10,693
2004	12,105
2005	14,337
2006	16,648
2007	18,181
2008	20,043
2009	21,904
2010	18,545
2011	17,848
2012	21,002
2013	23,183
2014	23,629
2015	25,087
2016	27,363
2017	26,471
2018	27,214
2019	28,144
2020	25,817
2021	29,420
2022	28,764

5.5.1.5 Lead Production

Production in Brazil is of secondary lead. According to the IPCC (2006), the process uses reducers such as coal, natural gas and metallurgical coke, and can also use petroleum coke in electric furnaces.

As mentioned above, the emissions corresponding to the production process are reported in the Other (Non-Ferrous Metals, Except Aluminum and Magnesium) (2.C.7) category7).

5.5.1.6 Zinc Production

Domestic zinc production begins with the dismantling of ore from the mines with a metal content ranging from 3.6% to 20.0%. After successive crushing, the ore is ground and then undergoes the flotation and filtering process to obtain the concentrate, which already has a zinc content of 45.0%. Only then is it converted by the chemical leaching process (hydrometallurgy), followed by electrolytic deposition, into SHG (Special High Grade) – type metal ingot with a zinc content greater than or equal to 99.99% (BRASIL, 2017).

This process does not use reducers and, therefore, does not emit CO_2 or other gases that can be reported in this inventory.

5.5.1.7 Other (Non-Ferrous Metals, Except Aluminum and Magnesium

In addition to aluminum and magnesium, other non-ferrous metals are produced in Brazil, including: lead (only secondary production), copper, tin, nickel, silicon metal and zinc. The production of these non-ferrous metals, except copper and zinc, uses fuels as oxide reducers in furnaces at some stage of the process, emitting CO_2.

For emissions in this category, in the absence of specific emission factors for non-ferrous metals, other than aluminum, we adopted the approach of using the fuels used in BEN (EPE, 2023) and which, according to BEU (EPE, 2005), are used for direct heating, generally as reducers.

The methodology for calculating CO_2 emissions follows Equation 5.18. Subsequently, the CO_2 emissions from aluminum production, already reported, were subtracted, since the fuels used in the process are listed together in BEN with those of other non-ferrous metals.

Dataframe 5.23. Equation for estimating CO_2 emissions from non-ferrous metals production.

Equations	GHG	Categories	Central equation	Reference
Equation 5.18	CO_2	2.C.7	$E_{CO2} = \sum_i (\text{Reducing fuel}_i \bullet EF_i) / 10^3$	EPE (2005; 2023)

In which:

E_{CO2} = CO_2 emissions (Gg);
Reducing fuel i = consumption of type i reducing fuel reported in BEU for direct heating (TJ); and
EFi = emission factor of type i reducer (t CO_2/TJ).

Due to the lack of more information, the carbon contained in non-ferrous metals was not taken into account. The CO_2 emission factors used are the same as those used in the Energy Sector (CRT 1), according to Table 5.47.

Table 5.47. CO_2 emission factors for reducers used in non-ferrous metals production.

Furnaces (AD)	kg CO_2/TJ
Petroleum coke	97,500
Bituminous coal (CV6000)	94,600
Coal coke	107,000
Charcoal	106,519

Source: Based on IPCC (2006).

Activity data and other parameters

The fuels used in the production of each metal are reported in Table 5.48 and are considered as reducers for non-ferrous metals and excluded from the Energy sector. The table includes information on the use of petroleum coke for aluminum production, which should be subtracted from the total for this fuel, as the emissions are already reported in the respective category.

Table 5.48. Energy sources used as reducers for the production of non-ferrous metals.

Year	Petroleum Coke	Coal Coke	Charcoal
	thousand m^3	thousand t	thousand t
1990	401.0	104.0	393.8
1991	447.0	98.0	315.9
1992	431.0	91.0	317.9
1993	474.0	253.9	174.9
1994	526.0	126.9	189.9
1995	547.0	243.9	225.9
1996	596.0	239.9	48.0
1997	492.0	117.0	40.0
1998	447.0	109.0	34.0
1999	462.0	109.0	4.0
2000	486.0	125.9	9.0
2001	437.0	125.9	9.0
2002	494.3	121.7	12.0
2003	578.0	157.0	12.0
2004	569.0	198.0	12.0
2005	587.2	201.3	12.2
2006	628.0	212.0	13.1
2007	668.3	219.0	13.7
2008	676.0	216.0	14.1
2009	676.0	199.8	13.1
2010	700.8	220.4	14.4
2011	843.8	335.4	13.9
2012	803.7	403.9	15.9
2013	751.5	400.0	17.5
2014	683.9	404.0	21.1
2015	586.7	355.5	16.4
2016	601.4	331.1	15.5
2017	597.8	348.8	16.7
2018	516.2	370.8	17.6
2019	514.0	378.9	16.9
2020	541.8	387.3	16.2
2021	506.5	464.7	17.1
2022	455.5	422.9	15.6

5.5.2 Quality assurance and quality control

The quality assurance/quality control (QA/QC) procedures for the Metal Industry subsector (2.C) were applied in accordance with the QA/QC plan described in section 2.5 of this NIR, and are in line with Volume 1, Chapter 6, of the 2006 IPCC Guidelines.

5.5.3 Assessment of uncertainty, consistency and recalculations of the time series

Uncertainty analysis was carried out using the random sampling methods and techniques described in the 2006 IPCC Guidelines. The uncertainty associated with emissions of CO_2, CH_4, N_2O and PFCs from the Metal Industry (2.C) is presented in Appendix II.

The updating of the inventory included revising the time series of activity data in view of access to data, generally obtained from Associations, such as IABr and ABAL, relating to iron and steel production and aluminum production, respectively, as well as from SIDRA/IBGE, BEN and UNFCCC (ABAL, 2019; IABR, 2017; 2023; EPE, 2023; IBGE, 2024b; UNFCCC, 2024). In summary, the main adjustments stem from:

- *Iron and Steel (2019-2020):* revision of production data previously extrapolated in Brasil (2022) due to lack of information;
- *Ferroalloys (2018-2020):* revision of production data previously extrapolated in Brasil (2022) due to lack of information;
- *Aluminum (2018-2020):* revision of aluminum production based on the sector's yearbook and data from producing companies, which were previously extrapolated;
- *Magnesium (2019-2020):* revision of production based on CDM project; and
- *Other non-ferrous metals (2020):* revision of previously extrapolated fuel use data.

Compared to the previous Inventory, the largest proportion of adjustments in this NIR 2024 is found in 2019 and 2020, with -10% and -9% changes in emissions from the Metal Industry (2.C), respectively. This Inventory accessed data that was not previously available, which reduced the use of extrapolations to estimate activity data. In fact, the impact of the COVID-19 pandemic on estimates has been noticeable, particularly in 2020. The impact on emissions is mainly due to the fall in the level of activity in the iron and steel sector, in view of the adoption of measures to contain the movement of workers, which affected the construction production chain. Between 2017 and 2020, the average adjustment in aggregate emissions was 4%, and in the period from 1990 to 2020, it was only 0.5%, thus demonstrating the consistency of the sector's time series (Figure 5.8).

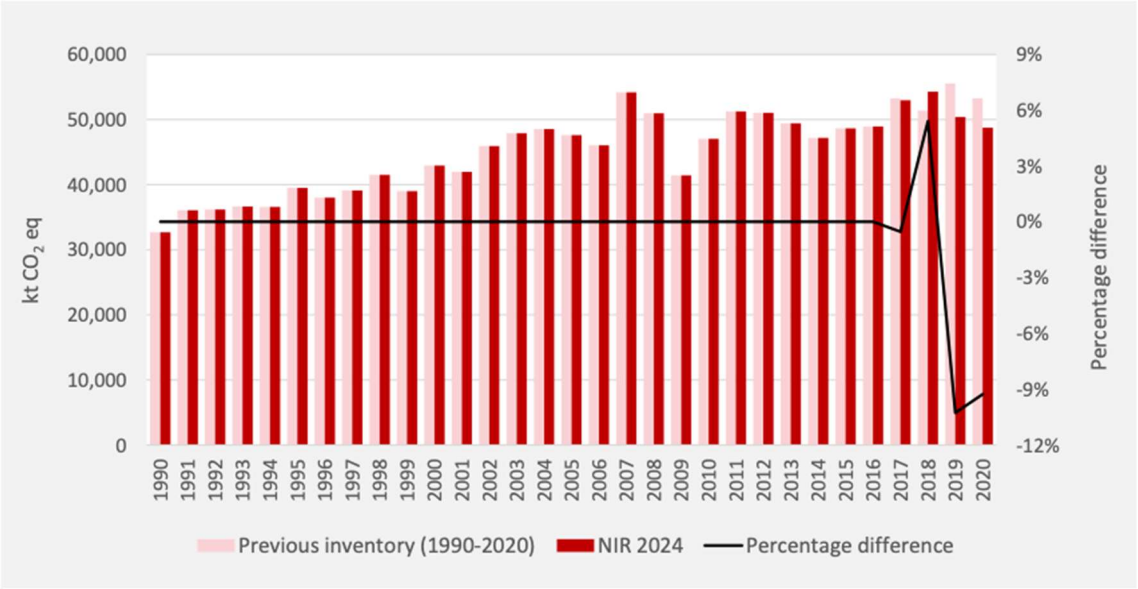


Figure 5.8. Comparison of estimated emissions from the Metal Industry subsector (2.C) between inventories.

5.5.4 Improvement plan

In view of the experience gained in drawing up national GHG inventories, the technical team proposed measures to improve the results of the Inventory, particularly in the Metal Industry (2.C) (Dataframe 5.24).

Dataframe 5.24. Potential improvements to improve the emissions inventory for the Metal Industry subsector (2.C).

Subsector	Category	Improvement
2.C. METAL INDUSTRY	General (all categories)	▪ Establish partnerships with a view to promoting the updating of the Useful Energy Balance on a four-yearly basis.
	2.C.1. Iron and Steel Production	▪ Establish Technical Cooperation Agreements or partnerships to obtain data on the sector's feedstocks and carbon, as well as disaggregated data by plant on industrial gases in blast furnaces and steelworks.
	2.C.2. Ferroalloys Production	▪ Establish partnerships with a view to promoting the systematic production of the Metal Sector's Yearbooks.
	2.C.3. Aluminum Production	▪ Establish partnerships to foster access to primary aluminum production data, as well as emission factors and other parameters, on a biennial basis.
	2.C.4. Magnesium Production	▪ Establish a dialogue with the company that holds the CDM project to facilitate access to removal data per project.

5.6 Non-Energy Products from Fuels and Solvent Use (CRT 2.D)

Emissions from the Non-Energy Products from Fuels and Solvent Use subsector (2.D) are related to the following categories: Lubricant Use (2.D.1) and Other (2.D.3). Emissions associated with Paraffin Wax Use (2.D.2) have been included in the Other category (2.D.3).

In 2022, the subsector emitted 843 kt CO_2 eq, which represented around 1% of total IPPU emissions. From 2020 to 2022, emissions from Non-Energy Products from Fuels and Solvent Use (2.D) increased by 3%. The Lubricant Use category (2.D.1) accounted for 85% of the subsector's total.

In this category, the emissions resulting from the use of lubricants in machinery and equipment are estimated only when burned in engines, and the rest is stored permanently. Emissions from the Other category (2.D.3), which complements the subsector, are related to the non-energy use of tar.

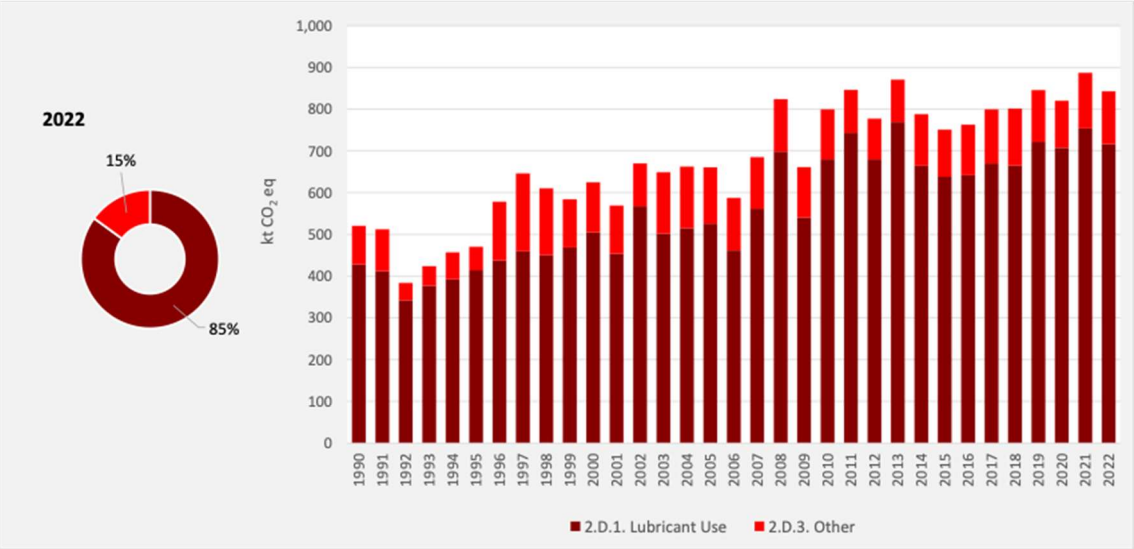


Figure 5.9. Emissions of Non-Energy Products from Fuels and Solvent Use (2.D), in kt CO_2 eq by category, from 1990 to 2022.

5.6.1 Methodological aspects

5.6.1.1 Lubricant Use

Lubricants are petroleum derivatives for use in machinery and equipment to prevent friction, in addition to their use in chemical industry processes. Although the source of information is the National Energy Balance (BEN), lubricants are covered in the Energy sector, but reported in the IPPU sector, according to the IPCC (2006). It is estimated that 80% of lubricants are stored permanently, and 20% are emitted in two-stroke engines, where they are burned along with the fuel.

To calculate CO_2 emissions from Lubricant Use, the default emission factor of 20 t C/TJ was used, which, then, needs to be multiplied by 44/12 to convert it into carbon dioxide.

Activity data and other parameters

BEN presents lubricant consumption figures in thousand m^3 (EPE, 2023). Therefore, it is necessary to use the conversion factors to toe, which varied annually, and the factor of 41.868 thousand toe/TJ, for conversion into terajoules (TJ). Table 5.49 shows the quantities consumed and the conversion factors.

Table 5.49. Lubricant consumption, excluding chemical use, 1990 to 2022.

Year	Non-energy consumption (non-chemical)	Conversion factor to toe
	thousand m^3	toe / m^3
1990	783	0.89031
1991	753	0.89031
1992	626	0.89031
1993	689	0.89031
1994	718	0.89031
1995	757	0.89031
1996	800	0.89031
1997	840	0.89031
1998	820	0.89408
1999	854	0.89320
2000	921	0.89232
2001	829	0.89056
2002	1,037	0.89100
2003	917	0.89100
2004	941	0.89100
2005	960	0.89100
2006	843	0.89100
2007	1,025	0.89100
2008	1,276	0.89100
2009	1,012	0.87000
2010	1,242	0.89100
2011	1,392	0.87000
2012	1,271	0.87000
2013	1,439	0.87000
2014	1,244	0.87000
2015	1,194	0.87000
2016	1,201	0.87000
2017	1,253	0.87000
2018	1,244	0.87000
2019	1,350	0.87000
2020	1,324	0.87000
2021	1,411	0.87000
2022	1,341	0.87000

5.6.1.2 Other

Tar is a secondary fuel derived from the processing of mineral coal in coking plants, used for energy (with emissions accounted for in the Energy sector) and non-energy purposes (with emissions accounted for in the IPPU sector. In the absence of more information, it was assumed that, according to the IPCC (1997) default values, 75% of the carbon is stored and the remaining 25% is finally emitted.

To calculate CO_2 emissions from the use of tar, the default emission factor of 22 t C/TJ was used, with subsequent multiplication by 44/12 for conversion into carbon dioxide.

In the case of evaporative emissions (NVMOC), emissions based on the use of asphalt used in paving were taken into account. In addition, emissions from dry natural gas, illuminating kerosene, anhydrous alcohol, hydrous alcohol and solvents were taken into account.

Given that this information was provided in EPE (2023), we proceeded directly with the transformation of the units from the values reported in BEN to units of mass. When asphalt is used for paving, volatile compounds are emitted at a rate of 320 kg NMVOC/t asphalt.

Activity data and other parameters

BEN presents tar consumption in thousand m^3 (EPE, 2023); for the conversion, the conversion factors to toe, which varied annually, and the factor of 41.868 thousand toe/TJ, for conversion into terajoules (TJ), were used. Table 5.50 shows the consumption and conversion factors.

Table 5.50. Tar consumption, excluding chemical use, 1990 to 2022.

Year	Non-energy consumption (non-chemical)	Conversion factor to toe
	thousand m^3	toe / m^3
1990	128	0.8547
1991	139	0.8547
1992	57	0.8547
1993	65	0.8547
1994	89	0.8547
1995	78	0.8547
1996	195	0.8547
1997	259	0.8547
1998	222	0.8547
1999	160	0.8547
2000	166	0.8547
2001	160	0.8547
2002	142	0.8550
2003	204	0.8550
2004	204	0.8550
2005	187	0.8550
2006	175	0.8550

Year	Non-energy consumption (non-chemical)	Conversion factor to toe
	thousand m^3	toe / m^3
2007	172	0.8550
2008	174	0.8550
2009	167	0.8550
2010	167	0.8550
2011	142	0.8550
2012	136	0.8550
2013	141	0.8550
2014	171	0.8550
2015	157	0.8550
2016	168	0.8550
2017	180	0.855
2018	189	0.855
2019	172	0.855
2020	156	0.855
2021	184	0.855
2022	175	0.855

For NMVOC emissions, the fuels listed in BEN (EPE, 2023) for the period from 1990 to 2022 were considered, along with the respective density information, as shown in Table 5.51.

Table 5.51. Fuel density for calculating NMVOC emissions.

Illuminating kerosene	790 kg/m^3
Anhydrous alcohol	791 kg/m^3
Hydrous alcohol	809 kg/m^3
Solvents	740 kg/m^3
Asphalt	1,040 kg/m^3
Other non-energy petroleum products	873 kg/m^3

Source: Based on EPE (2023).

5.6.2 Quality assurance and quality control

The QA/QC procedures adopted for the Non-Energy Products from Fuels and Solvent Use subsector (2.D) are described in section 2.5 of this document.

5.6.3 Assessment of uncertainty, consistency and recalculations of the time series

described in the 2006 IPCC Guidelines. The uncertainty associated with CO_2 emissions from Non-Energy Products from Fuels and Solvent Use (2.D) is presented in Appendix II.

The time series for activity data were revised in light of the publication of updated data from BEN (EPE, 2023). In summary, the main adjustments stem from:

- *Lubricants (2020):* revision of non-energy consumption of lubricants in light of the revision of the time series of the National Energy Balance; and
- *Tar (2017):* revision of the use of tar due to the revision of the data in the National Energy Balance.

When comparing the consolidated results of the previous Inventory with the results of this NIR 2024, the highest proportion of adjustments was seen in 2020, with a 3% difference between estimated emissions. It regards a revision of BEN's lubricant consumption data, which generally occurs for recent years in the time series, as mentioned in the Energy sector inventory. Between 2017 and 2020, the average adjustment in aggregate emissions was just 1%, and in the period from 1990 to 2020 it was 0.14%, demonstrating the consistency of the sector's time series (Figure 5.10).

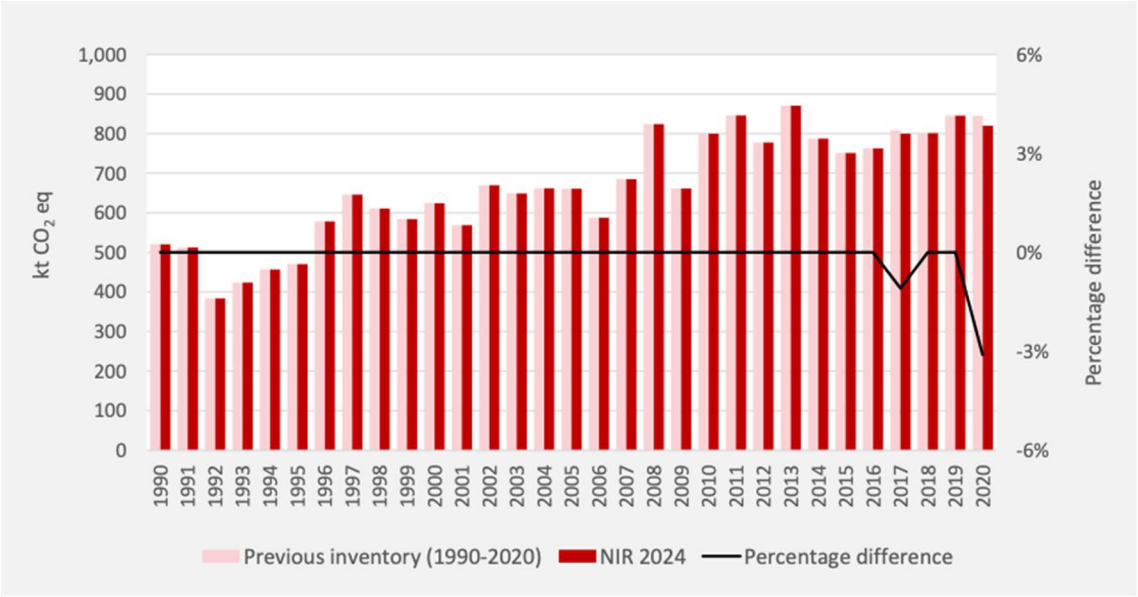


Figure 5.10. Comparison of estimated emissions from the Non-Energy Products from Fuels and Solvent Use subsector (2.D) between inventories.

5.6.4 Improvement plan

The experience gained in the periodic preparation of national GHG inventories has led to the proposal of a series of measures to improve the consistency and greater detailing of the Inventory's results, particularly in the Non-Energy Products from Fuels and Solvent Use subsector (2.D).

Dataframe 5.25. Potential improvements applicable to improving the emissions inventory for the Non-Energy Products from Fuels and Solvent Use subsector (2.D).

Subsector	Category	Improvement
2.D. NON-ENERGY PRODUCTS FROM FUELS AND SOLVENT USE	General (all categories)	▪ Deepen the studies on BEN's time series regarding tar and solvent consumption from 1990 to 2020.

5.7 Electronics Industry (CRT 2.E)

The Electronics Industry subsector (2.E) includes advanced electronics manufacturing processes, such as integrated circuits or semiconductors, thin-film transistor (TFT) flat panel displays, photovoltaics, heat transfer fluid, among others. These processes use fluorinated compounds and, for this NIR 2024, emissions of HFC-23 (CHF_3) and CF_4 have been identified and estimated.

Due to the impossibility of disaggregating the data, emissions related to the Integrated Circuit or Semiconductor (2.E.1) and TFT Flat Panel Display (2.E.2) categories have been reported in the Other category (2.E.5). The manufacture of photovoltaics in Brazil (emissions reported in the Photovoltaics category – 2.E.3) is still in its early stages, and it has not been possible to estimate the emissions related to this process due to the unavailability of data. In Brazil, there are no emissions related to the Heat Transfer Fluid category (2.E.4).

In 2022, the subsector emitted 1.2 kt CO_2 eq, which represented less than 0.1% of total IPPU emissions. From 2020 to 2022, emissions from the Electronics Industry (2.E) fell by 61% due to the fall in the level of activity in this subsector in the country, particularly in the semiconductor industry.

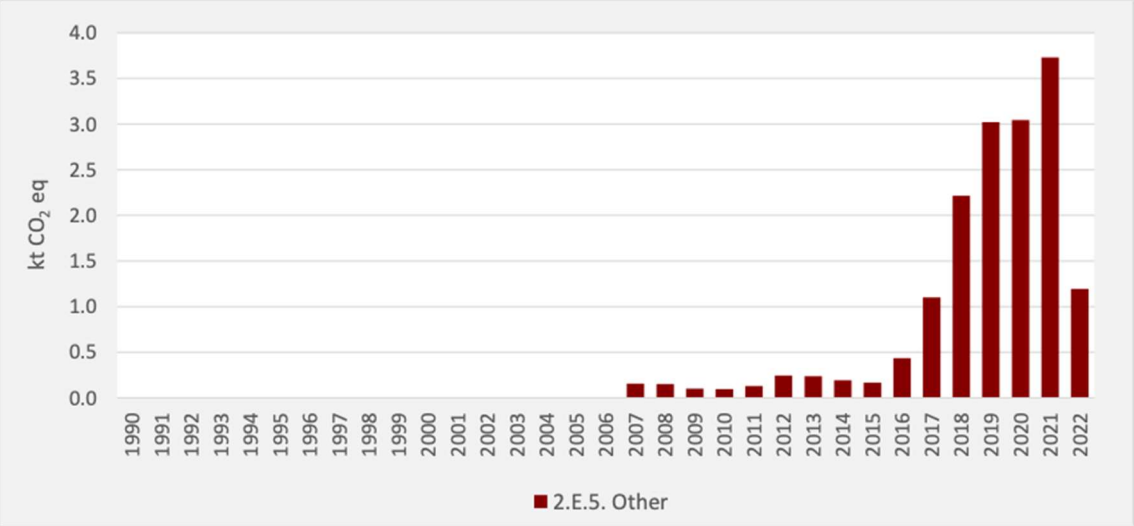


Figure 5.11. Emissions from the Electronics Industry (2.E), in kt CO_2 eq by category, from 1990 to 2022.

5.7.1 Methodological aspects

A metodologia utilizada para a obtenção das estimativas de emissões nesse subsetor é a The methodology used to obtain the emission estimates for this subsector is Tier 2a from chapter 6 of the IPCC (2006). Emissions are obtained using the default data provided by the IPCC and the amount of FC gases (fluorinated compounds) used to manufacture each type of product. It was not possible to obtain information on the amount of FC in each process. However, based on data obtained from other Tiers of the IPCC (2006), it was possible to determine which FCs are used in the manufacture of each type of equipment.

Considering that the semiconductor industry only began operating in the country in 2005 and that HFC-23 gas began to be imported in 2007, it was estimated using the emission factors for semiconductors. This use produces a small quantity of CF_4 as a by-product, which is also accounted for in this Inventory.

The FCs analyzed are also used in other sectors to manufacture various other electronic equipment, and the total of each CF imported will be applied to Equations 5.19 and 5.20 to obtain the emissions.

Dataframe 5.26. Equation for estimating FC emissions (Tier 2a).

Equations	GHG	Categories	Central equation	Reference
Equation 5.19	FC	2.E	$E_i = (1-h) \bullet FC_i \bullet (1-U_i) \bullet (1-a_i \bullet d_i)$	Equation 6.2 (IPCC, 2006, v. 3, p. 6.10)

In which:

Ei = emission of the gas, kg;
FCi = total consumption of gas i, (CF_4, C_3F_8, CHF_3, NF_3, SF_6), kg;
h = gas remaining in the container after processing (heel), fraction;
Ui = percentage of the gas used in the process (destroyed or transformed);
ai = fraction of the gas used in the process with emission control technologies; and
di = fraction of the gas destroyed by emission control technology.

Dataframe 5.27. Equation for estimating emissions from the co-product of CF_4.

Equations	GHG	Categories	Central equation	Reference
Equation 5.20	CF_4	2.E	$BPE_{CF4,i} = (1-h) \bullet B_{CF4i} \bullet FC_i \bullet (1-a_i \bullet d_{CF4})$	Equation 6.2 (IPCC, 2006, v. 3, p. 6.10)

In which:

BPE_{CF4i} = by-product of CF_4 as emission of the gas used, kg;
h = gas remaining in the container after processing (heel), fraction;
B_{CF4i} = emission factor, kg of CF_4 generated in the process, kg;
FCi = total consumption of gas i, (CF_4, C_3F_8, CHF_3, NF_3, SF_6) kg;
ai = fraction of the gas used in the process with emission control technologies; and
d_{CF4} = fraction of CF_4 destroyed by emission control technology.

Activity data and other parameters

HFC-23 import data was obtained from Comex Stat (MDIC, 2024) for the period from 2007 to 2022. The import figures for the substance, which is combined with various other gases, were used as a starting point. To disaggregate it, import data from January to May 2019 was obtained from the company Chemours Brasil for HFC-23 (CHEMOURS BRASIL, 2019), assuming that the import of the gas corresponds to 0.015% of the value presented by the Mercosur Common Nomenclature (NCM) that was considered.

Table 5.52 shows the HFC-23 activity data.

Table 5.52. HFC-23 activity data used to calculate emissions.

Year	Import	Export	Consumption	HFC-23 considered
2007	213,092	545	212,547	31.9
2008	206,717	554	206,163	30.9
2009	138,137	0	138,137	20.7
2010	130,130	45	130,085	19.5
2011	176,387	0	176,387	26.5
2012	334,316	19	334,297	50.1
2013	325,356	234	325,122	48.8
2014	261,703	81	261,622	39.2
2015	228,833	360	228,473	34.3
2016	592,908	36	592,872	88.9
2017	1,504,421	185	1,504,236	225.6
2018	3,036,255	10,613	30,25,642	453.8
2019	4,150,382	23,979	4,126,403	619.0
2020	4,182,123	23,135	4,158,988	623.8
2021	5,102,284	7,364	5,094,920	764.2
2022	1,632,182	796	1,631,386	244.7

Source: Based on Comex Stat (MDIC, 2024). Unit: kg.

The IPCC (2006) default emission factor for the "heel" or fraction of the purchased gas remaining in the shipping container after use (h) is 10% (0.1). It was adopted that, according to the IPCC, the default values for the destruction efficiency of FCs should be considered equal to 0 (zero) when it is not present in the processes that are performed. As the research did not indicate the use of these technologies, it was assumed as such.

Table 5.53. Emission factors applied to Equations 5.19 and 5.20.

Description	Parameter	Value	Reference
Heel (gas remaining in the container)	h	0.1	IPCC (2006)
Use of CHF_3	$1\text{-}Ui_{CHF3}$	0.4	
Destruction efficiency	$a_i{*}d_{CF4}$	0	
By-product of CF_4, when using CHF_3 in the process	B_{CF_4/CHF_3}	0.07	

5.7.2 Quality assurance and quality control

The QA/QC procedures adopted for the Electronics Industry subsector (2.E) are described in section 2.5 of this document.

5.7.3 Assessment of uncertainty, consistency and recalculations of the time series

Uncertainty analysis was carried out using the random sampling methods and techniques described in the 2006 IPCC Guidelines. The uncertainty associated with emissions of PFCs and HFCs from the Electronics Industry (2.E) is presented in Appendix II.

With regard to Brasil (2022), there was no need to revise the subsector's activity data. Therefore, the average adjustment in aggregate emissions was zero, thus demonstrating the consistency of the sector's time series.

5.7.4 Improvement plan

The experience gained in the periodic preparation of national GHG inventories has led to the proposal of a series of measures to improve the consistency and greater detailing of the Inventory's results, particularly in the Electronics Industry subsector (2.E).

Dataframe 5.28. Potential improvements applicable to improving the emissions inventory for the Electronics Industry subsector (2.E).

Subsector	Category	Improvement
2.E. ELECTRONICS INDUSTRY	2.E.3. Photovoltaics	▪ Establish partnerships with relevant companies and industry associations with a view to facilitating access to data to calculate the emissions related to solar panel production.
	2.E.5. Other	▪ Evaluate studies and national databases to identify HFC-23 import estimates.

5.8 Product Uses as Substitutes for Ozone Depleting Substances (CRT 2.F)

Hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) replace the ozone-depleting substances (ODS) controlled by the Montreal Protocol. There are several areas of application for these substances, such as refrigeration and air conditioning, firefighting, aerosol propellants and foams. Some of the categories into which these uses are grouped involve the storage of substances and their gradual release over the years due to leaks.

For this Inventory, emissions were estimated for the categories of Refrigeration and Air Conditioning (2.F.1), Foam Blowing Agents (2.F.2), Fire Protection (2.F.3) and Aerosols (2.F.4). Emissions related to Solvents (2.F.5), although they may exist, even in small quantities, have not been estimated, since uses in this category are very specific in certain electronic assembly and precision mechanics companies. In this subsector in particular, emissions cannot be obtained directly, as there is no reporting obligation on the part of companies, which has resulted in the use of support models and grouped import data for these substances.

The Product Uses as Substitutes for Ozone Depleting Substances subsector (2.F) emitted 8,891 kt CO_2 eq in 2022, contributing with 9% of IPPU emissions. Compared to 2020, emissions from the subsector increased by 13%, which can be explained by the increase in the rate of individual motorized transport to the detriment of the reduction of the use of public transport, as explained in section 3.1.

Figure 5.12 shows that the Refrigeration and Air Conditioning category (2.F.1) accounted for almost all of the subsector's emissions, with a share of 99% in 2022.

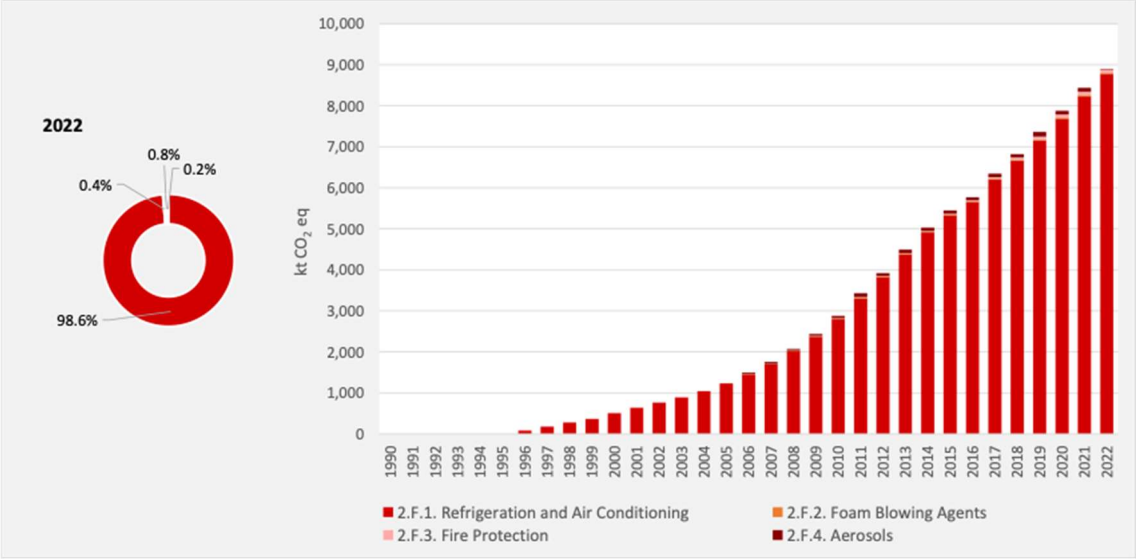


Figure 5.12. Emissions from Product Uses as Substitutes for Ozone Depleting Substances (2.F), in kt CO_2 eq, by category, from 1990 to 2022.

5.8.1 Methodological aspects

5.8.1.1 Refrigeration and Air Conditioning

In refrigeration and air conditioning, HFCs are used as alternatives to the refrigerants CFCs and HCFCs, the consumption of which has been and is being phased out in accordance

with the decisions of the Montreal Protocol. Refrigeration, air conditioning and heat pump applications constitute the sector with the highest consumption of substances used as refrigerants (UNEP, 2017).

For the various refrigeration and air conditioning applications, the Tier 2a methodology from chapter 7 of IPCC (2006) was used. This methodology was used due to the availability of the necessary activity data and because it provides more accurate estimates of emissions. The method is based on calculating emissions from the assembly, operation and final disposal of equipment, and follows Equation 5.21. Depending on the equipment or application in question, emissions can occur in all three phases or just in some of them.

Dataframe 5.29. Equation for estimating emissions from the co-product of CF_4.

Equations	GHG	Categories	Central equation	Reference
Equation 5.21	HFCs	2.F.1	$\text{Emissions}_{\text{total}} = \text{Emissions}_{\text{assembly}} + \text{Emissions}_{\text{operation}} + \text{Emissions}_{\text{disposal}}$	Equation 10 (IPCC, 2006, v. 3, p. 7.49)

In which:

> Emissions from Assembly = include emissions associated with product manufacture, even if the products are eventually exported;
> Emissions from Operation = include annual leaks of chemicals and emissions related to maintenance, which occur in all equipment in use. This calculation should include all units in the country, regardless of where they were manufactured; and
> Emissions from Disposal = include chemicals released from scrapped or finally disposed systems. Similarly to emissions from operation, they must include all equipment in the country where it was scrapped, regardless of where it was manufactured. In this inventory, emissions from the final disposal of refrigeration and air conditioning equipment have not yet been taken into account, as they are still considered to be within their useful life, since production with HFCs began. However, for the automotive sector, disposal was taken into account, as explained below.

Production of HFC-134a units began in 1997, taking into account the variation in CFC-12 consumption between 1996 and 2000. The hypothesis that was adopted was that the decrease in the manufacture of domestic refrigerators with CFC-12 refrigerant would be proportional to the decrease in CFC-12 consumption. It was also considered that the production of HFC-134a products began in 1997, taking into account the variation in CFC-12 consumption between 1996 and 2000, and that this decrease would be the same for the other refrigeration products. The values obtained with this method are shown in Table 5.54.

Table 5.54. Percentages of HFCs considered in the production of equipment, in the phase of replacement of CFCs, 1990 to 2022.

Year	Products with CFCs	Products with HFCs
	%	
1996	100%	0%
1997	69.7%	30.3%

Year	Products with CFCs	Products with HFCs
	%	
1998	54.8%	45.2%
1999	60.5%	39.5%
2000	0.3%	99.7%
2001-2022	0%	100%

Source: Based on Brasil (2021d).

Activity data and other parameters

For domestic refrigerators, production data was obtained from IBGE (2024b) and import and export data was obtained from Comex Stat (MDIC, 2024), listed in Table A.V.8 of Appendix V. From 2010, isobutane (HC-600a) began to enter the market as a substitute for HFC-134a. HC-600a is used in half of all domestic refrigerators produced nationally.

The rate of use of HFC-134a and HC-600a was obtained from data provided by experts in the field, and the rates shown in Table 5.55 were adopted. In addition, it was considered that the refrigerants used are HFC-134a and HC-600a, with a charge of 100g per unit (ELETROS – National Association of Manufacturers of Electrical and Electronic Products (Associação Nacional de Fabricantes de Produtos Eletroeletrônicos), 2024).

Table 5.55. Percentage of HFC-134a or HC-600a in the manufacture of domestic refrigerators.

Ano	HFC-134a	HC-600
2010	95%	5%
2011	95%	5%
2012	90%	10%
2013	90%	10%
2014	90%	10%
2015	90%	10%
2016	60%	40%
2017-2020	60%	40%

Source: Based on ELETROS (2024).

For commercial freezers, activity data was also obtained from MDIC (2024) and IBGE (2024b) – Table A.V.9 of Appendix V.

The refrigerants used to produce this equipment are HFC-134a and R-404A. For the period from 1990 to 2010, the ratio of 90% HFC-134a and 10% R-404A was maintained. From 2011 onwards, data was obtained from experts in the field (BRASIL, 2021d), which is why the average values of 70% HFC-134a and 30% R-404A were adopted. The average refrigerant charge for this equipment was considered to be equal to 150g.

Activity data for display cases, cold rooms and cooling units for water, juice and drinking fountains from IBGE (2024b) and MDIC (2024), listed in Table A.V.10 and Table A.V.11 (Appendix V) were also used.

For display cases and cold rooms, HFC-134a and an average refrigerant charge of 360g were considered to have been produced, and in the case of cooling units for water, juice and drinking fountains, they were considered to have all been produced with HFC-134a and with an average charge of 50g per unit.

Production and sales data for split air conditioners were obtained from ELETROS (2024) – Table A.V.12. The vast majority of compact air conditioners are still produced with HCFC-22 refrigerant. However, since 2010, some split-type appliances have started using R-410A refrigerant as a substitute. According to Eletros (2024), in 2016 the units produced with R-410A reached 20%, and the hypothesis is that the evolution of the use of R-410A between 2010 and 2022 has maintained this linear behavior.

Table 5.56. Percentage of Split air conditioner produced with R-410A.

Year	Percentage produced with R-410
2010	0%
2011	4%
2012	7%
2013	10%
2014	13%
2015	17%
2016-2022	20%

Source: Based on MITSIDI (2018).

The emissions from assembly were calculated using production data obtained by contacting the Superintendence of the Manaus Free Trade Zone (Suframa, Superintendência da Zona Franca de Manaus), while data for emissions due to use and handling from 2011 to 2016 were obtained from MITSIDI (2018) and ELETROS (2024). The year of 2010 was excluded from the emissions calculations, based on the assumption that no split air conditioning units with R-410A were produced in that year. A charge of 1kg per unit has been assumed for split air conditioners.

The activity data for central air conditioning (VRF) equipment (Table A.V.13) was estimated from information obtained from ABRAVA – Brazilian Refrigeration, Air Conditioning, Ventilation and Heating Association (Associação Brasileira de Refrigeração Ar Condicionado, Ventilação e Aquecimento) (2022), which is provided in cooling capacity, in TR,[45] of the total number of machines sold. The HFC refrigerant used was the same as for split (R- 410A) air conditioning with a linear progression from 0% to 20% until 2016, a level that remained constant until 2022.

Chillers are, basically, water chillers. The chilled water they produce is used to cool the air, products or equipment as required. For chillers, the activity data to calculate emissions was also estimated based on information obtained from Abrava (2022) – Table A.V.14, using the same procedure adopted for VRF equipment. It was considered that 30% of the total of this equipment was produced with HFC-134a from the moment CFCs ceased to be used, which

[45] Ton of refrigeration, 1 TR ~ 3.51 kW.

started from 1997. Data from Brasil (2015b) was adopted, considering the estimated refrigerant charge as 0.34 kg HFC-134a/kW cooling (LITTLE, 1999).

In order to estimate the number of vehicles (cars and light duty commercial vehicles), buses and trucks, due to the limitation of the vehicle scrapping curve used in Brasil (2015b; 2021d) which is restricted to 20 years, we opted to extrapolate from 2017 to 2022 based on the emissions trend from 2012 to 2016. In addition to this data, a linear regression was carried out to estimate the number of vehicles manufactured with air conditioning (Figure A.V.2, Appendix V).

According to Brasil (2015b), all vehicle air conditioning systems have been manufactured since 1996 using the refrigerant HFC-134a to replace CFC-12. The average HFC-134a refrigerant charge for vehicle air conditioning in cars and light duty commercial vehicles was estimated at 760g. This value, which differs from the one adopted in Brasil (2015b), was obtained from research on the amount of initial charge in each type of vehicle and the amount of each class of vehicle entering the market (Table 5.57).

Table 5.57. Entry in the national market by type of vehicle, 2008 to 2016.

Year	Distribution of vehicle sales				
	Small Hatch	SUV	Small Sedan	Large pickup truck	Other
2008	44.61%	5.53%	15.27%	3.59%	31.00%
2010	43.33%	6.27%	17.61%	3.92%	28.87%
2012	44.11%	7.51%	16.15%	4.54%	27.69%
2014	41.75%	8.98%	17.50%	5.14%	26.63%
2016	40.12%	15.20%	16.22%	7.87%	20.59%

Source: Based on Infomoney (2024).

For buses, it was also considered that HFC-134a was used in 100% of bus production from 1996 onwards. In line with Brasil (2015b; 2021d), of the total number of buses, 40% were considered to be for road transportation (coaches) and 60% for urban use (city buses). It was also considered that all coaches have air conditioning, but only 3% of the total urban bus fleet was considered to have this equipment. The average refrigerant charge for air conditioning systems in buses was considered to be 5kg per unit and the refrigerant used was considered to be HFC-134a for all units.

For road transportation with trucks, in line with Brasil (2021d), it was assumed that 1.63% of all trucks use refrigerated transportation with refrigerated chambers or trunks. Of these, 80% use the refrigerant HFC-134a, with a charge of 4.5kg; and the remaining 20% use R-404A, with a charge of 6kg. Replacement with these refrigerants occurs with the decrease in the production of systems containing CFCs established in the same way as with vehicle air conditioning, i.e., 0% in 1995 and 100% in 1996.

Finally, with regard to the use of air conditioning in trucks, no data was available on the proportion of trucks that have air conditioning systems, nor on the time variation of this

proportion over the period of the analysis. In view of that, initially, the number of trucks offered for sale by year of manufacture and the percentage that had an air conditioning system to cool the cab were surveyed (Table 5.58). (BRASIL, 2021d).

Table 5.58. Percentages obtained for the number of trucks produced with air conditioning systems.

Year	Percentage (%)
1995	2
1996	1.95
1997	2.75
1998	3.3
1999	2.2
2000	1.7
2001	1.45
2002	3.1
2003	2.6
2004	4.2
2005	4.1
2006	3.2
2007	3.8
2008	9.2
2009	7.25
2010	11.6
2011	15.4
2012	18.7
2013	23
2014	22.5
2015	32
2016-2022	27

From 2007 onwards, there was an increase in the percentage of truck units with air conditioning systems and, from that point onwards, we could see a greater increase of these systems in this type of vehicle. A second linear progression was adopted for these years, reaching 30% in 2016, that is, for the two periods, it was decided to consider two linear segments; the first being from 1995 to 2007 (variation from 2% to 4%), and the second from 2007 (variation from 4% to 30%). The percentages used of air-conditioned trucks obtained by linear progression are shown in Table 5.59. The average charge of HFC-134a refrigerant in truck air conditioning systems was set at 1.2kg per unit (HABEDA, 2017).

Table 5.59. Percentages used for the number of trucks produced with an air conditioning system.

Year	Percentage (%)
1995	2
1996	2.1
1997	2.2

Year	Percentage (%)
1998	2.3
1999	2.4
2000	2.6
2001	2.8
2002	3
2003	3.2
2004	3.4
2005	3.6
2006	3.8
2007	4
2008	7
2009	10
2010	13
2011	16
2012	19
2013	21
2014	24
2015	27
2016-2022	30

Lastly, Table 5.60 shows the emission factors used to estimate emissions for manufacture and use by type of refrigeration and air conditioning equipment (2.F.1).

Table 5.60. Emission factors for the manufacturing and handling (use) for Refrigeration and Air Conditioning (2.F.1).

Equipment description	Value for emissions during assembly	Value for emissions during handling (use)	Notes
Domestic refrigeration	0.6%	0.5%	Equation 7.4 (IPCC, 2006, v. 3, p. 7.17)
Commercial/industrial Refrigeration	1.75%	10%	
Cars/light duty commercial vehicles	0.5%	15%	
Buses	0.5%	30%	
Trucks with air conditioning	0.5%	15%	
Refrigerated trucks	0.5%	30%	
Chillers/Central air conditioning	1%	10%	
Drinking fountains	0.6%	10%	

Equipment description	Value for emissions during assembly	Value for emissions during handling (use)	Notes
Split air conditioning	0.5%	5%	

5.8.1.2 Foam Blowing Agents

For closed-cell foams, only around 10% of the blowing agent is released during the foaming process, while the remaining chemical substance is contained in the insulation. The amount that remains in the foam is slowly released over the 20 to 25 years of the foam's life.

Emissions were calculated according to Equation 5.22. It was assumed that the foam was manufactured in the middle of year t and, therefore, the portion of emissions related to the release of HFC contained in the foam will occur over the remaining half of the year in order to end the year under analysis. For the first year, a leakage rate of 50% was adopted.

Dataframe 5.30. Equation for estimating emissions from the co-product of CF_4.

Equations	GHG	Categories	Central equation	Reference
Equation 5.22	HFCs	2.F.2	$\text{Emissions}_t = 10\%\ \text{Quantity HFC}_t + 4.5\%\ \text{Quantity HFC}_{(t \text{ and } t-20)}$	Brasil (2021d).

In which:

> HFC emissions in year t = 10% of the total amount of HFC used in the manufacture of insulating foam in year t + 4.5% of the amount of HFC originally used in the foam manufactured between year t and t -20.

Activity data and other parameters

Surveys and contact with companies and associations in the sector carried out in Brasil (2015b) found that 50 tons of HFC-134a were used per year from 2006 to 2011 in the production of rigid foams. Further contact was made in Brasil (2021d), with a view to drawing up the inventory for the period from 1990 to 2016, which found that HFC-134a stopped being used in these applications from 2012 onwards. Therefore, their emissions were considered to be zero in following years.

For the HFC-365mfc/HFC-227ea blend, import and export data were obtained for 2017 and 2018 (BRASIL, 2021d). In view of that, an average value was estimated (Table 5.61) and applied to the period from 2007 to 2022, assuming that the average percentage remained constant over these years for this blowing agent, as shown in Table 5.62. The proportion of substances present in this HFC blend is 93% of HFC-365mfc and 7% of HFC-227ea. The calculations used are the same as for HFC-134a.

Table 5.61. Percentage of HFC-365mfc/227ea in Brazil in 2017 and 2018.

Year	Import (kg)	Export (kg)	NCM Total (kg)	Total HFC-365/227 (kg)	Percentage	Average
2017	3,508,948	42,673	3,466,275	19,200	0.55%	

2018	3,429,124	18,086	3,411,038	38,400	1.12%	0.84%

Source: Based on Brasil (2021d).

Table 5.62. Quantities of HFC-365mfc/227ea in NCM, 2007 to 2022.

Year	NCM Total (kg)	Quantity HFC-365mfc/227ea (kg)
2007	143,540	1,206
2008	83,997	706
2009	174,329	1,464
2010	211,809	1,779
2011	516,159	4,336
2012	943,918	7,929
2013	2,267,534	19,047
2014	2,463,626	20,694
2015	2,706,544	22,735
2016	2,849,597	23,937
2017	3,466,275	29,117
2018	3,411,038	28,653
2019	3,535,783	29,701
2020	3,761,239	31,594
2021	3,986,694	33,488
2022	4,212,150	35,382

Source: Based on Brasil (2021d); MDIC (2024).

5.8.1.3 Fire Protection

HFC-227ea is used in fire extinguishing systems where there is a large amount of electronic equipment and/or technology in general. At these sites, HFC-227ea gas suppression systems consist of the installation of HFC-227ea cylinders, which will be connected to the distribution networks in order to conduct the gas to the discharge sites. The substance is discharged into the emergency areas through special diffusers strategically installed in the protected areas.

Emissions were calculated using the IPCC (2006) default value for these systems, where 4% of this substance is leaked each year, so, the amount not emitted as leakage is added to the amount entering the market the following year to be a part of the emissions calculation for that year.

Activity data and other parameters

Data was obtained for the import of HFC-227ea for the years of 2017 and 2018. With the total import data for the product containing this substance, an average was extracted and used for the other years that were considered, according to Table 5.63.

Table 5.63. Percentage of HFC-227ea in Brazil in 2017 and 2018.

Year	Import (kg)	Export (kg)	Product Total (kg)	Total HFC-227ea (kg)	Percentage	Average
2017	1,503,885	185	1,503,700	119,358	8%	5.40%
2018	3,036,255	10,614	3,025,641	84,365	2.80%	

Source: Based on Brasil (2021d).

As with foams, an average value was estimated and applied for the period from 2007 to 2022, assuming that the average percentage remained constant over these years for this blowing agent, as shown in Table 5.64.

Table 5.64. Quantities of HFC-227ea in the product, 2007 to 2022.

Year	Product Total (kg)	Quantity HFC-227ea (kg)
2007	212,547	11,478
2008	206,163	11,133
2009	138,137	7,459
2010	130,085	7,025
2011	176,387	9,525
2012	334,297	18,052
2013	325,122	17,557
2014	261,622	14,128
2015	228,473	12,338
2016	592,872	32,015
2017	1,503,700	81,200
2018	3,036,119	163,950
2019	3,171,844	171,280
2020	3,854,274	208,131
2021	4,536,705	244,982
2022	5,219,135	281,833

Source: Based on Brasil (2021d); MDIC (2024).

It should be noted that the increase seen from 2017 onwards was found in imports, which practically doubled compared to 2016, and this annual growth pattern was maintained as a result of the extrapolation procedure adopted for 2019 to 2022.

5.8.1.4 Aerosols

Aerosol emissions usually occur shortly after production, on average six months after the sale. However, the period between manufacture and sale can vary significantly depending on the application involved. During the use of aerosols, 100% of the chemical substance is emitted.

Activity data and other parameters

The import fraction of HFC-134a for use in MDI reported for 2006 to 2016, according to Brasil (2021d), has been maintained. We decided to keep the fraction verified in 2016 for the 2017-2022 period, which, by applying new import data (MDIC, 2024), allows us to estimate consumption in MDI (kg), according to Table 5.65.

Table 5.65. Import, fraction and total, of HFC-134a used in MDIs.

Year	Import fraction of HFC-134a for use in MDI	Import of HFC-134a	Use in MDI
	%	kg	kg
2006	0.64	3,833,893	24,537
2007	0.64	6,023,421	38,550
2008	0.70	3,665,547	25,659
2009	0.65	5,194,744	33,766
2010	0.58	7,072,471	41,020
2011	1.11	6,756,598	74,998
2012	0.71	7,691,229	54,608
2013	0.74	9,056,364	67,017
2014	0.72	8,658,494	62,341
2015	0.72	8,479,463	61,052
2016	0.72	7,895,366	56,847
2017	0.72	9,339,421	67,244
2018	0.72	8,634,831	62,171
2019	0.72	12,390,438	89,211
2020	0.72	9,679,016	69,689
2021	0.72	10,258,874	73,864
2022	0.72	2,058,800	14,823

Source: Based on Brasil (2021d); MDIC (2024).

5.8.2 Quality assurance and quality control

The QA/QC procedures adopted for Product Uses as Substitutes for Ozone Depleting Substances (2.F) are described in section 2.5 of this document.

5.8.3 Assessment of uncertainty, consistency and recalculations of the time series

Uncertainty analysis was carried out using the random sampling methods and techniques described in the 2006 IPCC Guidelines. The uncertainty associated with HFC emissions for Product Uses as Substitutes for Ozone Depleting Substances (2.F) is presented in Appendix II.

The process of updating the national inventory took into account the revision of the time series of the activity data, in the light of the publication of updated documents covering,

above all, the export and import of HFCs of products in the 2.F. subsector. In summary, the main adjustments stem from:

- *Refrigeration and air-conditioning (2017-2020):* revision of the production of refrigerators and different types of air conditioning;
- *Foam Blowing Agents (2019-2020):* revision of the import and export of HFC-365mfc and HFC-227ea;
- *Fire protection (2019-2020):* revision of the import and export of HFC-227ea; and
- *Aerosols (2018-2019):* revision of the import and export of HFC-134ea for use in MDI.

When comparing the results consolidated in the previous Inventory with the ones carried out for this NIR 2024, the largest proportion of adjustments is seen in 2020, with a 1.3% difference between estimated emissions. Between 2017 and 2020, the average adjustment in aggregate emissions was only 0.6%, and in the period from 1990 to 2020 it was 0.08%, thus demonstrating the consistency of the sector's time series (Figure 5.13).

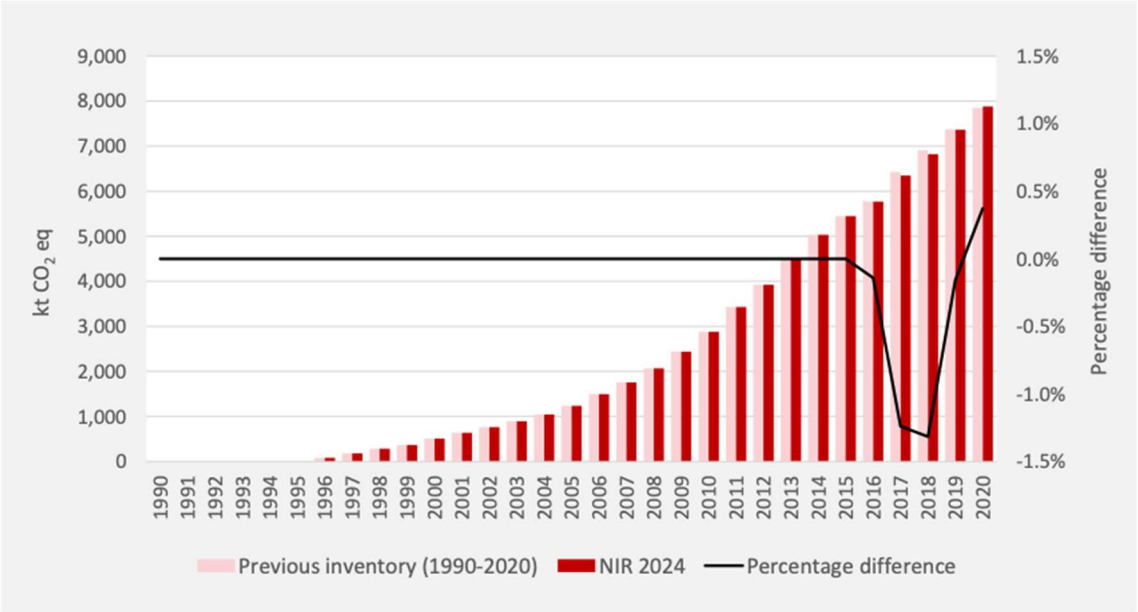


Figure 5.13. Comparison of estimated emissions from the Product Uses as Substitutes for Ozone Depleting Substances (2.F) subsector between inventories.

5.8.4 Improvement plan

In view of the limitations faced in drawing up the inventory for Product Uses as Substitutes for Ozone Depleting Substances (2.F), some actions are proposed to improve the results (Dataframe 5.31).

Dataframe 5.31. Potential improvements applicable to improving the emissions inventory for the Product Uses as Substitutes for Ozone Depleting Substances subsector (2.F).

Subsector	Category	Improvement
2.F. PRODUCT USES AS SUBSTITUTES FOR OZONE DEPLETING SUBSTANCES	2.F.1. Refrigeration and Air Conditioning	▪ Gather studies to assess the possibility of updating the vehicle scrapping curve used to estimate emissions in the category.
	2.F.2. Foam Blowing Agents	▪ Evaluate studies and databases on exports and imports of HFC-365mfc and HFC-227ea.
	2.F.3. Fire Protection	▪ Evaluate studies and databases on exports and imports of HFC-227ea.
	2.F.4. Aerosols	▪ Evaluate methodologies on how to obtain the HFC-134ea import fraction for use in MDI.
	2.F.5. Solvents	▪ Evaluate methodologies for the disaggregation of imports of HFCs and PFCs by solvent type.

5.9 Other Product Manufacture and Use (CRT 2.G)

The Other Product Manufacture and Use subsector (2.G) includes emissions from the use of SF_6, PFCs and N_2O in applications based on the different physical properties of these substances, such as the high dielectric constant of SF_6, the stability of PFCs and the anesthetic effects of N_2O. For this Inventory, only SF_6 emissions from the use in electrical power equipment were estimated, pertaining to the Electrical Equipment category (2.G.1).

There are no national emissions of SF_6 and PFCs in the Other Product Uses (2.G.2) and Other (2.G.4) categories, and the N_2O from Product Uses category (2.G.3), which covers anesthetic products, has not been estimated, due to the lack of data and the need for a more in-depth analysis of the data that has been recently systematized in Comex Stat (MDIC, 2024).

In 2022, emissions from the Other Product Manufacture and Use subsector (2.G) were estimated at 343 kt CO_2 eq and represented only 0.3% of total IPPU emissions. Compared to 2022, these emissions increased by 5%, and the variation is entirely related to the Electrical Equipment category (2.G.1).

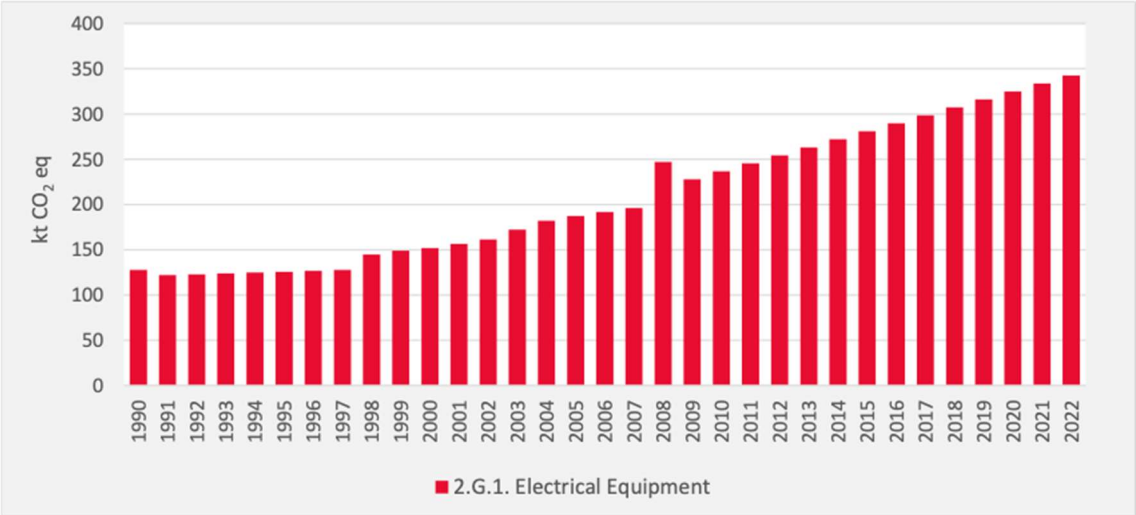


Figure 5.14. Emissions of SF_6 in Other Product Manufacture and Use (2.G), in kt CO_2 eq, from 1990 to 2022.

5.9.1 Methodological aspects

The estimates for SF_6 emissions involving the use in electrical power equipment, presented in Brasil (2010) and Brasil (2015b) were obtained through a survey of generation, transmission and distribution companies, referring to installed equipment facilities using SF_6 up to 2008, in terms of its nominal load.

The methodology used to estimate SF_6 is Tier 1, from Chapter 8 of IPCC (2006), which presents Equation 5.23. According to Table 8.3 (IPCC, 2006, p. 8.16), a leakage rate of 2.6% was adopted. Manufacturing emissions were ignored, since this equipment is not manufactured in Brazil, as well as destruction emissions, since the useful life of this equipment is over 35 years, so, it is not included in the data obtained and computed.

Dataframe 5.32. Equation for estimating emissions from the co-product of CF_4.

Equations	GHG	Categories	Central equation	Reference
Equation 5.23	HFCs	2.G.1	$\text{Emissions}_{\text{total}} = \text{Emissions}_{\text{manufacturing}} + \text{Emissions}_{\text{installation}} + \text{Emissions}_{\text{use}} + \text{Emissions}_{\text{destruction}}$	Equation 8.1 (IPCC, 2006, v. 3, p. 8.8)

In which:

Manufacturing emissions = Manufacturing emission factor - total consumption of SF_6 by manufactured equipment;
Installation emissions = Installation emission factor - Total nominal installed capacity of new equipment on site (not in the factory);
Equipment use emissions = Use emission factor - total nominal capacity of installed equipment. The "use emission factor" includes emissions due to leaks, service and maintenance, as well as failures; and
Emissions from the destruction of equipment = Total nameplate capacity of the depleted equipment - fraction of SF_6 remaining at the end of its useful life.

Activity data and other parameters

The installed capacity of SF_6 from electrical equipment from 1990 to 2008 was estimated. In the absence of new data for the period from 2009 to 2022, a linear extrapolation was made considering a series of 10 years of data, according to the parameters listed in Figure A.V.3 of Appendix V.

Table 5.66 shows the installed capacity of SF_6 in the electrical industry considered for estimating the emissions for category 2.G.1.

Table 5.66. Installed capacity of SF_6, 1990 to 2022.

Year	Installed capacity
1990	208,846
1991	199,627
1992	200,760
1993	202,415
1994	204,155
1995	205,467
1996	207,053
1997	208,844
1998	236,637
1999	243,837
2000	248,310
2001	255,931
2002	264,081
2003	281,954
2004	297,807
2005	306,316
2006	313,736
2007	320,629
2008	404,237
2009	373,063
2010	387,496
2011	401,929
2012	416,362
2013	430,795
2014	445,228
2015	459,661
2016	474,094
2017	488,527
2018	502,960
2019	517,393
2020	531,826
2021	546,259
2022	560,692

Source: Based on MCT (2009). Unit: kg.

5.9.2 Quality assurance and quality control

The QA/QC procedures adopted for Other Product Manufacture and Use (2.G) are described in section 2.5 of this document.

5.9.3 Assessment of uncertainty, consistency and recalculations of the time series

Foi realizada a análise da incerteza usando os métodos e técnicas de amostragem aleatória Uncertainty analysis was carried out using the random sampling methods and techniques described in the 2006 IPCC Guidelines. The uncertainty associated with SF_6 emissions from Other Product Manufacture and Use (2.G) is presented in Appendix II.

Given the extrapolation for the installed capacity of SF_6 from 2009 onwards, there was no need to revise the emissions time series. Consequently, no changes were identified in its time series, as can be seen in Figure 5.15.

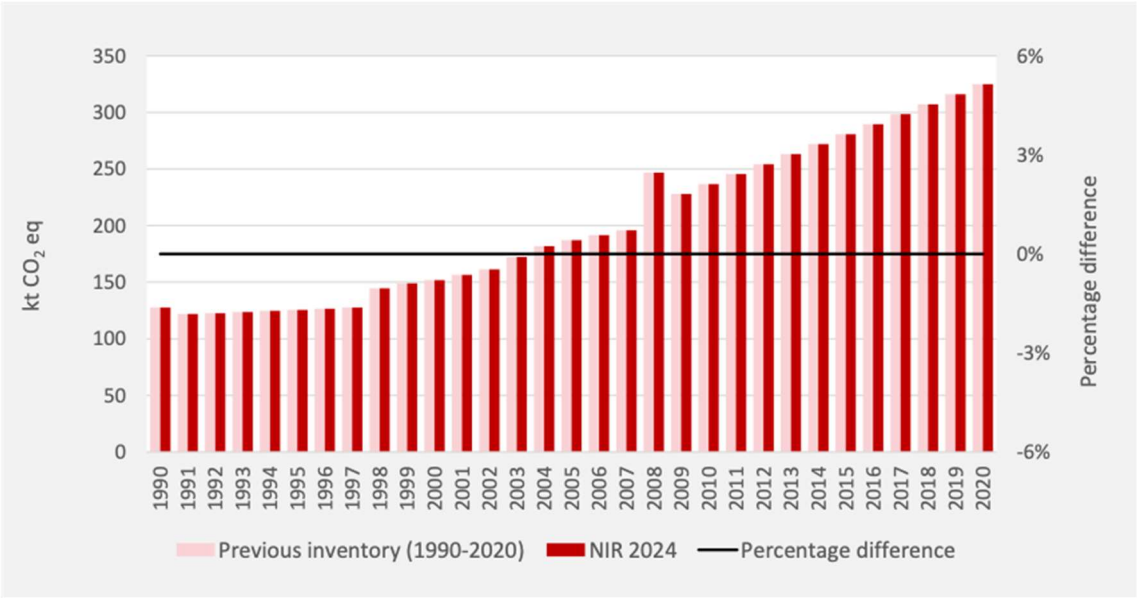


Figure 5.15. Comparison of estimated emissions from the Other Product Manufacture and Use subsector (2.G) between inventories.

5.9.4 Improvement plan

In view of the experience gained in preparing national GHG inventories, the technical team proposed measures to improve the results of the Inventory for the Other Product Manufacture and Use category (2.G) (Dataframe 5.3).

Dataframe 5.33. Potential improvements applicable to improving the emissions inventory for the Other Product Manufacture and Use subsector (2.G).

Subsector	Category	Improvement
2.G. OTHER PRODUCT MANUFACTURE AND USE	2.G.1. Electrical Equipment	▪ Evaluate how to promote the conduct of a new survey of generation, transmission and distribution companies with a view to updating the installed capacity of SF_6 in electrical equipment.
	2.G.3. N_2O from Product Uses	▪ Deepen studies on databases related to the import, export, production and consumption of anesthetic products.

5.10 Other (CRT 2.H)

The emissions related to the Pulp and Paper Industry (2.H.1) and Food and Beverage Industry (2.H.2) categories, which emit only precursor GHGs, are reported in this subsector.

The Pulp and Paper Industry category (2.H.1), due to the national pulp and paper production process, is responsible for all CO and NO_x emissions from the Other subsector (2.H), with 131 kt and 35 kt in 2022, respectively. In terms of NMVOC, the category accounted for 12% of emissions from the Other subsector (2.H) in 2022. Industrial food processing and beverage production (2.H.2) accounted for 88% of the subsector's NMVOC emissions in 2022, with sugar production accounting for 53% and the production of spirits accounting for 29%.

5.10.1 Methodological aspects

5.10.1.1 Pulp and Paper Industry

The preparation of cellulose pulp for paper and other purposes consists of separating the cellulose fibers from lignin – the substance that binds these fibers to the other components of the wood, which gives wood its rigidity. There are many processes for preparing cellulose pulp, ranging from the purely mechanical to the chemical ones, in which the wood is treated with chemicals, pressure and heat (temperatures above 150ºC) to dissolve the lignin. The use of chemicals in the process is what generates GHG emissions.

Pulp and paper production has three main stages: pulping, bleaching and paper production. The type of pulping and the amount of bleaching used depend on the nature of the raw material and the desired quality of the product. Kraft pulping is the most widely used process.

In Brazil, the most widely used process is a variation of the Kraft process, the Sulphate process, which uses the same chemical products, but with higher doses of sodium sulphide and caustic soda, as well as cooking for longer and at higher temperatures. It is considered the most suitable for obtaining chemical pulps from eucalyptus. During the process, there are emissions of CO, NO_x and NMVOC.

In the NIR 2024, the emission factors suggested in IPCC (1997) for the Kraft process were used for the Sulphate process, which is responsible for most of the production, and no information is available regarding the occurrence of emissions for the other processes. The default factors of 1.5 kg NO_x, 3.7 kg NMVOC and 5.6 kg CO per ton of chemical pulp produced by the Sulphate process were used.

Activity data and other parameters

Table 5.67 shows the pulp production values by type of process. The share of those produced by the sulphate process is only known up to 1994, and this share was used for the other years of the time series.

Table 5.67. Pulp production, 1990 to 2022.

Year	Chemical and semi-chemical pulp			High Yield pulp	TOTAL
	Sulphate	Other processes	Subtotal		
	tons				
1990	3,593,547	321,141	3,914,688	436,455	4,351,143
1991	4,018,086	328,434	4,346,520	431,596	4,778,116
1992	4,512,600	357,967	4,870,567	431,777	5,302,344
1993	4,723,283	286,905	5,010,188	460,742	5,470,930
1994	5,127,981	248,290	5,376,271	452,599	5,828,870
1995	5,191,573	251,369	5,442,942	492,965	5,935,907
1996	5,471,267	264,911	5,736,178	465,257	6,201,435
1997	5,631,457	272,668	5,904,125	427,037	6,331,162
1998	5,943,611	287,782	6,231,393	455,513	6,686,906
1999	6,452,406	312,417	6,764,823	444,309	7,209,132
2000	6,639,971	321,499	6,961,470	501,796	7,463,266
2001	6,622,799	320,667	6,943,466	468,561	7,412,027
2002	7,178,141	347,556	7,525,697	495,398	8,021,095
2003	8,212,564	397,641	8,610,205	459,042	9,069,247
2004	8,727,441	422,571	9,150,012	470,131	9,620,143
2005	9,397,450	455,012	9,852,462	499,651	10,352,113
2006	10,188,678	493,322	10,682,000	498,000	11,180,000
2007	10,946,963	530,037	11,477,000	521,000	11,998,000
2008	11,626,081	562,919	12,189,000	508,000	12,697,000
2009	12,291,845	595,155	12,887,000	428,000	13,315,000
2010	13,098,775	634,225	13,733,000	431,000	14,164,000
2011	12,864,136	622,864	13,487,000	435,000	13,922,000
2012	12,832,660	621,340	13,454,000	523,000	13,977,000
2013	13,935,273	674,727	14,610,000	520,000	15,130,000
2014	15,232,464	737,536	15,970,000	490,000	16,460,000
2015	16,119,515	780,485	16,900,000	500,000	17,400,000
2016	17,454,859	845,141	18,300,000	500,000	18,800,000
2017	18,160,684	879,316	19,040,000	490,000	19,530,000
2018	19,648,639	951,361	20,600,000	490,000	21,090,000
2019	18,304,710	886,290	19,191,000	500,000	19,691,000
2020	19,508,428	944,572	20,453,000	500,000	20,953,000
2021	20,893,371	1,011,629	21,905,000	600,000	22,505,000
2022	23,338,959	1,130,041	24,469,000	500,000	24,969,000

Source: Based on IBA (2019; 2021; 2023).

5.10.1.2 Food and Beverage Industry

No caso do processamento industrial de alimentos e bebidas, ocorre a emissão de In the case of industrial processing of food and beverages, NMVOC emissions occur. To estimate these emissions, the IPCC (1997) emission factors were used, as shown in Table 5.68.

Table 5.68. NMVOC emission factors for industrial processing of food and beverage.

Production	Unit	EF (kg NMVOC/unit)
Meat, fish and poultry	t	0.3
Sugar	t	10
Margarines and solid cooking fats	t	10
Cakes, cookies and breakfast cereals	t	1
Bread	t	8
Animal feed	t	1
Coffee roasting	t	0.55
Wine	hL	0.08
Beer	hL	0.035
Spirits	hL	15

Source: Based on IPCC (1997).

Activity data and other parameters

For beef, pork and poultry, the production of the Waste sector (CRT 5) from the NIR 2024 was used. An additional 0.67% was added to this total in order to include meat from horses, sheep and goats, according to the average share from 1990 to 1994. For fish, the production came from information from the Ministry of Fisheries and Aquaculture up to 2011, updated to 2022 by linear extrapolation from the last seven years of data.

The production of sugar and beer was also taken from the inventory of the Waste subsector (5.D). Margarines, animal feed and spirits (cachaça) were taken from the SIDRA database (IBGE, 2024b). For the production of bread, cakes, cookies and breakfast cereals, there are discrepancies between sources of information. We opted for Abitrigo (2024), which provided the total consumption of flour, from which the average bread production for the population was obtained, according to the data surveyed (ABIP, 2024), with the remainder being used for cakes and cookies.

For wine production, the series from the SIDRA database (IBGE, 2024b) from 2005 to 2022 was considered. For the beginning of the series from 1990, a correlation was made with wine sales in in the state of Rio Grande do Sul (RS), with information from Ibravin – Brazilian Wine Institute (Instituto Brasileiro do Vinho) (2022) between 2005 and 2009. As the analysis demonstrated that the production of the other states accounted for 17%, this value was added to the production of the state of Rio Grande do Sul in order to obtain the total national production.

With regard to coffee roasting, the data was obtained from ABIC – Brazilian Coffee Industry Association (Associação Brasileira da Indústria de Café) (2024), which considered data up to 2010. Subsequently, a correlation was made with the SIDRA database series for roasted coffee, which provides figures well below those previously considered. The average correction between 2005 and 2010 was of 143%.

Table 5.69 shows Brazilian food and beverage production for the cases in which there are associated NMVOC emissions, for the period from 1990 to 2022.

Table 5.69. National production of NMVOC-emitting food and beverage, 1990 to 2022.

Year	Meat, fish and poultry	Sugar	Margarines	Cakes, cookies and breakfast cereals	Breads	Animal feed	Coffee roasting	Wine	Beer	Spirits (cachaça)
	1000 t							1000 L		
1990	5,837	7,214	408	1,182	2,883	10,719	584	285,566	3,749,150	1,125,000
1991	6,242	7,365	385	1,323	3,226	11,180	624	270,825	3,881,100	1,080,000
1992	6,580	8,530	360	1,406	3,430	11,213	636	256,083	4,013,050	1,035,000
1993	6,805	9,264	348	1,492	3,638	11,679	642	241,341	4,145,000	1,080,000
1994	6,621	9,162	420	1,642	4,006	12,762	651	226,600	4,276,950	1,035,000
1995	6,367	12,652	436	1,797	4,383	13,771	685	236,853	8,037,262	1,139,503
1996	6,202	13,513	455	1,760	4,293	14,527	742	247,106	7,948,478	1,159,125
1997	6,037	14,828	472	1,787	4,359	14,182	781	259,742	8,089,990	1,178,746
1998	5,810	14,887	494	1,814	4,425	14,911	830	250,646	8,522,541	1,198,367
1999	6,759	18,024	511	1,910	4,658	15,932	886	278,329	8,519,562	1,217,989
2000	7,038	19,388	542	1,868	4,557	16,789	890	298,898	9,023,303	1,237,610
2001	9,614	16,198	554	1,895	4,622	17,773	943	293,333	9,140,460	1,257,232
2002	10,930	19,218	568	1,922	4,688	19,307	991	296,186	8,941,778	1,276,853
2003	12,133	22,567	602	2,021	4,929	18,954	991	281,480	8,458,608	1,296,474
2004	14,875	24,919	654	2,048	4,996	19,797	1,081	286,619	9,296,806	1,316,096
2005	16,556	26,685	688	2,278	5,214	19,971	1,134	293,369	9,865,939	1,073,583
2006	17,263	25,823	686	2,400	5,435	19,883	1,161	312,688	10,609,850	1,940,394
2007	19,028	29,988	744	2,056	5,661	20,997	1,218	297,970	11,486,301	1,266,089
2008	19,829	31,026	754	1,569	5,890	20,459	1,264	316,128	12,200,486	1,362,516
2009	20,168	31,049	833	1,534	6,123	22,394	1,279	289,376	12,481,097	1,347,986
2010	21,530	32,956	879	1,931	6,359	26,782	1,354	298,054	12,947,054	1,280,796
2011	24,088	38,006	883	2,134	6,567	30,367	1,286	376,635	13,743,457	1,536,869
2012	25,959	35,925	876	2,065	6,778	30,468	1,287	419,111	14,219,976	1,292,494
2013	33,397	38,246	897	1,735	6,991	28,811	1,336	278,266	13,599,280	1,110,957
2014	27,367	37,594	937	1,524	7,207	24,294	1,406	269,492	14,456,254	1,023,228
2015	28,188	35,571	809	752	7,427	24,686	1,419	348,576	14,260,955	1,064,073
2016	31,283	33,837	1,095	804	7,649	28,158	1,531	384,046	13,987,398	1,211,910
2017	39,917	38,734	903	808	7,683	33,221	1,780	404,824	13,714,714	1,156,207
2018	35,039	38,608	984	811	7,714	31,659	1,799	425,133	15,319,532	1,104,776
2019	31,840	29,053	832	818	7,775	32,137	1,900	432,044	17,269,543	1,065,526
2020	31,655	29,606	938	824	7,835	32,001	2,002	366,696	16,024,319	1,087,201
2021	32,666	41,503	877	830	7,893	33,697	2,103	383,664	16,948,931	1,021,035
2022	28,857	34,992	877	790	7,514	33,697	2,205	383,664	18,007,374	1,021,035

5.10.2 Quality assurance and quality control

The QA/QC procedures adopted for Other (2.H) are described in section 2.5 of this document.

5.10.3 Assessment of uncertainty, consistency and recalculations of the time series

No uncertainty analysis was carried out for the Other subsector (2.H), since only precursor GHGs are emitted, in this case, CO, NOx and NMVOC.

With regard to the consistency and recalculations of the time series, no discrepancies were identified in terms of activity data between the pulp and paper industry and the food and beverage industry categories, compared to the previous version of the inventory in which the precursor GHGs emitted in the subsector were estimated (BRASIL, 2021a). Therefore, no recalculations took place and, consequently, the inventoried emissions from 1990 to 2020 in terms of CO, NO_x and NMVOC for the Other subsector (2.H) remained unchanged.

5.10.4 Improvement plan

The experience gained in the periodic preparation of national GHG inventories has led to the proposal of a series of measures to improve the consistency and greater detailing of the Inventory's results, particularly in the Other subsector (2.H).

Dataframe 5.34. Potential improvements applicable to improving the emissions inventory of the Other subsector (2.H).

Subsector	Category	Improvement
2.H. OTHER	2.H.1. Pulp and Paper Industry	▪ Evaluate the possibility of establishing partnerships with associations in order to obtain data on cellulose pulp from sulphate.
	2.H.2. Food and Beverage Industry	▪ Evaluate the possibility of establishing Technical Cooperation Agreements or partnerships with associations representing the food industry in order to facilitate the collection of activity data on a biannual basis.

6 AGRICULTURE (CRT 3)

6.1 Sector overview

The Agriculture sector includes emissions from livestock and agricultural activities. It should be noted that the sector is of great importance to the country's economy in terms of its share of the national GDP, which in 2023 was 23.8% (CEPEA (Center for Advanced Studies in Applied Economics [Centro de Estudos Avançados em Economia Aplicada])/CNA (Brazil's Confederation of Agriculture and Livestock [Confederação da Agricultura e Pecuária do Brasil]), 2024), and in terms of its potential to develop a low-carbon economy.

Emissions from livestock farming are mainly related to the enteric fermentation process of ruminant animals (cows/steers, buffaloes, sheep and goats), and the main parameters used to estimate emissions refer to the size of the population, the type of confinement, digestibility, weight and animal productivity. On the other hand, emissions from agriculture are mainly related to the agricultural production process and the use of nitrogen fertilizers, while emissions and removals resulting from land-use and land-cover conversion processes and soil management are accounted for in the Land Use, Land-Use Change and Forestry (LULUCF) sector.

The sector includes the gases CH_4, N_2O and CO_2, as well as the precursor gases CO and NO_x. The subsectors covered, according to the IPCC (2006)[46] methodology, are: Enteric Fermentation (3.A), Manure Management (3.B), Rice Cultivation (3.C), Agricultural Soils (3.D), Field Burning of Agricultural Residues (3.F), Liming (3.G) and Urea Application (3.H).

The sector's emissions totaled 622,014 kt CO_2 eq in 2022, an increase of 6.6% compared to 2020. By analyzing the contribution by subsector, it is possible to identify that the Enteric Fermentation subsector was the most representative of the Agriculture sector, with 65% of total emissions in 2022, followed, in order of magnitude, by the Agricultural Soils subsector, with 23%. On the other hand, the Manure Management and Liming subsectors together contributed with approximately 9% of emissions, while the Rice Cultivation, Urea Application and Field Burning of Agricultural Residues subsectors together accounted for a smaller share of 3% of the sector's total emissions for that year (Figure 6.1).

[46] Agricultural, Forestry and Other Land Use (IPCC, 2006, v. 4).

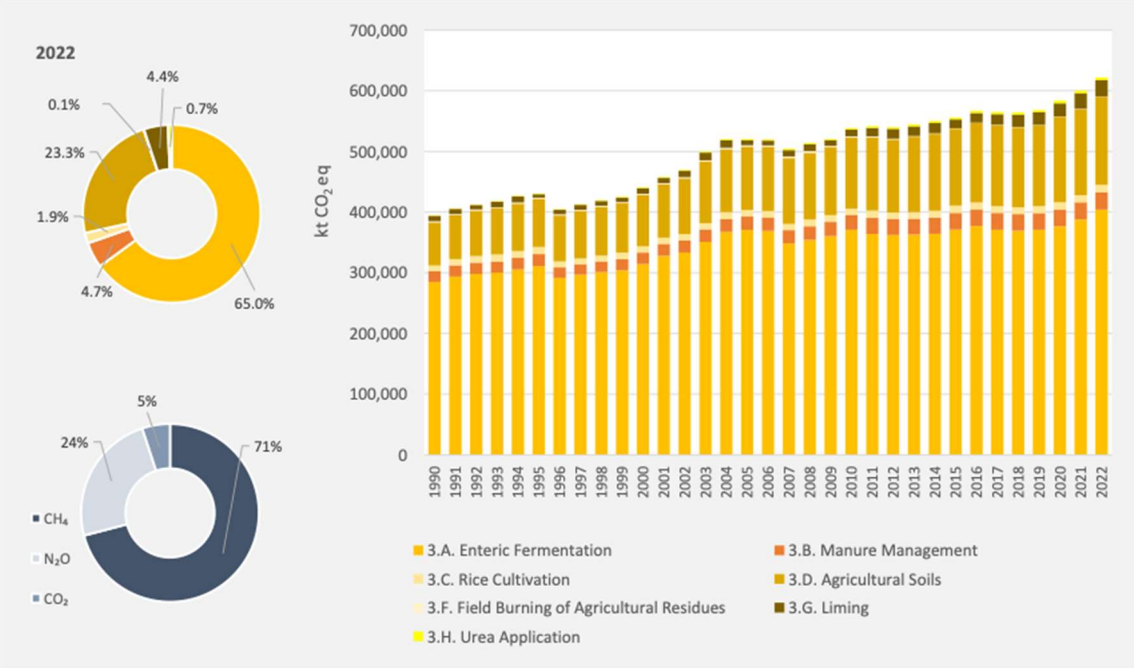


Figure 6.1. Emissions from the Agriculture sector, in kt CO_2 eq, by subsector, from 1990 to 2022.

In terms of contribution by gas, CH_4 emissions are the most representative for the sector, and come mainly from the Enteric Fermentation subsector, with 71%. This is followed by N_2O emissions, which originate from activities in the Agricultural soils subsector, with 24%, leaving a 5% share of CO_2 emissions, which are mainly related to the application of lime to the soil (3.G. Liming). Finally, CO and NO_x emissions are accounted for in the Field Burning of Agricultural Residues subsector (3.F).

6.2 Methodological aspects

The methodological basis used for the emissions estimates reported in the NIR 2024 is based on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006). In order to update the sector's estimates, public data from official sources obtained through the platforms of the institutions responsible for the data were mainly taken into account, and the parameters and emission factors of the Inventory of the Fourth National Communication (BRASIL, 2021) were kept.

Considering that the Enteric Fermentation subsector (3.A) has a relevant contribution in terms of emissions within the National Inventory, constituting a key category of emissions, as mentioned in Section 2.4, the Tier 2 method was adopted for the cattle animal category (3.A.1), following the guidelines of the IPCC (2006) methodology regarding the most representative emission categories for which a more in-depth and elaborate level of detailing should be adopted For the other animal categories (sheep, goats, asses, mules, equines, buffaloes), it was decided to use the Tier 1 method, due to the lower representativeness of national herds, and consequently, in terms of emissions.

For CH_4 and N_2O emissions from the Manure Management subsector (3.B), *Tier* 2 methods were adopted for the cattle (3.B.1) and swine (3.B.3) categories. For the other animal categories, the Tier 1 method was used, taking into account the population of each species and the default values of the emission factors determined by the IPCC (2006). In addition to categorizing emissions by animal species, the emission estimates for CH_4 and N_2O took into

account the breakdown of emissions by Federative Unit/State (FU), as each region of the country has different characteristics, both in terms of animal production and diet, as well as climate and soil.

The Rice Cultivation subsector (3.C) has local CH_4 emission factors for the state of Rio Grande do Sul, which accounts for approximately 90% of national production. The Tier 2 methodology was adopted exclusively for this state, with the emission factors and, therefore, the CH_4 emission estimates being stratified according to the soil preparation system. For the other states, where neither of the above conditions are met, the Tier 1 methodology was adopted. It should be noted that for the state of Santa Catarina, due to the availability of individualized activity data for the seven producing regions, the estimates were calculated by region.

In the Agricultural soils subsector (3.D), N_2O emissions were estimated using the Tier 2 method for all categories due to the availability of national and state data to estimate emissions.

The approach adopted for the calculations of the Field Burning of Agricultural Residues subsector (3.F) used the Tier 2 method for the emissions of all gases emitted. For Field Burning of Agricultural Residues from sugar cane cultivation (3.F.1), the emission factors, the ratio of straw to stalks and the combustion factor are specific to the crop inventoried, and the biomass available for combustion and the area burned are specific to each FU/State. With regard to emissions from Field Burning of Agricultural Residues from cotton cultivation, Tier 1 was applied to all gases.

For the Liming (3.G) and Urea Application (3.H) subsectors, the Tier 1 methodology was adopted for CO_2 emission estimates.

Dataframe 6.1 shows the details of the methodologies, parameters, emission factors and sources of information used in each category of the Agriculture sector.

Dataframe 6.1. Methodological levels applied by gas and references of the Agriculture sector.

			ESTIMATED GASES AND METHODOLOGIES					REFERENCES	
Subsector	Category	Subcategory	CO_2	CH_4	N_2O	CO	NO_x	Activity data	Emission factors
3.A. ENTERIC FERMENTATION	3.A.1. Cattle	3.A.1.a. Beef cattle	NA	T2	NA	NA	NA	Animal population data from the Municipal Livestock Survey (PPM, Pesquisa da Pecuária Municipal), by Federative Unit/State from 1990 to 2022 (IBGE – Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística), 2024a); Agricultural Census (IBGE, 1996; 2006) and Anualpec (Brazilian livestock yearbook [anuário da pecuária brasileira]) (FNP, 1997; 2001; 2005; 2013). Breakdown of the herd by purpose, sex, age and weight.	IPCC (2006, v. 4, chap. 10) with calculation of Tier 2 emission factor. Taking into account national and international bibliographical references of the parameters applied.
		3.A.1.b. Dairy cattle	NA	T2	NA	NA	NA		
	3.A.2. Sheep		NA	T1	NA	NA	NA	Animal population data from the Municipal Livestock Survey (PPM, Pesquisa da Pecuária Municipal), by Federative Unit/State from 1990 to 2022 (IBGE, 2024a).	IPCC (2006, v. 4, chap. 10).
	3.A.3. Swine	3.A.3.a. Breeding	NA	T1	NA	NA	NA		
		3.A.3.b. Suckling/ Nursery	NA	T1	NA	NA	NA		
		3.A.3.c. Finishing	NA	T1	NA	NA	NA		
	3.A.4. Other animals	3.A.4.a. Buffaloes	NA	T1	NA	NA	NA		
		3.A.4.b. Goats	NA	T1	NA	NA	NA		
		3.A.4.c. Horses	NA	T1	NA	NA	NA		
		3.A.4.d. Mules	NA	T1	NA	NA	NA		
		3.A.4.e. Asses	NA	T1	NA	NA	NA		
3.B. MANURE MANAGEMENT	3.B.1. Cattle	3.B.1.a. Beef cattle	NA	T2	T2	NA	NA	Animal population data from the Municipal Livestock Survey (PPM, Pesquisa da Pecuária Municipal), by	Cattle, swine and poultry categories: (IPCC, 2006, v. 4, chap. 10);

Subsector	Category	Subcategory	ESTIMATED GASES AND METHODOLOGIES					REFERENCES	
			CO_2	CH_4	N_2O	CO	NO_x	Activity data	Emission factors
	3.B.2. Sheep	3.B.1.b. Dairy cattle	NA	T2	T2	NA	NA	Federative Unit/State from 1990 to 2022 (IBGE, 2024a); Agricultural Census (IBGE, 1996; 2006) and Anualpec (Brazilian livestock yearbook [anuário da pecuária brasileira]) (FNP, 1997; 2001; 2005; 2013). Data from SESI (Industry Social Service [Serviço Social da Indústria]) (2019) and ABPA (Brazilian Animal Protein Association [Associação Brasileira de Proteína Animal]) (2019) were also used for the swine category.	The calculation of the emission factor for each category of cattle, swine and poultry was based on national and international bibliographical references for each federative unit/state and year for the following parameters: weight, digestibility, excretion rate, type of manure management for each animal category, etc. Other animals: IPCC (2006, v. 4, chap. 10).
			NA	T1	NO	NA	NA		
	3.B.3. Swine	3.B.3.a. Breeding	NA	T2	T2	NA	NA		
		3.B.3.b. Suckling/ Nursery	NA	T2	T2	NA	NA		
		3.B.3.c. Finishing	NA	T2	T2	NA	NA		
	3.B.4. Other Animals	3.B.4.a. Buffaloes	NA	T1	NO	NA	NA		
		3.B.4.b. Goats	NA	T1	NO	NA	NA		
		3.B.4.c. Horses	NA	T1	NO	NA	NA		
		3.B.4.d. Mules	NA	T1	NO	NA	NA		
		3.B.4.e. Asses	NA	T1	NO	NA	NA		
		3.B.4.f. Poultry	NA	T1	T1	NA	NA		
	3.B.5. Indirect emissions of N_2O	3.B.5.a. Cattle	NA	NA	T1	NA	NA		
		3.B.5.b. Other	NA	NA	T1	NA	NA		
3.C. RICE CULTIVATION	3.C.1. Irrigated	3.C.1.a. Continuously flooded	NA	T1, T2	IE	NA	NA	Data on rice cultivation area, by Federative Unit/State and year (stratified by water regime): Embrapa Arroz e Feijão (Embrapa – Brazilian Agricultural Research Corporation (Empresa Brasileira de Pesquisa Agropecuária) Rice and Beans (2018) and DCI/(Commercial and Industrial Department [Departamento	IPCC (2006, v. 4, chap. 5); Embrapa Arroz e Feijão (2018); Yan *et al*. (2005); Epagri (2019).

Subsector	Category	Subcategory	ESTIMATED GASES AND METHODOLOGIES					REFERENCES	
			CO_2	CH_4	N_2O	CO	NO_x	Activity data	Emission factors
		3.C.1.b. Intermittently flooded	NA	T1, T2	IE	NA	NA	Comercial e Industrial])/IRGA (Rio Grande do Sul Rice Institute [Instituto Rio Grandense do Arroz]) (IRGA, 2018); Cultivation period, by federative unit/state and year (stratified by seeding system): Embrapa (2018); Note: Regional data was used only for the state of Santa Catarina: Cultivated area (stratified by water regime) from Embrapa Arroz e Feijão (2018) and Epagri (Agricultural Research and Rural Extension Company of Santa Catarina [Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina]) (2019). Cultivation period (stratified by cultivar cycle) from Epagri (2019).	
	3.C.2. Rain-fed		NA	NO	NA	NA	NA		
3.D. AGRICULTURAL SOILS	3.D.1. Direct emissions	3.D.1.a. Inorganic N Fertilizers	NA	NA	T2	NA	NA	The amount of N in urea was disaggregated from the total nitrogen fertilizer data based on national import, export, production and stock data for each federative unit/state from 1990 to 2020, from ANDA – National Association for the Diffusion of Fertilizers (Associação Nacional para Difusão de Adubos) (ANDA, 2020). Note: For the estimation of N in the form of Inorganic N Fertilizers applied in irrigated rice cultivation areas, it was considered that only urea is applied in irrigated rice, and that only the southern region of the country has areas with significant production and productivity, to consider that there has been a significant application of Inorganic N Fertilizers (ANDA, 2020; Embrapa Arroz e Feijão, 2018, IRGA, 2018 and IBGE, 2019).	IPCC (2006, v. 4, chap. 11).
		3.D.1.b. Organic N Fertilizers	NA	NA	T1, T2	NA	NA	Data on ethanol and sugar production from by-products of vinasse and filter cake, produced in the country by federative unit/state and year, was obtained from the Sugar cane Industry Association (UNICA, União da Indústria de Cana-de-Açúcar) 2022).	IPCC (2006, v. 4, chap. 11); Paredes *et al*. (2014); Parameters for estimating the amount of N in vinasse and filter cake: Elia Neto (2016); Gurgel (2012); Bernardinho *et al*. (2018); Bonassa *et al*. (2015) and Embrapa (2019); Direct

Subsector	Category	Subcategory	ESTIMATED GASES AND METHODOLOGIES					REFERENCES	
			CO_2	CH_4	N_2O	CO	NO_x	Activity data	Emission factors
								Animal population data from the Municipal Livestock Survey – PPM, by federative unit/sate from 1990 to 2022 (IBGE, 2018a) and the Agricultural Census (IBGE, 1996; 2006); Anualpec (FNP, 1997; 2001; 2005; 2013); SESI (2019) and ABPA (2019).	emission factors of N_2O from vinasse and filter cake applied to soil cultivated with Sugar cane Oliveira *et al*. (2013); Siqueira Neto *et al*. (2016); Sousa Neto (2012) The definition of the weight, excretion factor and disposal of the manure for each animal category was based on various national bibliographical references, for each federative unit/state and year.
		3.D.1.c. Animal manure deposited by grazing animals	NA	NA	T1, T2	NA	NA	Animal population data from the Municipal Livestock Survey (PPM, Pesquisa da Pecuária Municipal), by Federative Unit/State from 1990 to 2022 (IBGE, 2024a) and Agricultural Census (IBGE, 1996; 2006); Anualpec (FNP, 1997; 2001; 2005; 2013); SESI (2019) and ABPA (2019).	IPCC (2006, v. 4, chap. 11); Bastos (2018). The definition of the weight, excretion factor and disposal of the manure for each animal category was based on various national bibliographical references, for each federative unit/state and year.
		3.D.1.d. Crop Residues	NA	NA	T1, T2	NA	NA	Productivity and harvested area data for the main agricultural crops in the country, by federative unit/state and year from the Municipal Agricultural Production – PAM (Produção Agrícola Municipal), from 1990 to 2022 (IBGE, 2024b); Rice cultivation data (by FU/state and year): Embrapa (2018); DCI/IRGA (IRGA, 2018); Activity data for Grassland Remaining Grassland and Grassland converted to other uses, and the respective amounts of biomass considered (by FU/state and year) included in Brasil (2020; 2021).	IPCC (2006, v. 4, chap. 11). Parameters used to calculate the amount of N in grassland renewal Carvalho *et al*. (1991); Oliveira *et al*. (2004); Piccolo *et al*. (2005); Santos *et al*. (2007); Fabrice *et al*. 2014
		3.D.1 e. Mineralization of N associated with loss of C in soil	NA	NA	T2	NA	NA	Mineralized N was calculated by multiplying 1/R by the amount of soil organic carbon lost due to the use conversion (considering the C:N ratio associated with each land-cover class of the initial use class), based on the maps generated by the Land Use, Land-Use Change and Forestry (LULUCF) sector in Brasil (2020; 2021).	IPCC (2006, v. 4, chap. 11).

Subsector	Category	Subcategory	ESTIMATED GASES AND METHODOLOGIES					REFERENCES	
			CO_2	CH_4	N_2O	CO	NO_x	Activity data	Emission factors
		3.D.1.f. Cultivation of Organic Soils	NA	NA	T2	NA	NA	Brazil's soil maps, IBGE (2001). In addition to the areas of organic soils, maps showing areas with different land uses of the Land Use, Land-Use Change and Forestry (LULUCF) sector were also used. (BRASIL, 2020; 2021).	IPCC (2006, v. 4, chap. 11).
	3.D.2. Indirect N_2O Emissions from managed soils	3.D.2.a. Atmospheric deposition	NA	NA	T1, T2	NA	NA	Same as the information for the Inorganic N Fertilizers categories (3.D.1.a.), Organic N Fertilizers (3.D.1.b.); Animal Manure Applied Directly to the Soil (3.D.1.c.).	IPCC (2006, v. 4, chap. 11).
		3.D.2.b. Nitrogen leaching and run-off	NA	NA	T1, T2	NA	NA	Same as the information for the Inorganic N Fertilizers categories (3.D.1.a.), Organic N Fertilizers (3.D.1.b.); Animal Manure Applied Directly to the Soil (3.D.1.c.); Crop Residues (3.D.1.d.) and Mineralization/immobilization associated with loss/gain of soil organic matter (3.D.1.e.). Development of maps containing areas where the excessive rainfall in relation to ETP exceeded the of soils' AWC, based on data from INMET – National Institute of Meteorology (Instituto Nacional de Meteorologia) (2019) and Xavier (2019).	IPCC (2006, v. 4, chap. 11).
3.E. PRESCRIBED BURNING OF SAVANNAHS			NE	NE	NE	NE	NE		
3.F. FIELD BURNING OF AGRICULTURAL RESIDUES	3.F.1. Sugar cane		NA	T2	T2	T2	T2	Mass available for combustion (MB): Value specific to each municipality and reference year, calculated based on data from the Municipal Agricultural Production – PAM (IBGE, 2018b); Varieties cultivated: Braga *et al*. (2017); RIDESA (2018); straw to stalks ratio – average values by FU/state: Hassuani *et al*. (2005); Franco *et al*. (2007); Tasso Junior *et al*. (2011); Marques; Pinto (2013); and Ivo *et al*. (2015).	- Combustion factor (Cf): IPCC (2006, v. 4, chap. 5). - Emission factor (Gef): CH_4 Yokelson. (2008) / CO: Yokelson *et al*. (2008); Lopes; Carvalho (2009); and França *et al*., (2012) / NO_x: França *et al*. (2012) / N_2O: IPCC (2006); Andrea; Merlet (2001).
	3.F.2. Cotton		NA	T1	T1	T1	T1	Mass available for combustion (MB): Annual value specific to each FU/state and reference year (BRASIL, 2016).	Combustion factor (Cf) and Emission factor (Gef): IPCC (2006, v. 4, chap. 5).

Subsector	Category	Subcategory	ESTIMATED GASES AND METHODOLOGIES					REFERENCES	
			CO_2	CH_4	N_2O	CO	NO_x	Activity data	Emission factors
3.G. LIMING			T1	NA	NA	NA	NA	Limestone production and consumption data for each federative unit/state from 1990 to 2020, from the Brazilian Limestone Producers Association (ABRACAL, Associação Brasileira dos Produtores de Calcário), 2020).	IPCC (2006, v. 4, chap. 11).
3.H. UREA APPLICATION			T1	NA	NA	NA	NA	The amount of N in urea was disaggregated from the total nitrogen fertilizer data based on national import, export, production and stock data for each federative unit/state from 1990 to 2020, from ANDA – National Association for the Diffusion of Fertilizers (Associação Nacional para Difusão de Adubos) (ANDA, 2020).	IPCC (2006, v. 4, chap. 11).
3.I. OTHER CARBON-CONTAINING FERTILIZERS			NO	NA	NA	NA	NA		

Note: Methodological levels (IPCC, 2006) – T1: Tier 1; T2: Tier 2; T3: Tier 3.
Notations: NA (Not applicable) – Activity in a given source/sink category that occurs in the country, but did not result in emissions or removals of a specific gas; IE (Included elsewhere) – Included in another location/category of emissions or removals; NO (Not occurring) – Categories and processes that do not occur in the country; NE (Not estimated) – Activity data and/or emissions by sources and removals by sinks of GHG that have not been estimated, but for which a corresponding activity may occur in the country.

Dataframe 6.2 and Dataframe 6.3 show categories that were relocated or could not be estimated in the NIR 2024.

Dataframe 6.2. Category with values assigned to another category (IE) in the Agriculture sector.

IPCC CODES	REALOCATED CATEGORIES	REALLOCATION DESTINATION
3.C.1	Irrigated	N_2O emissions reallocated to subsector 3.D. Agricultural soils.[47]

Dataframe 6.3. Sub-sector not estimated (NE) in the Inventory for the Agriculture sector.

IPCC CODES	CATEGORIES NOT ESTIMATED	NOTES
3.E.	Prescribed Burning of Savannahs	Emissions were not estimated because differentiating the burning of savannahs due to anthropogenic or natural causes, as well as monitoring the dynamics of these fires over the years in the national territory is not simple and requires the development of a more complex methodology to ensure that fires are properly linked to their respective causes.

6.3 Enteric Fermentation (CRT 3.A)

This subsector includes CH_4 emissions generated by animal enteric fermentation. The methane produced in animal production systems comes mainly from enteric fermentation (85 to 90%), with the remainder being produced from animal manure (MACHADO *et al.*, 2011). The animal categories that undergo this physiological process and had their emissions estimated were: ruminant animals – cattle, buffaloes, sheep, goats; non-ruminant animals – equines, asses, mules; and monogastric animals – swine.

In 2022, emissions from Enteric Fermentation totaled 404,062 kt CO_2 eq, while in 2020 they totaled 376,720 kt CO_2 eq, representing a variation of 7.3%. The Beef Cattle subcategory (3.A.1.a) accounted for 87% of the subsector's emission share, while the Dairy Cattle subcategory (3.A.1.b) accounted for 10%. The other animal subcategories were less representative, with 11,759 kt CO_2 eq, corresponding to 3.0% of the subsector in 2022 (Figure 6.2).

[47]According to IPCC (2006), N_2O emissions generated from irrigated rice cultivation should be allocated to the Agricultural Soils category.

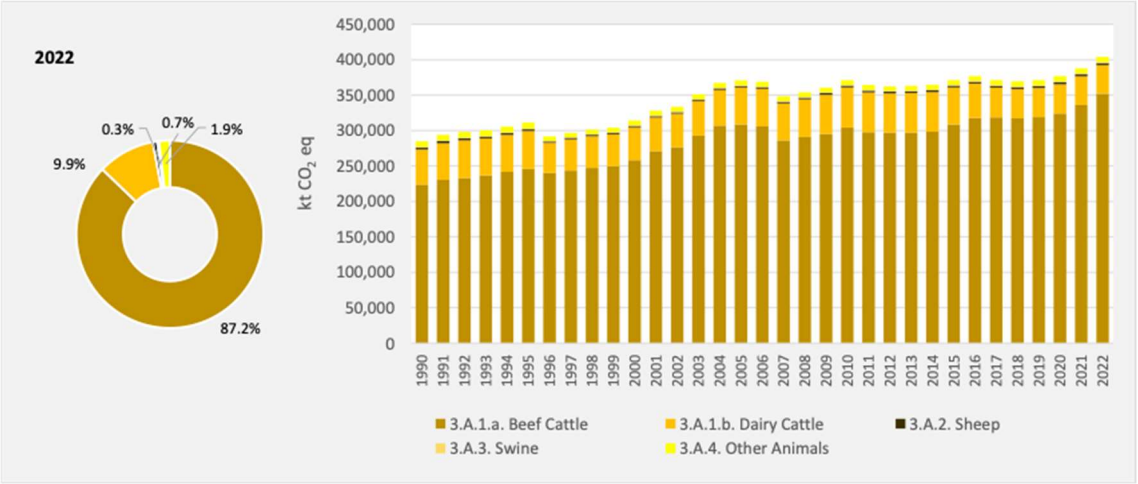


Figure 6.2. Emissions from Enteric Fermentation (3.A), in kt CO_2 eq by category, from 1990 to 2022.

6.3.1 Methodological aspects

To calculate CH_4 emissions from the categories of the Enteric Fermentation (3.A) subsector, equations 6.1 to 6.11 were used, shown in Dataframe 6.4, with Tier 2 and Tier 1 methodological details.

Dataframe 6.4. Equations for estimating emissions from the Enteric Fermentation subsector (3.A).

Equations	GHG	Categories	Central equation	Reference
Equation 6.1	CH_4	All	$\text{Emissions of } CH_4 = EF_{(T)} \times \frac{N_{(T)}}{10^6}$	Equation 10.19 (IPCC, 2006, v. 4, chap. 10)
Equation 6.2	CH_4	All	$EF_{(T)} = GE \times \frac{Y_m}{100} \times \frac{365}{55.65}$	Equation 10.21 (IPCC, 2006, v. 4, chap. 10)
Equation 6.3	CH_4	All	$GE = \left(\frac{(NE_m + NE_a + NE_i + NE_{work} + NE_p)}{REM}\right) + \left(\frac{\left(\frac{NE_g + NE_{wool}}{REG}\right)}{\left(\frac{DE\%}{100}\right)}\right)$	Equation 10.16 (IPCC, 2006, v. 4, chap. 10)
Equation 6.4	CH_4	All	$NE_m = CF_i \times (BW) \times 0.75$	Equation 10.3 (IPCC, 2006, v. 4, chap. 10)
Equation 6.5	CH_4	All	$NE_a = Ca \times NE_m$	Equation 10.4 (IPCC, 2006, v. 4, chap. 10)
Equation 6.6	CH_4	All	$NE_g = 22.02 \times \left(\frac{BW}{C} \times MW\right) 0.75 \times WG \times 1.097$	Equation 10.6 (IPCC, 2006, v. 4, chap. 10).
Equation 6.7	CH_4	3.A.2.b	$NE_i = Milk \times (1.47 + 0.40 \times Fat)$	Equation 10.8 (IPCC, 2006, v. 4, chap. 10)

Equations	GHG	Categories	Central equation	Reference
Equation 6.8	CH_4	All	$NE_{work} = 0.10 \times NE_m \times Hours$	Equation 10.11 (IPCC, 2006, v. 4, chap. 10)
Equation 6.9	CH_4	All	$NE_p = C_{pregnancy} \times NE_m$	Equation 10.13 (IPCC, 2006, v. 4, chap. 10)
Equation 6.10	CH_4	All	$REM = [1.123 - (4.092 \times 10^{-3} \times DE\%) + [1.126 \times 10^{-5} \times (DE\%)^2] - (25.4/DE\%)]$	Equation 10.14 (IPCC, 2006, v. 4, chap. 10)
Equation 6.11	CH_4	All	$REG = [1.164 - (5.160 \times 10^{-3} \times DE\%) + [1.308 \times 10^{-5} \times (DE\%)2] - (37.4/DE\%)]$	Equation 10.15 (IPCC, 2006, v. 4, chap. 10)

In which:

$EF_{(T)}$ = Emission factor for the defined livestock population, kg CH_4 $head^{-1}year^{-1}$;
$N_{(T)}$ = Number of head of livestock species/animal category T in the country;
T = Livestock species/animal category;
GE = Gross energy intake, MJ $head^{-1}$ day^{-1};
Y_m = methane conversion factor, percentage of gross energy intake converted into methane. The factor 55.65 (MJ/kg CH_4) is the energy contained in methane;
NE_m = net energy requirement for animal maintenance, MJ day^{-1};
NE_a = net energy for animal activity, MJ day^{-1};
NE_l = net energy for lactation, MJ day^{-1};
NE_{work} = net energy for work, MJ day^{-1};
NE_p = net energy requirement for gestation, MJ day^{-1};
REM = rate of net energy used for maintenance (% of digestible energy);
NE_g = net energy required for growth, MJ day^{-1};
NE_{wool} = net energy required to produce one year of wool, MJ day^{-1} (not applicable);
REG = rate of net energy used for growth (% of digestible energy);
DE% = digestible energy (% of gross energy);
Cf_i = coefficient that varies for each animal category MJ $day^{-1}kg^{-1}$;
BW = animal's live body weight, kg;
Ca = coefficient corresponding to the animal's feed situation. For animals confined to small areas, a value of 0.0 is assumed for the coefficient; for animals grazing on grassland with sufficient forage, requiring moderate energy expenditure to obtain food, a value of 0.17 is assumed; and for animals grazing on open or mountainous terrain with significant energy expenditure to obtain food, a value of 0.36 is recommended (IPCC, 2006);
BW = average live body weight of the animals in the population, kg;
C = coefficient ranging from 0.8 for females, 1.0 for castrated males and 1.2 for breeders (NRC, 1996, *apud* IPCC, 2006);
MW = live mature body weight of an adult female in moderate body condition, kg;
WG = average daily weight gain per animal within a population, kg day^{-1};
Milk = amount of milk production, kg of milk day^{-1};
Fat = fat content in milk, % by weight;
Hours = number of hours of work per day; and
$C_{pregnancy}$ = gestation coefficient.

Activity data and other parameters

The main activity data used to estimate emissions from the Enteric Fermentation subsector is the animal population. Population data for the entire time series (1990-2022) was obtained from the database of the Brazilian Institute of Geography and Statistics (IBGE), from the Municipal Livestock Survey – PPM (IBGE, 2024a), which provides annual statistical data on livestock numbers and animal products, broken down by Federative Unit (UF/state), and from the 2006 Agricultural Census (IBGE, 2006).

The cattle population was broken down into beef and dairy cattle. For beef cattle, the disaggregation was carried out according to age, sex and type of animal confinement, as follows: "under 1 year old", "1 to 2 years old", "bulls", "male beef cattle > 2 years old (not confined)", "female beef cattle > 2 years old (not confined)" and "other animals > 2 years old (confined)". For dairy cattle, the classification adopted took animal productivity into account, and was broken down into "high-production dairy cattle" and "low-production dairy cattle".

For the other animal categories, i.e. swine, buffaloes, sheep, goats, horses, asses and mules, no subdivision of categories was made, due to the low representativeness in methane emissions of these categories within the subsector, considering the evaluation of key categories. For the herd of asses and mules, due to the fact that the herds of these species have not been surveyed since 2013, an estimate was made of the average number of animals in the herd over the previous five years, plus the sum of the previous year for which the estimate was made. Thus, with the exception of the categories of asses and mules, the time series of the population data was updated until 2022 using the IBGE's Municipal Livestock Survey (PPM) database (Table 3939, from the IBGE Automatic Recovery System – SIDRA, Sistema de Recuperação Automática).

6.3.1.1 Beef cattle farming

To classify the beef cattle herd categories, the herd was first broken down into "cattle under 1 year old", "cattle between 1 and 2 years old", "bulls" and "other cattle over 2 years old" (including dairy cattle).[48] This disaggregation was based on data from Table 925 of the 2006 Agricultural Census (IBGE, 2006), from properties with more than 50 head of cattle, by Federative Unit (FU)/State. It was assumed that properties with 50 head or less would be dairy cattle, whose animal population would be the result of the difference between the total cattle population in the 2006 Agricultural Census and the total population in Table 925. The ratios of males and females and the respective ages of the animals on dairy farms in Table 925 were maintained for this population in farms with 50 head or less. Once the populations per category had been added up, the ratios of each category in relation to the total herd were calculated. These ratios were considered to be the same for all the years of the Inventory.

In a second stage, the population of "dairy cattle", published annually by the IBGE, and the population of "other cattle over 2 years old, confined", reported annually in the Brazilian Livestock Yearbook (ANUALPEC) (FNP, 1997; 2001; 2005; 2013; 2017; S&P GLOBAL, 2022) were subtracted from the estimated population of "other cattle over 2 years old", resulting in the category of "other cattle over 2 years old, not confined".

[48] "Milked cow" population reported by IBGE (2018).

In order to differentiate between males and females of "cattle over 2 years old, not confined", it was first necessary to estimate the population of cattle over 2 years old that are female, using as a basis the data on the sum of females over 2 years old for breeding purposes, excluding those for dairy purposes, from Table 925 of the 2006 IBGE Agricultural Census (A), and the total cattle populations from the 2006 Census (B) and the IBGE PPM for 2006 (C). Next, the population of beef female cattle adjusted for the 2006 PPM was obtained by multiplying the sum of females over 2 years old for breeding purposes, minus those for dairy purposes, by the ratio between the total cattle population from the 2006 Census and the IBGE PPM for that year. With this result, it was possible to obtain the fraction of "female beef cattle over 2 years old (not confined)". The remaining population was classified as "male beef cattle, over 2 years old (not confined)".

In a final stage, the classification of "other beef cattle, over 2 years old (confined)" was carried out using data from ANUALPEC (FNP, 1997; 2001; 2005; 2013; 2017; S&P, 2022). ANUALPEC provides information on the time series of cattle herds confined annually in Brazil, by FU/State. This information is not individualized only for some FUs/States,[49] in which the sum of all confined cattle is presented, reported as "cattle confined in other states". Thus, for the federative units/states that have this disaggregated information, the ANUALPEC populations were used to classify "other cattle over 2 years old, confined".[50] For the population of confined cattle in the FU/States that do not have this disaggregated information, we used Table 919 of the 2006 IBGE Agricultural Census (IBGE, 2006) as a basis, which shows the amount of confined cattle by FU/State. The IBGE ratio was, then, applied to the data reported by ANUALPEC (FNP, 1997; 2001; 2005; 2013; 2017).

In order to estimate emissions from the enteric fermentation of beef cattle, it is necessary to calculate and/or define some specific parameters and factors, which vary according to animal category, FU/region which influence the emissions. The parameters and factors used in the final calculation of GHG emissions for the different beef herd categories are described below.

- Animal weight (BW)

To estimate the animal weight (BW) of the young categories, i.e. the weight at 6 months of age (animals between 0 and < 1 year old), and the weight at 18 months of age (animals between 1 and 2 years old), the BW function was used = $33.15 + 28.07t - 1.203t^2 + 0.025t^3$ (r^2=0.97; p<0.001), which relates age (t; in months) to body weight (BW; in kg), obtained from data in the literature (KOURY FILHO et al., 2010; YOKOO et al., 2007; REIS et al., 2008; GAMA, 2017; FERREIRA et al., 2019; PASSAFARO et al., 2016; TORAL et al., 2009).

For cattle aged 2 years and over, the animal weight estimate was based on quarterly raw data from IBGE (2019b) on total carcass production and the number of slaughtered steers and cows, at state level, from 1997 to 2016. The carcass weight per head was calculated for each FU/state, followed by the average weight per region for each year from 1997 to 2016, as not all states had available data.[51] The average carcass yield values suggested by Scot Consultoria (2019) were applied to the carcass weights, i.e., 52% and 48% for steers and cows on pasture, respectively, and 54% and 50% for steers and cows in feedlots. In this way, it was possible to obtain the average annual slaughter weight by region for each year. The animal weight was calculated on the basis that it corresponds to 80% of the slaughter weight, which is the body weight corresponding to half the time between the age of 24

[49] Rondônia, Acre, Amazonas, Roraima, Pará, Amapá, Maranhão, Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe and the Federal District.
[50] There is no national data for defining the sex of confined cattle. Therefore, no distinction was made between males and females for this animal category.
[51] IBGE does not publish data when there are fewer than three informants.

months and the age at slaughter weight, obtained from the body weight equation mentioned above, using the slaughter weights (Dataframe 6.5).

Dataframe 6.5. Methodology applied to obtain the average weight of each animal category of beef cattle.

Code	Classification	Description	Methodology	Data source
3.A.1.a	Beef cattle	-	-	--
3.A.1.a.i	Cattle < 1 year	Average weight of cattle at 6 months of age.	Application of the BW function = 33.15 + 28.07t - 1.203t^2 + 0.025t^3 (r^2=0.97; p<0.001), which relates age "t in months to body weight "BW" in kg.	Compilation of data from scientific articles.
3.A.1.a.ii	1 year old < cattle < 2 years old	Average weight of cattle at 1 year and 6 months of age.	Application of the BW function = 33.15 + 28.07t - 1.203t^2 + 0.025t^3 (r^2=0.97; p<0.001), which relates age "t in months to body weight "BW" in kg.	Compilation of data from scientific articles.
3.A.1.a.iii	Bulls > 2 years old	Average weight of breeding bulls .	Based on the IBGE database – Municipal Livestock Production (PPM) by federative unit/state and the 2006 Agricultural Census.	Compilation of data from scientific articles and IBGE Table 1092.
3.A.1.a.iv	Male Beef Cattle> 2 years old (Not confined)	Average weight of male beef cattle at 2 years and 3 months of age.	Animal body mass was estimated using quarterly raw data from the IBGE on total carcass production and the number of slaughtered steers and cows at state level from 1997 to 2016.	Compilation of data from scientific articles and IBGE Table 1092
3.A.1.a.v	Female Beef Cattle > 2 years old (Not confined)	Average weight of female beef cattle at 2 years and 3 months of age.	Animal body mass was estimated using quarterly raw data from the IBGE on total carcass production and the number of slaughtered steers and cows at state level from 1997 to 2016.	Compilation of data from scientific articles and IBGE Table 1092.
3.A.1.a.vi	Other > 2 years old confined	Average weight of confined beef cattle at 2 years and 3 months of age.	Animal body mass was estimated using quarterly raw data from the IBGE on total carcass production and the number of slaughtered steers and cows at state level from 1997 to 2016.	Compilation of data from scientific articles and IBGE Table 1092.

- Digestibility rate (DE%)

Obtaining the digestibility rate (DE%) was based on a review of approximately 40 scientific articles (expert information), which made it possible to compile more than 200 "*in vitro*" and "*in situ*" dry matter digestibility data for 25 different genera, including grasses and legumes (mainly brachiaria and *panicum*, two species that are widely used in Brazil), covering more than 50 species, in the five major regions of the country, between 1990 and 2018. Based on this data, a regression analysis was carried out to investigate the existence of a relationship between digestibility and the years of observation. A positive linear effect was observed as a function of the years (P<0.0001) (Figure A.VI.1, Appendix VI). Thus, for the period between 1990 and 2016, the model was used to estimate the average value for 5-year intervals. For the years between 2017 and 2022, the average value adopted for the period of 2011-2016 was maintained. Considering the scarcity of publications with information on the digestibility of forage plants in some regions, it was decided to use the national average value for all FUs/states in the country.

- Daily weight gain (WG)

The value of this factor (WG) was determined based on consultations with experts from Embrapa Cattle Southeast (Embrapa Pecuária Sudeste) and according to the values used in the Third National Communication Inventory (BRASIL, 2016), with an average daily weight gain during the year of 300 g/day (0.3 kg) for all categories of the beef cattle herd, a value that takes into account the differences between the dry season and the wet season for cattle raised on pasture, which is predominant in Brazil for the entire time series (1990-2022).

- Pregnancy rate ($C_{pregnancy}$)

The pregnancy rate is needed to calculate the amount of energy the animal will use during pregnancy (NEp). The IPCC recommends a default value of 10% of the energy required for animal maintenance (NEm) as the energy required for pregnancy. Therefore, due to the lack of national literature, this value was used for the entire national territory. The IPCC (2006) also indicates a 67% pregnancy rate as a default value. However, according to Embrapa – Brazilian Agricultural Research Corporation (Empresa Brasileira de Pesquisa Agropecuária) experts and to the values used in Brasil (2016), pregnancy rates for female beef cattle in the country are between 60% and 67%. Therefore, a value of 65% was used as the pregnancy rate for female beef cattle within a one-year interval.

- Milk production (Milk)

In order to estimate methane emission factors using default values, 1.1 kg/cow/day was considered, as recommended by the IPCC (2006) for beef cattle.

- Milk fat content (Fat)[52]

In order to define the value of this parameter, a literature review was carried out (SILVA *et al*., 1995; RESTLE *et al*., 2003). Thus, for the emission estimates, the value of 4.9% was considered for the North, Northeast, Southeast and Center-West regions, and for the South region, the average value of 4.38% fat content (native pastures) was considered. The IPCC mentions 4% as the default value for milk fat content in beef cattle. However, the value of 4.3% for the North, Northeast, Southeast and Center-West regions was also taken into account when calculating methane emissions for the period from 2007-2010, while the value of 3.5% was used for the South region (BRASIL, 2016).

It is important to note that the values of the parameters for "milk production", "pregnancy rate (and pregnancy percentage)" and "milk fat content" were only applied to the "female beef cattle > 2 years old, not confined" cattle category. Dataframe 6.6 shows the parameters and factors that were used in the final calculation of methane emissions (CH_4) for the different beef cattle herd categories.

[52] A gordura do leite é o componente do leite que mais varia ao longo da lactação, e de maneira geral a percentagem de gordura do leite aumenta gradualmente ao longo do dia da lactação, estando negativamente correlacionada com a produção de leite da vaca (RESTLE *et al*.,2003).

Dataframe 6.6. Summary of the parameters and factors used to calculate emissions for all categories of beef cattle.

Categories	Parameters	Emission factors						Reference
		B>2 (3.A.1.a.i)	MBC>2NC (3.A.1.a.ii)	FBC>2NC (3.A.1.a.iii)	O>2C (3.A.1.a.iv)	C<1 (3.A.1.a.v)	1<C<2 (3.A.1.a.vi)	
3.A.1.a.	Live animal weight (BW) (kg)	550	374 - 410[a]; 337 - 388[b]; 366 - 408[c]; 366 - 383[d]; 392 - 450[e]	298 - 320[a]; 266 - 306[b]; 302 - 340[c]; 317 - 348[d]; 303 - 343[e]	347 - 372[a]; 316 - 350[b]; 340 - 382[c]; 350 - 373[d]; 354 - 405[e]	163	293	Brasil, 2021
3.A.1.a.	Mature animal weight (MW) (kg)	330	330	330	330	330	330	Brasil (2021)
3.A.1.a.	Digestibility rate (DE) (%)	55.6[1]; 56.8[2]; 57.9[3]; 58.8[4]; 59.8[5];	55.6[1]; 56.8[2]; 57.9[3]; 58.8[4]; 59.8[5]	55.6[1]; 56.8[2]; 57.9[3]; 58.8[4]; 59.8[5]	55.6[1]; 56.8[2]; 57.9[3]; 58.8[4]; 59.8[5]	55.6[1]; 56.8[2]; 57.9[3]; 58.8[4]; 59.8[5]	55.6[1]; 56.8[2]; 57.9[3]; 58.8[4]; 59.8[5]	Brasil (2021)
3.A.1.a.	Weight gain/day (WG) (kg/day)	-	0.3	-	0.3	0.3	0.3	Brasil (2021)
3.A.1.a.	Milk production (kg/day)	-	-	1.1	-	-	-	IPCC (2006, v. 4, chap. 10)
3.A.1.a.	Fat content in milk production (Fat) (%)	-	-	4.9	-	-	-	IPCC (2006, v. 4, chap. 10)
3.A.1.a.	Pregnancy rate ($C_{pregnancy}$) (%)	-	-	10	-	-	-	(IPCC (2006, v. 4, chap. 10)
3.A.1.a.	Percentage of females that become pregnant (%)	-	-	65	-	-	-	Brasil (2015).
3.A.1.a.	Coefficient for Nem (C_f)	0.37	0.37	0.37	0.37	0.37	0.37	IPCC (2006, v. 4, chap. 10)
3.A.1.a.	Coefficient for NEa (C_a)	0.36	0.36	0.36	0.36	0.36	0.36	IPCC (2006, v. 4, chap. 10)
3.A.1.a.	Methane conversion rate (Y_m)	0.065	0.065	0.065	0.065	0.065	0.065	IPCC (2006, v. 4, chap. 10)

Note: B>2 – Bull older than 2 years; MBC>2NC – Male Beef Cattle older than 2 years not confined; FBC>2NC – Female Beef Cattle older than 2 years, not confined; O>2C – Other, confined cattle; C<1 – Cattle under 1 year old; 1<C<2 – Cattle between 1 and 2 years old;
[1] 1990-1995; [2] 1996-2001; [3] 2002-2006; [4] 2007-2010; [5] 2011-2022;
[a] average animal weight (1990-2022) North Region; [b] average animal weight (1990-2022) Northeast Region; [c] average animal weight (1990-2022) Southeast Region; [d] average animal weight (1990-2022) South Region; [e] average animal weight (1990-2022) Center-West Region.
For categories 3.A.1.a.ii, 3.A.1.a.iii and 3.A.1.a.iv the animal weight values also vary according to the year.

6.3.1.2 Dairy cattle farming

Dairy cattle population data was obtained from the IBGE database of the Municipal Livestock Survey (PPM) by FU/State and municipality (5,569). Tables of the population of milked cows and milk production from 1990 to 2022 were obtained, broken down by municipality. A subdivision of the "dairy cattle" population was included, resulting in the categories of "high- and low-production dairy cattle" based on the recommendations by the IPCC (2006), but suited to the Brazilian milk production systems, which are quite heterogeneous given the cultural diversity of the Brazilian population and the soil and climate differences throughout the country.

This subdivision was based on the classification of milk production systems proposed by Assis *et al*. (2005), which is also in line with the one described by Stock et al. (2007), who proposed a subdivision of the Brazilian herd based on animal productivity. Thus, the milk productivity threshold of 2,000 kg/milked cow/year was used as the dividing line between high and low production cows. Animals with milk productivity below this value were classified as low-production dairy cattle, and those with productivity above this value were classified as high-production dairy cattle.

Milk production above 2,000 kg/cow/year, as described by Assis *et al*. (2005), include intensive production systems (grazing and confinement), in which there is greater specialization in dairy farming with the use of volume supplementation in the dry season and the supply of concentrates and mineral mixtures throughout the year on farms, which consists of a higher nutritional quality of the diets supplied in these systems compared to extensive and semi-extensive farming systems. According to the IPCC (2006), the digestibility of the diet supplied to animals has a major impact on enteric methane emissions, and is highly related to the quality of the feed provided and the nutritional management implemented.

Once the thresholds for classification had been defined, productivity was calculated at municipal level and, then, classified into high- and low-production municipalities. Productivity was obtained by dividing milk production by the herd of milked cows in a given municipality in the year analyzed. The municipalities were identified in terms of the federative unit/state and major region to which they belonged and classified in terms of productivity. Those who didn't have milked cows were classified as "without a herd".

As in the case of beef cattle, in order to estimate emissions from enteric fermentation in dairy cattle, it is necessary to calculate and/or define some specific parameters and factors, which vary according to animal category and state or region and which influence emissions. To this end, 42 studies published in national and international scientific journals and theses that were published in different Brazilian regions between 1995 and 2017 were reviewed. Information on the following parameters was taken from these studies: live weight (Weight), dry matter intake (DMI), apparent digestibility of the dry matter (ADDM), milk production (Milk) and milk fat content (Fat).

The database consisted of purebred animals of European origin (*Bos taurus*) and crossbred animals (*Bos taurus x Bos taurus indicus*), representing 61 and 92 treatments, respectively. In these studies, the animals were subjected to different diets and nutritional regimes, referring to animals specialized in milk production, with a minimum daily milk production of 8.2 liters and a maximum of 26.9 liters. Table 6.1 below shows the descriptive statistics of the data collected.

Table 6.1. Descriptive statistics of the database containing national studies with lactating cows from different genetic groups.

Variable	Genetic group	Average	Median	Standard Deviation	CoefVar	Minimum	Maximum
Weight (kg)	Crossbred	508	513	44.7	8.79	400	602
	European	531	534	48.9	9.21	448	611
DMI (kg/day)	Crossbred	14.7	14.9	3.03	20.6	7.95	20.7
	European	16.6	16.7	2.63	15.9	10.9	21.9
ADDM (%)	Crossbred	67.6	67.9	5.03	7.43	55.6	79.1
	European	66.6	67.1	5.50	8.26	55.3	77.7
Milk (kg/day)	Crossbred	16.4	16.1	4.78	29.1	8.20	26.3
	European	20.2	20.4	4.09	20.3	10.1	26.9
Fat (%)	Crossbred	3.99	3.92	0.45	11.4	3.10	5.30
	European	3.67	3.71	0.43	11.8	2.35	4.45

Source: Valvassori *et al.* (1995); Legi *et al.* (1998); Derez *et al.* (2001); Oliveira *et al.* (2001); Silva *et al.* (2001); Jobim *et al.* (2002); Melo *et al.* (2003A; 2003B); Primavesi *et al.* (2004); Magalhães *et al.* (2004, 2006); Silva *et al.* (2005); Rocha *et al.* (2006); Cavalcanti *et al.* (2006, 2008); Pina *et al.* (2006); Jobim *et al.* (2006); Ramalho *et al.* (2006); Cordeiro *et al.* (2007); Ribeiro Filho *et al.* (2007); Oliveira *et al.* (2007A,B); Bumbieris Junior (2007); Maixner *et al.* (2007); Benedeti *et al.* (2008); Ribeiro Filho *et al.* (2009); Soares *et al.* (2009); Modesto *et al.* (2009A; 2009B); Silva *et al.* (2009); Pedreira *et al.* (2009); Alves *et al.* (2010); Teixeira *et al.* (2011); Wanderley *et al.* (2012); Freitas Junior *et al.* (2013); Oliveira *et al.* (2014); Almeida (2015); Silva Junior *et al.* (2015); Ribeiro *et al.* (2016); Kolling *et al.* (2016); Cunha *et al.* (2016); Nascimento (2017); Silva *et al.* (2017); Silvi (2017); Moura (2017); Carvalho *et al.* (2018); Dias (2018); Matiello (2018).

- Live weight (BW)

The average live weight (BW) was obtained based on the general average observed for each genetic group, so the average BW for crossbred animals (508 kg) was used as a reference value for the federative units/state of the North, Northeast, Midwest and Southeast regions, while for the Southern region of Brazil, the average value found for animals of European origin was used (531 kg), represented mainly by Holstein breed animals, with a 98% share. The use of the average BW obtained for lactating cows of European or crossbreed origin as a reference value for the states of the different regions is based on the fact that the southern region of the country, due to its different soil and climate conditions, uses more *Bos Taurus* animals, while the other regions of Brazil use more Holstein-Zebu crossbreeds. According to Braga *et al.* (2015), European breeds, despite their low overall use, have been more closely linked to specialized dairy farms, with the proportion of farms using European breeds increasing the further one moves towards the southern states of the country.

- Pregnancy rate ($C_{pregnancy}$)

The pregnancy rate is needed to calculate the amount of energy the animal will use during pregnancy (NEp). The IPCC (2006) recommends a default value of 10% for the energy required for animal maintenance (NEm) as the energy percentage required for pregnancy (NEp) Therefore, due to the lack of national bibliography, this value was used for the entire national territory. The IPCC (2006) also indicates a 67% pregnancy rate as a default value. However, according to Embrapa experts and to the values used in Brasil (2016), pregnancy rates for female beef cattle in the country are between 60% and 67%. Therefore, a value of 60% for the southern region and 55% for the other regions of the country was used as the pregnancy rate for female beef cattle within a one-year period.

- Milk production (*Milk*)

Milk production was calculated according to the segregation by category carried out considering productivity in "high and low production" municipalities. After the classification, the amount of milk produced for each category was added up and, then, divided by the respective number of cows milked. This value was divided by 365 (days of the year), thus obtaining, for each state, the average daily milk production for high- and low-producing animals. Thus, high-producing animals were defined as those with a production above 5.48 liters/cow/day and low-producing animals below this value.

- Digestibility rate (DE%)

The digestibility rate was obtained based on the literature review of studies on the digestibility of tropical forages published in specialized national journals. Forty studies published between 1990 and 2018 were used, comprising 206 observations of digestibility *in vitro* (DIMS) and *in situ* of 25 different genera of tropical forages used to feed cattle in the country. The maximum and minimum digestibility values found were 71.0% and 41.0%. Grasses of the *Brachiaria* (*Urochloa* sp.) genus accounted for 39.8% of the observations collected.

Based on the data collected, regression analysis was carried out to investigate the existence of a relationship between digestibility and the years of observation (1990 to 2018). The result showed a positive linear effect as a function of the years ($P<0.0001$; $R^2=8.1\%$). In this way, the model was used to estimate the average value for each year and, then, the average was obtained for each period evaluated. Thus, the averages obtained for each period were used as reference values for the low-producing cow category, since it characterizes the extensive farming system in which the animals receive no supplementation, with grass being the exclusive feed source.

Similarly, digestibility values were obtained for high-producing cows using a database made up of animals specialized in milk production. The digestibility values also increased over the years (Figure A.VI.2, Appendix VI), and the annual average was obtained with the model used ($P<0.0001$; $R^2=11.4\%$). The maximum and minimum values observed for ADDM were 55.2% and 79.1%, respectively. The average values obtained for each study period were used for the high-producing cow category.

Dataframe 6.7 shows the parameters and factors that were used in the final calculation of methane emissions (CH_4) from the low and high producing categories of the dairy herd.

Dataframe 6.7. Parameters and factors used to calculate emissions from dairy cattle.

Categories	Parameters	Emission factors		Reference
		Low Production	High Production	
3.A.1.b.	Live weight (BW) (Kg)	Crossbred 508 Bulls: 531[a]	Crossbred 508 Bulls: 531[a]	Brasil (2021)
3.A.1.b.	Digestibility rate (DE%) (%)	55.6[1]; 56.8[2]; 57.9[3]; 58.8[4]; 59.8[5]	61.4[1]; 63.4[2]; 65.2[3]; 66.7[4]; 68.4[5]	Brasil (2021)
3.A.1.b.	Weight gain/day (WG) (kg/day)	0	0	IPCC (2006, v. 4, chap. 10)
3.A.1.b.	Milk production (kg/day)	<5.48	>5.48	Assis *et al.* (2005).
3.A.1.b.	Milk fat content (Fat) (%)	3.99	3.67	Brasil (2021)

Categories	Parameters	Emission factors		Reference
		Low Production	High Production	
3.A.1.b.	Pregnancy rate (CPregnancy) (%)	10	10	IPCC (2006, v. 4, chap. 10)
3.A.1.b.	Percentage of females that become pregnant (%)	55.0[a]; 60.0	55.0[a]; 60.0	Brasil (2015).
3.A.1.b.	Coefficient for NEg (C)	-	-	IPCC (2006, v. 4, chap. 10)
3.A.1.b.	Coefficient for Nem (Cf)	0.386	0.386	IPCC (2006, v. 4, chap. 10)
3.A.1.b.	Coefficient for NEa (Ca)	0.17	0.17	IPCC (2006, v. 4, chap. 10)
3.A.1.b.	Methane conversion rate (Ym)	0.065	0.065	IPCC (2006, v. 4, chap. 10)

Note: [a] Values for the Southern region; [1] 1990 to 1995; [2] 1996 to 2001; [3] 2002 to 2006; [4] 2007 to 2010; [5] 2011 to 2022.

6.3.1.3 Other animal categories

For other animal species, such as swine, buffaloes, sheep, goats, horses, mules and asses, enteric methane emission factors were used, which were pre-established for each animal group, indicated as a default values by the IPCC 2006 (IPCC 2006, Vol. 4, Chap.10, Section 10.2 and Annex 10A.1).

6.3.2 Quality assurance and quality control

The QA/QC procedures adopted for the Enteric Fermentation subsector (3.A) are described in Section 2.5 of this document.

6.3.3 Assessment of uncertainty, consistency and recalculations of the time series

Uncertainty analysis was carried out using the random sampling methods and techniques described in the 2006 IPCC Guidelines. The uncertainty associated with CH_4 emissions from Enteric Fermentation (3.A) is shown in Appendix II.

The process of updating the national inventory considered the revision of the time series of population data for the different categories of animals. As for the emission factors, these have not been modified. In summary, the main adjustments stem from:

- *Cattle (2017-2022):* the same percentage assumptions as in previous inventories were used to break down the categories of beef cattle (by sex, age and type of animal confinement) and dairy cattle (between low- and high-producing cattle);
- *Swine (2017-2022):* the same percentage assumptions as in previous inventories were used to break down the categories of swine (by production purpose); and
- *Asses and mules (2013-2022):* due to the lack of data from 2013 to 2022, a linear extrapolation of the data was carried out (trend line, by the average variation from 2008 to 2012 – the last year of the series).

Comparing the consolidated results of the previous Inventory with the one carried out for this NIR 2024, the largest proportion of adjustments is seen in 2020, with a 3.7% difference between estimated emissions, due to the revision of population data for animal herds. Between 2017 and 2020, the average adjustment in aggregate emissions was 2.5%, and in the period from 1990 to 2020, it was 0.3%, which demonstrates the consistency of the subsector's time series (Figure 6.3).

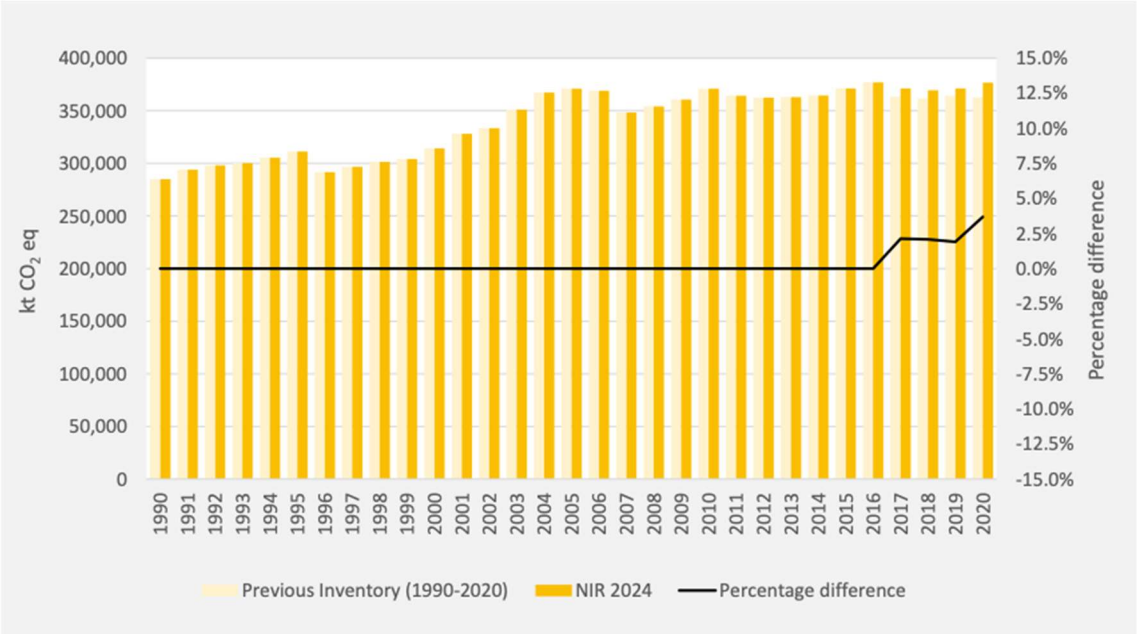


Figure 6.3. Comparison of estimated emissions from the Enteric Fermentation subsector (3.A) between inventories.

6.3.4 Improvement plan

The experience gained in the periodic preparation of national GHG inventories has led to the proposal of a series of measures to improve the consistency and greater detailing of the results of the Inventory, in particular of Enteric Fermentation (3.A). Dataframe 6.8 summarizes the potential improvements for implementation in future editions of this subsector's inventory.

Dataframe 6.8. Potential improvements applicable to improving the emissions inventory for the Enteric Fermentation subsector (3.A).

Subsector	Category	Improvement
3.A. ENTERIC FERMENTATION	3.A.1. Cattle	▪ Conduct further studies with a view to assessing the possibility of revising the method of disaggregating cattle herds, specifically with regard to the fractions determined by category, and by FU/state. ▪ Expand studies aimed at mapping new parameters of: animal weight, average daily weight gain and digestibility rate for the different categories of cattle herds.

Subsector	Category	Improvement
	3.A.4. Other Animals	▪ Carry out studies to assess the possibility of revising the default enteric methane emission factor for the buffalo animal category, in view of the value contained in the 2019 IPCC Guide.

6.4 Manure Management (CRT 3.B)

Manure management includes emissions of CH_4 and N_2O from animal categories used for production purposes in Brazil: cattle (beef and dairy cattle), swine, sheep, goats, asses, mules, horses, buffaloes and poultry. And the term "manure" includes the liquid and solid excretions produced by animals.

Emissions of CH_4 occur during the decomposition of manure under anaerobic conditions (in the absence of oxygen), during its treatment or disposal, and are influenced by the amount of manure generated and the type of treatment system adopted. Emissions of N_2O occur directly through nitrification and denitrification of the nitrogen (N) contained in the manure, and indirectly through the volatilization of ammonia (NH_3) during the treatment and disposal of animal manure.

In 2022, emissions from Manure Management (3.B) totaled 29,012 kt CO_2 eq, representing 4.7% of the sector's emissions in that year. Cattle and swine accounted for 44% and 42% of the category's total emissions, respectively. Indirect N_2O emissions due to atmospheric deposition (subcategory 3.B.5) accounted for 8% of the category's emissions (Figure 6.4).

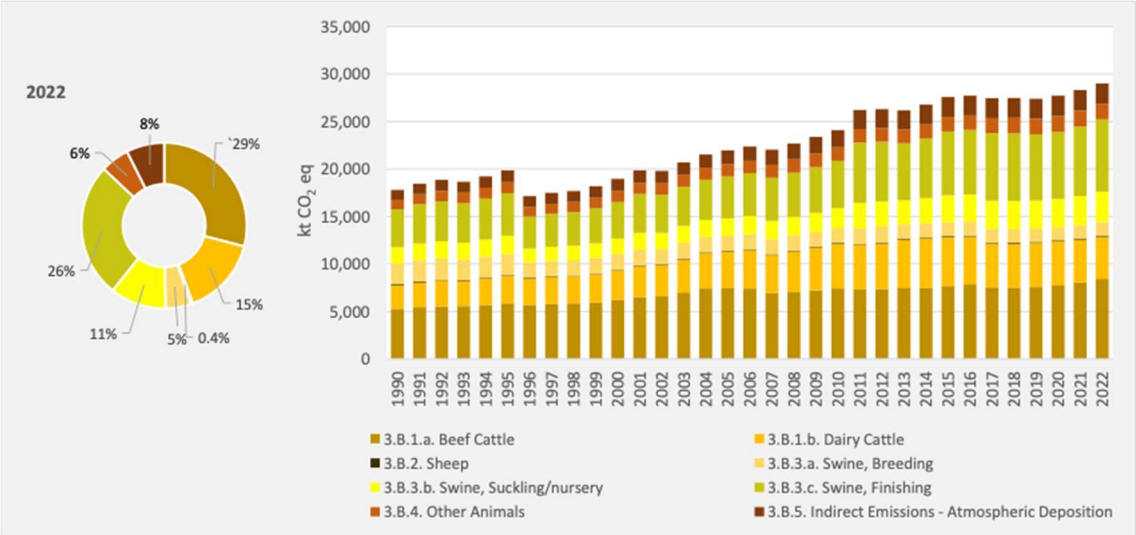


Figure 6.4. Emissions from Manure Management (3.B), in kt CO_2 eq per category, from 1990 to 2022.

6.4.1 Methodological aspects

To calculate CH_4 and N_2O emissions from the categories in the Manure Management subsector (3.B), equations 6.12 to 6.18 were used, shown in Dataframe 6.9, with Tier 2 and Tier 1 methodological detailing.

Dataframe 6.9. Equations for estimating emissions from the Manure Management subsector (3.B).

Equations	GHG	Categories	Central equation	Reference
Equation 6.12	CH_4	3.B.1 3.B.2 3.B.3 3.B.4	$\text{Emissions of } CH_4 = \sum_{(T)} \frac{(EF_{(T)} \times N_{(T)})}{10^{-6}}$	Equation 10.22 (IPCC, 2006, v. 4, chap. 10)
Equation 6.13	CH_4	3.B.1 3.B.2 3.B.3 3.B.4	$EF_{(T)} = (VS_{(T)} \times 365) \times [Bo_{(T)} \times 0.67 \times \left(\sum_{(S,K)} \frac{MCF_{S,K}}{100}\right) \times MS_{(T,S,K)}]$	Equation 10.23 (IPCC, 2006, v. 4, chap. 10)
Equation 6.14	CH_4	3.B.1 3.B.2 3.B.3 3.B.4	$VS_{(T)} = [GE \times \left(1 - \left(\frac{\%DE}{100}\right) + UE \times GE\right] \times [\left(1 - \frac{ASH}{18.45}\right)]$	Equation 10.24 (IPCC, 2006, v. 4, chap. 10)
Equation 6.15	N_2O	3.B.1 3.B.2 3.B.3 3.B.4	$N_2OD_{(MM)} = [\sum_{S}[\sum_{T}(N_{(T)} \times Nex_{(T)} \times MS_{(T,S)})] \times EF_{3(S)}] \times \frac{44}{28}$	Equation 10.25 (IPCC, 2006, v. 4, chap. 10)
Equation 6.16	N_2O	3.B.1 3.B.2 3.B.3 3.B.4	$Nex_{(T)} = Nrate_{(T)} \times \frac{TAM}{1000} \times 365$	Equation 10.30 (IPCC, 2006, v. 4, chap. 10)
Equation 6.17	N_2O	3.B.5	$N_2OG_{(MM)} = (N_{volatilization} - MMS \times EF_4) \times \frac{44}{28}$	Equation 10.26 (IPCC, 2006, v. 4, chap. 10)
Equation 6.18	N_2O	3.B.5	$N_{volatilization} - MMS = [\sum_S[\sum_T(N_{(T)} \times Nex_{(T)} \times MS_{(T,S)})] \times \frac{FracGas_{MS}}{100}_{(T,S)}]$	Equation 10.26 (IPCC, 2006, v. 4, chap. 10)

In which:

$EF_{(T)}$ = Emission factor for the defined animal population (kg CH_4 head^{-1} year^{-1});
$VS_{(T)}$ = Daily volatile solid excreted for animals in category T (kg/MS/animal^{-1}/day^{-1});
365 = Basis for calculating annual VS production (days/year^{-1});
$Bo_{(T)}$ = Maximum methane production capacity for manure produced by the animal category, m^3/CH_4/kg^{-1} of VS excreted;
0.67 = Conversion factor from m^3 CH_4 to kg of CH_4;
$MCF_{s,k}$ = Methane conversion factors for each manure management system S by climate region K (%);
$MS_{(T,\ S,\ k)}$ = Fraction of animal category T's manure handled using manure management system S in the climate region k;
$N_{(T)}$ = Number of head per animal species (by category in the country);
VS = volatile solid excretion per day based on dry matter (DM), kg VS day^{-1};
GE = gross energy intake, MJ day^{-1};

DE% = feed digestibility in percent (%);
(UE x GE) = urinary energy expressed as a fraction of GE;
ASH = The ash content of manure, calculated as a fraction of the dry matter feed intake (DMI);
18.45 = conversion factor for dietary GE per kg of DM (MJ kg-1). This value is a constant across a wide range of forage and grain-based feeds consumed by livestock;
$N_2OD_{(mm)}$ = direct N_2O emissions from manure management in the country, kg N_2O $year^{-1}$;
$N_{(T)}$ = number of head of species/category T in the country;
$Nex_{(T)}$ = annual average N excretion per head of species/category T in the country, kg N $animal^{-1}$ $year^{-1}$;
$MS_{(T,S)}$ = fraction of total annual nitrogen excretion for each livestock species/category T that is managed in the country's manure management system S, dimensionless;
$EF_{3(S)}$ = emission factor for direct N_2O emissions from manure management system S in the country, kg N_2O-N/kg N in manure management system S;
S = manure management system;
T = species/category of livestock;
44/28 = conversion of (N_2O-N)(mm) emissions into N_2O(mm) emissions;
Nvolatilization-MMS = amount of nitrogen from manure that is lost due to volatilization of NH_3 and NO_x, kg N $year^{-1}$; and
$FracGas_{MS}$ = percentage of nitrogen from manure managed for category T animals that volatilizes as NH_3 and NO_x in manure management system S (%).

Activity data and other parameters

The main activity data used to estimate emissions from the Manure Management subsector are the populations of each category of animal species in the herd and the proportion of each category that is reared in conditions where the manure that is produced is treated or managed. The data by type of animal herd is presented below.

6.4.1.1 Cattle farming

The method used to break down the beef and dairy cattle herd population into categories in the Manure Management subsector is the same as the one used in the Enteric Fermentation subsector. The disaggregation for cattle was based on data from Table 925 of the 2006 Agricultural Census (IBGE, 2006), from properties with more than 50 head of cattle, by Federative Unit (FU)/State. On the other hand, the disaggregation of dairy cattle into low and high production was based on the recommendations made by the 2006 IPCC Guidelines, but adapted to the Brazilian production systems, which are quite heterogeneous in view of the cultural diversity of the Brazilian population and the soil and climate differences present throughout the country. The emission factors for each type of gas, CH_4 or N_2O, are described below.

6.4.1.2 Swine

The swine population was disaggregated according to age and rearing system, as recommended by (Embrapa Swine and Poultry (Embrapa Suínos e Aves), and with reference to data from the Industry Social Service (SESI, Serviço Social da Indústria), the Brazilian Animal Protein Association (ABPA) and the IBGE. The IBGE's time series of the total swine population has included the breeding population since 2013, making it possible to have a breakdown of the total population at state level. In order to obtain the complete series from

1990 to 2022, information from the 2006 Agricultural Census (Table 936) (IBGE, 2006), which breaks down the population into sows, boars and other swine, was used. The sum of the populations of sows and boars made it possible to create the "breeding" category, whose ratio in relation to the total population in 2006 was applied to the total swine population in each state for the years of the Inventory from 1990 to 2012. From 2013 onwards, the breeding population was corrected according to the percentage of sows and boars in Table 936.

Table 6.2 shows the results of the factors applied to obtain the fraction of breeding swine.

Table 6.2. Fraction of breeding swine, by FU (Federative Unit)/State and period.

Federative Unit (FU/State)	Fraction of Breeding Swine	
	Factor applied to the total swine population (1990 to 2012)	Factor applied to the breeding population (from 2013 onwards)
Rondônia	0.2446	1.3330
Acre	0.4232	1.4695
Amazonas	0.3578	1.4711
Roraima	0.3972	1.3762
Pará	0.2851	1.4634
Amapá	0.4290	1.4580
Tocantins	0.2807	1.3716
Maranhão	0.2759	1.3375
Piauí	0.3372	1.3073
Ceará	0.2506	1.3422
Rio Grande do Norte	0.2388	1.4059
Paraíba	0.2056	1.3938
Pernambuco	0.2319	1.3318
Alagoas	0.1684	1.2303
Sergipe	0.1876	1.2785
Bahia	0.2672	1.3864
Minas Gerais	0.1253	1.1953
Espírito Santo	0.1228	1.2419
Rio de Janeiro	0.1532	1.2756
São Paulo	0.1443	1.2055
Paraná	0.1322	1.1890
Santa Catarina	0.0980	1.1177
Rio Grande do Sul	0.1148	1.1457
Mato Grosso do Sul	0.1254	1.2513
Mato Grosso	0.1713	1.2248
Goiás	0.2027	1.3077
Federal District	0.1166	1.0949

Source: Based on IBGE (2006).

The difference between the total swine population and the breeding population represents the population with individuals from birth to finishing, who are fed different diets which have an impact on Nitrogen excretion. This population was, then, broken down into swines in the "Suckling-Nursery" and "Finishing" phases. For this breakdown, the duration of each phase was taken into account, i.e., 65 days for the first phase and 110 days for the last one, considering a cycle of 175 days from birth to slaughter. Based on the duration of each phase in relation to the total time to slaughter, it was estimated that 37% of the population (minus the breeding stock) represents the "Swine in Suckling-Nursery" category, and the rest represents the "Swine in the Finishing phase" category.

The estimates of breeding stock made using the IBGE populations are higher than the population for industrial purposes reported by ABPA, similarly to the rest of the swine population. The IBGE's surplus swine population was considered to be from subsistence swine farming, i.e., those raised as free-range, outside the industrial confinement regime, which is relevant information for Manure Management estimates. The "industrial breeders" category was defined, whose population was estimated based on the proportion of industrial breeders in relation to the total number of industrial swine published for the period from 2002 to 2016 in the ABPA yearbooks; for the years from 1990 to 2001, the value of the intersection (b=0.431866) of the linear regression (y=a*x+b) estimated from the fractions obtained between the years of 2002 and 2016 was considered. These proportions were maintained for all states. The "Subsistence breeders" category was estimated based on the difference between IBGE's "Breeders" and "Industrial Breeders" (Table 6.3).

Table 6.3. Fraction of breeding swine in industrial farming system.

Year	Fraction of breeding swine in industrial farming system
1990 – 2001	0.432
2002	0.412
2003	0.446
2004	0.419
2005	0.392
2006	0.410
2007	0.414
2008	0.413
2009	0.409
2010	0.396
2011	0.393
2012	0.403
2013	0.375
2014	0.357
2015	0.352
2016	0.345
2017	0.346
2018	0.347
2019	0.342
2020	0.330
2021	0.331
2022	0.337

Source: Based on IBGE (2006) and ABPA – Brazilian Animal Protein Association (Associação Brasileira de Proteína Animal) (2019).

Considering the ratios between ABPA (2019) industrial slaughtering and subsistence slaughtering, published by SESI (2019), the industrial and subsistence populations were broken down into the categories of "Swine in Suckling-Nursery phase" and "Swine in Finishing phase". Lastly, the following categories of swine were defined: "Breeders/Industrial", "Breeders/Subsistence", "Suckling-Nursery/Industrial", "Suckling-Nursery/Subsistence", "Finishing/Industrial" and "Finishing/Subsistence".

The calculation of CH_4 emissions from swine herds used, in part, the default values indicated by the IPCC (2006) and data obtained from literature review. A review of 40 research studies conducted in the country was carried out to collect data on digestibility,

live weight and feed consumption for the following categories of swine: Suckling/Nursery, Finishing, and Breeding.

No data was found for these zootechnical indicators in all regions between 1990 and 2022. Therefore, an overall average was made of the data found for each category, and these values were assigned to all Brazilian states. The feed intake and digestibility data for industrial growing swine, industrial finishing swine and industrial breeding swine were the same as those used for subsistence suckling/nursery swine, subsistence finishing swine and subsistence breeding swine, respectively. The emission factors for each type of gas, CH_4 or N_2O, are described below.

6.4.1.3 Other animal categories

Due to their lesser importance in relation to GHG emissions, the populations of buffaloes, goats, sheep, horses, mules and asses were not disaggregated, and are presented as a single category. We used the total of the species considered within each category, whose data was taken from the IBGE's Automatic Recovery System (SIDRA) database, table 3939 of the Municipal Livestock Survey (PPM). In the case of the categories of asses and mules, because the species in these categories were no longer surveyed from 2013 onwards, the population was estimated by taking the average number of animals in the herd from the previous five years plus the sum from the year before the estimate was made. The emission factors for each type of gas, CH_4 or N_2O, are described below.

The population of the poultry animal category was disaggregated based on information from the IBGE's Municipal Livestock Survey database (2018a; 2024a), which reports the populations of total chickens and hens. The difference was considered to include the populations of chicks, male and female broilers and roosters. The hen population was considered to be for laying purposes. It was considered unnecessary to disaggregate roosters from the broiler and chick population, which were considered to be meat animal population. IBGE also reports on the quail population, which are considered here to be for laying purposes. Thus, for poultry, the following categories were considered: "laying hens", "broilers, chicks and roosters" and "quails" (Table A.VI.2, Appendix VI).

6.4.1.4 Emission factors and other parameters of CH_4 emissions

- Beef cattle farming

The digestibility rate (DE%) values were obtained by reviewing data in the literature and by means of a regression analysis, which indicated a linear effect as a function of the years. The resulting digestibility data generated, per year and per period analyzed, are synchronized with those used to estimate methane emissions from enteric fermentation in beef cattle.

Dataframe 6.10 summarizes the parameters and factors used to estimate beef cattle emissions from manure management.

Dataframe 6.10. Summary of the parameters and factors used to calculate emissions from beef cattle in the Manure Management subsector.

Categories	Parameters	Emission factors						Reference
		B>2 (3.B.1.a.i)	MBC>2NC (3.B.1.a.ii)	FBC>2NC (3.B.1.a.iii)	O>2C (3.B.1.a.iv)	C<1 (3.B.1.a.v)	1<C<2 (3.B.1.a.vi)	
3.B.1.a.	Gross Energy Intake (GE) (MJ kg^{-1})	186.8[1]; 180.4[2]; 175.0[3]; 170.9[4]; 166.5[5]	171.8[1]; 164.8 - 171.6[2]; 157.4 - 165.1[3]; 152.4 - 159.0[4]; 154.3 - 158.0[5]	180.7-196.4[1]; 173.5-193.9[2]; 175.8-186.7[3]; 170.1-189.9[4]; 167.5-187.1[5]	107.5-116.6[1]; 141.6-159.0[2]; 144.0-153.3[3]; 140.0-150.8[4]; 136.4-149.3[5]	90.2[1]; 87.0[2]; 83.9[3]; 81.6[4]; 79.1[5]	140.8[1]; 135.1[2]; 130.3[3]; 126.6[4]; 122.8[5]	Equation 10.16 (IPCC, 2006, v. 4, chap. 10)
3.B.1.a.	Digestibility rate (DE%) (%)	55.6[1]; 56.8[2]; 57.9[3]; 58.8[4]; 59.8[5]	55.6[1]; 56.8[2]; 57.9[3]; 58.8[4]; 59.8[5]	55.6[1]; 56.8[2]; 57.9[3]; 58.8[4]; 59.8[5]	55.6[1]; 56.8[2]; 57.9[3]; 58.8[4]; 59.8[5]	55.6[1]; 56.8[2]; 57.9[3]; 58.8[4]; 59.8[5]	55.6[1]; 56.8[2]; 57.9[3]; 58.8[4]; 59.8[5]	Brasil, 2021
3.B.1.a.	Maximum methane production capacity (Bo) (kg CH_4/VS)	0.1	0.1	0.1	0.1	0.1	0.1	IPCC (2006, v. 4, chap. 10)
3.B.1.a.	Methane conversion factor (MCF) (%)	1.5 to 2	1.5 to 2	1.5 to 2	1.5 to 2	1.5 to 2	1.5 to 2	Table 10.17 (IPCC, 2006, v. 4, chap.10)
3.B.1.a.	Fraction of use of each manure management system (MS)	100% pasture	100% pasture	100% pasture	92% Solid Storage, 7% Dry Lot, 1% Anaerobic Digestor	100% pasture	100% pasture	Confined animals: Costa Jr. *et al.*, 2013.
3.B.1.a.	Urinary energy expressed as a fraction of GE (UE x GE) (MJ day^{-1})	0.02	0.02	0.02	0.02	0.02	0.02	IPCC (2006, v. 4, chap. 10)
3.B.1.a.	Ash content in manure (ASH) (%)	8	8	8	8	8	8	IPCC (2006, v. 4, chap. 10)

Note: B>2 – Bull over 2 years old; MBC>2NC – Male beef cattle over 2 years old, not confined; FBC>2NC – Female beef cattle over 2 years old, not confined; O>2C – Other cattle, confined; C<1 – Cattle under 1 year old; 1<C<2 – Cattle between 1 and 2 years old; [1] 1990-1995; [2] 1996-2001; [3] 2002-2006; [4] 2007-2010; [5] 2011-2016.

- Dairy cattle farming

With regard to Gross Energy Intake (GE), the same results were used as for the portion of gross energy intake from enteric fermentation in dairy cattle, obtained from Equation 10.16, recommended by IPCC (2006). In order to obtain feed intake (kg/day), the GE value was divided by the dietary conversion factor of 18.45 (MJ kg^{-1}), according to IPCC (2006). The digestibility rate used was the same as that presented for dairy cattle (category 3.A.1.b), but the values for high- and low-producing dairy cattle were differentiated over the years. For urinary energy, which is expressed as a fraction of gross energy intake (MJ day^{-1}), the default value of 0.04 for GE excretion for low-producing cows, and 0.02 for high-producing cows was considered. According to the IPCC (2006), urinary energy can be reduced by 0.02 for ruminants fed with 85% or more of grains in the diet.

With regard to the Methane Conversion Factor (MCF) values, specific values were determined that vary according to the type of manure management system (MS) and climate (k). The climate values (cold, hot or temperate) were adjusted according to the average temperature of each FU/State.

Dataframe 6.11 below summarizes the parameters and factors used to estimate emissions from dairy cattle manure management.

Dataframe 6.11. Summary of the parameters and factors used to calculate emissions for the dairy cattle categories in the Manure Management subsector.

Categories	Parameters	Emission factors		Reference
		Low Production	High Production	
3.B.1.b.	Gross Energy Intake (GE) (MJ kg^{-1})	194.4 – 238.2[1]; 96.7 – 38.1[2]; 191.1 – 30.4[3]; 176.4 – 223.1[4]; 71.8 – 217.5[5]	164.5 – 252.0[1]; 157.0 – 239.4[2]; 150.8 – 233.2[3]; 146.0 – 234.3[4]; 141.2 – 229.3[5]	Equation 10.16 (IPCC, 2006, v. 4, chap. 10)
3.B.1.b.	Digestibility rate (DE%) (%)	55.6[1]; 56.8[2]; 57.9[3]; 58.8[4]; 59.8[5]	61.4[1]; 63.4[2]; 65.2[3]; 66.7[4]; 68.4[5]	Brasil, 2021
3.B.1.b.	Maximum methane production capacity (B_o) (kg CH_4/VS)	0.13	0.13	IPCC (2006, v. 4, chap. 10)
3.B.1.b.	Methane conversion factor (MCF) by type of manure management system (S) and climate (k)	Table 6.12	Table 6.12	Table 10.17 (IPCC 2006, v. 4. chap. 10)
3.B.1.b.	Fraction of use of each manure management system (MS)	Table 6.10	Table 6.10	Brasil, 2016
3.B.1.b.	Urinary energy expressed as a fraction of GE UE x GE) (MJ day^{-1})	0.04	0.02	IPCC (2006, v. 4, chap. 10)
3.B.1.b.	Ash content in manure (ASH) (%)	8	8	IPCC (2006, v. 4. cap. 10)

Note: [1]1990 to 1995; [2]1996 to 2001; [3]2002 to 2006; [4]2007 to 2010; [5]2011 to 2016.

- Swine

Dataframe 6.12 summarizes the parameters and factors used to estimate emissions from swine based on manure management. For regions with lower Urinary Energy (UE) levels from subsistence swine farming, the same database as the one in the industrial swine farming category was used.

Dataframe 6.12. Summary of the parameters and factors used to calculate emissions from swine in the Manure Management subsector.

Categories	Parameters	Emission factors	Reference
3.B.3.	Maximum methane production capacity (Bo)	0.29 m^3 CH_4 / kg	IPCC (2006, v. 3, chap.2)

Categories	Parameters	Emission factors	Reference
3.B.3.	Gross Energy Intake (GE) (MJ kg^{-1})	18.45	Table 2.4 (IPCC, 2006, v. 3, chap.2)
3.B.3.	Digestibility rate (DE%) (%)	87% high technological level; 70 to 80% for finishing swine; 80 to 90% for growing swine; 50 to 70% for free range swine (*free range* system)	IPCC (2006, v. 3, chap.2)
3.B.3.	Urinary energy (UE) (MJ day^{-1})	0.02	IPCC (2006, v. 3, chap.2)
3.B.3.	Ash content in manure (ASH) (%)	3% (South, Southeast and Center-West regions); 4% (North and Northeast regions)	IPCC (2006, v. 3, chap.2)
3.B.3.	Methane conversion factor (MCF)	Specific values according to the manure management system and based on the average annual temperature in each FU/state.	Table 10.17 (IPCC 2006, v. 4. chap. 10)

- Other animal categories

Methane emission factors indicated as default factors by the IPCC 2006 were used for the other animal categories: buffaloes, sheep, goats, horses, mules, asses and poultry, according to the climate ranges indicated in Table A.VI.1 (Appendix VI), corresponding to each FU/State.

6.4.1.5 Emission factors and other parameters of N_2O emissions

- Annual N excretion rate ($N_{ex\,(T)}$)

Based on the review of the literature[53] on national research to survey the amount of N excretion from the most significant herd categories in the country, it was possible to define the annual N excretion rates for cattle, swine and poultry. Sheep and goats were also included due to the reasonable number of publications (Table 6.4). For the other categories, it was decided to use the IPCC 2006 default values.

Table 6.4. Annual N excretion rate ($Nex_{(T)}$) and body mass of a typical animal (TAM) from the national herd species categories.

Animal category	Animal subcategory	$Nex_{(T)}$[1]	TAM[2]	
		kg N/1000 kg of body mass	kg/animal head	Reference
BEEF CATTLE (3.B.1.A)	Cattle < 1 year	102.2	163	Koury Filho *et al.* (2010); Yokoo *et al.* (2007); Reis *et al.* (2008); Gama (2017); Ferreira, *et al.* (2019); Passafaro *et al.* (2016); Toral *et al.* (2009); Scot consultoria (2019) and IBGE (2019b).
	Cattle 1 year < 2 years	102.2	293	
	Bulls > 2 years old	102.2	550	
	Male cattle aged 2 years and over (not confined)	102.2	389a 362b 389c 372d 406e	
	Female cattle aged 2 years and over (not confined)	102.2	308a 288b 314c 329d 314e	

[53] For the bovine animal category, 25 articles were considered that measured the N excretion rate for different breeds, sexes, ages and diets. For the other species, 21 articles were found, mostly for swine and sheep.

Animal category	Animal subcategory	$Nex_{(T)}$[1]	TAM[2]	
		kg N/1000 kg of body mass	kg/animal head	Reference
	Other cattle aged 2 years and over (confined)	102.2	356a 331b 359c 358d 367e	
DAIRY CATTLE (3.B.1.B)	High Production	164.25	508 and 531	Toral *et al.* (2009); Scot Consultoria (2019) and IBGE (2019b).
	Low Production	164.25	508 and 531	
SWINE (3.B.3)	Breeding – industrial farming	109.5	155	Leal *et al.* (2015); Favaro; Bellaver (2019); Marinho *et al.* (2007); IBGE (2019b); ABCS (2014).
	Breeding – subsistence farming	109.5	155	
	Breeding/rearing – industrial farming	189.8	11	
	Breeding/rearing – subsistence farming	189.8	11	
	Finishing – industrial farming	189.8	34a; 42b; 58c; 63d; 62e.	
	Finishing – subsistence farming	189.8	34a; 42b; 58c; 63d; 62e.	
OTHER ANIMALS (3.B.4)	Chickens and layers	299.3	2.0	Figueiredo, *et al.* (2003).
	Chicks, broilers and roosters	357.7	0.95a; 0.92b,c; 0.81d; 0.91e.	Stringhini *et al*. (2003); Rosa, (2010); IBGE (2019b); Santos (2005).
	Quails	219	0.18	IPCC (2006).
	Goats	383.3	30	IPCC (2006).
	Sheep	215.4	28	IPCC (2006).
	Buffaloes	116.8	380	IPCC (2006).
	Horses	167.9	238	IPCC (2006).
	Mules	167.9	130	IPCC (2006).
	Asses	167.9	130	IPCC (2006).

Note: $Nex_{(T)}$: Annual N excretion rate; TAM: Typical body mass of an animal in a given category. a – average animal weight (1990-2016) North; b – average animal weight (1990-2016) Northeast; c – average animal weight (1990-2016) Southeast; d – average animal weight (1990-2016) South; e – average animal weight (1990-2016) Center-West.

The data collected[54] showed that for cattle, broilers and buffaloes, the national average values for N excretion rates were similar to the IPCC (2006) default values. Swine, sheep and goats had very discrepant results and were always lower, although in the case of goats and sheep, the default value was within the range of measured data, even if in the upper range (Figure A.VI.3, Appendix VI).

- Animal body mass (TAM)

The "TAM" variable corresponds to the body mass of the animal that represents the population of a given category, i.e., the mass that corresponds to half of the time interval considered for categorization by age, using the body weight gain equations for each component of the herd. This parameter was detailed for cattle, swine and poultry, given the importance of these species for manure production and the availability of carcass production data series from the IBGE.

[54] For beef and dairy cattle, 93 pieces of data were gathered from different publications, while for swine and broilers, 19 pieces of data were identified. For sheep and goats, 48 and 16 studies were carried out respectively, and only 4 for each of the other species.

- Cattle

The definition of the body mass of cattle follows the same methodological framework used in the "Enteric Fermentation" subsector.

- Swine

For Swine, the BW function = 143.9/{1+ exp[-((t-112.3)/32.1))]}, which relates body weight (BW) to growth time (t), was obtained from data from the Brazilian Association of Swine Farmers (ABCS, Associação Brasileira de Criadores de Suínos) (ABCS, 2014). The equation was used to obtain the TAM for the Suckling-nursery category at 32 days of age. For the finishing category, the TAM estimate was based on quarterly raw data from IBGE (2019b; 2024a) on total carcass production and the number of animals slaughtered, at state level, from 1997 to 2016. The average carcass weight was calculated by geographical region for each year from 1997 to 2016, as not all states had data available. The average carcass yield of 72% was applied to the carcass weights (Favaro; Bellaver, 2001; Marinho *et al.*, 2007) in order to obtain the average annual slaughter weight by region for each year, keeping the value observed in 2016 constant for the period of 2017 to 2022. The TAM was calculated on the basis that it represents 53% of the slaughter weight, or the body weight corresponding to half the time between the age of 64 days and the age at slaughter weight, obtained from the body weight equation mentioned above using the slaughter weights calculated based on the carcass production data. It was assumed that there was no difference in weight between the animals from industrial and subsistence farming systems.

- Poultry

In the case of laying hens, the Leghorn breed is the main one used in egg production, with an average weight of 2.0 kg, according to Figueiredo *et al.* (2003), and it can be used as a reference. For hens and quails, the respective average weights were obtained from the literature, while for the roosters, chicks and broilers category, quarterly raw data from the IBGE (2019b) on total carcass production and number of animals slaughtered, at state level from 1997 to 2016, were used. The average carcass weight was calculated by geographical region for each year from 1997 to 2016, as not all states had data available. With regard to carcass weights, the average carcass yield of 85% was applied (Stringhini *et al.*, 2003; Rosa *et al.*, 2010) to obtain the average annual slaughter weight by region for each year, and the value obtained in 2016 was maintained for the period from 2017 to 2022. The TAM was calculated considering that it represents 38% of the slaughter weight, or the body weight at 22 days of age, obtained from the equations published by Santos *et al.* (2005) for the Cobb breed of male broilers (BW = 5,723*exp[-exp(-0.039*(t-37))]; r^2 = 0.99; p<0.001) and female broilers (BW = 4,704*exp[-exp(-0.037*(*t*-36))] r^2 = 0.99; p<0.001), assuming a similar population between males and females.

- Other animals

For the other animal categories, the total amount of N present in manure was quantified based on population data, combined with parameters for estimating the total excretion of N in manure ($N_{ex(T)}$), and the proportion of N excreted from manure that had undergone management. The methodology for estimating this amount of N requires the daily excretion rate of N in kg ($N_{ex(T))}$) per 1,000 (kg^{-1}) of body mass of animals in each category, and the

respective typical masses of 1 animal (TAM), in kg. The default values for TAM from Chapter 10 of the 2006 IPCC Guidelines were used.

- N loss factors during manure management

During the period in which the manure is undergoing a given type of management, N losses occur through volatilization. Losses due to nitrogen leaching and run-off are considered to be negligible. Likewise, during management, emissions of N_2O occur. Estimating these losses involves using a factor on the amounts of N managed.

- Volatilization

The default loss factors provided in IPCC (2006) were used, as described in Table 6.5. The factors vary depending on the species of animal in the herd, as it is assumed that the management system is specific to each species. The unmanaged fraction of manure is taken into account in estimates for the management of agricultural soils, as it is considered to be a direct application of N to the agricultural system, i.e., to grassland soils and paddocks with plants. Composting and biodigester systems, although used in Brazil for some animal categories, do not result in N losses through volatilization.

Table 6.5. N loss factor through ammonia volatilization for each manure management system (FracGasMS), applied to the amounts of N managed for each category of animals in the national herd.

Category of animal in the herd	Management system	$Frac_{GasMS}$
Beef cattle	Dry Lot	0.30
	Solid storage	0.45
Dairy cows	Anaerobic lagoon	0.35
	Solid storage	0.30
Swine	Anaerobic lagoon	0.40
	Pit storage	0.25
	Liquid/slurry	0.48
Poultry	Poultry without litter	0.55
	Poultry with litter	0.40

Source: Based on IPCC (2006).

6.4.1.6 Manure management systems and percentage use of each system (MS)

The most commonly used manure management systems in Brazil, with the IPCC (2006) nomenclature duly adapted to the nomenclature commonly used in Brazil, are as follows: 1) Anaerobic lagoon, 2) Anaerobic digester, 3) Solid storage, 4) Pit storage, 5) Liquid/Slurry, 6) Composting, 7) Poultry manure without litter, 9) Poultry manure with litter.

With regard to the percentage of use of the systems, for young cattle, male and female cattle over 2 years old (not confined), buffaloes, goats, sheep, horses, mules and asses, it was considered that 100% of the manure is not managed. For confined beef cattle, dairy cattle, swine and poultry, it was considered that these animals are totally or partially in farming systems that manage manure.

N_2O emissions occur directly and indirectly and are calculated by applying emission factors to the quantities of N managed, in the case of direct emissions, and to the quantities lost through volatilization, in the case of indirect emissions. As there are no factors developed in Brazil, the default IPCC (2006) factors were used, as shown in Table 6.6.

Table 6.6. Direct N_2O emission factor for estimating emissions from manure management systems.

System	Emission factor (EF)
Solid storage	0.005
Dry Lot	0.020
Liquid/slurry	0.005
Pit storage	0.002
Composting - passive windrow	0.010
Poultry without litter	0.001
Poultry with litter	0.001

Source: Based on IPCC (2006).

Management systems in anaerobic lagoons and biodigesters do not produce N_2O due to the extreme conditions of potential oxidation–reduction. For indirect emissions of N_2O, the default emission factor of 0.01 is applied to the amounts of N volatilized, regardless of the management system used.

6.4.2 Quality assurance and quality control

The QA/QC procedures adopted for the Manure Management subsector (3.B) are described in Section 2.5 of this document.

6.4.3 Assessment of uncertainty, consistency and recalculations of the time series

Uncertainty analysis was carried out using the random sampling methods and techniques described in the 2006 IPCC Guidelines. The uncertainty associated with CH_4 and N_2O emissions from Manure Management (3.B) is presented in Appendix II.

The process of updating the national inventory considered the revision of the time series of population data for the different categories of animals. In summary, the main adjustments stem from:

- *Cattle (2017-2022):* The same percentage assumptions as in previous inventories were used to break down the categories of beef cattle (by sex, age and type of animal confinement) and dairy cattle (between low- and high-producing cattle);
- *Swine (2017-2022):* The same percentage assumptions as in previous inventories were used to break down the categories of swine (by production purpose); and
- *Asses and mules (2013-2022):* Due to the lack of data from 2013 to 2022, a linear extrapolation of the data was carried out (trend line, by the average variation from 2008 to 2012 – the last year of the series).

Comparing the consolidated results of the previous Inventory with the one carried out for this NIR 2024, the largest proportion of adjustments is seen in 2020, with a 1.1% difference between estimated emissions. Between 2017 and 2020, the average adjustment in aggregate emissions was only 0.9%, and in the period from 1990 to 2020, it was 0.1%, which demonstrates the consistency of the subsector's time series (Figure 6.5).

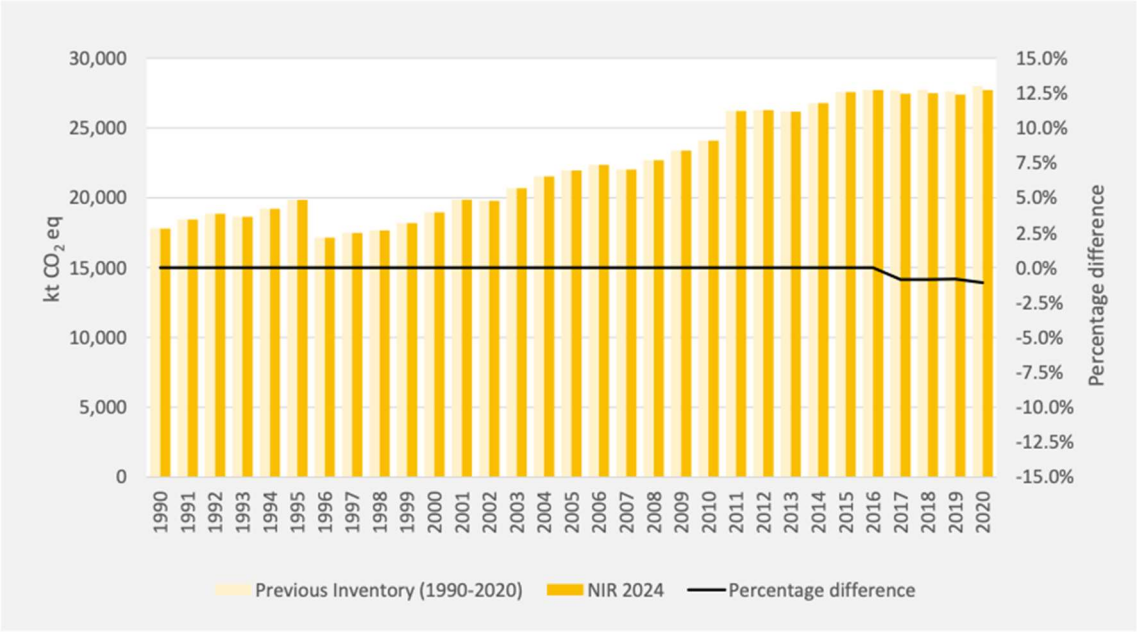


Figure 6.5. Comparison of estimated emissions from the Manure Management subsector (3.B) between the inventories.

6.4.4 Improvement plan

The experience gained in the periodic preparation of national GHG inventories has led to the proposal of a series of measures to improve the consistency and greater detailing of the Inventory's results, particularly for Manure Management (3.B).

Dataframe 6.13 summarizes the potential improvements for implementation in future editions of this subsector's inventory.

Dataframe 6.13. Potential improvements applicable to the emissions inventory for the Manure Management subsector (3.B).

Subsector	Category	Improvement
3.B. MANURE MANAGEMENT	General (all categories)	▪ Assess the possibility of establishing partnerships with associations and research institutions to explore the possibility of obtaining data on the rates of the types of manure management by animal category.

Subsector	Category	Improvement
	3.B.3. Swine	▪ Expand the dialogue with Embrapa Swine and Poultry (Embrapa Suínos e Aves) to assess the feasibility of revising local factor values for losses due to volatilization and revising the subsector's N_2O estimates; ▪ Assess the possibility of establishing Technical Cooperation Agreements or partnerships with producer associations, with a view to regionalizing digestibility, live weight and feed intake rates for each category of swine in the future.

6.5 Rice cultivation (CRT 3.C)

Emissions from rice cultivation refer to the CH_4 gas and are associated with the irrigated system by soil flooding, which creates anaerobic conditions for the decomposition of organic matter, leading to the generation of CH_4. In Brazil, rice is produced in irrigated and rainfed systems. The magnitude of CH_4 emissions is strongly associated with the variation in the area cultivated with rice in the irrigated system, as well as the amount of organic material added to the soil. However, they can also be subject to changes due to the time variation of the representativeness of the systems associated with tillage used, as in the case of Rio Grande do Sul (conventional tillage, early tillage and other systems), for which different emission factors were considered and, as a result, CH_4 emissions were influenced. In Santa Catarina, variations in CH_4 emissions were also influenced by changes in the water regime, the type and timing of incorporation of organic material into the soil and the duration of the rice-growing season.

According to the classification of water regimes for rice cultivation established by the IPCC (2006), three subcategories of irrigated rice cultivation are used in Brazil: continuous flooding, intermittent flooding with single aeration, and intermittent flooding with multiple aeration. Of these, the continuous flooding subcategory accounts for almost the entire area of irrigated rice in the country (Embrapa Arroz e Feijão, 2018). The rain-fed rice category does not generate CH_4 emissions, which is why it is not considered for the purposes of accounting for CH_4 emissions in this NIR.

In 2022, emissions from irrigated Rice Cultivation (3.C.1) were estimated at 11,901 kt CO_2 eq, i.e., only 1.0% higher than emissions in 2020 (11,779 kt CO_2 eq). Emissions are associated with the area cultivated in an irrigated system, as well as with the amount of organic material added to the soil. The largest share within the subsector was emissions from irrigated Rice Cultivation by Continuous Flooding (3.C.1.a), with 96% of the total (Figure 6.6).

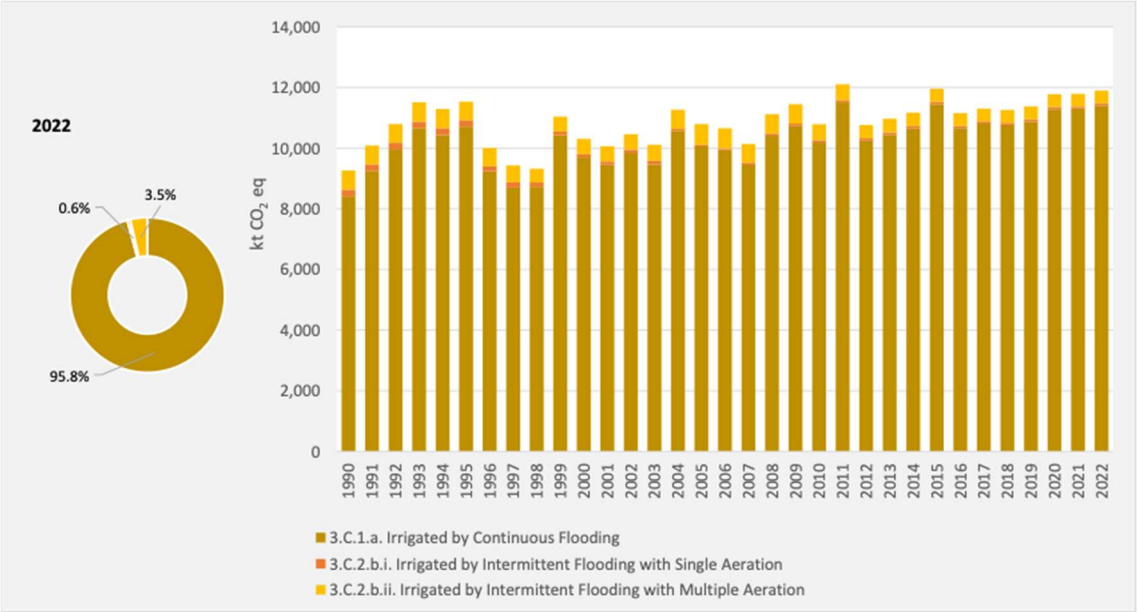


Figure 6.6. Emissions from Rice Cultivation (3.C), in kt CO_2 eq by category, from 1990 to 2022.

6.5.1 Methodological aspects

Equations 6.19 to 6.21, shown in Dataframe 6.14, with Tier 2 and Tier 1 methodological detailing, were used to calculate CH_4 emissions from the categories in the Rice Cultivation subsector (3.C).

Dataframe 6.14. Equations for estimating emissions from the Rice Cultivation subsector (3.C).

Equations	GHG	Categories	Central equation	Reference
Equation 6.19	CH_4	3.C.1	$Emissions\ of\ CH_4 = \sum_{i,j,k} (EF_{i,j,k}\ x\ t_{i,j,k}\ x\ A_{i,j,k}\ x\ 10^{-6})$	Equation 5.1 (IPCC, 2006, v. 4, chap.5)
Equation 6.20	CH_4	3.C.1	$EF_{i,j,k} = EF_c\ x\ SF_W\ x\ SF_p\ x\ SF_o\ x\ SF_{s,r}$	Equation 5.2 (IPCC, 2006, v. 4, chap.5)
Equation 6.21	CH_4	3.C.1	$SF = \left(1 + \sum_i ROA_i\ x\ CFOA_i\right)^{0,59}$	Equation 5.3 (IPCC, 2006, v. 4, chap.5)

In which:

CH_4 rice = annual emissions of CH_4 from rice cultivation, in Gg CH_4 $year^{-1}$;
$EF_{i,j,k}$ = daily emission factor for conditions i, j, and k, in kg CH_4 ha^{-1} day^{-1};
$t_{i,j,k}$ = rice cultivation period for conditions i, j, and k, in days;
$A_{i,j,k}$ = area of rice harvested annually, for conditions i, j, and k, in ha $year^{-1}$;
i, j and k = represent the different ecosystems, water management regimes, type and quantity of organic amendment and other conditions that may influence CH_4 emissions from rice cultivation;

EF_i = daily emission factor for a given harvested area, in kg CH_4 ha^{-1} day^{-1};
EF_c = baseline emission factor for rice cultivation areas irrigated by continuous flooding, without organic amendment in kg CH_4 ha^{-1} day^{-1};
SF_w = scaling factor to account for the differences in water regime during the rice cultivation period;
SF_p = scaling factor to account for the differences in water regime in the pre-season before the cultivation period (off-season);
SF_o = scaling factor to account for the variations in the type and quantity of organic amendment added to the soil;
$SF_{s,r}$= scaling factor for soil type, rice cultivars, etc. if available;
ROA_i = rate of organic amendment applied, based on dry matter for rice straw and fresh matter for other residues, in t ha^{-1}. In the country, it was assumed that the ROA_i parameter corresponds to 80% of the average productivity of rice grains;[55] and
$CFOA_i$ = conversion factor for organic amendment input, in terms of its effect with respect to rice straw applied shortly before cultivation.

For both methodological levels, a single equation (Equation 6.19) is adopted for estimating CH_4 emissions from rice cultivation, which associates daily emission factors with cultivation periods and areas cultivated with rice during the year. In this equation, it should be noted that, in areas where rice straw is cultivated, the cultivation period should be extended by the number of days spent on this activity. On the other hand, in areas with more than one crop throughout the year, the harvested area is considered to be the sum of the area cultivated in each crop.

Considering the wide variability of environmental conditions and rice cultivation in Brazil, the area of rice harvested in the country was broken down into sub-units, represented by the 27 FUs/states. The IPCC (2006) default emission factor was used to calculate the estimates of CH_4 emissions from rice cultivation for all federative units/states, with the exception of Rio Grande do Sul, which uses validated local emission factors for the two most representative tillage systems adopted (conventional tillage and early tillage). The daily CH_4 emission factor (EF_i) in Equation 6.19 was calculated according to Equation 6.20.

The scaling factor SF_w explains the differences in water regime during the rice cultivation period, i.e., it reflects the associated effect of the ecosystem (highlands and lowlands) and the water management regime (irrigated by continuous or intermittent flooding; rain-fed and deepwater). The IPCC (2006) methodology proposes reference values for the SF_w scaling factor disaggregated by water regime for use in calculating the estimates of CH_4 emission from rice cultivation. In rice cultivation conditions in Brazil, the following water regimes are identified: rain-fed; irrigated by continuous flooding; irigated by intermittent flooding with single aeration; and irrigated by intermittent flooding with multiple aeration. Of these regimes, only the last three have an impact on CH_4 emissions and are taken into account for inventory purposes, given that the SF_w scaling factor that considers the water regime during the cultivation period is null for irrigated and rain-fed rice cultivation.

Another aspect considered when establishing the CH_4 emission factor for rice cultivation (EFi) is the water regime in the areas in the period that precedes cultivation, i.e., during the off-season. In almost all of Brazil's rice cultivation regions, there is only one harvest per year, so the areas are kept drained during the off-season for more than 180 days. An exception to

[55] The productivity values available in the Embrapa Arroz e Feijão (2018) database, which presents data by year, disaggregated by water regime for all Federative Units/States with records of rice cultivation, according to the agricultural census carried out by the IBGE, were used.

this behavior occurs in the state of Santa Catarina, specifically in the regions of Blumenau, Itajaí and Joinville, where the period of time in which the soil is kept drained during the off-season is less than 180 days, requiring the use of a SF_p scaling factor that is different from the rest of the country. However, it should be noted that this happens despite the fact that only one rice crop is grown per year in these regions.

The last scaling factor considered for establishing the CH_4 emission factor for rice cultivation (EF_i) in the IPCC (2006) methodology is the one that takes into account the application of organic amendment to the soil (SF_o). Establishing this factor is a little more complex than the previous ones, as it requires knowledge of a number of variables, including the type and quantity of the organic amendment, as well as the time when it is applied to the soil in relation to the rice cultivation period. The SF_o scaling factor is determined based on Equation 6.21.

Although the IPCC (2006) methodology recommends the use of a scaling factor that takes into account variations in soil type (SF_s) and between rice cultivars (SF_r) to establish the daily CH_4 emission factor (EF_i), the great variability of the available data has so far made it impossible to indicate default values that take these variables into account. Therefore, and in the absence of local scaling factors that take them into account, scaling factors for soil types and rice cultivars were not used in the estimates of CH_4 emissions in this Inventory.

Activity data and other parameters

The magnitude of CH_4 emission is associated with the period in which the soil is kept flooded, since CH_4 is the product of the decomposition of organic matter under anaerobic conditions, established by the flooding of the soil.

Considering that, in most of Brazil, rice is produced using a dry soil sowing system, in which irrigation of the crop normally begins between 2 and 4 weeks after the seedlings emerge, the average period of time when the soil was flooded was assumed for the purposes of estimating CH_4 emissions, i.e., the time interval in which the soil is kept dry was deducted from the total period. In most of the country, the cultivation period in the conventional tillage and early tillage systems is of 100 days, and other tillage is of 130 days (BRASIL, 2016). On the other hand, in the areas cultivated using the pre-germinated system, which is predominant in Santa Catarina, and in the "other systems" subcategory of soil tillage in Rio Grande do Sul, the cultivation period was considered to extend from sowing to rice ripening, since this system involves sowing rice in flooded soil. The inclusion of these considerations was the result of consultation with experts and consultation with experts from national research and rural extension institutions, particularly Embrapa Rice and Beans, Epagri – Agricultural Research and Rural Extension Company of Santa Catarina (Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina) and Embrapa Temperate Climate (Embrapa Clima Temperado).

- Rice harvested area stratified by water regime

Esta variável inclui as seguintes categorias: i) arroz de terras altas/sequeiro, ii) arroz irrigado
This variable includes the following categories: i) rain-fed rice, ii) rice irrigated by continuous

flooding, iii) rice irrigated by intermittent flooding with single aeration and iv) rice irrigated by intermittent flooding with multiple aeration.

For the purposes of estimating CH_4 emissions, data disaggregated by state was used, with the exception of the state of Santa Catarina, for which the rice cultivation areas were further separated into seven producing regions (Araranguá, Blumenau, Criciúma, Itajaí, Joinville, Rio do Sul and Tubarão), which differ in terms of the water regime during and before rice cultivation and the type and quantity of organic amendment added to the soil. For Rio Grande do Sul, the rice harvested area was subdivided into soil tillage systems (conventional, early tillage, and other systems).

The information on the rice harvested area, stratified by water regime and FU/state, was obtained mainly from the Embrapa Rice and Beans Economics Data Center, whose data sources include Conab – Brazil's National Supply Company (Companhia Nacional de Abastecimento), the IBGE/Cepagro Systematic Survey of Agricultural Production (LSPA, Levantamento Sistemático da Produção Agrícola) and the DCI/IRGA – Rio Grande do Sul Rice Institute (Instituto Rio Grandense do Arroz). Due to the lack of data on the irrigation by intermittent flooding with single aeration regime in the information provided by Embrapa Rice and Beans (2018), for some FUs/states in different periods, the data on the rice cultivated area used to calculate the estimates include adjustments resulting from the comparison of the available official databases with information from literature and local experts.

Table 6.7 below summarizes the activity data used and its data source.

Table 6.7. Summary of the activity data used to calculate CH_4 emissions from rice cultivation in Brazil.

Activity data	Level of disaggregation	Data source	Notes
Cultivated area (ha)	State[1]	Embrapa Rice and Beans (2018)	Stratified by water regime
Cultivated area (ha)	Regional[2]	Embrapa Rice and Beans (2018); Personal Communication – Epagri	Stratified by water regime
Cultivation period (day)	State[1]	Personal Communication – Embrapa	Stratified by sowing system
Cultivation period (day)	Regional[2]	Personal Communication – Epagri	Stratified by cultivar cycle

Note: [1] Used in all Federative Units/States, with the exception of Santa Catarina. [2] Used in Santa Catarina.

The data on the rice harvested area by water supply regime until 2019 was updated by FU/State with values made available by the Embrapa Rice and Beans Economics Data Center (Embrapa, 2021), whose data source is the IBGE's Systematic Survey of Agricultural Production – LSPA/Cepagro – Center for the Study and Promotion of Group Farming (Centro de Estudos e Promoção da Agricultura de Grupo), Conab and DCI/IRGA. Specifically for the state of Rio Grande do Sul, the main national producer of rice, area data for soil tillage systems provided by the Sectoral Policy Sector of the Rio Grande do Sul Rice Institute (IRGA) was used. Due to the lack of data at state level for the period from 2020 to 2022, the updating of the data on the harvested area was carried out taking into account only data at

country level from the Report on Production Statistics 2023 from Embrapa Rice and Beans (Embrapa, 2024). Consequently, the estimate of CH_4 emissions was made only at the national level, under the following assumptions and hypotheses:

- According to Embrapa (2020), based on data from Conab (2018), the predominance of the irrigated system, both in terms of planted area, average yield and relative production, is in the southern region of the country. Since 1995, the Southern Region has been responsible for the largest area planted with rice in the country, and that is mainly concentrated in the states of Rio Grande do Sul and Santa Catarina;
- According to Embrapa (2023), 93.1% of total national rice production in 2022 came from the irrigated cultivation system with controlled irrigation, followed by the rain-fed system, with 6.9% representation, and irrigated rice without controlled irrigation or from natural floodplains, which did not record production data, possibly because it became inoperative; and
- According to data from 2013-2022 from Embrapa (2023) (Table 6.8), on the one hand, as of 2018, around 75% of the total rice harvested area corresponds to the irrigated system with controlled irrigation, and the rest corresponds to the rain-fed rice harvested area, which has had a continuous reduction since 2013, accumulating a decrease of 67.1% by 2022. On the other hand, as of 2018, the irrigated rice harvested area without controlled irrigation has no longer been included in the rice production statistics, most likely because it gave way to other crops or became an environmental preservation area.

Table 6.8. Evolution of rice harvested area in the cultivation systems, from 2013 to 2022, in Brazil.

Crop year	Cultivation System			Total (1,000 ha)
	Rain-fed (1,000 ha)	Irrigated with controlled irrigation (1,000 ha)	Irrigated without controlled irrigation (1,000 ha)	
2013	943	1,405	1	2,349
2014	911	1,438	1	2,350
2015	694	1,448	1	2,143
2016	564	1,375	1	1,940
2017	597	1,432	1	2,030
2018	482	1,387	-	1,869
2019	406	1,299	-	1,705
2020	382	1,298	-	1,680
2021	380	1,300	-	1,680
2022	310	1,312	-	1,622

Source: Data from IBGE/LSPA – Systematic Survey of Agricultural Production, adapted by SILVA, O. F. da, at Embrapa Rice and Beans/Socioeconomics Center (2023).

Based on these assumptions, for the calculation of CH_4 emissions from 2020 to 2022 by continuous flooding, a cultivation period of 110 days was considered, equivalent to the average of the values of the cultivation periods in the conventional tillage and early tillage systems (100 days) and others (130 days) used in the calculation of CH_4 emissions from previous years in the time series, and a weighted average emission factor of 2.97 for Rio Grande do Sul, estimated based on the 2010-2022 historical average of the three tillage

systems (67% Early tillage, 22% Conventional Tillage, 11% Others). For the other states, the average emission factor of 2.38 estimated for the same period was used. For the calculation of emissions from intermittent flooding, with single and multiple aeration, the values of 2.62 and 15.07, respectively, were used, which correspond to the values applied in the 2017 to 2019 time series.

To estimate CH_4 emissions from rice cultivation, the daily CH_4 emission factors (EF_i) were defined for each year of the time series, FU/state and rice cultivation category. The emission factor EF_i varies according to the water regime during and prior to the rice cultivation period, the type, quantity and time of incorporation of organic amendment into the soil, among other aspects that are included in Equation 6.20.

Dataframe 6.15 summarizes the emission factors and parameters that were used to calculate CH_4 emissions from this subsector.

Dataframe 6.15. Summary of emission factors and parameters used to calculate CH_4 emissions from rice cultivation.

Categories	Product	Emission factors	Reference
3.C.	EF_i	Miscellaneous (Appendices 1 to 29[1])	Appendices 1 to 29[1] (IPCC, 2006, v.4, chap.5)
3.C. Continuous flooding	EF_i for the conventional tillage system in RS (Rio Grande do Sul State)	3.6	Bayer *et al*. (2015)
3.C. Continuous flooding	EF_i for the early tillage system in RS	2.8	Bayer *et al*. (2015)
3.C.	EFc	1.32	Yan *et al*. (2005)
3.C.	SF_w	Table 7[2]	Yan *et al*. (2005)
3.C.	SF_p	Table 8[2]	Yan *et al*. (2005)
3.C.	SF_o	Miscellaneous (Appendices 1 to 29[1])	IPCC (2006, v. 4, chap.5)
3.C.	ROA_i	Miscellaneous (Appendix 30)	Embrapa Arroz e Feijão (2018)
3.C.	ROA_i	2 Mg ha^{-1} (rice straw) 4 Mg ha^{-1} (manure)	Epagri (2019)
3.C.	$CFOA_i$	Table 92	Yan *et al*. (2005)

Note: [1] The IPCC 2006 default emission factor was adopted only in the "Other tillage systems" subcategory; [2] The Tables and Appendices indicated are included in the subsector's Reference Report of the Fourth National Communication Inventory (BRASIL, 2021).

6.5.2 Quality assurance and quality control

The QA/QC procedures adopted for the Rice Cultivation subsector (3.C) are described in Section 2.5 of this document.

6.5.3 Assessment of uncertainty, consistency and recalculations of the time series

Uncertainty analysis was carried out using the random sampling methods and techniques described in the 2006 IPCC Guidelines. The uncertainty associated with CO_2 emissions from Rice Cultivation (3.C) is presented in Appendix II.

The process of updating the NIR 2024 considered the review of the time series of rice cultivation data and the updating of the values for the years between 2020 and 2022. In summary, the main adjustments stem from:

- *Rice harvested area (1990-2022)*: updated by FU/state with values made available by the Embrapa Rice and Beans Economics Data Center (Embrapa, 2021), whose data source is the Systematic Survey of Agricultural Production – LSPA of IBGE/Cepagro, Conab and DCI/IRGA. Specifically for the state of Rio Grande do Sul, we used area data for tillage systems provided by the Sectoral Policy Sector of the Rio Grande do Sul Rice Institute (IRGA).

Comparing the consolidated results of the previous Inventory with the one carried out for this NIR 2024, the largest proportion of adjustments is seen in 2020, with a 5.8% difference between estimated emissions. Between 2017 and 2020, the average adjustment in aggregate emissions was only 1.5%, and in the period from 1990 to 2020, it was 0.2%, which demonstrates the consistency of the subsector's time series (Figure 6.7).

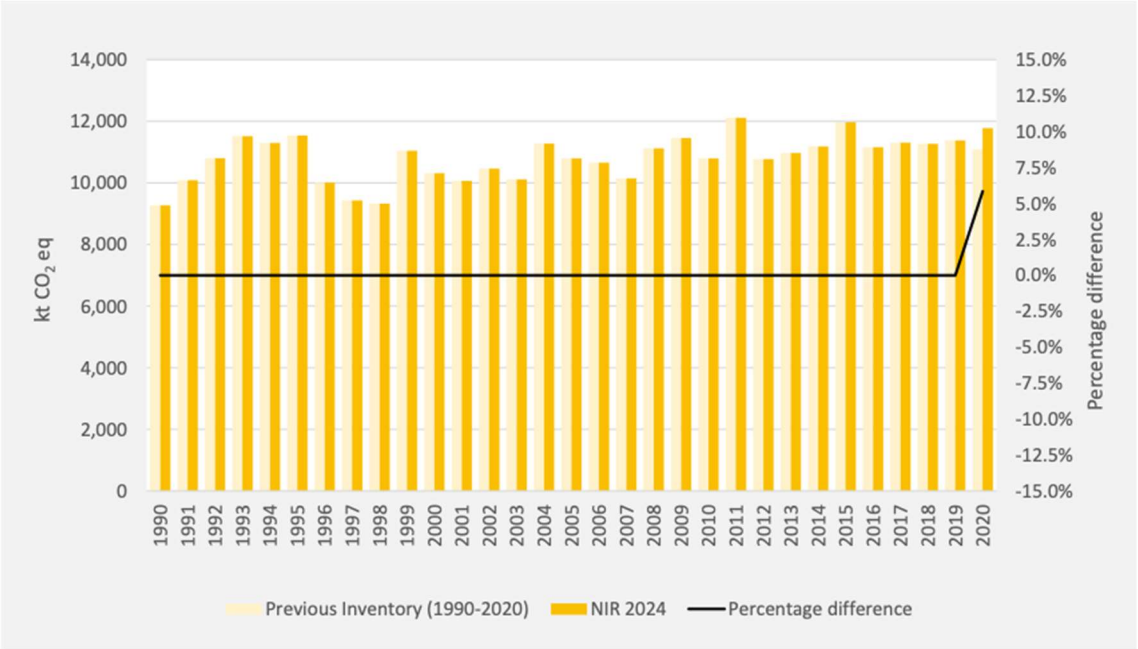


Figure 6.7. Comparison of estimated emissions from the Rice Cultivation subsector (3.C) between inventories.

6.5.4 Improvement plan

The experience gained in the periodic preparation of national GHG inventories has led to the proposal of a series of measures to improve the consistency and greater detailing of the Inventory's results, particularly for Rice Cultivation (3.C).

Dataframe 6.16 summarizes the potential improvements for implementation in future editions of this subsector's inventory.

Dataframe 6.16. Potential improvements applicable to improving the emissions inventory for the Rice Cultivation subsector (3.C).

Subsector	Category	Improvement
3.C. RICE CULTIVATION	General (all categories)	▪ Establish a Technical Cooperation Agreement or partnership with Embrapa Rice and Beans in order to facilitate obtaining data on rice cultivation period; ▪ Review the literature on the parameters associated with the scaling factors (SFw, SFp and SFo) that influence the magnitude of EF_i.

6.6 Agricultural Soils (CRT 3.D)

N_2O emissions from soils are due to the process of nitrification and denitrification caused by the increase in the amount of Nitrogen (N) in the soil as a result of the use of inputs and plant and soil management, which results in direct and indirect N_2O emissions. Emissions can, therefore, result from the application of nitrogen fertilizers (synthetic and organic – of animal origin), the deposition and incorporation of crop harvest residues and pasture renovation, the deposition of animal manure directly onto the soil (unmanaged manure), nitrogen mineralization resulting from the loss of organic matter from the soil, and the cultivation of organic soils.

In Brazil, agriculture has been increasingly intensified, with the growing use of inputs such as fertilizers and organic fertilizers and agricultural operations. However, the adoption of biological nitrogen fixation to replace the use of nitrogen fertilizers in Brazil has contributed to a significant reduction in N_2O emissions in the country. It is estimated that between 2010 and 2016 the adoption of biological nitrogen fixation in a cultivated area of 10 million hectares contributed to a reduction of 10,000 kt CO_2 eq in the country (MANZATTO *et al.*, 2020).

Emissions from Agricultural Soils (3.D) amounted to 145,078 kt CO_2 eq in 2022 and were largely produced by Direct N_2O Emissions from Managed Soils (3.D.1), with 77% of the volume emitted. Of the direct emissions, Animal Manure Deposited by Grazing Animals (3.D.1.c) was the most representative, accounting for 36% of the subsector's total emissions. Next, the Crop Residues category (3.D.1.d) accounted for 21% and included emissions from permanent and temporary crops. Indirect N_2O Emissions from Managed Soils (3.D.2), which occur after the deposition of volatilized and leached nitrogen, accounted for 23% of the subsector's total in 2022. Compared to 2020 emissions (141,045 kt CO_2 eq), 2022 emissions showed a 3% increase (Figure 6.8).

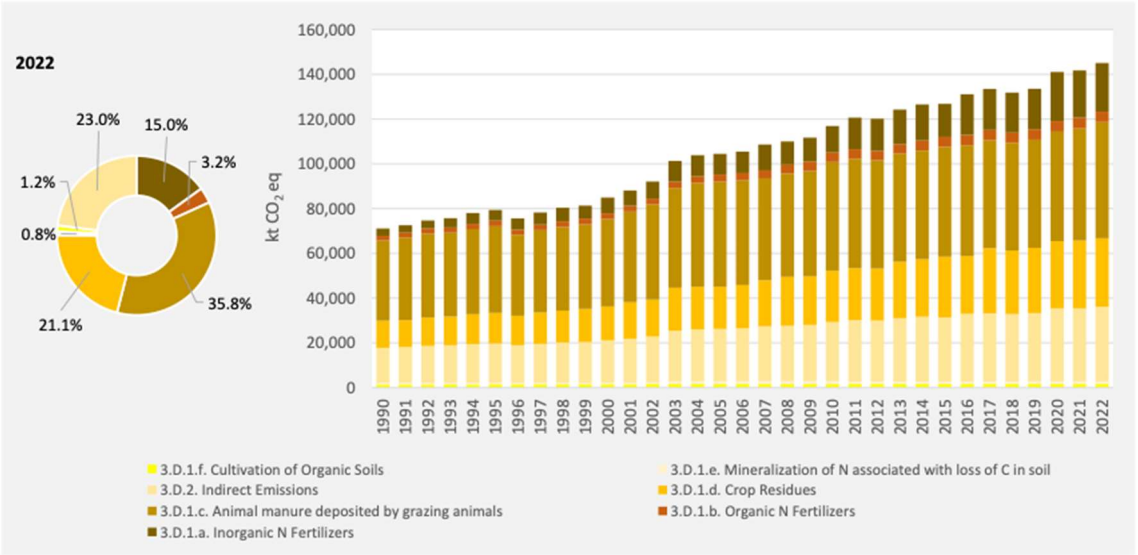


Figure 6.8. Emissions from Agricultural Soils (3.D), in kt CO_2 eq by category, from 1990 to 2022.

6.6.1 Methodological aspects

To calculate N_2O emissions from the categories in the Agricultural Soils subsector (3.D), equations 6.22 to 6.29 were used, shown in Dataframe 6.17, with Tier 2 and Tier 1 methodological detailing.

Dataframe 6.17. Equations for estimating emissions from the Agricultural Soils subsector (3.D).

Equations	GHG	Categories	Central equation	Reference
Equation 6.22	N_2O	3.D.1.a, 3.D.1.b, 3.D.1.c, 3.D.1.d, 3.D.1.e, 3.D.1.f	$N_2O\ \text{direct} - N = N_2O - N_{N\ \text{inputs}} + N_2O - N_{OS} + N_2O - N_{PRP}$	Equation 11.1 (IPCC, 2006, v. 4, chap. 11)
Equation 6.23	N_2O	3.D.1.a, 3.D.1.b, 3.D.1.c, 3.D.1.d, 3.D.1.e, 3.D.1.f	$N_2O - N_{N\ \text{inputs}} = [(F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}) \times EF_1] + [(F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM})_{FR} \times EF_{1FR}]$	Equation 11.1 (IPCC, 2006, v. 4, chap. 11)
Equation 6.24	N_2O	3.D.1.b.	$N_2O - N_{OS} = (F_{OS,CG,Temp} \times EF_{2CG,Temp}) + (F_{OS,CG,Trop} \times EF_{2CG,Trop}) + (F_{OS,F,Temp,NR} \times EF_{2F,Temp,NR}) + (F_{OS,F,Temp,NP} \times EF_{2F,Temp,NP}) + (F_{OS,F,Trop} \times EF_{2F,Trop})$	Equation 11.1 (IPCC, 2006, v. 4, chap. 11)
Equation 6.25	N_2O	3.D.1.c.	$N_2O - N_{PRP} = (F_{PRP,CPP} \times EF_{3PRP,CPP}) + (F_{PRP,SO} \times EF_{3PRP,SO})$	Equation 11.1 (IPCC, 2006, v. 4, chap. 11)
Equation 6.26	N_2O	3.D.1.d.	$FCR = \sum_T \{Frac_{renew(T)} \times [(Area_{(T)} - Areaburnt_{(T} \times CF) \times AG_{DM(T} \times 1000 \times N_{AG(T)} \times (1 - Frac_{remove(T)})]\}$	Equation 11.6 (IPCC, 2006, v. 4, chap. 11)
Equation 6.27	N_2O	3.D.1 e.	$\Delta C\text{mineral} = \frac{(SOC_0 - SOC_{(0-T)})}{D}$ $SOC = \sum_{c,s,i} (SOC_{REF\ c,s,i} \times F_{LUc,s,i} \times F_{MGc,s,i} \times F_{Ic,s,i} \times A_{c,s,i})$	Equation 2.25 (IPCC, 2006, v. 4, chap. 2)

Equations	GHG	Categories	Central equation	Reference
Equation 6.28	N_2O	3.D.2.a	$N_2O_{(ATD)} - N = \{\sum_i (F_{SNi} \times Frac_{GASFi}) + [(F_{ON} + F_{PRP}) \times Frac_{GASM}]\} \times EF_4$	Equation 11.11 (IPCC, 2006, v. 4, chap. 11)
Equation 6.29	N_2O	3.D.2.b	$N_2O_{(L)} - N = (F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}) \times Frac_{LEACH-(H)} \times EF_5$	Equation 11.10 (IPCC, 2006, v. 4, chap. 11)

In which:

Direct N_2O -N = annual direct N_2O-N emissions from agricultural soils, kg N_2O-N $year^{-1}$;
N_2O-NN inputs = annual direct N_2O-N emissions from N inputs to agricultural soils, kg N_2O-N $year^{-1}$;
N_2O-NOS = annual direct emissions of N_2O-N from managed organic soils, kg N_2O-N $year^{-1}$;
N_2O-NPRP = annual direct emissions of N_2O-N from urine and dung inputs to grazed soils, kg N_2O-N $year^{-1}$;
FSN = annual amount of synthetic fertilizer N applied to soils, kg N $year^{-1}$;
FON = = annual amount of organic N additions applied to soils (manure, industrial waste, vinasse, etc.) kg N $year^{-1}$;
FCR = annual amount of N in crop residues (above-ground and below-ground), including N-fixing crops, and from forage/pasture renewal, returned to soils, kg N $year^{-1}$;
F_{SOM} = annual amount of N in mineral soils that is mineralized in association with the loss of soil C from soil organic matter as a result of changes in land use or management, kg N $year^{-1}$;
F_{OS} = annual area of managed/drained organic soils, ha (Note: the subscripts CG, F, Temp, Trop, NR and NP refer to Cropland and Grassland, Forest Land, Temperate, Tropical, Nutrient Rich, and Nutrient Poor, respectively).
F_{PRP} = annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N yr_{-1} (Note: the subscripts CPP and SO refer to Cattle, Poultry and Pigs, and Sheep and Other animals, respectively)
EF_1 = emission factor for N_2O emissions from N inputs, kg N_2O-N (kg N input)$^{-1}$ (Table 11.1);
EF_{1FR} = emission factor for N_2O emissions from N inputs to flooded rice, kg N_2O-N (kg N input) $^{-1}$ (Table 11.1);
EF_2 = emission factor for N_2O emissions from drained/managed organic soils, kg N_2O–N ha-1 yr-1; (Table11.1) (Note: the subscripts CG, F, Temp, Trop, NR and NP refer to Cropland and Grassland, Forest Land, Temperate, Tropical, Nutrient Rich, and Nutrient Poor, respectively);
EF_{3PRP} = emission factor for N_2O emissions from urine and dung N deposited on pasture, range and paddock by grazing animals, kg N_2O–N (kg N input)$^{-1}$; (Table 11.1) (Note: the subscripts CPP and SO refer to Cattle, Poultry and Pigs, and Sheep and Other animals, respectively)
$Crop_{(T)}$ = harvested annual dry matter yield for crop T, kg d.m. ha^{-1};
$Area_{(T)}$ = total annual area harvested of crop T, ha $year^{-1}$;
$Area\ burnt_{(T)}$ = annual area of crop T burnt, ha $year^{-1}$;
Cf = combustion factor (dimensionless) (refer to Chapter 2, Table 2.6);
$FracRenew_{(T)}$ = fraction of total area under crop T that is renewed annually. For countries where pastures are renewed on average every X years, FracRenew = 1/X. For annual crops FracRenew = 1;
$RAG_{(T)}$ = ratio of above-ground residues dry matter ($AGDM_{(T)}$) to harvested yield for crop T ($Crop_{(T)}$),kg d.m. (kg d.m.)$^{-1}$, = $AGDM_{(T)}$ x 1000 / $Crop_{(T)}$ (calculating $AGDM_{(T)}$ from the information in Table 11.2);
$NAG_{(T)}$ = N content of above-ground residues for crop T, kg N (kg d.m.) $^{-1}$, (Table 11.2, chapter 11, v.4, IPCC, 2006);
$FracRemove_{(T)}$ = fraction of above-ground residues of crop T removed annually for purposes such as feed, bedding and construction, kg N (kg crop-N) $^{-1}$;
$RBG_{(T)}$ = ratio of below-ground residues to harvested yield for crop T, kg d.m. (kg d.m.)$_{-1}$. When it was not available, $RBG_{(T)}$ was calculated by multiplying RBG-BIO (in Table 11.2, chapter 11,

V. 4, IPCC 2006) by the ratio of total above-ground biomass to crop yield ($RBG_{(T)}$ = [($AGDM_{(T)}$ x 1000 + $Crop_{(T)}$) / $Crop_{(T)}$]), (also calculating $AGDM_{(T)}$ from the information in Table 11.2);
$NBG_{(T)}$ = N content of below-ground residues for crop T, kg N (kg d.m.)$^{-1}$, (Table 11.2);
T = crop or forage type;
ΔCMineral = annual change in carbon stocks in mineral soils, tons C year^{-1};
SOC_0 = stock of soil organic carbon in the last year of an inventory period, tons C;
$SOC_{(0-T)}$ = soil organic carbon stock at the beginning of the inventory time period, tons C SOC_0 and $SOC_{(0-T)}$ are calculated using the SOC equation in the box where the reference carbon stocks and stock change factors are assigned according to the land-use and land-management activities and corresponding areas at each of the points in time (time = 0 and time = 0-T);
T = number of years over a single inventory time period, year;
D = time dependence of stock change factors which is the default time period for transition between equilibrium SOC values, year. Commonly 20 years, but it depends on assumptions made in computing the factors FLU, FMG and FI. If T exceeds D, use the value for T to obtain an annual rate of change over the inventory time period (0-T years);
c = represents the climate zones, s the soil types, and i the set of management systems that are present in a country;
SOC_{REF} = the reference carbon stock, tons C ha^{-1} (Table 2.3);
FLU = stock change factor for land-use systems or sub-systems for a particular land-use, dimensionless [Note: FND is substituted for FLU in forest soil C calculation to estimate the influence of natural disturbance regimes;
FMG = stock change factor for management regime, dimensionless ;
F_I = stock change factor for input of organic matter, dimensionless; and
A = land area of the stratum being estimated, ha. All land in the stratum should have common biophysical conditions (i.e., climate and soil type) and management history over the inventory time period to be treated together for analytical purposes.

Activity data and other parameters

6.6.1.1 Direct Emissions

- Inorganic N Fertilizers (F_{SN})

The amount of N in the form of fertilizer applied to the soil (F_{SN}), in kg N year^{-1}, was obtained from the statistical yearbooks of ANDA – The National Association for the Diffusion of Fertilizers (Associação Nacional para Difusão de Adubos), which provide annual data on stocks, production, imports and exports by type of fertilizer (1990 to 2020), with disaggregated data at state level. Due to the unavailability of data from 2020 onwards, since ANDA had not yet made the 2022 Yearbook data available, a linear extrapolation was carried out for the years of 2021 and 2022, with data from the previous five years (2016-2020).

ANDA's yearbooks provide information on the quantity of fertilizers delivered to the end consumer, which was considered to be the fertilizer used in the FU/State. From 1990 to 2012, ANDA reported the total amount of N delivered in the North region, without breaking it down by state, except for Tocantins, which had individualized information, like the states in the other regions of the country. In order to complete the series, it was considered that the proportions by FU/state of total N in fertilizers in the Northern region in 2013, with the exception of Tocantins, corresponded to the previous years up to 1990, allowing the region's totals to be distributed among the FUs/States.

To estimate the amount of N fertilizer applied to flooded rice crops, we used the total area occupied by the crop reported by the IBGE and the proportion of the total rice area used as

flooded rice (irrigated rice, lowlands) estimated in the Inventory of the Fourth National Communication (BRASIL, 2021). The amount of N used in these areas was estimated by multiplying the flooded rice area by 70 kg N ha^{-1}, assumed to be an average of the fertilization recommended by experts from Embrapa Temperate Climate (Embrapa Clima Temperado) (2018)[56] for soils with average organic matter content and for an expected medium production.

- Organic N Fertilizers (F_{ON})

The total N content of organic N fertilizers corresponded to that present in the managed manure (F_{ON}), in vinasse and filter cake (F_{OOA}) produced in the sugar and alcohol industry and returned annually to agricultural soils.

- Manure (F_{AM})

The populations of the species in the national herd with their levels of disaggregation, as reported in the Enteric Fermentation (3.A) and Manure Management (3.B) subsectors, were considered as activity data.

Part of the total N in manure is lost through volatilization, a process that begins where the animals are, and continues during manure management, where the amount that is actually used as fertilizer must be deducted from these losses. The IPCC (2006) has default factors, shown in Table 6.9, for estimating losses due to volatilization, which are applied to the total quantities of N in manure that is managed.

Table 6.9. N loss factors (FracLossMS) which include N losses from the place occupied by the animals to the place where the manure is managed.

Category of animal in the herd	Management system	$Frac_{LossMS}$
Beef cattle	Dry Lot	0.40
	Solid storage	0.50
Dairy cattle	Anaerobic lagoon	0.77
	Solid storage	0.40
Swine	Anaerobic lagoon	0.78
	Pit storage	0.25
	Liquid/slurry	0.48
Poultry	Poultry without litter	0.55
	Poultry with litter	0.50

Source: IPCC (2006, v. 4, chap. 11); $Frac_{LossMS}$ is the fraction of N in a given management system that is lost and not accounted for as Organic N Fertilizer.

- Vinasse and Filter Cake (F_{OOA})

Using ethanol and sugar production data obtained from the Brazilian Sugar cane Industry Association (UNICA, União da Indústria de Cana-de-Açúcar) covering the entire time series of the inventory, the parameters obtained from the literature were applied to calculate the volume of vinasse and the mass of filter cake, and the respective amounts of N.

[56] Value recommended at a technical meeting on irrigated rice cultivation at Embrapa Temperate Climate.

The total amounts of N in vinasse and filter cake were estimated based on a review of specialized literature (ELIA NETO; NAKAHODO, 1995; SIQUEIRA NETO *et al*. 2016; ELIA NETO, 2016).

For vinasse, the values found by Elia Neto (2016) were used to estimate vinasse production, i.e., for each liter of ethanol produced, an average of 11.5 liters of vinasse is generated, with an average concentration of 0.433 kg N m^{-3}. According to several studies (Carmo *et al*., 2013; Paredes *et al*., 2014; Siqueiro Neto *et al*., 2016), vinasse contributes to N_2O emissions through its use as an organic N fertilizer, but the loss of N through volatilization in the form of NH_3 according to Paredes *et al*. (2014) does not seem to occur significantly in vinasse, contributing only to direct N_2O emissions. Filter cake is a waste product from sugar cane industrial procedures due to the process of filtering the juice extracted in the rotary vacuum filter, in which each ton of filtered sugar cane results in around 40 kg of filter cake (Gurgel, 2012; Bernardinho *et al*., 2018; Bonassa *et al*., 2015). Its use in agriculture can complement mineral fertilizers, which is why it has been used on a large scale in the country (Gurgel, 2012). Different values for the nitrogen content of filter cake have been generated in research. Gurgel (2012) estimated around 0.4%, Embrapa (2019a) only 0.28%, Tellechea (2015) between 1 and 1.4%. Bernardinho *et al*. (2018) reports values ranging from 0.95% to 1.87%. To calculate the amount of N present in the filter cake, a value of 1.5% (15 g N kg^{-1} of filter cake) was considered, corresponding to the average N content reported by Bernardinho *et al*. (2018).

To estimate the total amount of filter cake produced, it was assumed that an average of 8.5 tons of sugar cane are needed as raw material to produce one ton of sugar and that 0.085 m^3 of ethanol are generated from the residual honey. And, according to Cortez *et al*. (1992), each ton of sugar cane produces approximately 70 liters of ethanol, meaning that for every m^3 of ethanol produced, 14.3 tons of sugar cane are filtered (Table 6.10). Therefore, in order to estimate the total amount of filter cake generated by ethanol production, the amount of ethanol produced as a residue from sugar production must be subtracted, so as not to overestimate the volume of filter cake generated.

Table 6.10. Parameters used to estimate the amount of N in vinasse and filter cake.

Parameter name	Value	Unit of Measure
Tons of cane filtered for every 1 ton of sugar production	8.5	tons
Tons of cane filtered per m^3 of ethanol produced	14.3	tons
"Residual" ethanol produced with 1 ton of sugar production	0.085	m^3
Filter cake produced for each ton of cane filtered	0.040	tons
N content in filter cake	0.015	kg N/kg
Production of vinasse for every 1 m^3 of ethanol produced	11.5	m^3
N content in vinasse	0.433	kg N/m^3

Source: Elia Neto (2016), Gurgel (2012); Bernardinho *et al*. (2018); Bonassa *et al.* (2015); Embrapa (2019b).

To determine the value of the vinasse emission factor (EF_1), a literature review was carried out and it was decided to use a specific emission factor of 0.0052 kg N/kg N in vinasse.

- Crop residues and pasture renewal (F_{CR})

The activity data for calculating the amount of N in crop residues (F_{CR}) were productivity and harvested area for the main crops, considered as such because they represent more than 90% of the area cultivated with annual species in the country.

With regard to the estimates for flooded rice crops, the activity data is described in Section 6.5.1. In addition to annual crops, grassland that remained as grassland and grassland converted to other uses, considered in section 7.2 of this document, regarding the Land Use, Land-Use Change and Forestry sector, were also used as activity data. For the estimates related to the sugar cane crops, the activity data is described in Section 6.7.1 of this NIR, taking into account, in this case, the unburnt residue.

The conversion from grassland to other use from 1994 to 2002 was considered to have taken place in a linear fashion, i.e., in equal portions year after year. For grassland that have remained as grassland, it is suggested as a default value (IPCC, 2006) to consider that the areas are renewed every 10 years, i.e., one tenth of the area that remains as grassland is renewed every year. The estimated renewal time was established based on consultation with grassland specialists, resulting in converging opinions regarding the time, which can vary from 10 to 20 years, but more often it is 10 years (Brasil, 2020). This value is close to the default time (IPCC, 2006) and may be close to an average for the Brazilian reality. The default factor for direct emission of N_2O (EF_1) was applied to the quantities of N in the residues (Table A.VI.4, Appendix VI).

Estimating the amount of N from crop harvest residues is done by using certain parameters, such as the ratio between the dry matter of the harvested product and the dry matter of the residues left in the field, the area planted and the N content in the residues. It is necessary to calculate the contribution of aerial and below-ground residues (N_{bg}), i.e., the amount of N in the roots is also a source of N_2O, just like the aerial residues mentioned above. Rice, sugar cane, beans, manioc, corn, soybeans and wheat crops account for most of the area planted and harvested among temporary crops in the country, for which specific parameters were developed based on information available in the national literature (Table A.VI.5, Appendix VI).

- Mineralization of N due to loss of C from the soil (F_{SOM})

To calculate mineralized N (F_{SOM}), when it occurs due to a loss of carbon from the soil due to its use, the areas of the different biomes under different uses from mapping carried out for the Land Use, Land-Use Change and Forestry sector in Brasil (2020) for the years of 1994, 2002, 2010 and 2016 were used, considering the uses of "Native vegetation", "Reforestation", "Grassland" and "Crops" and their respective subcategories. To estimate the changes in soil C stocks by FU/State for the years of 2017-2022, the changes in land use for this period were estimated by applying the annual deforestation rates by biome as proxy (surrogate data method) to extrapolate (only) the gross CO_2 emissions. The rest of the net soil emissions and gross removals from vegetation growth (which includes removals from growth in grassland and crops) was kept fixed (i.e., the 2016 values were replicated). The deforestation data were as follows: Amazon and Cerrado (INPE – National Institute for Space Research (Instituto Nacional de Pesquisas Espaciais), 2024a; 2024b), Atlantic Forest (SOS Atlantic Forest Foundation (Fundação SOS Mata Atlântica) and INPE, 2023), Pantanal (SOS Pantanal, 2020) and Caatinga and Pampa (MMA – Ministry of the Environment (Ministério do Meio Ambiente), 2012). Table A.VI.6 (Appendix VI) shows these variations

according to land use and land- use change between the years that were considered in the digital mapping of 1994, 2002, 2010 and 2016.

In cases where the variation in soil C stocks implied a loss, the amount of mineralized N was estimated by multiplying the R factor, which is the opposite of the soil's C/N ratio.

By analyzing data from the literature that reported soil C and N contents for the 0-30 cm layer, the C/N ratios were grouped by biome, and into subgroups of uses called "native vegetation (NV)", "grassland (G)" and "crops (C)" (Figure A.VI.4, Appendix VI). Based on the results of the statistical analysis, the C/N ratio was established as = 12 for all biomes, regardless of land use, except for the Cerrado biome, where use with grassland or crops results in a C/N ratio = 15, and native vegetation has a C/N ratio = 14.

- N input from unmanaged animal manure (F_{PRP})

Based on the meta-analysis carried out by Bastos (2018), it was confirmed that unmanaged cattle manure could be disaggregated into urine and feces as a direct source of N_2O, with emissions from feces being half that of urine. Therefore, the direct N_2O emission factor from cattle manure was set at 0.015. On the other hand, the direct N_2O emission factor for manure from other animals was kept as the default one (IPCC, 2006).

- Cultivation of Organic Soils (F_{OS})

The cultivation of organic soils used organic soil areas in Brazil as activity data, which was taken from the soil map of Brazil and refined with more detailed state maps. The data is shown in Table A.VI.3 (Appendix VI). This soil map was cross-referenced with the land use map from the Land Use, Land-Use Change and Forestry sector, thus obtaining the areas of organic soils managed annually. Default emission factors for tropical ($EF_{2CG,Trop}$) and temperate ($EF_{2CG,Temp}$) environments were applied to the managed area.

Dataframe 6.18 shows the direct N_2O emission factors taken into account when estimating N_2O emissions from the management of agricultural soils.

Dataframe 6.18. Summary of the emission factors used to calculate the categories of direct emissions of N_2O.

Categories	Parameters	Emission factors	Reference
3.D.1.a, 3.D.1.b, 3.D.1.d, 3.D.1.e	EF_i	0.01	Tabela 11.1 IPCC (2006, v. 4, cap.11)
3.D.1.b	$EF_{1Vinasse}$	0.52	Oliveira *et al.* (2013); Siqueira Neto *et al.* (2016); Sousa Neto (2012); Silva (2014); Paredes *et al.* (2014); Zuchello (2010)
3.D.1.d.iv	EF_{1FR}	0.003	Tabela 11.1 IPCC (2006, v. 4, cap.11)
3.D.1.f	$EF_{2CG,Temp}$	8	Tabela 11.1 IPCC (2006, v. 4, cap.11)
3.D.1.f	$EF_{2CG,Trop}$	16	Tabela 11.1 IPCC (2006, v. 4, cap.11)
3.D.1.f	$EF_{2F,Temp,NR}$	0.6	Tabela 11.1 IPCC (2006, v. 4, cap.11)
3.D.1.f	$EF_{2F,Temp,NP}$	0.1	Tabela 11.1 IPCC (2006, v. 4, cap.11)
3.D.1.f	$EF_{2F,Trop}$	8	Tabela 11.1 IPCC (2006, v. 4, cap.11)

Categories	Parameters	Emission factors	Reference
3.D.1.c	$EF_{3PRP,CPP}$	0.02	Tabela 11.1 IPCC (2006, v. 4, cap.11)
3.D.1.c	$EF_{3PRP,CPP\ cattle}$	0.015	Bastos (2018)
3.D.1.c	$EF_{3PRP,SO}$	0.01	Tabela 11.1 IPCC (2006, v. 4, cap.11)

Note: [1.] The IPCC (2006) default emission factor was adopted only in the "Other tillage systems" subcategory.

6.6.1.2 Indirect N_2O Emissions

Indirect emissions result from the deposition of volatilized N and N leached from the N sources described for direct emissions. However, indirect emissions from leaching depend on the balance between rainfall/irrigation and evapotranspiration during the rainy season (defined as the period when rainfall was greater than 0.5 x evaporation in the same period). In order to assess the occurrence of leaching at the micro-region level, it was necessary to annually analyze the locations where rainfall deducted from potential evapotranspiration (ETP) exceeded the soil's capacity to retain water.

In order to carry out this assessment in the country, some adaptations and considerations were required. The rainy seasons were defined using climatological normal data from the National Institute of Meteorology (INMET, Instituto Nacional de Meteorologia) from 1981 to 2010, in a state-by-state approach, i.e., a state has the same rainy season for its entire territory, based on average monthly rainfall data. As there was no evaporation data, data from the Piché evaporimeter was used. Thus, it was possible to define the months of the year whose rainfall exceeded 0.5 times the Piché evaporation.

A new criterion, not provided for in the IPCC (2006) methodology, was included in order to select only the months in which rainfall was most intense. The month was classified as rainy only when the volume of rainfall was greater than 0.5 times the Piché evaporation (IPCC, 2006) and greater than 6% of the FU/state's annual rainfall (Table A.VI.7, Appendix VI). Of the 338 months analyzed (12 per FU/state, with the exception of Rondônia), only 7 had months with accumulations greater than 0.5x Piché evaporation and monthly averages above 6% of the FU/state's annual average, all of them in the Northeast. As a result, the number of sites where leaching occurred increased compared to what would have been obtained with the IPCC (2006) method alone. The annual water surplus maps were obtained by cross-referencing the annual rainfall surplus maps (resulting from the rainfall – ETP operation) with the soil water storage capacity map (CAD). Due to the large volume of data and analysis, the approach was simplified, considering that the micro-region had an area greater than 20% with water surplus.

N losses due to volatilization are estimated by applying the volatilization factor FracGASF to the amounts of N in fertilizers (F_{SN}). A value of 0.30 is used for N used in the form of urea, and 0.10 for other nitrogen fertilizers.

The FracGASM factor is used to estimate the volatilization of N from organic N fertilizers (F_{ON}) and from unmanaged manure (F_{PRP}). The volatilization fraction of vinasse was disaggregated, and was considered to be equal to zero. For the other fertilizers, $Frac_{GASM}$ was kept equal to 0.20.

N losses through leaching are estimated by applying the $Frac_{LEACH(H)}$ factor, which by default is equal to 0.30 (IPCC, 2006) for sites where the water balance favors the process, and equals zero in the condition where the balance indicates that there is no leaching. To analyze whether or not there was leaching, the map of Brazil's micro-regions was used. Indirect emissions were estimated by applying the IPCC's default emission factors (Dataframe 6.19).

Dataframe 6.19. Indirect N_2O emission factors for managed agricultural soils.

Categories	Parameters	Emission factors	Reference
3.D.2.a	EF_4	0.01	Table 11.3 (IPCC, 2006, v. 4, chap.11)
3.D.2.b	EF_5	0.0075	Table 11.3 (IPCC, 2006, v. 4, chap.11)

6.6.2 Quality assurance and quality control

The QA/QC procedures adopted for the Agricultural Soils subsector (3.D) are described in Section 2.5 of this document.

6.6.3 Assessment of uncertainty, consistency and recalculations of the time series

Uncertainty analysis was carried out using the random sampling methods and techniques described in the 2006 IPCC Guidelines. The uncertainty associated with N_2O emissions from Agricultural Soils (3.D) is presented in Appendix II.

The process of updating the national inventory considered the revision of the time series of activity data on agricultural soil management. In summary, the main adjustments stem from:

- *Inorganic N Fertilizers (2021-2022):* Due to the lack of data for these years, the fertilizer consumption values were estimated by linearly extrapolating the results from the previous five years (2016-2020); and
- *Grassland area (2021-2022):* The net soil emissions and gross removals from vegetation growth (which includes the removal from growth in grassland and crops) replicates the 2016 value for the period from 2017 to 2022, as mentioned in Section 7.2.5 of this NIR.

Comparing the consolidated results of the previous Inventory with the one carried out for this NIR 2024, the largest proportion of adjustments is seen in 2018, with a 10.8% difference between estimated emissions. Between 2017 and 2020, the average adjustment in aggregate emissions was of 10.6%, and in the period from 1990 to 2020, it was 1.4%, which demonstrates the consistency of the subsector's time series (Figure 6.9).

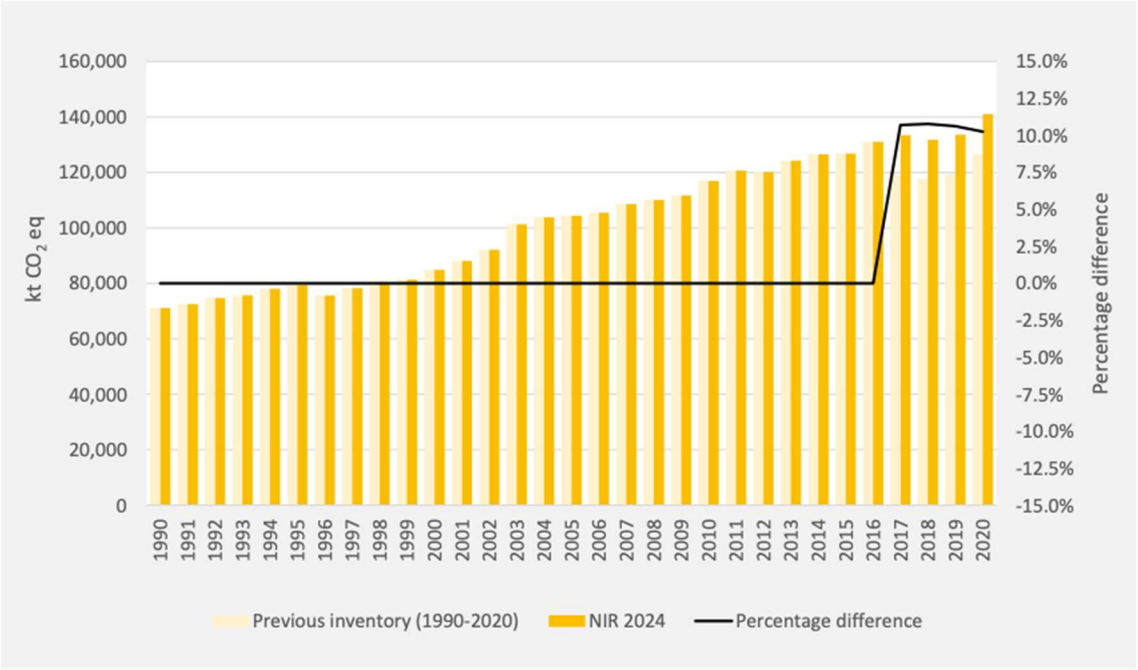


Figure 6.9. Comparison of estimated emissions from the Agricultural Soils subsector (3.D) between inventories.

6.6.4 Improvement plan

The experience gained in the periodic preparation of national GHG inventories has led to the proposal of a series of measures to improve the consistency and greater detailing of the Inventory's results, particularly for Agricultural Soils (3.D).

Dataframe 6.20 summarizes the potential improvements to be implemented in future editions of this subsector's inventory.

Dataframe 6.20. Potential improvements applicable to the emissions inventory of the Agricultural Soils subsector (3.D).

Subsector	Category	Improvement
3.D. AGRICULTURAL SOILS	General (all categories)	▪ Establish partnerships to promote the systematic collection and gathering of data on pasture cultivation and renewal practices; ▪ Establish Technical Cooperation Agreements or partnerships with research institutions with a view to assessing the possibility of revising the methods and/or parameters used to calculate the quantities of biomass and N returned to the soil due to pasture renewal; ▪ Conduct further studies on emission factors with a view to the future regionalization of this parameter, which would allow local soil management characteristics to be taken into account.

6.7 Field Burning of Agricultural Residues (CRT 3.F)

The Field Burning of Agricultural Residues subsector accounts for emissions of CH_4 and N_2O resulting from the pre-harvest burning of sugar cane and the post-harvest burning of herbaceous cotton, the latter of which took place until 1994. This document also includes estimates of carbon monoxide (CO) and nitrogen oxide (NO_x) emissions, which are also caused by field burning of agricultural residues. Although CO_2 may be emitted during the process of burning the residue, this is reabsorbed by the next harvest through photosynthesis and is part of the biological cycle with the atmosphere, and, therefore, it is not accounted for in the national inventory (IPCC, 2006). The magnitude of GHG emissions from the burning of sugar cane straw is associated with the production data and emission and combustion factors used.

The burning of sugar cane residues is still used in Brazil as a method for removing the straw prior to harvesting. However, unlike the other subsectors, the Field Burning of Agricultural Residues subsector has seen a sharp decrease since 2007 as a result of the implementation of mechanization in the sugar cane harvesting process, mainly in the state of São Paulo, where the largest area of sugar cane production is concentrated.

The Field Burning of Agricultural Residues subsector accounted for 0.1% of the Agriculture sector's emissions in 2022, corresponding to 477 kt CO_2 eq. From 2020 to 2022, there was a 0.9% increase in emissions from burning of sugar cane residues in the country, despite the fact that the harvested area decreased by 1.3%, according to data from PAM – Municipal Agricultural Production (Produção Agrícola Municipal) (2024). This is probably associated with an increase in the area burnt in FUs/states in regions where manual harvesting still takes place, where field burning is still practiced, such as in the Northeast region, which increased its harvested area by 3.4% from 2020 to 2022. However, this reflects the fact that the transition process from manual to mechanized harvesting is still being consolidated in the country (Figure 6.10).

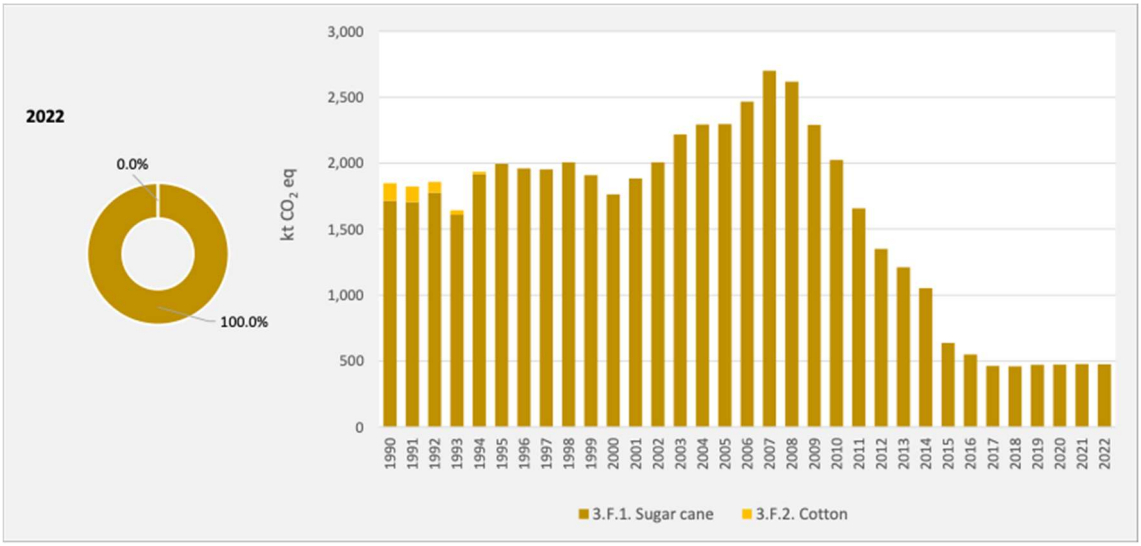


Figure 6.10. Emissions from Field Burning of Agricultural Residues (3.F), in kt CO_2 eq by category, from 1990 to 2022.

6.7.1 Methodological aspects

To calculate the emissions from the categories of the Field Burning of Agricultural Residues subsector (3.F), equation 6.30 was used, shown in Dataframe 6.21, with Tier 2 and Tier 1 methodological detailing.

Dataframe 6.21. Equations for estimating emissions from the Field Burning of Agricultural Residues subsector (3.F).

Equações	GEE	Categorias	Equação central	Referência
Equation 6.30	CH_4, CO, NO_x e N_2O	3.F.1 3.F.2	$L_{fire} = A \times MB \times C_f \times G_{ef} \times 10^{-3}$	Equation 2.27 (IPCC, 2006, v. 4, chap. 2)

In which:

L_{fire} = amount of CH_4, CO, NO_x and N_2O emissions from burning of residues, in tons (t);
A = area burnt, in hectares (ha);
MB = biomass available for combustion, in t/ha;
C_f = combustion factor, dimensionless (default values, Table 2.6, IPCC 2006, vol.4); and
G_{ef} = emission factor, in g kg^{-1} of dry matter burnt (IPCC 2006 default values).

The burnt area (A) corresponds to the product between the harvested area and the percentage of manual harvesting, since its use is linked to the use of fire as an agricultural practice in sugar cane harvesting. The biomass available for combustion (MB) corresponds to the product between the productivity and the straw/stalk ratio - which is related to the sugar cane variety. The combustion factor (C_f) is the ratio between the dry matter burnt and the dry matter available for burning. Lastly, the emission factor (G_{ef}) is the amount of gas emitted in relation to the amount of dry matter burnt (IPCC, 2006). Thus, the accounting of GHG emissions from the burning of sugar cane residues is preceded by an extensive survey of parameters and factors, which are included in Equation 6.30.

Activity data and other parameters

- Biomass available

Since the biomass available for combustion (MB) is the product between productivity and the straw/stalk ratio, data was collected on productivity, the percentage of the variety harvested and its respective values for straw and stalk phytomass (straw/stalk ratio).

- Productivity (production/harvested area)

Data on harvested area, production and productivity of sugar cane[57] were collected from the IBGE databases of the Municipal Agricultural Production (PAM) survey (IBGE, 2024b). Although the National Supply Company (Conab) also provides data on harvested area, production and productivity (Table 6.11), this data is only available from 2007 onwards, and the smallest territorial level is the FU/state. Therefore, IBGE data was used, as it has a longer

[57] Long-duration temporary crops, whose vegetative cycles exceed twelve months, such as sugar cane, which has extended harvest periods, the harvests carried out within each calendar year are taken into account in the survey carried out by PAM (IBGE, 2024b).

historical follow-up and is also available at municipal level. The calculation of GHG emissions from sugar cane was based on data at municipal level.

Table 6.11. Evolution of the harvested area and the amount of sugar cane produced in Brazil.

Years	Harvested area (thousand ha)	Production (thousand t)	Productivity (t/ha)
1990	4,272.60	262,674.2	61.5
1991	4,210.95	260,887.9	62.0
1992	4,202.60	271,474.9	64.6
1993	3,863.70	244,530.7	63.3
1994	4,345.26	292,101.8	67.2
1995	4,559.06	303,699.5	66.6
1996	4,750.30	317,106.0	66.8
1997	4,814.08	331,612.7	68.9
1998	4,985.82	345,255.0	69.2
1999	4,898.84	333,847.7	68.1
2000	4,804.51	326,121.0	67.9
2001	4,957.90	344,292.9	69.4
2002	5,100.41	364,389.4	71.4
2003	5,371.02	396,012.2	73.7
2004	5,631.74	415,205.8	73.7
2005	5,805.52	422,956.6	72.9
2006	6,355.50	477,410.7	75.1
2007	7,080.92	549,707.3	77.6
2008	8,140.09	645,300.2	79.3
2009	8,617.56	691,606.1	80.3
2010	9,076.71	717,463.8	79.0
2011	9,601.32	734,006.1	76.4
2012	9,705.39	721,077.3	74.3
2013	10,195.17	768,090.4	75.3
2014	10,419.68	736,108.5	70.6
2015	10,111.38	750,290.3	74.2
2016	10,222.92	768,563.7	75.2
2017	10,189.21	758,646.2	74.5
2018	10,024.10	747,556.8	74.6
2019	10,092.43	753,470.5	74.7
2020	9,996.13	756,070.6	75.6
2021	9,971.37	715,679.3	71.8
2022	9,870.59	724,428.1	73.4

Source: Modified from IBGE (2018) – Table 1612 – Planted area, harvested area, amount produced, average yield and value of crop production.

- Straw and stalk phytomass values

Straw and stalk phytomass values vary depending on the sugar cane variety grown. As a result, a survey of the main varieties grown in Brazil was carried out, followed by a literature review focusing on the ratio of straw production/stalk production for each of the varieties surveyed.

- Variedades cultivadas

The most commonly harvested sugar cane varieties, at national and state level, were obtained from the IAC Varietal Census of sugar cane in the Center-South region of Brazil –

2016/17 Harvest (Braga *et al*., 2017), for the Center-South region, and from RIDESA's Brazil Varietal Census – 2017 (2018), for the main producing states. Data from IACs' – Agronomic Institute (Instituto Agronômico) and from Inter-University Network for the Development of the Sugar-Energy Sector's (RIDESA, 2018) varietal censuses are shown in Figure A.VI.5 (Appendix VI), along with production and harvested area data for the FUs/states.

- Straw production/stalk production ratio

An extensive literature review was carried out to obtain the values for the straw/stalk ratio for the varieties surveyed in the IAC's and RIDESA's censuses. Subsequently, the average sugar cane straw/stalk ratio was calculated for the FUs/states surveyed based on the weighted average of the straw/stalk ratios of the five most commonly cultivated varieties, using the areas of the sugar cane varieties in each FU/state as a weight. For the varieties for which no straw and stalk production values were found, a generic production value was adopted, according to Hassuani *et al*. (2005). The values for the average straw/stalk ratio by FU/state are shown below in Table 6.12.

Table 6.12. Average straw/stalk ratio of the FUs/states according to the IAC's and Ridesa's varietal census.

FU/State	IAC	Ridesa	Average
AL (Alagoas)	-	0.172	0.172
ES (Espírito Santo)	0.193	-	0.193
GO (Goiás)	0.185	-	0.185
MA (Maranhão)	-	0.179	0.179
MG (Minas Gerais)	0.184	0.185	0.185
MS (Mato Grosso do Sul)	0.183	0.185	0.184
MT (Mato Grosso)	0.193	-	0.193
PB (Paraíba)	-	0.173	0.173
PE (Pernambuco)	-	0.175	0.175
PI (Piauí)	-	0.179	0.179
PR (Paraná)	0.192	-	0.192
RN (Rio Grande do Norte)	-	0.173	0.173
SP (São Paulo)	0.183	0.187	0.185
Brazil	**-**	**-**	**0.187**

The result of the averages shows that the states in the Center-South region have a higher straw/stalk ratio than the states in the Northeast. In other words, the Northeastern states have a lower dry biomass production per fresh biomass production than the Central-Southern states.

- Burnt area

Although burning in sugar cane plantations still occurs in Brazil, there is no official data on the proportion of this practice per harvested area. However, the fifth volume of "Monitoring of the Brazilian sugar cane harvest" (Conab, 2018) presents the percentage of mechanized and manual harvesting, by region and FU/state, from 2007 to 2016. Since manual harvesting without prior burning has a lower yield than harvesting with prior burning, it becomes more costly, which ends up making the operation economically unfeasible (Conab, 2018).

The burnt area data was obtained from the percentage of the harvest carried out manually presented in the fifth volume of the Monitoring of the Brazilian sugar cane harvest (Conab, 2018), assuming that it is indicative of the percentage of the area harvested using burning (Table 6.13), which is corroborated by the work of Fernandes *et al*. (2013). Based on the percentages of manual harvesting by FU/state (Table A.VI.8, Appendix VI), the sugar cane burnt area was also estimated by municipality from 1990 to 2022.

Table 6.13. Percentage of manual harvesting and estimation of the burnt area in sugar cane crops.

Year	Manual harvesting	Estimated burnt area
	%	thousand ha
1990	100.00	4,272.60
1991	100.00	4,210.95
1992	100.00	4,202.60
1993	100.00	3,863.70
1994	100.00	4,345.26
1995	100.00	4,559.06
1996	94.75	4,500.98
1997	90.95	4,378.64
1998	89.71	4,472.83
1999	88.37	4,329.08
2000	84.23	4,046.65
2001	84.98	4,213.42
2002	85.39	4,355.34
2003	86.36	4,638.44
2004	85.32	4,805.24
2005	84.43	4,901.34
2006	80.34	5,106.13
2007	75.90	5,374.46
2008	63.38	5,158.98
2009	52.45	4,519.72
2010	45.59	4,138.24
2011	36.40	3,494.61
2012	30.78	2,987.06
2013	25.96	2,646.78
2014	23.39	2,436.79
2015	14.95	1,511.99
2016	10.84	1,108.16
2017	10.25	1,043.97
2018	8.80	882.12
2019	8.40	847.76
2020	8.21	820.97
2021	10.58	1,054.53
2022	10.65	1,050.88

Source: Based on Conab – Brazil's National Supply Company (Companhia Nacional de Abastecimento) (2018) and Packer *et al*. (2015).

Lastly, Dataframe 6.22 summarizes the emission factors for the Field burning of Agricultural Residues subsector (3.F).

Dataframe 6.22. Emission factors for Field Burning of Agricultural Residues (3.F).

Categories	Parameters	Emission factors	Reference
3.F.1, 3.F.2	Combustion factor (Cf)	0.8	Table 2.5 (IPCC, 2006, v. 4, chap.11)
3.F.1, 3.F.2	EF CH_4	0.933 (g/kg dry matter burnt)	Yokelson *et al*. (2008)
3.F.1, 3.F.2	EF CO	40.43 (g/kg dry matter burnt)	Yokelson *et al*. (2008); Lopes; Carvalho (2009); França *et al*. (2012)
3.F.1, 3.F.2	EF NO_x	1.5 (g/kg dry matter burnt)	França *et al*. (2012)
3.F.1, 3.F.2	EF N_2O	0.07 (g/kg dry matter burnt)	Table 2.5 (IPCC, 2006, v. 4, chap. 11); Andreaa; Merlet (2001)

6.7.2 Quality assurance and quality control

The QA/QC procedures adopted for the Field Burning of Agricultural Residues subsector (3.F) are described in Section 2.5 of this document.

6.7.3 Assessment of uncertainty, consistency and recalculations of the time series

Uncertainty analysis was carried out using the random sampling methods and techniques described in the 2006 IPCC Guidelines. The uncertainty associated with CO_2 emissions form Field Burning of Agricultural Residues (3.F) is presented in Appendix II of this NIR.

The consistency of the time series of the estimates was maintained, as a result of the availability of the key data, harvested area and productivity, to generate the burnt area data and the straw/stalk ratio; and, on the other hand, the emission factors data remained constant, and the same values defined in Brasil (2021) were used.

Comparing the consolidated results of the previous Inventory with the one carried out for this NIR 2024, the largest proportion of adjustments is seen in 2018, with a 0.6% difference between estimated emissions. Between 2017 and 2020, the average adjustment in aggregate emissions was only 0.3%, and in the period from 1990 to 2020, it was 0.04%, which demonstrates the consistency of the subsector's time series (Figure 6.11).

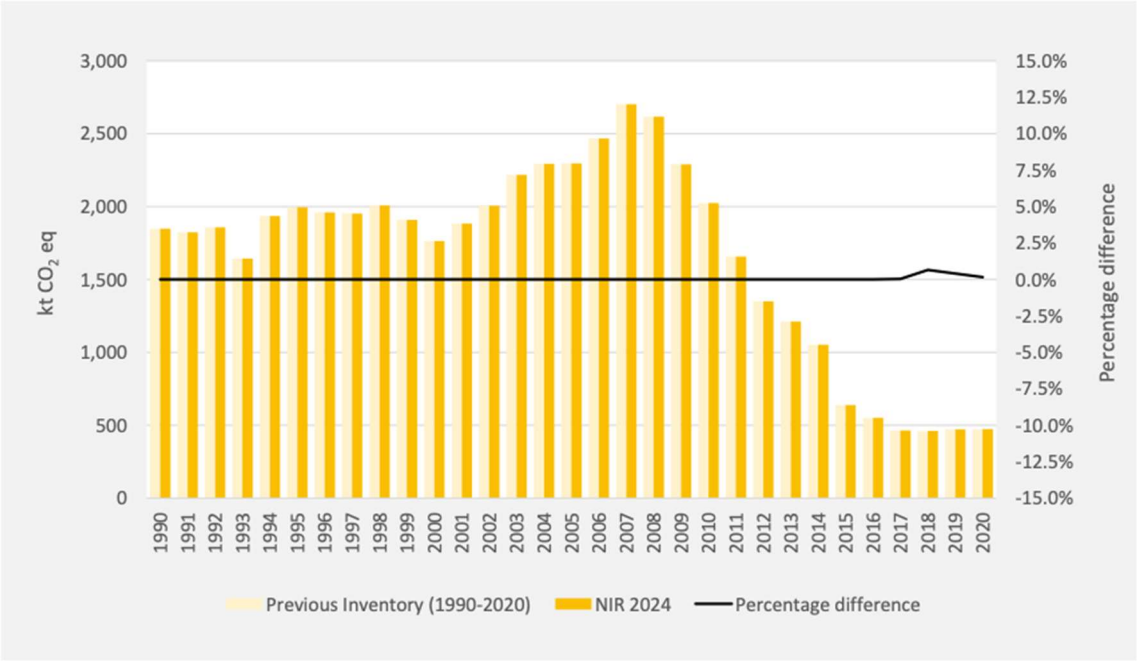


Figure 6.11. Comparison of estimated emissions from the Field Burning of Agricultural Residues subsector (3.F) between inventories.

6.7.4 Improvement plan

The experience gained with the periodic preparation of national GHG inventories has led to the proposal of a number of measures to improve the consistency and greater detailing of the Inventory's results, particularly for the Field Burning of Agricultural Residues subsector (3.F).

Dataframe 6.23 summarizes the potential improvements for implementation in future editions of the inventory for this subsector.

Dataframe 6.23. Potential improvements applicable to the inventory of emissions from the Field Burning of Agricultural Residues subsector (3.F).

Subsector	Category	Improvement
3.F. FIELD BURNING OF AGRICULTURAL RESIDUES	General (all categories)	▪ Broaden the analysis base for the definition of GHG emission factors, through a new review of scientific work carried out in the regions/FUs/states with the highest production levels.

6.8 Liming (CRT 3.G)

Emissions from Liming include only CO_2 emissions. In Brazil, limestone has been increasingly used to supply calcium (Ca) and magnesium (Mg) to plants and, above all, to reduce the acidity that is characteristic of its soils. Calcium stimulates root growth, helping plants to search for water and nutrients in the soil. It is essential for a healthy soil, as it increases the soil's microbial activity, resulting in greater mineralization of organic matter and biological nitrogen fixation. However, after being added, limestone releases carbonate which reacts in the soil, releasing CO_2 into the atmosphere.

The Liming subsector accounted for 4% of the Agriculture sector's emissions in 2022, corresponding to 27,087 kt CO_2 eq. From 2020 to 2022, there was a 25% increase in emissions due to the increase in harvested areas (Figure 6.12).

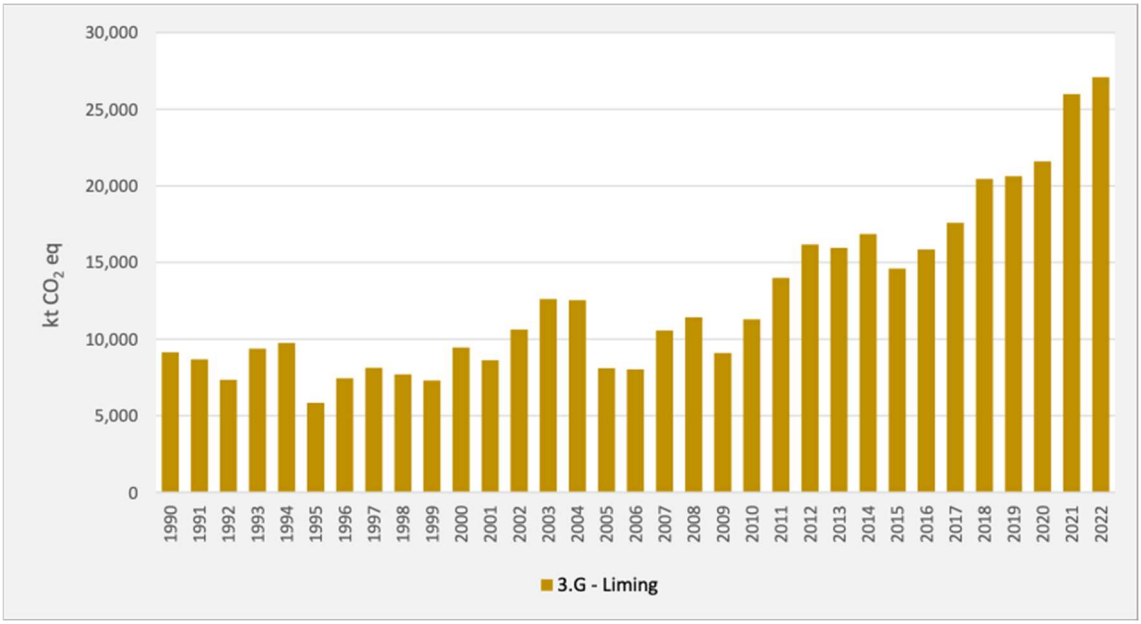


Figure 6.12. Emissions from Liming (3.G), in kt CO_2 eq per category, from 1990 to 2022.

6.8.1 Methodological aspects

To calculate the CO_2 emissions of the categories in the Liming subsector (3.G), equation 6.31, shown in Dataframe 6.24, was used, with Tier 1 methodological detailing.

Dataframe 6.24. Equations for estimating emissions from the Liming subsector (3.G).

Equations	GHG	Categories	Central equation	Reference
Equation 6.31	CO_2	3.G	$\text{Emissions of } CO_2 - C = (M_{Limestone} \text{ X } EF_{Limestone}) + (M_{Dolomite} \text{ X } EF_{Dolomite})$	Equation 11.2 (IPCC, 2006, v. 4, chap. 11)

In which:

CO_2 emitted = amount of CO_2 emitted in year T (kt CO_2. year^{-1});
$M_{Limestone}$ = amount of calcitic limestone (kt);
$EF_{Limestone}$ = emission factor of calcitic limestone;
$M_{Dolomite}$ = amount of dolomitic limestone (kt); and
$EF_{Dolomite}$ = emission factor of dolomitic limestone.

Activity data and other parameters

To calculate CO_2 emissions from liming, data on the apparent consumption of dolomitic limestone, which is the type of limestone used in the country's agricultural activity due to its high Ca and Mg content, was used.

The data on the apparent consumption of limestone in Brazil from 2017 to 2022 was obtained from the Brazilian Agricultural Limestone Producers Association (ABRACAL, Associação Brasileira dos Produtores de Calcário Agrícola), which reports figures by FU/state or national total, and takes into account own production, subtracting the exported volume and adding the imported volume. The time series has apparent consumption data for the country's main agricultural producers, but does not provide this data for the FUs/states. For those federative units/states that do not report apparent consumption, the data on the amounts of limestone consumed are grouped under "other states".

Thus, the amount of limestone consumed by the "other states" individually was obtained by considering the percentage of each state's planted area, using a weighted average, with different weights for each state's land use in 2016, multiplied by the total for each year (ABRACAL, 2022). Thus, the limestone consumption data used in the emissions calculation are shown in Table 6.14 below.

Table 6.14. Amounts of limestone consumed in the country from 1990 to 2022.

Year	Limestone tons	Year	Limestone tons
1990	19,176,307	**2007**	22,160,700
1991	18,194,375	**2008**	23,972,000
1992	15,408,000	**2009**	19,078,600
1993	19,659,000	**2010**	23,690,100
1994	20,435,000	**2011**	29,352,900
1995	12,262,200	**2012**	33,943,000
1996	15,617,000	**2013**	33,471,000
1997	17,059,400	**2014**	35,377,700
1998	16,135,900	**2015**	30,641,900
1999	15,304,400	**2016**	33,238,900
2000	19,812,200	**2017**	36,911,000
2001	18,077,600	**2018**	42,909,900

Year	Limestone
	tons
2002	22,286,400
2003	26,462,900
2004	26,319,800
2005	16,987,300
2006	16,849,800

Year	Limestone
	tons
2019	43,296,200
2020	45,299,700
2021	54,517,700
2022	56,826,800

Source: Based on Abracal – Brazilian Limestone Producers Association (Associação Brasileira dos Produtores de Calcário) (2022).

The CO_2 emissions from limestone are estimated by applying the CO_2 emission factors to the activity data relating to the amount of limestone. The emission factors for limestone used were those defined in the IPCC (2006) methodology (Dataframe 6.25).

Dataframe 6.25. Factors used to calculate CO_2 emissions from Liming.

Categories	Parameters	Emission factors	Reference
3.G.	$EF_{Dolomite}$	0.13	(IPCC, 2006, v. 4, chap. 11)

6.8.2 Quality assurance and quality control

The QA/QC procedures adopted for the Liming subsector (3.G) are described in Section 2.5 of this document.

6.8.3 Assessment of uncertainty, consistency and recalculations of the time series

Uncertainty analysis was carried out using the random sampling methods and techniques described in the 2006 IPCC Guidelines. The uncertainty associated with CO_2 emissions from Liming (3.G) is presented in Appendix II.

The process of updating the national inventory took into account the time series of activity data on limestone application in light of the publication of updated documents. However, no differences were identified, which is why in this NIR 2024 there were also no changes between the estimated annual emissions for the time series of the Liming subsector (3.G) (Figure 6.13).

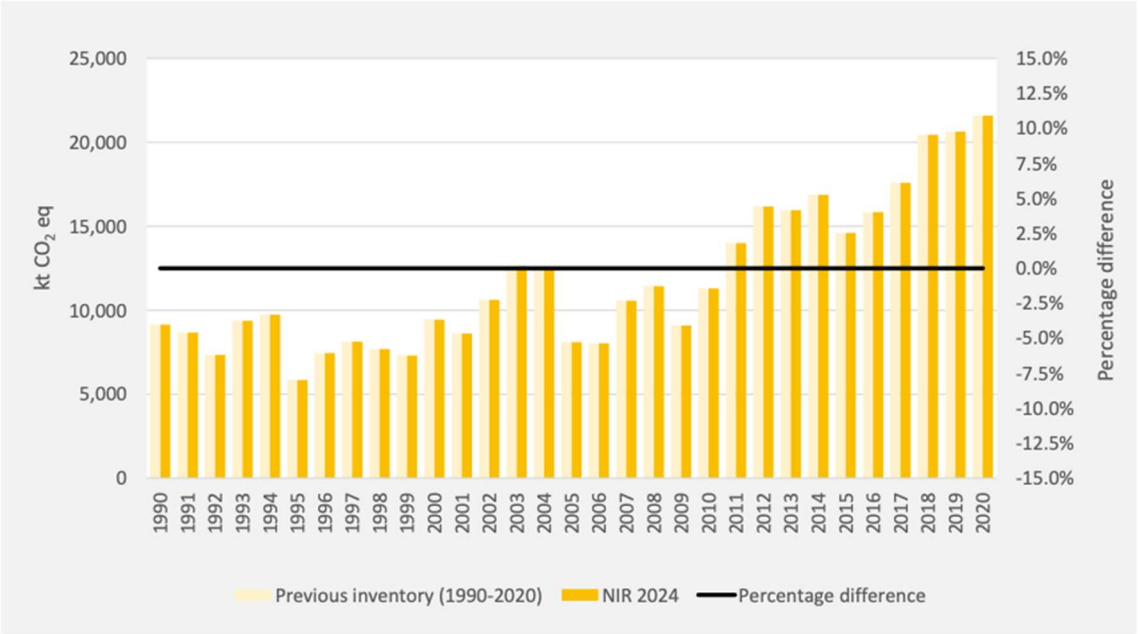


Figure 6.13. Comparison of estimated emissions from the Liming subsector (3.G) between inventories.

6.8.4 Improvement plan

The experience gained in the periodic preparation of national GHG inventories has led to the proposal of a series of measures to improve the consistency and greater detailing of the results of the Inventory, in particular of the Liming subsector (3.G).

Dataframe 6.26 summarizes the potential improvements to be implemented in future editions of this subsector's inventory.

Dataframe 6.26. Potential improvements applicable to the emissions inventory for the Liming subsector (3.G).

Subsector	Category	Improvement
3.G. LIMING	General (all categories)	▪ Assess the possibility of establishing partnerships with institutions that manage limestone consumption and application data in order to improve the quality and regionalize the activity data.

6.9 Urea Application (CRT 3.H)

In Brazil, urea is widely used as an organic fertilizer and, as with Liming, its application generates CO_2 emissions. Urea has carbon in its composition and, when applied to the soil, it goes through the hydrolysis process, which generates ammonia for the plants and CO_2 which is released into the atmosphere.

The Urea Application subsector accounted for 0.7% of the Agriculture sector's emissions in 2022, corresponding to 4,397 kt CO_2 eq. From 2020 to 2022, there was a 0.5% reduction in emissions (Figure 6.14).

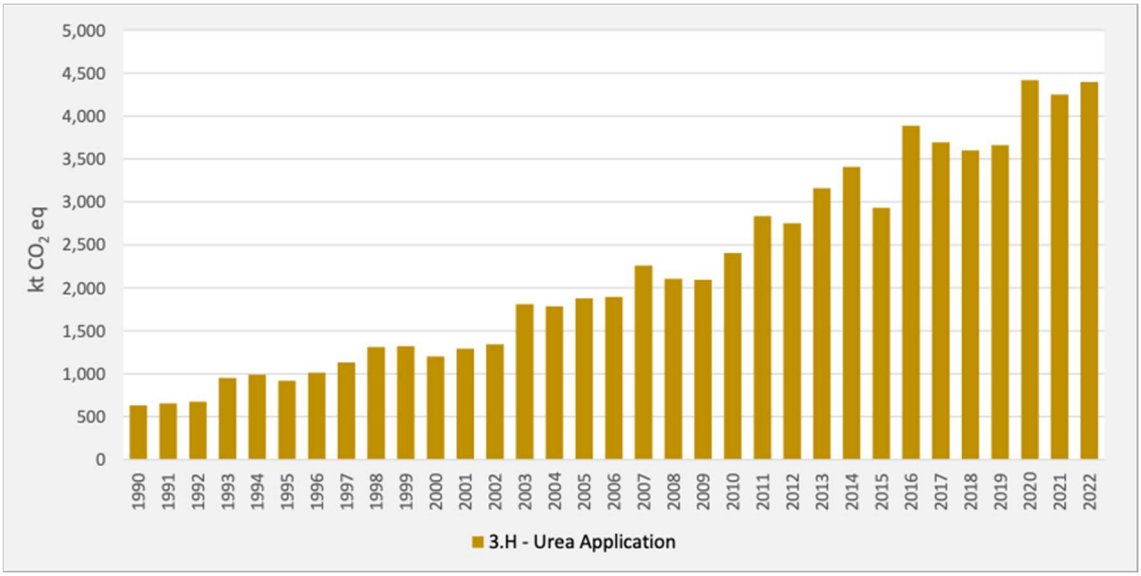


Figure 6.14. Emissions from Urea Application (3.H), in kt CO_2 eq by category, from 1990 to 2022.

6.9.1 Methodological aspects

To calculate CO_2 emissions from the categories of the Urea Application subsector (3.H), equation 6.32, shown in Dataframe 6.27, was used, with Tier 1 methodological detailing.

Dataframe 6.27. Equations for estimating emissions from the Urea Application subsector (3.H).

Equations	GHG	Categories	Central equation	Reference
Equation 6.32	CO_2	3.H	Emissions of $CO_2 - C = M \times EF$	Equation 11.11 (IPCC, 2006, v. 4, chap. 11)

In which:

CO_2 emitted = amount of CO_2 emitted in year T (kt CO_2. year^{-1});
M = amount of Urea (kt); and
EF = emission factor.

Activity data and other parameters

To calculate CO_2 emissions from the use of urea, the data on the amount of urea consumed in the country over the years of the inventory is used, and it is obtained for the estimate of F_{SN}, in the amount of N, but expressed and listed as the amount of fertilizer. By consulting ANDA's statistical yearbooks, the total amount of urea was broken down into consumed urea and other sources. This disaggregation was carried out on the basis that the amount of

urea consumed in a given year corresponds to the difference in stocks at the end and at the beginning of the year, added to the amount manufactured and the amount imported, minus the amount exported. These figures were not broken down at state level, so it was assumed that the percentage of urea in relation to total fertilizer consumption in the country was the same for each state. The urea consumption data used to calculate emissions is shown in Table 6.15 below.

Table 6.15. Amounts of urea consumed in the country from 1990 to 2022.

Year	Urea	Year	Urea
	tons		tons
1990	860,050	**2007**	3,082,120
1991	893,235	**2008**	2,871,713
1992	919,133	**2009**	2,855,578
1993	1,296,002	**2010**	3,280,297
1994	1,347,879	**2011**	3,866,403
1995	1,254,713	**2012**	3,753,797
1996	1,379,902	**2013**	4,307,956
1997	1,542,742	**2014**	4,646,897
1998	1,787,490	**2015**	3,997,773
1999	1,800,629	**2016**	5,302,413
2000	1,638,097	**2017**	5,035,974
2001	1,760,927	**2018**	4,907,887
2002	1,830,635	**2019**	4,992,272
2003	2,465,713	**2020**	6,022,992
2004	2,432,772	**2021***	5,794,367
2005	2,560,902	**2022***	5,995,837
2006	2,582,137		

Source: Based on Abracal – Brazilian Limestone Producers Association (Associação Brasileira dos Produtores de Calcário) (2022) and ANDA – National Association for the Diffusion of Fertilizers (Associação Nacional para Difusão de Adubos) (2021). * Values estimated based on extrapolation of the last 5 years (2016-2020).

CO_2 emissions from urea are estimated by applying the CO_2 emission factors to the activity data relating to the amount of urea. The emission factors for urea used were those defined in the IPCC (2006) methodology (Dataframe 6.28).

Dataframe 6.28. Factors used to calculate CO_2 emissions from Urea Application.

Categories	Parameters	Emission factors	Reference
3.H.	EF_{Urea}	0.20	IPCC (2006, v.4, chap. 11)

6.9.2 Quality assurance and quality control

The QA/QC procedures adopted for the Urea Application subsector (3.H) are described in Section 2.5 of this document.

6.9.3 Assessment of uncertainty, consistency and recalculations of the time series

Uncertainty analysis was carried out using the random sampling methods and techniques described in the 2006 IPCC Guidelines. The uncertainty associated with CO_2 emissions from Urea Application (3.H) is presented in Appendix II.

The process of updating the national inventory took into account the review of the time series of the activity data on urea application in light of the publication of updated documents. Comparing the consolidated results of the previous Inventory with the one carried out for this NIR 2024, the largest proportion of adjustments is seen in 2020, with a 0.12% difference between estimated emissions. Between 2017 and 2020, the average adjustment in aggregate emissions was only 0.06%, and in the period from 1990 to 2020, it was 0.01%, which demonstrates the consistency of the subsector's time series (Figure 6.15).

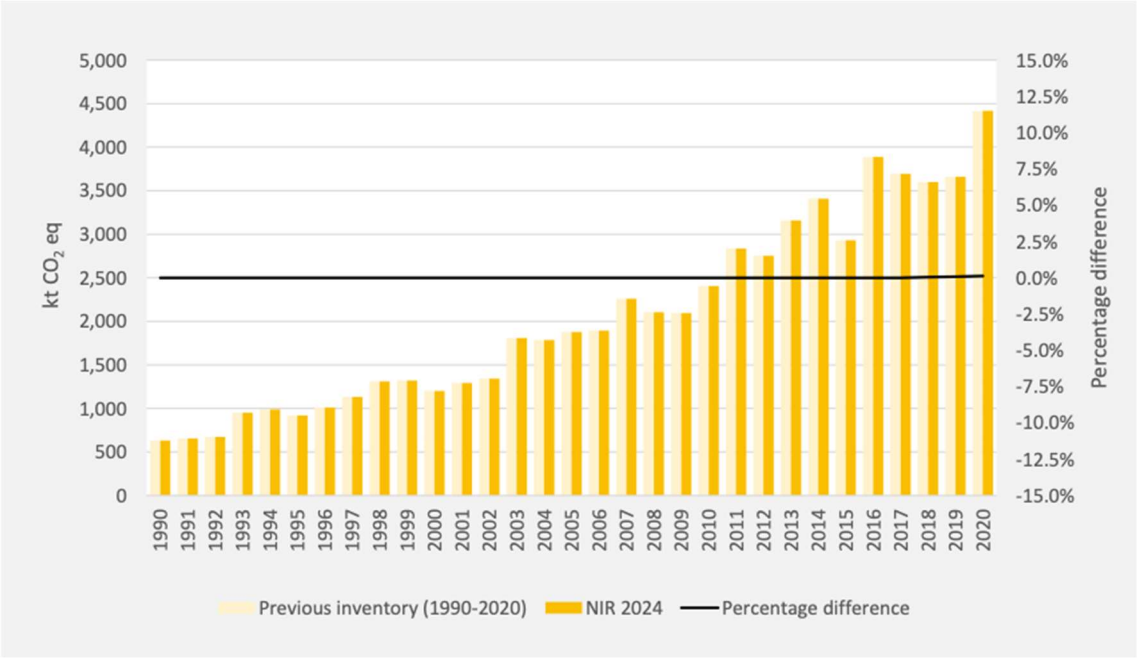


Figure 6.15. Comparison of estimated emissions from the Urea Application subsector (3.H) between inventories.

6.9.4 Improvement plan

The experience gained in the periodic preparation of national GHG inventories has led to the proposal of a series of measures to improve the consistency and greater detailing of the results of the Inventory, in particular of the Urea Application subsector (3.H).

Dataframe 6.29 summarizes the potential improvements to be implemented in future editions of this subsector's inventory.

Dataframe 6.29. Potential improvements applicable to the emissions inventory for the Urea Application subsector (3.H).

Subsector	Category	Improvement
3.H. UREA APPLICATION	General (all categories)	▪ Assess the possibility of establishing partnerships with institutions that manage urea consumption and application data in order to improve the quality and regionalize the activity data.

7 LAND USE, LAND-USE CHANGE AND FORESTRY (CRT 4)

7.1 Sector overview

The Land Use, Land-Use Change and Forestry (LULUCF) sector presents anthropogenic emissions and removals of CO_2 from the loss and gain of carbon (C), associated with land use and with land-use and land-cover change. In addition, emissions of CH_4 and N_2O and of precursor gases (CO and NO_X) from biomass burning associated with land-use and land-cover change are estimated. Emissions and removals of CO_2 from Harvested Wood Products (HWP), i.e., products that are manufactured/processed after the harvesting of wood from planted forests, such as paper, sawnwood and wood panels, are also taken into account.

The LULUCF subsectors are: Forest Land (4.A), Cropland (4.B), Grassland (4.C), Wetlands (4.D), Settlements (4.E), Other Land (4.F) and Harvested Wood Products (4.G).

For this sector, the results are presented in net emissions or removals. These estimates result from the balance between gross emissions (of CO_2 from HWP and of CO_2 and non-CO_2 gases associated with land use and land-use and land-cover change) and removals of CO_2 (by land use and land-use and land-cover change and by HWP). When gross emissions are greater than removals, there are net emissions; when removals are greater than gross emissions, there are net removals.

Net emissions from the LULUCF sector totaled 805,694 kt CO_2 eq in 2022, which indicated an increase of 21% compared to 2020 (Figure 7.1). Although the sector has presented an increase in emissions since 2018, it should be noted that the Action Plans for the Prevention and Control of Deforestation and Fires (BRASIL, 2023a; 2023b) have been an effective public policy for reducing emissions from this sector since 2005, given that emissions in 2022 were approximately 69% lower than in 2004.

CO_2 emissions accounted for 93% of total net emissions (751,467 kt CO_2 eq), while CH_4 (41,885 kt CO_2 eq) and N_2O (12,342 kt CO_2 eq) emissions accounted for 5% and 2%, respectively. In 2022, the sector's most representative net emissions were from the Grassland subsector (4.C) (959,862 kt CO_2 eq), mainly reflecting conversions from Forest Land to Grassland (949,958 kt CO_2 eq). The largest net removals were from the Forest Land subsector (4.A), which accounted for -312,125 kt CO_2 eq (Figure 7.1), resulting mainly from protected vegetation within Conservation Units (CUs) and Indigenous Lands (ILs).

Emissions of CH_4 and N_2O, resulting from the burning of biomass associated with the dynamics of land use and land cover, were mainly from the Grassland subsector (4.C), which accounted for 35,353 kt CO_2 eq (or 84%) and 10,282 kt CO_2 eq (or 83%) of emissions of these gases in the sector, respectively, in 2022.

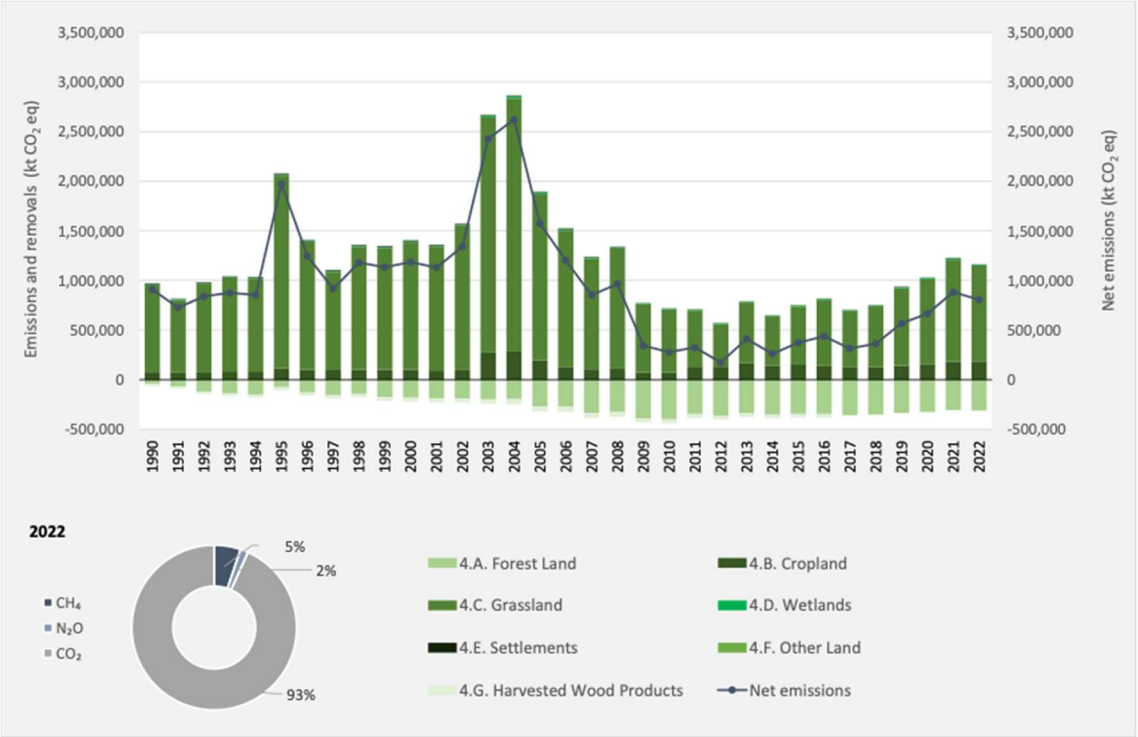


Figure 7.1. Emissions from the LULUCF sector, in kt CO_2 eq, by subsector, from 1990 to 2022.

7.2 General methodological aspects of the sector

Estimates of emissions and removals of CO_2 from land use and land-use and land-cover change and from harvested wood products, as well as emissions of non-CO_2 gases, were based on the IPCC (2006) methodology.[58] The methodological levels applied per gas for the LULUCF categories are shown in Dataframe 7.1.

In order to better represent the variations in carbon stocks in its territory, a database was created with several layers of spatial information for the entire territory – IPCC Approach 3 (2006).[59] Once the managed areas had been identified, the emissions and removals from the LULUCF sector were estimated. Land-use and land-cover maps were produced for the whole country for the years of 1994, 2002, 2005 (for the Amazon only), 2010 and 2016, based on the visual interpretation of satellite images, as shown in Figure 7.2.

The country's managed areas[60] are made up of: *anthropized areas* – classified as Cropland, Grassland, Mining, Bare soil, Settlements, Reservoirs, Forest Plantation, Selective Logging (forests under selective logging regime), Secondary forests, Secondary grassland, Other secondary wooded land – as well as *protected natural areas*, located in CUs and ILs – classified as Managed Forest Land, Managed Grassland, Other Managed Wooded Land, Managed Dunes, Managed Rock Outcrops.[61]

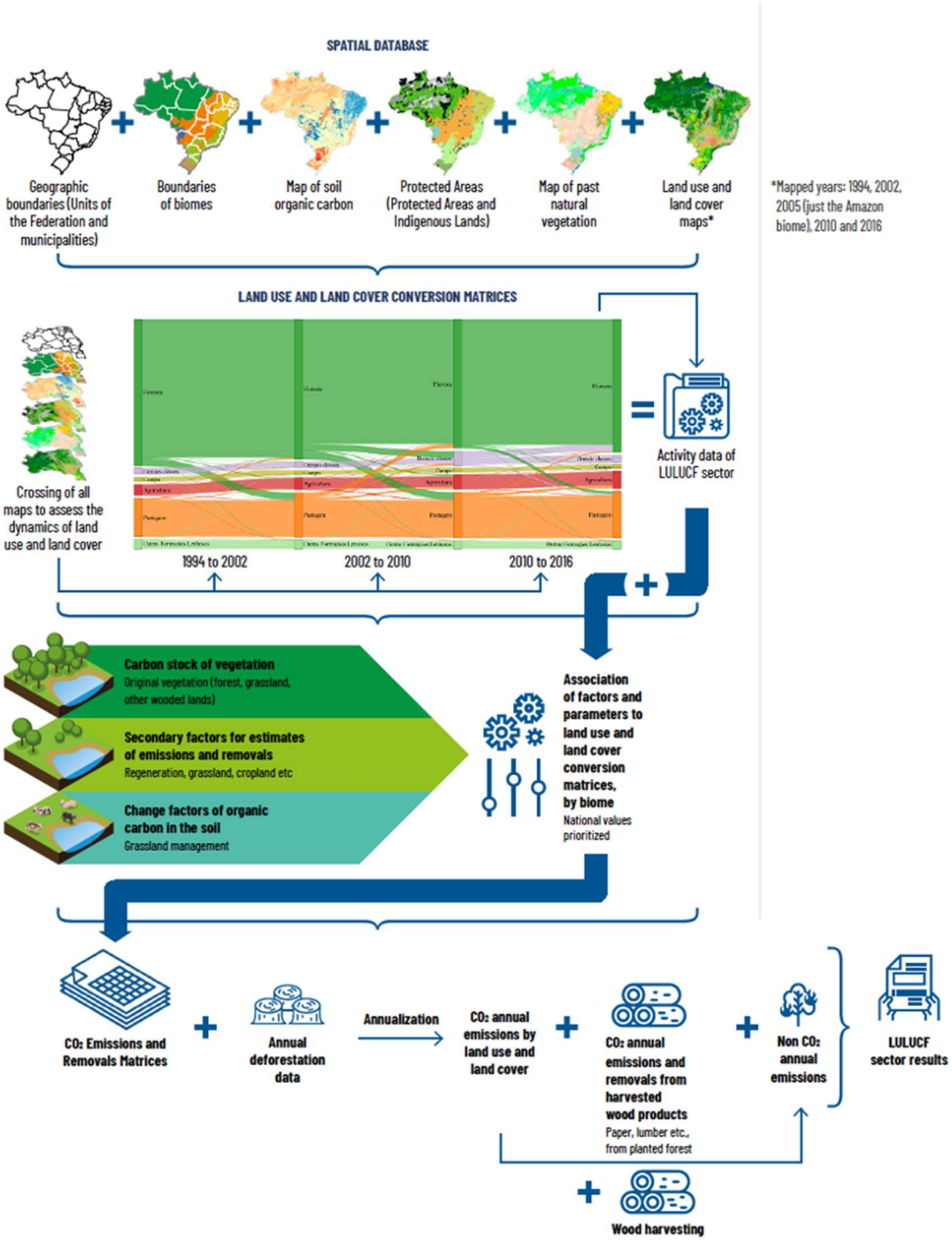
[58] Agriculture, Forestry and Other Land Use (IPCC, 2006, v. 4).
[59] IPCC (2006, v. 4, chap. 3).
[60] Managed areas consist of areas where human interventions and practices have been applied to perform productive, ecological or social functions" (IPCC 2006, v. 4, chap. 3, p. 3.6).
[61] Emissions from unmanaged areas – classified as Unmanaged Forest Land, Unmanaged Grassland, Other Unmanaged Wooded Land, Unmanaged Dunes, Unmanaged Rock Outcrops, Water, as well as Areas not

Based on the cross-referencing of this information, land-use and land-cover matrices and CO_2 emissions and removals matrices were generated by assessed periods and by biome, which will have their methodological procedures described in Sections 7.2.1, 7.2.2 and 7.2.3. The annualization of gross CO_2 emissions was based on the annual deforestation rates by biome (Section 7.2.4). The estimates for the period from 1990 to 1994, prior to the complete mapping of the territory (carried out from 1994 onwards), were recalculated by weighting the data collected in Brazil's Initial National Communication to the UNFCCC (BRASIL, 2004) and the information and mappings (1994 and 2002) produced in the Inventory presented in the Fourth National Communication. (BRASIL, 2021). The extrapolation of emissions beyond the mapping period (Section 7.2.5) was carried out using the surrogate data method (IPCC, 2006),[62] based on annual deforestation by biome. Non-CO_2 emissions from biomass burning associated with land-use change were also accounted for, based on gross CO_2 emission data and national fuelwood and roundwood harvesting data (Section 7.2.6). Emissions and removals of Harvested Wood Products (HWP) (category 4.G) were based on the atmospheric flow method (Tier 1) (IPCC, 2006)[63] (Section 7.9).

Observed – are not accounted for. The carbon stocks in Reservoirs, Bare Soil, Mining, Rock Outcrops, Dunes and Settlements are considered to be zero.

[62] IPCC (2006, v. 1, chap. 5, p. 5.10).

[63] IPCC (2006, v. 4, chap. 12).



Note: In the annualization procedure, annual deforestation rates were used to distribute annually the gross CO_2 emissions from vegetation by period.

Figure 7.2. Flowchart of the methodology used to draw up the inventory of the LULUCF sector.

Dataframe 7.1. Methodological levels applied per gas for the LULUCF sector categories.

Subsector	Category	Subcategory	ESTIMATED GASES AND METHODOLOGIES					
			CO_2	CH_4	N_2O	CO	NO_x	NMVOC
4.A. FOREST LAND	4.A.1. Forest Land Remaining Forest Land		T1/T2	T1/ T2	T1/T2	T1/T2	T1/T2	NA
	4.A.2. Land Converted to Forest Land	4.A.2.a. Cropland Converted to Forest Land	T1/T2	NA	NA	NA	NA	NA
		4.A.2.b. Grassland Converted to Forest Land	T1/T2	T1/T2	T1/T2	T1/T2	T1/T2	NA
		4.A.2.c. Wetlands Converted to Forest Land	T1/T2	NA	NA	NA	NA	NA
		4.A.2.d. Settlements Converted to Forest Land	NO	NA	NA	NA	NA	NA
		4.A.2.e. Other Land Converted to Forest Land	T1/T2	NA	NA	NA	NA	NA
4.B. CROPLAND	4.B.1. Cropland Remaining Cropland		NE	IE	IE	IE	IE	NA
	4.B.2. Land Converted to Cropland	4.B.2.a. Forest Land Converted to Cropland	T1/T2	T1/T2	T1/T2	T1/T2	T1/T2	NA
		4.B.2.b. Grassland Converted to Cropland	T1/T2	T1/T2	T1/T2	T1/T2	T1/T2	NA
		4.B.2.c. Wetlands Converted to Cropland	T1/T2	NA	NA	NA	NA	NA
		4.B.2.d. Settlements Converted to Cropland	NO	NA	NA	NA	NA	NA
		4.B.2.e. Other Land Converted to Cropland	T1/T2	NA	NA	NA	NA	NA

Subsector	Category	Subcategory	ESTIMATED GASES AND METHODOLOGIES					
			CO_2	CH_4	N_2O	CO	NO_x	NMVOC
4.C. GRASSLAND	4.C.1. Grassland Remaining Grassland		T1/T2	T1/T2	T1/T2	T1/T2	T1/T2	NA
	4.C.2. Land Converted to Grassland	4.C.2.a. Forest Land Converted to Grassland	T1/T2	NA	NA	NA	NA	NA
		4.C.2.b. Cropland Converted to Grassland	T1/T2	NA	NA	NA	NA	NA
		4.C.2.c. Wetlands Converted to Grassland	NO	NA	NA	NA	NA	NA
		4.C.2.d. Settlements Converted to Grassland	NO	NA	NA	NA	NA	NA
		4.C.2.e. Other Land Converted to Grassland	T1/T2	NA	NA	NA	NA	NA
4.D. WETLANDS	4.D.1. Wetland Remaining Wetland		NA	NA	NA	NA	NA	NA
	4.D.2. Land Converted to Wetland	4.D.2.a. Forest Land Converted to Wetland	T1/T2	T1/T2	T1/T2	T1/T2	T1/T2	NA
		4.D.2.b. Cropland Converted to Wetland	T1/T2	NA	NA	NA	NA	NA
		4.D.2.c. Grassland Converted to Wetland	T1/T2	T1/T2	T1/T 2	T1/T2	T1/T2	NA
		4.D.2.d. Settlement Converted to Wetland	NA	NA	NA	NA	NA	NA
		4.D.2.e. Other Land Converted to Wetland	NA	NA	NA	NA	NA	NA
4.E. SETTLEMENTS	4.E.1. Settlements remaining Settlements		NA	NA	NA	NA	NA	NA
	4.E.2. Land Converted to Settlements	4.E.2.a. Forest Land Converted to Settlements	T1/T2	T1/ T2	T1/T2	T1/T2	T1/T2	NA

Subsector	Category	Subcategory	ESTIMATED GASES AND METHODOLOGIES					
			CO_2	CH_4	N_2O	CO	NO_x	NMVOC
		4.E.2.b. Cropland Converted to Settlements	T1/T2	NA	NA	NA	NA	NA
		4.E.2.c. Grassland Converted to Settlements	T1/T2	T1/T2	T1/T2	T1/T2	T1/ T2	NA
		4.E.2.d. Wetlands Converted to Settlements	NA	NA	NA	NA	NA	NA
		4.E.2.e. Other Land Converted to Settlements	T1/T2	NA	NA	NA	NA	NA
4.F. OTHER LAND	4.F.1. Other Land remaining Other Land		NA	NA	NA	NA	NA	NA
	4.F.2. Land Converted to Other Land	4.F.2.a. Forest Land Converted to Other Land	T1/T2	T1/T2	T1/T2	T1/T2	T1/T2	T1/T2
		4.F.2.b. Cropland Converted to Other Land	T1/T2	NA	NA	NA	NA	NA
		4.F.2.c. Grassland Converted to Other Land	T1/T2	T1/T2	T1/T2	T1/T2	T1/T2	T1/T2
		4.F.2.d. Wetlands Converted to Other Land	NA	NA	NA	NA	NA	NA
		4.F.2.e. Settlements Converted to Other Land	NA	NA	NA	NA	NA	NA
4.G. HARVESTED WOOD PRODUCTS			T1	T1	T1	T1	T1	T1

Note: Methodological levels (IPCC, 2006) – T1: Tier 1; T2: Tier 2; T3: Tier 3.
Notations: NA (Not applicable) – Activity in a given source/sink category that occurs in the country, but did not result in emissions or removals of a specific gas; IE (Included elsewhere) – Included in another location/category of emissions or removals; NO (Not occurring) – Categories and processes that do not occur in the country; NE (Not estimated) – Activity data and/or emissions by sources and removals by sinks of GHG that have not been estimated, but for which a corresponding activity may occur in the country.

Emissions and removals from mineral soils and organic soils in the LULUCF sector have not been disaggregated and non-CO_2 emissions from the Cropland Remaining Cropland category (4.B.1) have been included (IE) in the Field Burning of Agricultural Residues subsector (3.F) of the Agriculture sector (Chapter 6 in the NIR).

In fires in which there is the conversion of land-use and land-cover class, only the CO_2 emissions associated with the loss of carbon stock in the original vegetation class are estimated. Emissions of CO_2 and non-CO_2 gases from fires in which there is no conversion of land-use and land-cover class have not yet been accounted for in this NIR. Monitoring the dynamics of fires and vegetation regeneration over the inventoried years is not simple, as it requires access to satellite images on a more regular basis, as well as specific scientific data on vegetation growth rates. Furthermore, differentiating between natural fires and those caused by anthropogenic factors is not easy.

CO_2 emissions and removals from Cropland Remaining Cropland (4.B.1) have not been accounted for due to the unavailability of specialized data by type of crop for the periods prior to 2022. Although Degraded Pastures (DP) were mapped in the Fourth National Communication inventory, CO_2 removals were only accounted for areas converted from uses other than pastures to well-managed pastures, for the entire time series. These estimates were made by applying soil organic carbon change factors stratified proportionally by Federative Unit (FU/State) in relation to pasture quality (natural/planted in good condition/planted in poor condition). Box 7.1 discusses the accounting of CO_2 removals from vegetation in the National Inventory.

Box 7.1. Accounting of CO_2 Removals from Vegetation

CO_2 removals are the result of photosynthesis, a process in which carbon is fixed in biomass. When there is conversion of land use or land cover, removals associated with the carbon fixation of the new vegetation class are accounted for. In addition, when a vegetation class remains in the same class, removals are accounted for in two cases: in primary vegetation located in a protected area and in forest areas with selective logging (SL).

Removals in secondary vegetation are only accounted for when there is a conversion from a use and cover class to the secondary vegetation class (Secondary forest, Other secondary wooded land and Secondary grassland). The determination of the growth patterns and dynamics of secondary vegetation areas is not well established for all Brazilian vegetation formations. Due to the impossibility of identifying the dynamics and growth time of these areas between the mapped years, the removals from areas that were converted to secondary vegetation were only accounted for in the first period identified in the mapping.

Dataframe 7.2 summarizes the methods, and describes the main references for activity data, emission factors, assumptions and other parameters taken into account when calculating emission estimates for the LULUCF sector.

Dataframe 7.2. Methodological summary and references to activity data, emission factors, assumptions and other parameters for estimating emissions and removals from the LULUCF sector.

LAND-USE AND LAND-COVER CHANGE – CO_2 EMISSIONS AND REMOVALS

Method: IPCC 2006, Approach 3: All land-use and land-cover categories and their changes are considered spatially across the entire territory. The parameters and emission/removal factors for each carbon pool of the different land uses and covers were estimated based on studies carried out in the country (Tier 2) and, in the absence of national data, default IPCC data (Tier 1) was used.

Activity data	Emission factor (EF) and other parameters	Other assumptions or parameters for the estimated years
Land-use and land-cover conversion matrices obtained from cross-referencing the maps of all Brazilian biomes for the years of 1994, 2002, 2005 (for the Amazon only), 2010 and 2016, based on images from the Landsat and Resourcesat-1 satellites at a scale of 1:250,000 and a minimum area of 6 ha. The classes considered were: Managed Forest Land (MFL),[64] Unmanaged Forest Land (UFL), Secondary Forest (SecF), Selective Logging (SL) (only for the Amazon biome), Forest Plantation (FP), Managed Grassland (MG), Unmanaged Grassland (UG), Secondary Grassland (SecG), Pasture (P),[65] Cropland (C),[66] Settlement (S), Water (W, rivers and lakes), Artificial reservoirs (Res), Rock Outcrop (MRO, URO), Dunes (MD, UD), Bare Soil (BS), Mining (Min) and Areas Not Observed (NO, areas covered by clouds and/or shadows). The land-use and land-cover maps were also cross-referenced with other layers of information: biome boundary map (IBGE – Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística), 2004), municipal boundary map (IBGE, 2017), past natural	The association of the land-use and land-cover conversion matrices with the IPCC 2006 carbon loss and gain equations and the factors described below, allowed us to generate the matrices of gross vegetation emissions, vegetation removals, net soil emissions/removals and net emissions/removals, by biome and period. Vegetation carbon: biomass carbon values for each pool were associated with the phytophysiognomies of the map of past natural vegetation of each biome: above ground (AGB); below ground (BGB) and dead organic matter (DOM, consisting of standing and fallen dead wood and litter), based on field data and scientific literature and, in the absence of information, on IPCC default ratios and/or values (dead wood from IPCC, 2003 and BGB from IPCC, 2006). The carbon content of dry forest biomass was 47% for all pools, with the exception of litter (46%) (IPCC, 2006; Ometto *et al*., 2006). For grassland and other wooded land, 47% was considered for AGB and BGB, 50% for dead wood and 40% for litter (IPCC, 2006). Vegetation emission/removal factors: the increase in vegetation biomass/carbon was estimated based on scientific literature and, in some cases, IPCC default values were used in relation to BGB (IPCC, 2006). Other parameters: stocks and/or increase of grassland and cropland were estimated based on scientific literature and IPCC 2006 default values. Classes such as Urban Area, Bare Soil, Mining, Reservoir, Dunes and Rock Outcrops had their carbon stocks associated with zero. Soil organic carbon stock: the methodology developed by Bernoux *et al*. (2002) was adapted, which estimates the amount of soil organic carbon according to	Annualization of emissions (categories 4.A to 4.F): For the annualization of gross CO_2 emissions between the mapped years, annualization rates based on the annual deforestation of each biome were calculated to distribute gross emissions over the assessed period, when available: INPE's – National Institute for Space Research (Instituto Nacional de Pesquisas Espaciais) Prodes – Program to Calculate Deforestation in the Legal Amazon Region (Sistema de Monitoramento do Desmatamento na Amazônia Legal) (2024a) for the Amazon, Atlas of Forest Remnants of the Atlantic Forest for the Atlantic Forest (SOS Atlantic Forest Foundation (Fundação SOS Mata Atlântica); INPE, 2023), Prodes Cerrado for the Cerrado (INPE, 2024b), Atlas of Vegetation Cover Monitoring in the Upper Paraguay River Basin (SOS Pantanal, 2020) and PMDBBS – Project of Satellite Deforestation Monitoring of the Brazilian Biomes (Projeto de Monitoramento do Desmatamento nos Biomas Brasileiros por

[64] Protected natural formations, i.e., within Conservation Units and Indigenous Lands
[65] For 2016, degraded pastures in the Amazon and Cerrado biomes were mapped.
[66] For 2016, annual, perennial and semi-perennial crops were differentiated. For previous years, the IBGE's proportions of types of crops were used.

vegetation map[67] (adapted from IBGE, 2019) by SFB – Brazilian Forest Service (Serviço Florestal Brasileiro) and Rede CLIMA, soil organic carbon map (adapted from Bernoux *et al.*, 2002) and protected areas map (FUNAI – National Indian Foundation (Fundação Nacional do Índio), 2016; ICMBio – Chico Mendes Biodiversity Conservation Institute (Instituto Chico Mendes de Conservação da Biodiversidade), 2016).

soil type and vegetation type, both classified by the authors into 6 and 15 large groups, respectively.

Soil organic carbon change factors: Carbon change factors due to land-use and land-cover change (fLU), management regime (fMG) and additions (fI) were developed for forest plantation, crop cultivation (no-till vs. conventional tillage) and pastures (natural/planted in good condition/planted in poor condition/degraded). The latter two were applied, considering the proportions by FU/state from IBGE (2017).

Satélite) for Caatinga, Pampa (MMA – Ministry of the Environment (Ministério do Meio Ambiente), 2012). In the absence of annual deforestation data, the arithmetic average of emissions for the period was used. To estimate net emissions by biome, annualized gross CO_2 emissions were added to net soil emissions/removals and vegetation removals were subtracted (both distributed equally by year, with the exception of removals from natural formations within protected areas).[68]

Emissions for the period from 2017 to 2022 (subsectors 4.A. to 4.F.): Gross CO_2 emissions were estimated using the surrogate data method (IPCC 2006),[69] based on annual deforestation data up to 2022 for the Amazon (INPE, 2024a), Cerrado (INPE, 2024b) and Atlantic Forest (SOS Atlantic Forest Foundation; INPE, 2023); up to 2019 for the Pantanal (SOS Pantanal, 2020); and up to 2011 for the Caatinga and Pampa (MMA, 2012). In the absence of data for the years from 2017 to 2022, the values for the last year with available data were replicated. The 2016 data for removals from vegetation and soil emissions/removals were replicated. Net emissions by biome consisted of the sum of gross CO_2 emissions and net soil emissions/ removals, minus the removals from vegetation.

Biomass burning associated with land-use and land-cover change – Emissions and removals of CO_2 and non-CO_2 gases

[67] It allows the identification of phytophysiognomies and their categories (Forest Land, Grassland or Other Wooded land).
[68] The country accounts for removals from protected natural formations from the date of their creation.
[69] IPCC (2006, v. 1, chap. 5, p. 5.10).

Method: Emissions due to the burning of biomass left in the field, associated with the conversion of natural formations to other uses, were calculated in accordance with the IPCC (2006), according to the Tier 1 and 2 methodological levels.
Non-CO_2 gas emissions from fires in which there was no conversion of land-use and land-cover class were not accounted for.

Activity data	Emission factor (EF) and other parameters	Other assumptions or parameters for the estimated years
Based on gross CO_2 emissions from deforestation, it was possible to estimate the original dry matter of the vegetation before it was converted to other uses. From this original dry matter, the values for fuelwood and roundwood from wood harvesting were obtained (IBGE, 2024), thus, obtaining the dry matter remaining in the field and available for burning.	Combustion factors for each biome and vegetation structure were obtained from literature review. IPCC (2006) default EF (CH_4, N_2O, NO_x and CO) per ton of dry matter burnt, taking into account the differentiation between forest land, grassland and other wooded land.	
Harvested Wood Products (HWP) (subsector 4.G)		

Method IPCC 2006 atmospheric flow approach.

Activity data	Emission factor (EF) and other parameters	Other assumptions or parameters for the estimated years
Production, imports and exports of sawnwood, wood panels, Paper and paperboard (FAO, 2024). Waste from wood, Paper and paperboard and waste from parks and gardens.	The unit conversion factors (density, carbon fraction and carbon factor) for i) roundwood, industrial roundwood, sawnwood, pulpwood, chips, particles, fuelwood, wood waste; ii) charcoal; iii) wood panels; iv) paper and paperboard, pulp, recycled fiber pulp and recycled paper were the IPCC (2006) *default* values.	

7.2.1 Representation of land use and land cover

This NIR uses as a basis the information produced in the inventory of the Fourth National Communication (Brasil, 2020; 2021), for the representation of land use and land cover and GHG estimates from 1990 to 2016, for which spatially explicit land-use and land-cover conversion data were used for the entire national territory.

In this spatial analysis, the entire country was subdivided into units in the form of polygons, which resulted from the cross-referencing of the following layers of information:

- Brazilian biomes, according to the official boundaries (IBGE, 2004).
- Official state and municipal boundaries 2016.
- Protected areas: Conservation Units (CUs) and Indigenous Lands (ILs) until 2016, according to the ICMBIO[70] – Chico Mendes Biodiversity Conservation Institute (Instituto Chico Mendes de Conservação da Biodiversidade) (2018) and FUNAI – National Indian Foundation (Fundação Nacional do Índio)[71] (2018) databases.
- Past natural vegetation (distribution of phytophysiognomies), according to the IBGE vegetation map (2017) adapted by the Brazilian Forest Service (Serviço Florestal Brasileiro, SFB) and Rede CLIMA – Brazilian Research Network on Global Climate Change (Rede Brasileira de Pesquisas sobre Mudanças Climáticas Globais).
- Soil-vegetation association, adapted from Bernoux *et al*. (2002).
- Maps of land use and land cover in 1994, 2002, 2005 (for the Amazon only), 2010 and 2016.

Based on the association of this information with the carbon stocks data, the loss or gain of carbon from land use and land-use and land-cover change was estimated and, with their sum, the emissions and removals of CO_2 were estimated for the periods accounted for. The information from the emissions and removals matrices by biome, disaggregated by land-use and land-cover class, was put together in single spreadsheets, whose data was aggregated by IPCC (2006) category (4.A – 4.C) and categories according to the respective phytophysiognomies (for further details, see Appendix A.VII.1).

Brazil has continental dimensions and has six biomes with great environmental, ecological and socio-economic diversity (Amazon, Cerrado, Atlantic Forest, Caatinga, Pampa and Pantanal) (Figure 7.3). The activity data and emission and removal factors were considered regionally by biome in order to better address their specificities.

[70] The Conservation Units database was provided by the responsible body (ICMBio) and the data was obtained on July 19 and 31, 2018 from http://mapas.mma.gov.br/mapas/aplic/probio/datadownload.htm?/dados/shape_file.

[71] The spatial data of the Indigenous Lands (ILs) was provided by FUNAI and obtained on July 19 and 31, 2018 from www.funai.gov.br/index.php/i3geo.

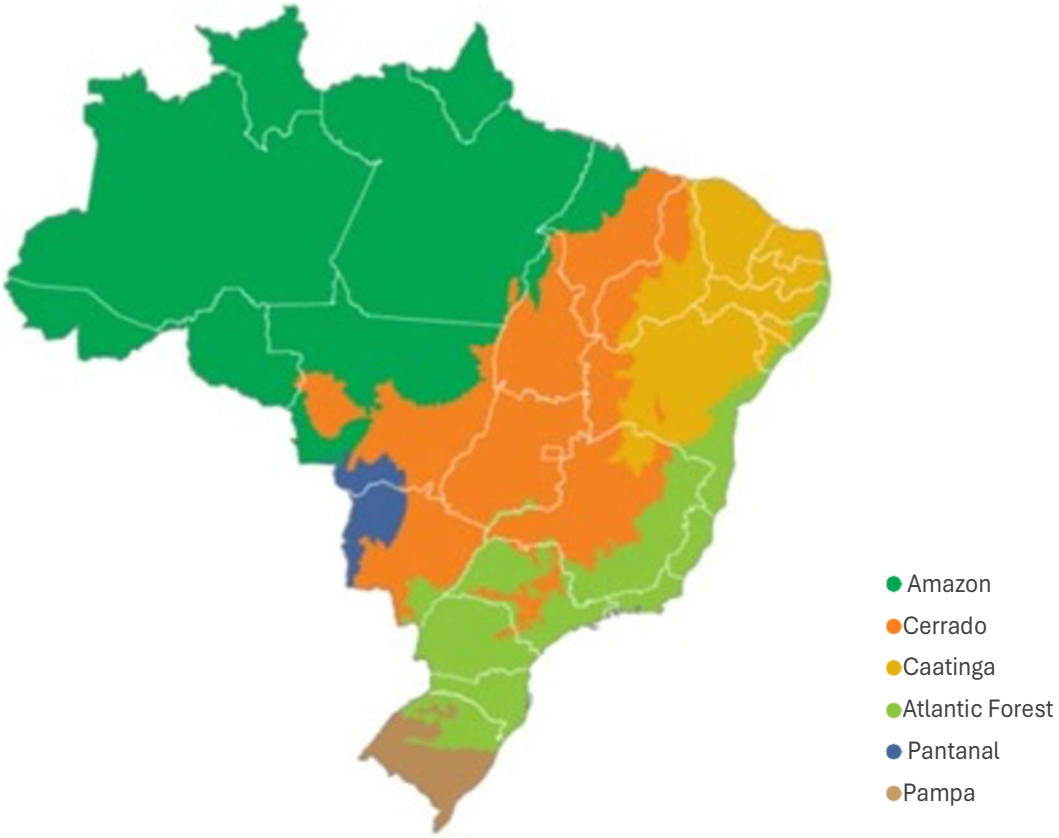


Figure 7.3. Distribution of Brazilian biomes in the national territory.

Source: IBGE (2004).

Brazil has a great variety of plant formations, with great biodiversity and structural complexity. The definition of phytophysiognomies followed the technical manual of Brazilian vegetation developed by the IBGE (IBGE, 2012). The phytophysiognomies were grouped, in terms of vegetation structure, into the categories of Forest Land, Grassland and Other Wooded Land (Dataframe 7.3), based on the past vegetation map (Figure 7.4).

The methodological details of the past vegetation map can be found in Appendix A.VII.2. This map was used as the basis for the past vegetation carbon stocks.[72] This classification was based on the Brazilian communication to the Global Forest Resources Assessment (FRA) (FAO, 2015), prepared by the Brazilian Forest Service with the aim of maintaining the consistency between the different Brazilian reports and adapting them to maintain the consistency with the classification proposed by the IPCC (IPCC, 2006). Although the vegetation structure category of Other Wooded Land is different from the Grassland category in the FRA (FAO, 2015), it has been included as Grassland, in accordance with the 2006 IPCC Guidelines.[73]

[72] The carbon stocks of the vegetation classes are shown in Appendix A.VII.3 (Tables A.VII.2 to A.VII.8).
[73] According to IPCC (2006), many shrub formations with a high proportion of perennial woody biomass can be considered as Grassland and countries may choose to include some or all of these formations in the Grassland category.

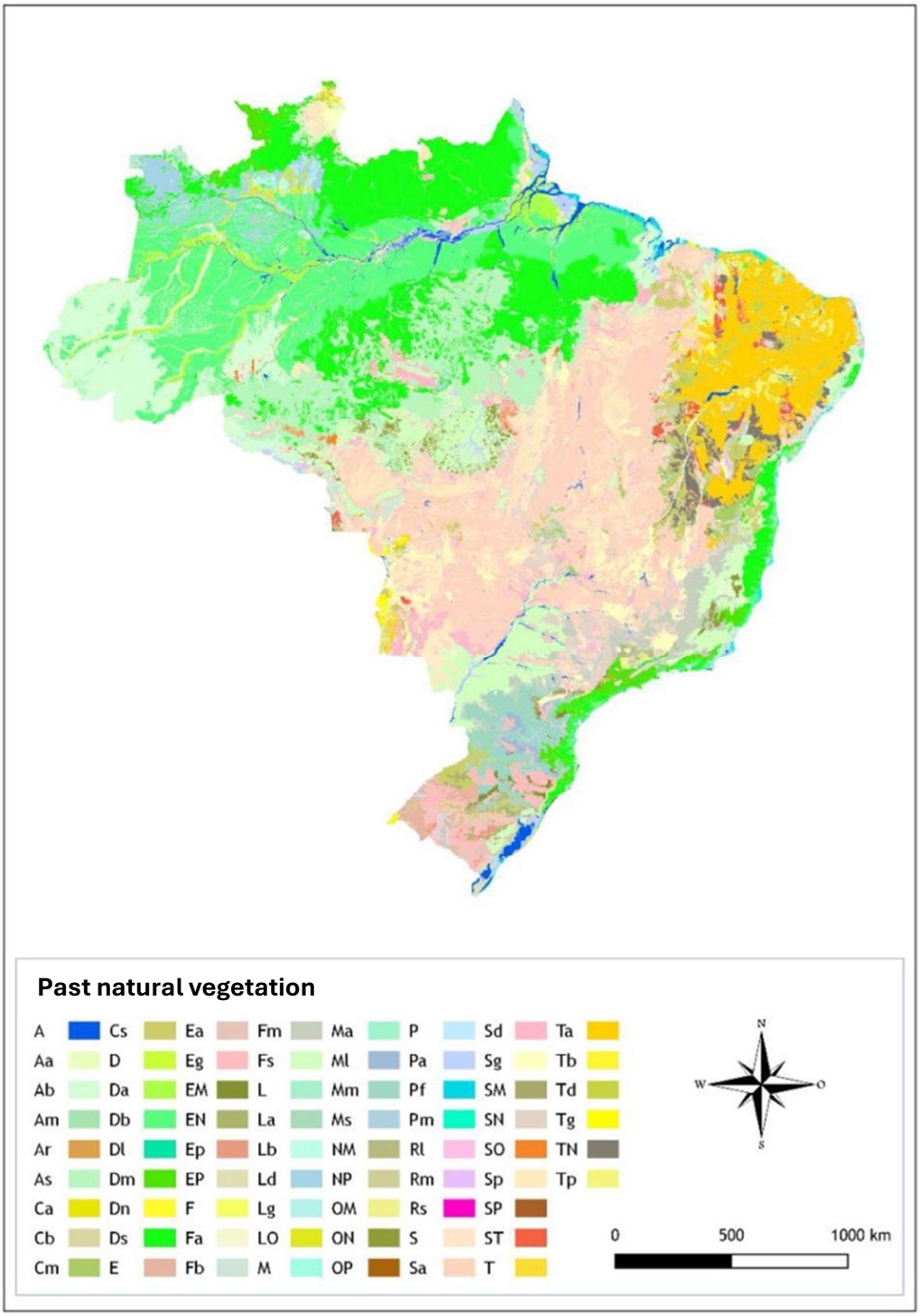


Figure 7.4. Map of Brazil's past natural vegetation. The acronyms are described in Dataframe 7.3 below.

Source: IBGE (2017), adapted by SFB – Brazilian Forest Service (Serviço Florestal Brasileiro) and Rede CLIMA – Brazilian Research Network on Global Climate Change (Rede Brasileira de Pesquisas sobre Mudanças Climáticas Globais). Note: Vegetação pretérita (Past vegetation).

Dataframe 7.3. Phytophysiognomies from the map of past natural vegetation and their correspondence with IPCC classes (2006).

IPCC CLASS	STRUCTURE	PHYTOPHYSIOGNOMY	ACRONYM
Forest Land (FL)	Forest Land	Open Ombrophilous Forest – Alluvial	Aa
		Open Ombrophilous Forest – Lowlands	Ab
		Open Ombrophilous Forest – Montane	Am
		Open Ombrophilous Forest – Submontane	As
		Seasonal Deciduous Forest – Alluvial	Ca
		Seasonal Deciduous Forest – Lowlands	Cb
		Seasonal Deciduous Forest – Montane	Cm
		Seasonal Deciduous Forest – Submontane	Cs
		Dense Ombrophilous Forest – Alluvial	Da
		Dense Ombrophilous Forest – Lowlands	Db
		Dense Ombrophilous Forest – Montane	Dm
		Dense Ombrophilous Forest – Submontane	Ds
		Steppe	E
		Steppe – Wooded	Ea
		Steppe/Formations Transition	EP
		Seasonal Semideciduous Forest – Alluvial	Fa
		Seasonal Semideciduous Forest – Lowlands	Fb
		Seasonal Semideciduous Forest – Montane	Fm
		Seasonal Semideciduous Forest – Submontane	Fs
		Campinarana	L
		Campinarana – Wooded	La
		Forested Campinarana	Ld
		Campinarana / Ombrophilous Forest Transition	LO
		Mixed Ombrophilous Forest – Alluvial	Ma
		Mixed Ombrophilous Forest – High Montane	Ml
		Mixed Ombrophilous Forest – Montane	Mm
		Mixed Ombrophilous Forest – Submontane	Ms
		Seasonal Forest/Mixed Ombrophilous Forest Transition	NM
		Seasonal Forest/Pioneer Formations Transition – Specific to Marine Influenced Pioneer Formation (Restinga (sandbank vegetation))	NP
		Dense Ombrophilous Forest / Mixed Ombrophilous Forest Transition	OM
		Ombrophilous Forest/Seasonal Forest Transition	ON
		Ombrophilous Forest/Pioneer Formations Transition – Specific to Marine Influenced Pioneer Formation (Restinga (sandbank vegetation))	OP
		Pioneer Formation Areas	P
		Fluviomarine Influenced Vegetation	Pf
		Marine Influenced Vegetation (Restinga (sandbank vegetation))	Pm
		Savannah	S
		Savannah – wooded	Sa
		Savannah – forested	Sd
		Savannah/Mixed Ombrophilous Forest Transition	SM
		Savannah/Seasonal Forest Transition	SN
		Savannah/Ombrophilous Forest Transition	SO

IPCC CLASS	STRUCTURE	PHYTOPHYSIOGNOMY	ACRONYM
		Savannah/Steppic Savannah Transition	ST
		Savannah/Steppic Savannan/Seasonal Forest Transition	STN
		Savannah/Steppic Savannah Transition	ST
		Steppic Savannah	T
		Steppic Savannah – wooded	Ta
		Steppic Savannah – forested	Td
		Steppic Savannan/Seasonal Forest Transition	TN
Grassland (G)	Grassland	Steppe – Grassy-Woody	Eg
		Steppe – Park	Ep
		Steppe/Mixed Ombrophilous Forest Transition	EM
		Steppe/Seasonal Forest Transition	EN
		Campinarana – Grassy-Woody	Lg
		Savannah – Grassy-Woody	Sg
		Steppic Savannah – Grassy-Woody	Tg
	Other Wooded Land	Campinarana – shrub	Lb
		Fluvial and/or Lacustrine Influenced Vegetation	Pa
		High Mountain Refuges	Rl
		Mountain Refuges	Rm
		Submontane Refuge	Rs
		Savannah – park	Sp
		Steppic Savannah – park	Tp
Other Land (O)	Other Land	Rock outcrops	Ar
		Dunes	Dn

Thus, the categories were divided according to the diversity of plant formations, Brazilian biomes and land use in the country, as shown in Dataframe 7.4. The Grassland subsector includes the natural formations of Grassland and Other Wooded Land, as well as Pastures.[74]

Dataframe 7.4. LULUCF sector categories according to the IPCC (IPCC, 2006[75]) and their divisions according to national specificities.

CATEGORIES (IPCC)	DIVISION OF CATEGORIES ACCORDING TO NATIONAL SPECIFICITIES	ACRONYMS
Forest Land	Managed Forest Land	MFL
	Unmanaged Forest Land	UFL
	Secondary forest	SecF
	Selective logging	SL
	Forest plantation	FP
Grassland	Managed grassland	MG
	Unmanaged grassland	UG

[74] The "Grassland" category includes pastures that are not considered cropland. It also includes systems with wooded vegetation and other non-grass vegetation, such as herbs and shrubs, which fall below the thresholds used in the Forest Land category. The category also includes all pastures, from natural pastures to recreational areas, as well as agricultural and silvopastoral systems, consistent with the national definitions" (IPCC 2006, v. 4, chap. 6, p. 6.3).
[75] IPCC (2006, v. 4, chap. 3).

CATEGORIES (IPCC)	DIVISION OF CATEGORIES ACCORDING TO NATIONAL SPECIFICITIES	ACRONYMS
	Secondary grassland	SecG
	Pasture	P
	Degraded pasture	DP
	Other managed wooded land	OMWL
	Other unmanaged wooded land	OUWL
	Other secondary wooded land	OSWL
Cropland	Annual Cropland	AC
	Perennial Cropland	PER
	Semi-perennial Cropland	SUGAR CANE
Wetlands	Water	W
	Reservoir	Res
Settlements	Settlements	S
Other land	Managed dunes	MD
	Unmanaged dunes	UD
	Managed rock outcrops	MRO
	Unmanaged rock outcrops	URO
	Mining	Min
	Bare soil	BS
	Areas not observed[76]	NO

Removals of CO_2 from primary vegetation that remains as primary vegetation were accounted for in Protected Areas (CUs and ILs). Box 7.2 presents the definition of protected areas adopted in Brazil, and describes the methodological procedures for accounting for them in this NIR, according to the total mapped area per biome during the preparation of the inventory of the Fourth National Communication.

[76] Clouds or shadows on satellite images.

Box 7.2. Definition of protected areas

Conservation Units (CUs) are "territorial spaces and their environmental resources, with relevant natural characteristics, which have the function of ensuring the representativeness of significant and ecologically viable samples of the different populations, habitats and ecosystems of the national territory and jurisdictional waters"[77] (resulting from the approval of Law nº 9,985/2000, which established the Brazilian System of Conservation Units – SNUC (Sistema Nacional de Unidades de Conservação)).

Indigenous Lands (ILs) are "a portion of the national territory, owned by the Federal Union, inhabited by one or more indigenous peoples, used by them for their productive activities, essential to the preservation of the environmental resources required for their well-being, and necessary for their physical and cultural reproduction, according to their habits, customs and traditions".

Methodological aspects

- The removals from Protected Areas were accounted for from their dates of creation (Table 7.1). Only areas classified as a Protected Area until 2016 were considered.
- The information and polygons for the CUs were provided by ICMBIO (2018).[78] Federal, state and municipal CUs were included (with the exception of Private Natural Heritage Reserves.
- The information and polygons for the ILs were provided by Funai (2018).[79] Some ILs had no date associated with any of the implementation phases (approximately 0.37% of the territorial extension of the protected areas) and, in these cases, even though the natural vegetation was classified as "managed", the removals of CO_2 were not accounted for. In any case, they were taken into account when calculating managed areas.
- The original base was adjusted in cases where there was an overlap between Protected Areas in order to avoid double counting. In these cases, the earliest date of creation and original delimitation was taken into account.

Table 7.1. Area of Conservation Units and Indigenous Lands created up to 1994 and in subsequent periods (2002, 2010 and 2016).

Biomes	Created until 1994	Created between 1995 and 2002	Created between 2006 and 2010	Created between 2011 and 2016
Amazon	93,442,923	141,734,221	202,314,334	212,165,968
	(22)	(34)	(48)	(50)
Cerrado	9,705,964	20,306,539	22,773,945	23,208,206
	(5)	(10)	(11)	(11)

[77] The Conservation Units database was provided by the responsible body (ICMBio) and the data was obtained on July 19 and 31, 2018 from the website. Available at: https://antigo.mma.gov.br/areas-protegidas/unidades-de-conservacao/o-que-sao.html. Accessed on May 7, 2024.
[78] The Conservation Units database was provided by the responsible body (ICMBio) and the data was obtained on July 19 and 31, 2018 from http://mapas.mma.gov.br/mapas/aplic/probio/datadownload.htm?/dados/shape_file.
[79] The spatial data of the Indigenous Lands (ILs) was provided by FUNAI. Available at: https://www.gov.br/funai/pt-br/atuacao/terras-indigenas/geoprocessamento-e-mapas. Accessed on: Jul. 05, 2024.

Atlantic Forest	5,053,003	7,656,443	8,931,858	9,586,251
	(5)	(7)	(8)	(9)
Caatinga	801,238	4,983,674	6,469,078	6,645,582
	(1)	(6)	(8)	(8)
Pampa	396,630	504,133	504,599	505,933

Note: The cumulative relative share (%) of protected areas in relation to the total area of each biome is in brackets.

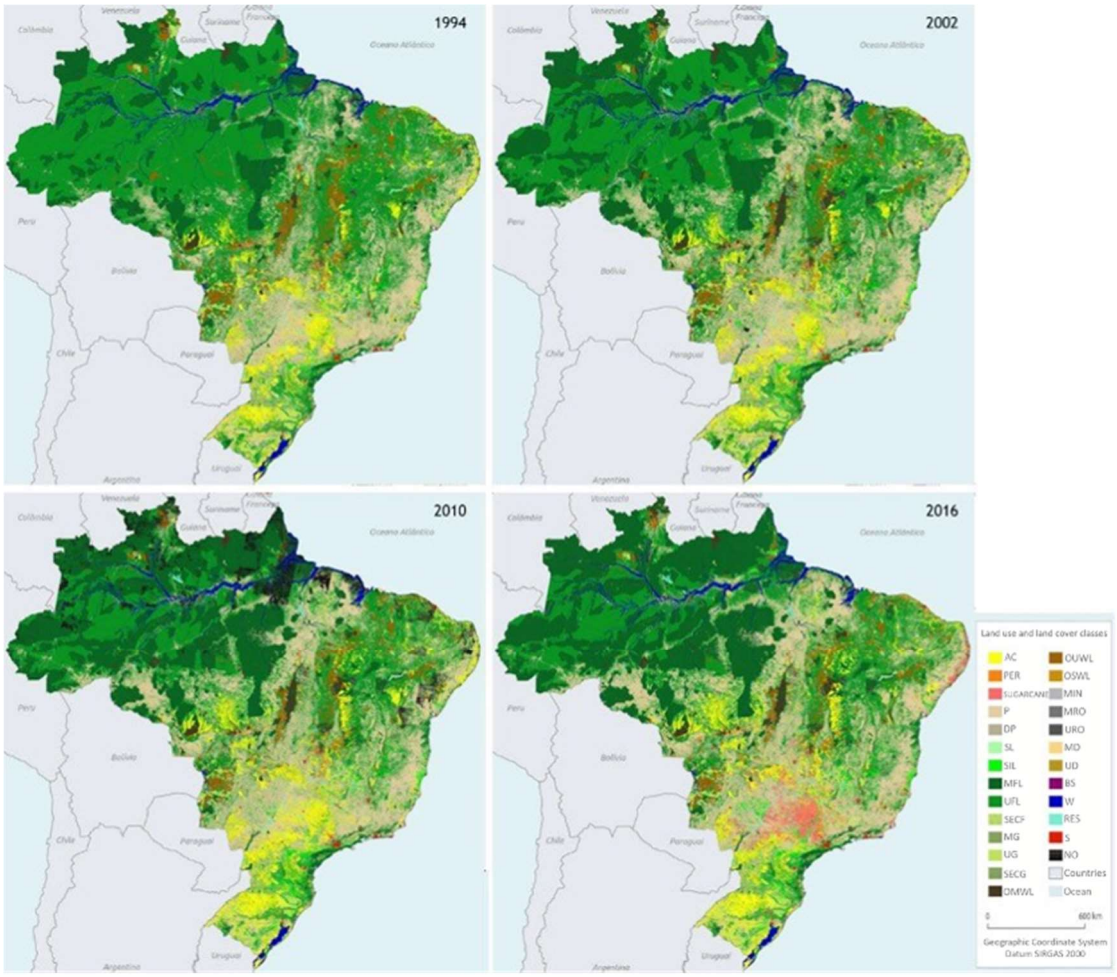
Secondary vegetation is associated with the process of natural regeneration or planting of native species/forest restoration. The determination of the growth patterns and dynamics of secondary vegetation areas is not well established for all Brazilian vegetation formations. Due to the impossibility of identifying the dynamics and growth time of these areas between the mapped years, only removals of CO_2 from land use and cover classes that have been converted to secondary vegetation were considered, i.e., removals from secondary vegetation that remains as secondary vegetation were not taken into account. Within the scope of this inventory, the Forest Plantation category relates to the commercial planting of exotic species.

7.2.2 Estimates between 1995 and 2016 based on the mapping of land use and land cover

The land-use and land-cover maps were produced during the preparation of the inventory of the Fourth National Communication, based on the visual interpretation of a mosaic of images of the national territory obtained via satellite (Appendix A.VII.1). Each homogeneous portion of the territory was manually vectorized and associated with one of the land-use categories/subcategories defined in Dataframe 7.4, generating land-use and land-cover maps for the assessed years.

The activity data for estimating the net emissions associated with land-use and land-cover conversion were produced based on spatially explicit data – IPCC Approach 3 (IPCC, 2006).[80] To that end, the entire country was mapped (by biome) based on visual interpretation of satellite images (TM/OLI sensors from the Landsat-5/8 satellite) for the years of 1994, 2002, 2010 and 2016 (Figure 7.5). Given the importance of the Amazon and the need to better understand transitions in use, especially the impacts of the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (Plano de Ação para Prevenção e Controle do Desmatamento na Amazônia, PPCDAm), which began in 2004, the mapping of this biome was also carried out for 2005.

[80] IPCC (2006, v. 4, chap. 3, p. 3.13).



Note: The acronyms are described in Dataframe 7.4.

Figure 7.5. Land-use and land-cover maps of Brazil for the years of 1994, 2002, 2010 and 2016.

In the inventory of the Fourth National Communication, the land-use and land-cover maps were combined with various layers of spatial information. This generated over 23 million polygons,[81] which resulted in land-use and land-cover conversion matrices for the periods of 1994-2002, 2002-2010 and 2010-2016.[82] Appendix A.VII.1 presents the methodological procedures adopted in the mapping.

The carbon stocks of the following pools were taken into account: Biomass (above and below ground), dead organic matter (litter and dead fallen and standing wood) and soil (soil organic carbon) (IPCC, 2006).[83] The amount of carbon in the biomass of each pool was calculated based on estimates of the carbon fraction of dry biomass obtained from

[81] Each polygon represented a land-use and land-cover conversion for the assessed periods.

[82] The land-use and land-cover conversion matrices consider the annual emissions after the first year of mapping and the annual emissions from the last mapping of each time interval. In other words, the 1994-2002 matrix considers the annual emissions from 1995 to 2002, the 2002-2010 matrix considers the annual emissions from 2003 to 2010, and so on. For the Amazon, transition matrices were also generated for the periods of 2002-2005 and 2005-2010. Brazil's land-use and land-cover matrices for the periods of 1994-2002, 2002-2010 and 2010-2016 can be found in Appendix A.VII.3 (Tables A.VII.9 to A.VII.11). The other transition matrices for land use and land cover and for emissions/removals for Brazil and its biomes are available at: http://www.ccst.inpe.br/cn/.

[83] IPCC (2006, v. 4, chap. 1, p. 1.9, Table 1.1).

literature for Brazil's data and IPCC default values (IPCC, 2006) (Dataframe 7.5). Estimates were made for all vegetation classes and by biome.

Dataframe 7.5. Carbon content in dry biomass used for different vegetation pools and structure classes.

POOL	FOREST LAND/OTHER WOODED LAND	SOURCE	GRASSLAND	SOURCE
AGB	0.47	IPCC (2006, v. 4, chap. 4, p. 4.48, tab. 4.3); Ometto *et al*., 2006	0.47	IPCC (2006, v. 4, chap. 4, p. 6.29)
BGB	0.47	IPCC (2006, v. 4, chap. 4, p. 4.48, tab. 4.3)	0.47	IPCC (2006, v. 4, chap. 4, p. 4.48, Tab. 4.3)
DW	0.47	IPCC (2006, v. 4, chap. 4, p. 4.48, tab. 4.3)	0.50	IPCC (2006, v. 4, chap. 6, p. 6.11)
Litter	0.46	Ometto *et al*., 2006	0.40	IPCC (2006, v. 4, chap. 6, p. 6.11)

Note: AGB = above-ground biomass, BGB = below-ground biomass, DW = dead wood.

Carbon emission and removal factors were associated with each land-use and land-cover class (Tables A.VII.8, A.VII.12 and A.VII.13, Appendix A.VII.3). Values published in scientific articles and national data for each biome were prioritized (Tier 2), adopting the IPCC default factors (IPCC, 2006) only when national information was not available (Tier 1).

Based on this set of information, CO_2 emissions and removals from land use and land cover were estimated for each category and subcategory, according to the methodology proposed by the IPCC (IPCC, 2006),[84] with equations adapted to the national circumstances.

According to the accounting methodology used in the national inventory, a carbon balance is taken of a given area at two timepoints (stock-difference method) (IPCC, 2006).[85] For example, when a Forest Land is converted into Cropland, it is initially considered that all its carbon is emitted (gross emissions) and, at the final timepoint, when carbon is also found in the vegetation of the new use (removals). The difference between these initial and final carbon stocks corresponds to the net emissions from the vegetation in this area, plus the net emissions from the soil (Table A.VII.14, Appendix A.VII.3).

7.2.2.1 Soil organic carbon

Net soil carbon emissions were based on the soil organic carbon (SOC) stock for each vegetation class and emission and removal factors.[86] The gain or loss of SOC resulting from the change in land use and land cover that occurs over 20 years, the period established for a category to be finally classified as another one, was considered (IPCC, 2006). The estimates were based on Equation 2.25 of the IPCC (2006),[87] adapted in the equation below

[84] IPCC (2006, v. 4, chap. 2).
[85] IPCC (2006, v. 4, chap. 2).
[86] Emissions and removals from mineral soils and organic soils from LULUCF have not been disaggregated.
[87] IPCC (2006, v. 4, chap. 2, p. 2.30).

to take into account the period between the mappings of the national inventory (referring to the variable "T").

Dataframe 7.6. Equations for estimating net emissions due to changes in soil carbon.

Equations	Description	Central equation	Reference
Equation 7.1	Net carbon emissions from the soil	$SE_i = A_i \times C_{soil} \times [f_c(t_0) - f_c(t_f)] \times {}^{(T/2)}/_{20}$	Adapted from Equation 2.25 (IPCC 2006, v. 4, chap. 2)
Equation 7.2	Soil carbon change factors	$f_c(t) = f_{lU} \times f_{MG} \times f_I$	Adapted from Equation 2.25 (IPCC 2006, v. 4, chap. 2)

In which:

SE_i= net emission associated with polygon i in the period T due to the change in soil carbon (t C);
A_i=polygon area i (ha);
C_{soil} = soil organic carbon under the polygon's soil-vegetation association (reference carbon);
$f_c(t)$ = soil carbon change factor at the timepoint t (dimensionless);
T = number of years of the period evaluated in the inventory (years);
f_{lU}= stock change factor due to land-use type or land-use change;
f_{MG} = stock change factor due to management regime; and
f_I = stock change factor due to the addition of organic matter.

Soil carbon stock

The average SOC stock was estimated using the soil-vegetation association methodology, adapted from Bernoux *et al*. (2002), based on the following steps: i) adaptation of the soil map of Brazil (Embrapa – Brazilian Agricultural Research Corporation (Empresa Brasileira de Pesquisa Agropecuária), 2003) at a scale of 1:5,000,000; ii) adaptation of the vegetation map of Brazil (IBGE, 2004) at a scale of 1:5,000,000; and iii) generation of the soil-vegetation association map.

Firstly, the 69 classes included in the 18 orders of the Brazilian Soil Classification System (Embrapa, 2003) were reclassified according to the protocol proposed by the IPCC (2006), which takes into account soil texture, base saturation and moisture. The details of this class association are presented in Bernoux *et al*. (2002). These classes were regrouped into six major soil class groups: (S1) Soils with high-activity clay; (S2) Latosols with low-activity clay; (S3) Non-Latosols with low-activity clay; (S4) Sandy soils; (S5) Hydromorphic soils; and (S6) Other soils (Figure A.VII.26, Appendix A.VII.3). The vegetation classes were grouped into 15 categories, taking into account the main vegetation groups, their phytophysiognomy and/or geographical location (Bernoux *et al.*, 2002) (Figure A.VII.27, Appendix A.VII.3).

For each association between soil class and vegetation, carbon stock estimates were established up to a depth of 30 cm (Figure 7.6 and Table A.VII.15, Appendix A.VII.3).

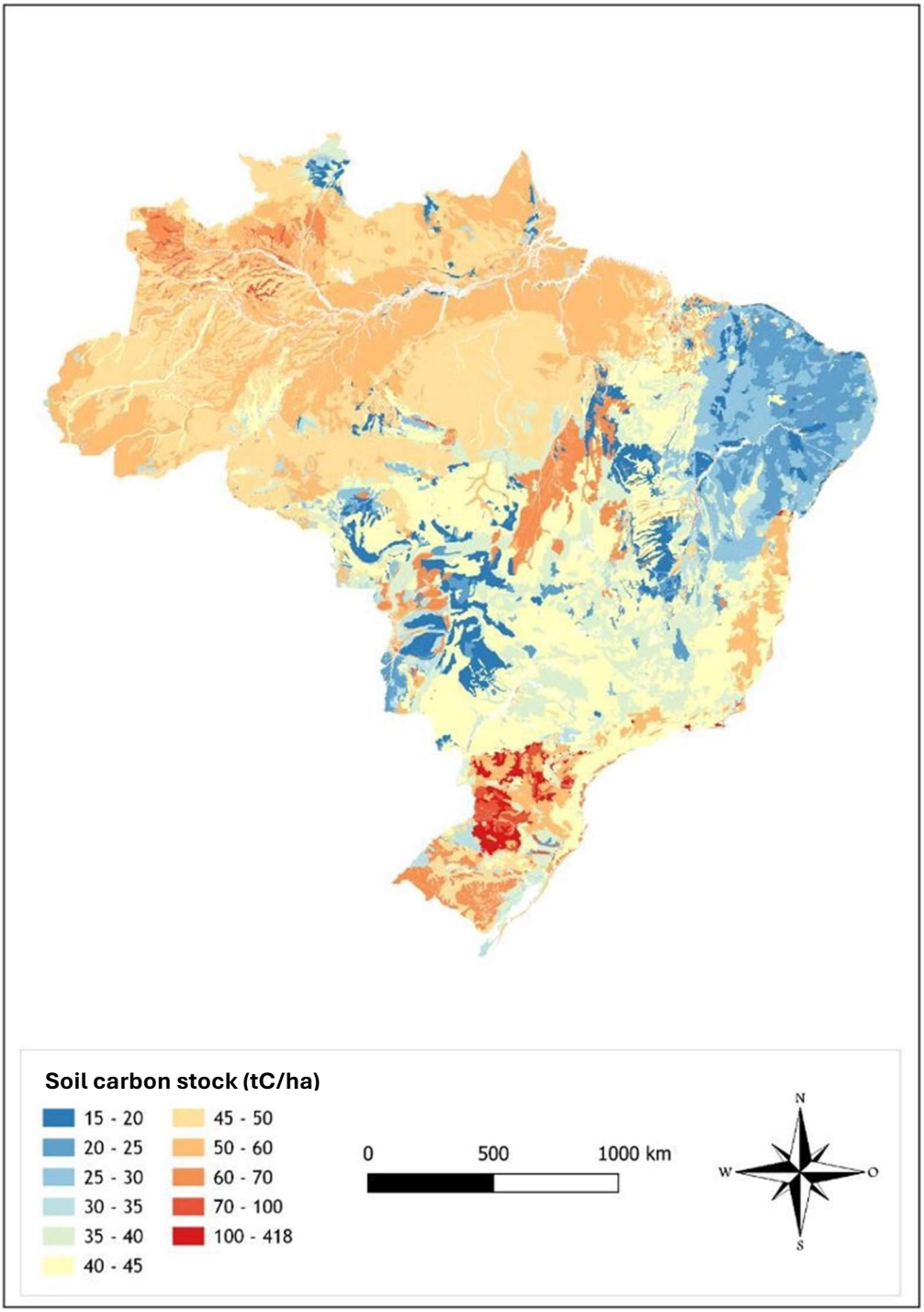


Figure 7.6. Carbon stocks in Brazil's soils, adapted from Bernoux *et al*. (2002).

Soil organic carbon change factors

To quantify the change in SOC, the IPCC (2006) suggests using change factors depending on land use or land management for the layer of 0-30 cm depth and a 20-year conversion period. The carbon change factors due to land use (f_{lU}), management system (f_{MG}) and additions (f_I) (Table A.VII.16, Appendix A.VII.3) were selected based on the values suggested by the IPCC (2006) and on consultation with experts (Brasil, 2010). A linear mixed regression model, described in Box 7.3, which includes fixed and random effects (Pinheiro; Bates, 2000), was used to calculate the SOC stock change factors associated with the different types of crops and pastures.

Box 7.3. Calculation of soil carbon stock change factors

A mixed regression model was used to calculate the SOC stock change factors.

The response variable for the different management systems was the proportion of the average SOC stock of a given land-use system (conventional tillage, no-till and pasture), divided by the average SOC stock of the previous use (native vegetation).

The random effects variables were municipalities and farms. The types of soils and biomes were treated as indicator variables, also known as "dummy" (categorical) variables. Some studies had data from multiple sites (farms) and were treated as separate data points in the statistical analysis (Pinheiro; Bates, 2000; Ogle *et al.*, 2005). The fixed effects variables were: types of soil, mineralogy, sampling depth, time of land-use change and management system.

To calculate the SOC change factors based on the change of native vegetation to different pasture conditions (Table A.VII.17 and Table A.VII.18, Appendix A.VII.3), 582 records were used, from 50 scientific articles and 12 theses.

Soil mineralogy was based on the classification proposed by the IPCC (IPCC, 2006):

i) Soils with a high clay content (HAC);
ii) Soils with a low clay content (LAC);
iii) Soils with > 70% sand content and < 8% clay content (Sandy soils).

The inclusion of studies with different depths in the data set was carried out according to the procedure proposed by Ogle *et al.* (2004). Two regression models (X_1 and X_2) were generated from the upper and lower values of the increment of a soil layer, based on a quadratic function (assuming that impacts are greater at the surface and decrease with depth in the profile). The average SOC stock ratio for a single increment was an integral of the upper to lower depth of the quadratic function divided by the thickness of the increment. The quadratic function was integrated by increasing the depth, using the following equations for the variables X_1 and X_2.

$$X_1 = \frac{L^2 - U^2}{2 \times (L - U)} \qquad X_2 = \frac{L^3 - U^3}{3 \times (L - U)}$$

Where: L (cm) represents the lower depth of the increment and U (cm) the upper depth. Uncertainties were estimated by predicting the standard deviation of the value of each SOC stock change factor. Adjustments were made to SOC stocks - including cases of soil density change following conversion from native vegetation to different management systems – using the equivalent soil mass approach, according to the procedure proposed by Sisti *et al*. (2004).

The soil carbon change factors were weighted for natural and planted pastures in good and poor condition, by FU/state and biome, based on IBGE data, since the land-use and land-cover maps only made it possible to identify degraded pastures in the Cerrado and Amazon biomes.

The determination of SOC change factors in cropland considered the different planting systems (conventional tillage or no-till) by biome. In order to apply them, the factors were weighted by FU/state, based on data from IBGE (2018d; 2018e) (Table A.VII.19 and Table A.VII.20, Appendix A.VII.3), since it was not possible to obtain them from the land-use and land-cover maps).

7.2.3 Emissions estimates for the period from 1990-1994

Since the mapping prior to 1994 had methodological assumptions that were different from the Fourth National Communication inventory, adjustments and recalculations had to be made to estimate emissions and removals from 1990 to 1994, based on weightings from the inventories of Brazil's Initial Communication (Brasil, 2004) and the Fourth National Communication (Brasil, 2020; 2021), in order to maintain the consistency in the time series of this Inventory. The updates are described below (Dataframe 7.7).

Dataframe 7.7. Methodological specificities of the inventory of Brazil's Initial Communication and procedures for calculating the estimates for 1990-1994.

METHODOLOGICAL SPECIFICITES OF THE INVENTORY OF BRAZIL'S INITIAL COMMUNICATION
Mapping • The Amazon, Cerrado and Caatinga biomes were analyzed by sampling, according to the degree of anthropism. The Atlantic Forest and Pantanal biomes were analyzed in their entirety. • Only areas converted from natural formations to other uses (without detailing the end use) and regeneration areas (with the exception of the Caatinga biome) were identified.
Removals • The Initial Inventory did not include CO_2 removals from managed (protected) natural formations, which was taken into account from the Second National Communication Inventory onwards.
Forest plantation • The forest plantation calculation methodology considered the increase in the area of planted forest per year, of eucalyptus and pine, and estimated the annual carbon increase considering the years of the logging cycle.
Soil emissions • The methodology used to estimate annual CO_2 emissions for changes in land-use and management practices and organic soils was different from the subsequent inventories.
Methodological procedure for weighting of the emissions from 1990-1994

METHODOLOGICAL SPECIFICITES OF THE INVENTORY OF BRAZIL'S INITIAL COMMUNICATION

Biomass carbon stock of past natural vegetation

- The stocks were updated by biome, considering the average carbon stock. In the Initial Inventory, total carbon emissions and respective areas were considered. In this inventory, the carbon stocks were weighted by the representative area of each phytophysiognomy on the map of past natural vegetation.

Gross CO_2 emissions by land-use and land-cover transition

- Gross emissions were corrected according to the change in carbon stock from the inventory of the Initial Communication, per biome. For the Pampa, which had not been analyzed, the annual average for the following period (1994 to 2002) was taken into account. For the Amazon, the inventory of the Initial Communication estimated annual net emissions based on the change in the biome's deforestation rates. To maintain consistency with the methodology applied in the inventory, only gross emissions were modulated; the simple average was maintained for the other biomes.

Removals from vegetation:

- The removal factors were updated, based on the variation in the average removal rates from the inventory of the Initial Communication, to the factors applied from the inventory of the Fourth National Communication onwards.
- The removal factors were estimated by a weighted average according to the different transitions to secondary vegetation (SecF, SecG and OSWL), with the appropriate removal rates for each transition, from the land-use and land-cover transition matrices for the period of 1994-2002.
- For the Caatinga and Pampa biomes, the annual removals from the subsequent period (1994-2002) calculated in the inventory of the Fourth National Communication were used directly. The simple averages of removals for all biomes were maintained.
- The removals from forest plantation for 1990-1994, calculated in the Initial Inventory, were disregarded in the inventories of the Second and Third National Communications. These estimates were again taken into account from the inventory of the Fourth National Communication onwards. The distribution of these removals was divided proportionally between the biomes, according to their gross emissions.

Removals from protected areas:

- The removals from protected natural formations from 1990-1994 were calculated from the date of creation of the CUs and ILs.

Soil emissions:

- The annual estimates obtained for the period of 1994-2002 were used.

7.2.4 Annualization of emission and removal estimates

The mapping of land use and land cover makes it possible to estimate emissions and removals only per period assessed. This sector's gross CO_2 emissions are mainly associated with the suppression of natural vegetation (Table 7.2). For this reason, secondary data on annual deforestation by biome was used as a proxy to annually distribute the gross CO_2 emissions estimated per assessed period. The sum of the annualization rates for a given period is exactly the number of years in that period (for example, between 1994 and 2002, the sum of the annualization rates for the period will be 8 years). The method was based on annualization rates per biome, based on Equations 7.3 and 7.4.

Dataframe 7.8. Equations for estimating gross annual CO_2 emissions, based on the emissions per period.

Equations	Description	Notes	Central equations	Reference
Equation 7.3	Annualization rate	Based on annual deforestation	$\mathrm{AR}_{\text{year i period j}} = \frac{\mathrm{AD}_{\text{year i}}}{\overline{\mathrm{AD}}_{\text{period j}}}$	Brasil (2022)
Equation 7.4	Annual gross CO_2 emissions	Based on the annualization rate	$\mathrm{E}_{\text{year i}_{\text{period j}}} = \mathrm{AR}_{\text{year i}_{\text{period j}}} \times \overline{\mathrm{E}}_{\text{period j}}$	Brasil (2022)

In which:

$\mathrm{AR}_{\text{year i period j}}$ = annualization rate (AR) for year i in period j for the biome (dimensionless);
$\mathrm{AD}_{\text{year i}}$ = area deforested (AD) in year i in the biome (km^2);
$\overline{\mathrm{AD}}_{\text{period j}}$ = arithmetic average of the area deforested (AD) in period j for the biome (km^2);
$\mathrm{E}_{\text{year i}_{\text{period j}}}$ = annual gross CO_2 emission for year i in the biome (kt); and
$\overline{\mathrm{E}}_{\text{period j}}$= arithmetic average of gross CO_2 emissions in period j for the biome (kt).

The annualization of gross CO_2 emissions for the years in which there was no annual deforestation data was obtained from the arithmetic average of the emissions for each assessed period. For the soil pool, the estimates of net emissions and removals were distributed equally for each year of the periods.

The removals from vegetation were distributed equally for each year of the period, with the exception of those from protected vegetation,[88] since they could be annualized based on the creation dates of the CUs and ILs. Thus, for cases where the vegetation remained protected throughout the period,[89] removals were distributed equally each year. In cases where areas became protected during the period,[90] removals were counted from the year of creation of the CUs and ILs.[91]

The annual emissions of non-CO_2 gases were estimated based on the gross annual emissions of CO_2 and according to the annual values for fuelwood and roundwood harvesting in Brazil (IBGE, 2024).

[88] Represented by the Managed Forest Land (MFL), Managed Grassland (MG) and Other Managed Wooded Land (OMWL) classes.
[89] In the conversion matrices, they are represented by MFL-MFL, MG-MG and OMWL-OMWL.
[90] In the conversion matrices, they are represented by UFL-MFL and OUWL-OMWL.
[91] The increase in recorded removals is related to the creation of new CUs and ILs over time.

Table 7.2. Values for annual deforestation (AD) by biome and annualization rates (AR) used to estimate annual gross CO_2 emissions between 1990 and 2016.

Year	Legal Amazon[92]		Cerrado		Caatinga		Atlantic Forest		Pantanal		Pampa	
	AD (km^2 $year^{-1}$)	AR	AD (km^2 $year^{-1}$)	AR	AD (km^2 $year^{-1}$)	AR	AD (km^2 $year^{-1}$)	AR	AD (km^2 $year^{-1}$)	AR	AD (km^2 $year^{-1}$)	AR
1990	13,730	1.00	-	-	-	-	1,073	-	-	-	-	-
1991	11,030	0.81	-	-	-	-	1,001	1.00	-	-	-	-
1992	13,786	1.01	-	-	-	-	1,001	1.00	-	-	-	-
1993	14,896	1.09	-	-	-	-	1,001	1.00	-	-	-	-
1994	14,896	1.09	-	-	-	-	1,001	1.00	-	-	-	-
1995	29,059	1.52	-	-	-	-	1,001	1.30	-	-	-	-
1996	18,161	0.95	-	-	-	-	892	1.16	-	-	-	-
1997	13,227	0.69	-	-	-	-	892	1.16	-	-	-	-
1998	17,383	0.91	-	-	-	-	892	1.16	-	-	-	-
1999	17,259	0.90	-	-	-	-	892	1.16	-	-	-	-
2000	18,226	0.95	-	-	-	-	892	1.16	-	-	-	-
2001	18,165	0.95	26,933	-	-	-	350	0.45	-	-	-	-
2002	21,650	1.13	26,933	-	-	-	350	0.45	-	-	-	-
2003	25,396	1.06	28,767	1.67	2,762	1.13	350	1.17	563	1.019	366	1.00
2004	27,772	1.15	28,767	1.67	2,762	1.13	350	1.17	563	1.019	366	1.00
2005	19,014	0.79	16,879	0.98	2,762	1.13	350	1.17	563	1.019	366	1.00
2006	14,286	1.34	16,879	0.98	2,762	1.13	343	1.15	563	1.019	366	1.00
2007	11,651	1.09	13,314	0.77	2,762	1.13	343	1.15	563	1.019	366	1.00

[92] The "Legal Amazon" concept is part of the Amazon Economic Enhancement Plan. The Legal Amazon, whose delimitation was defined by Law No. 5,173 of October 27, 1966, covers the region comprised of the states of Acre, Pará and Amazonas, the Federal Territories of Amapá, Roraima and Rondônia, as well as the areas of the state of Mato Grosso north of the16th parallel, the state of Goiás north of the 13th parallel, and the state of Maranhão west of the 44th meridian.

Year	Legal Amazon[92]		Cerrado		Caatinga		Atlantic Forest		Pantanal		Pampa	
	AD (km^2 $year^{-1}$)	AR	AD (km^2 $year^{-1}$)	AR	AD (km^2 $year^{-1}$)	AR	AD (km^2 $year^{-1}$)	AR	AD (km^2 $year^{-1}$)	AR	AD (km^2 $year^{-1}$)	AR
2008	12,911	1.21	13,314	0.77	2,762	1.13	343	1.15	563	1.019	366	1.00
2009	7,464	0.70	9,910	0.58	1,921	0.78	152	0.51	522	0.944	331	0.90
2010	7,000	0.66	9,910	0.58	1,134	0.46	152	0.51	522	0.944	415	1.13
2011	6,418	1.07	8,976	0.88	494	-	141	0.67	380	0.840	329	-
2012	4,571	0.76	8,976	0.88	-	-	220	1.05	380	0.840	-	-
2013	5,891	0.98	13,482	1.33	-	-	239	1.14	439	0.971	-	-
2014	5,012	0.84	10,904	1.07	-	-	183	0.87	439	0.971	-	-
2015	6,207	1.03	11,129	1.10	-	-	184	0.88	538	1.189	-	-
2016	7,893	1.32	7,497	0.74	-	-	291	1.39	538	1.189	-	-

Note:

- Hyphens represent the years for which there is no deforestation data.
- Deforestation data for the Legal Amazon was used for the Amazon biome. Prodes only accounts for deforestation of forest vegetation by clearcut logging in the Legal Amazon. Although the program considers a different threshold, the same values were used for the calculations of the previous Inventory (BRASIL, 2022), since the area covered by forest vegetation is similar to that of the Amazon biome.
- For the Amazon and Cerrado biomes, for which Prodes data was used, the mapping reporting period corresponds to August 1st (of the previous year) to July 31st (of the reported year).
- For the Atlantic Forest biome, the area deforested within the limits of the Atlantic Forest Law (BRASIL, 2006) was considered.

Source: Based on Amazon and Cerrado (INPE, 2024a; 2024b), Atlantic Forest (SOS Atlantic Forest Foundation and INPE, 2023), Pantanal (SOS Pantanal, 2020), Caatinga and Pampa (MMA, 2012).

7.2.5 Emissions estimates for the period from 2017-2022

Gross CO_2 emissions

Greenhouse gas emissions from the LULUCF sector are related to the dynamics of land use and land cover, mainly related to deforestation. The latest mapping of land use and land cover covers the year of 2016. For this reason, gross CO_2 emissions from 2017 onwards were estimated using the surrogate data method (IPCC, 2006),[93] based on the annual deforestation rates available by biome and annualization rates (Equations 7.5 and 7.6). For biomes for which no deforestation data was available, gross CO_2 emissions were replicated referring to the last year with deforestation data available. Thus, the gross CO_2 emission values for 2011 for the Caatinga and Pampa biomes, and for 2019 for the Pantanal biome, were replicated for the years from 2017 to 2022, and a procedure similar to that applied in the previous Inventory (BRASIL, 2022) was adopted. On the other hand, CO_2 removals from vegetation, as well as net emissions from soil, were kept constant from 2017 to 2022 in relation to the values obtained in 2016.

The results of annual emissions and removals by biome (estimated based on annual deforestation data) were broken down by land-use and land-cover class. They were, then, aggregated by IPCC category (categories 4.A – 4C) and subcategories, according to their respective phytophysiognomies.

Dataframe 7.9. Equations for estimating annual gross CO_2 emissions from 2017 to 2022, based on annual deforestation rates.

Equations	Description	Central equations	Reference
Equation 7.5	Surrogate data method	$\mathrm{ARe}_{\mathrm{year\ i}} = \frac{\mathrm{AD}_{\mathrm{year\ i}}}{\mathrm{AD}_{\mathrm{year\ i-1}}}$	Adapted from Equation 5.2 (IPCC, 2006, v. 1, p. 5.10)
Equation 7.6	Surrogate data method	$\mathrm{E}_{\mathrm{year\ i}} = \mathrm{AR}_{\mathrm{year\ i}} \times \mathrm{E}_{\mathrm{year\ i-1}}$	Adapted from Equation 5.2 (IPCC, 2006, v. 1, p. 5.10)

In which:

$\mathrm{ARe}_{\mathrm{year\ i\ period\ j}}$ = annualization rate (AR) for extrapolating emissions to year i (dimensionless) of the biome;
$\mathrm{AD}_{\mathrm{year\ i}}$ = area deforested (AD) in year i in the biome (km^2);
$\mathrm{AD}_{\mathrm{year\ i-1}}$= area deforested (AD) in the year immediately prior to year i in the biome (km^2);
$\mathrm{E}_{\mathrm{year\ i}}$ = annual gross CO_2 emission extrapolated to year i for each category in the biome (kt); and
$\mathrm{E}_{\mathrm{year\ i-1}}$= annual gross CO_2 emission estimated for the year immediately prior to year i for each biome category in the biome (kt).

[93] IPCC (2006, v. 1, chap. 5, p. 5.10).

Table 7.3. Values for annual deforestation (AD) by biome and annualization rates (AR) used to estimate gross annual CO_2 emissions between 2017 and 2022.

Year	Unit	2017	2018	2019	2020	2021	2022
Legal Amazon	AD (km^2 $year^{-1}$)	6,947	7,536	10,129	10,851	13,038	11,594
	Are	0.88	1.08	1.34	1.07	1.20	0.89
Cerrado	AD (km^2 $year^{-1}$)	7,117	7,260	6,319	7,905	8,531	10,689
	Are	0.95	1.02	0.87	1.25	1.08	1.25
Caatinga	AD (km^2 $year^{-1}$)	-	-	-	-	-	-
	Are	-	-	-	-	-	-
Atlantic Forest	AD (km^2 $year^{-1}$)	126	114	144	131	216	201
	Are	0.43	0.91	1.26	0.91	1.66	0.93
Pantanal	AD (km^2 $year^{-1}$)	533	446	263	-	-	-
	Are	0.991	0.837	0.591	-	-	-
Pampa	AD (km^2 $year^{-1}$)	-	-	-	-	-	-
	Are	-	-	-	-	-	-

Source: Based on Amazon and Cerrado (INPE, 2024a; 2024b), Atlantic Forest (SOS Atlantic Forest Foundation and INPE, 2023), Pantanal (SOS Pantanal, 2020), Caatinga and Pampa (MMA, 2012).

Note:

- Hyphens represent the years for which there is no deforestation data.
- Deforestation data for the Legal Amazon was used for the Amazon biome. Prodes only accounts for deforestation of forest vegetation by clearcut logging in the Legal Amazon. Although the program considers a different threshold, the same values were used for the calculations of Annual Estimates, since the area covered by forest vegetation is similar to that of the Amazon biome.
- For the Amazon and Cerrado biomes, for which Prodes data was used, the mapping corresponds to the one reported from August 1st (of the previous year) to July 31st (of the reported year).
- For the Atlantic Forest biome, the area deforested within the limits of the Atlantic Forest Law (Brasil, 2006) was considered. For 2018, the images were selected mainly in the second half of the year. For 2019 to 2022, images were selected mainly in the second half of the year, with October as the reference month.
- In the case of the Pantanal biome, monitoring uses the *Sentinel* 2 satellite, which is the reference basis for mapping. The first step was to select images from May to September with less cloud cover in order to create the 2018 and 2019 mosaics.

Net CO_2 emissions from soil

Emissions and removals from transitions that change the soil organic carbon stock in all biomes between 2017 and 2022 were estimated by repeating the value from the last year assessed (2016) in the Fourth National Communication inventory.

CO_2 removals

As the number of protected areas was identical to that considered in the inventory of the Fourth National Communication (which covered the period from 1990 to 2016), removals

from CUs or ILs created between 2017 and 2022 were not taken into account. Thus, removals of preserved vegetation in protected areas created until 2016 were fully considered.

Harvested Wood Products

Emissions from Harvested Wood Products were based on updated data from FAOSTAT – Food and Agriculture Organization Statistics (FAO, 2024) and the fixed value (from 2016) was maintained for variable 1B for the years from 2017 to 2022, due to the unavailability of updated data. The methodology used for this subsector will be described in Section 7.9.

Net CO_2 emissions

As emissões líquidas anuais do setor foram obtidas por meio da soma das emissões brutas The sector's annual net emissions were obtained through the sum of gross emissions from vegetation, net emissions from soil, and removals, both from vegetation and from harvested wood products.

Non-CO_2 gas emissions

Emissions of non-CO_2 gases were estimated using the same method and data source used to estimate emissions from 1990 to 2016. Data on annual gross CO_2 emissions estimated for the period from 2017 to 2022 and updated values for fuelwood and roundwood harvesting from IBGE (IBGE, 2024) were used.

Aggregation of estimates by biome for IPCC categories

The results of annual emissions and removals by biome (estimated based on annual deforestation data) were aggregated by land-use and land-cover class and, then, by IPCC category (4.A – 4C) and subcategories.

7.2.6 Estimates of non-CO_2 gases

The estimation of non-CO_2 gases (CH_4, N_2O, CO and NO_x) is associated with the burning of vegetation. When natural vegetation is converted to anthropogenic use, part of the original biomass is removed in the form of commercial timber for different purposes. The area is, then, usually burnt, leading to emissions of non-CO_2gases. Thus, estimates for these gases were based on the conversion of natural vegetation to anthropogenic use.[94]

As mentioned in section 7.2, non-CO_2 gas emissions from fires in which land-use and land-cover class conversions occurred were estimated. Monitoring the dynamics of fires over the inventoried years is not simple, as it requires access to satellite images on a more regular basis, as well as specific scientific data on vegetation growth rates. Furthermore, differentiating between natural fires and those caused by anthropogenic factors is not easy.

The estimate of emissions of non-CO_2 gases was based on Equation 2.27 of the IPCC (2006)[95] (Equation 7.7). The biomass left in the field for burning was estimated based on the difference between the biomass[96] of the original vegetation in the deforested area and the

[94] Non-CO_2 gas emissions from the Cropland Remaining Cropland category (4.B.1) have been included in the Field Burning of Agricultural Residues subsector (3.F) of the Agriculture sector.
[95] IPCC (2006, v. 4, chap. 2).
[96] For non-CO_2 gases, the biomass of the original vegetation was estimated based on the gross annual emissions, applying conversion factors from CO_2 eq to carbon (3.667) and from carbon to biomass (0.47).

biomass of the wood (fuelwood and roundwood) harvested in Brazil (IBGE, 2024).[97] The amount of fuelwood and roundwood produced during wood harvesting was converted from stereo cubic meters to dry biomass, based on the basic wood density (0.631 t dry biomass/solid cubic meter)[98] and on the conversion factor from stereo cubic meters to solid cubic meters (0.6141 solid m^3/stereo m^3).[99]

Dataframe 7.10. Equation for estimating non-CO_2 gas emissions from the burning of biomass left in the field.

Equations	Description	Central equations	Reference
Equation 7.7	Estimate of non-CO_2 gas emissions from fire	$L_{fire} = A \times M_B \times C_f \times G_{ef} \times 10^{-3}$	Equation 2.27 (IPCC, 2006, v.4, p. 2.42)

In which:

L_{fire} = greenhouse gas emissions from fire (t of gas);
A = area burnt (ha);
M_B = mass of fuel available for combustion (t ha^{-1}). This includes the biomass of litter and dead wood;
C_f= combustion factor (dimensionless); and
G_{ef}= emission factor (g kg^{-1}).

The combustion factors (by vegetation class and biome) (Table 7.4) and the emission factors (Table 7.5) suggested by the IPCC (2006)[100] were used. CO_2 emissions from burning were not taken into account, since these emissions are already considered in the land-use and land-cover conversion process.

Table 7.4. Combustion factors and references, by biome and vegetation category.

Biome	Category	Value (Dimensionless)	Phytophysiognomies assessed	References
Amazon	FL	0.368	Da, Db, Ds, Aa, Ab, As, Cs, Fa, Fb, Fs, Pa, Sd, Td, Sa, La	Ward *et al.*, 1992; Kauffman *et al.*, 1995; Araujo *et al.*, 1999; Fearnside *et al.*, 1993; 1999; 2001; Carvalho Jr *et al.*, 1995; 1998; 2001; Graça *et al.*, 1999; Balch *et al.*, 2008; Castro; Kauffman, 1998
	G	0.771	Sg, Tg, Lg, Rm	Barbosa; Fearnside, 2005 – Average Sg, Sp, Tg, Tp

[97] Data available in Table 289 (Amount produced and value of production in wood harvesting, by type of harvested wood product) at: https://sidra.ibge.gov.br/tabela/289. As the data is for the whole of Brazil, the amount was distributed proportionally to the conversion of vegetation (from Forest Land, Grassland and Other Wooded Land) in each biome.
[98] Average obtained from various studies (Barbosa; Fearnside, 2004; Nogueira *et al.*, 2007; Barbosa; Ferreira, 2004; Nogueira; Fearnside, 2008; Moreira; Moutinho, 2018; Silveira *et al.*, 2013).
[99] Average obtained from various studies (Scolforo *et al.*, 2004; Batista; Couto, 2002; Paiva, 2019; Batista; Couto, 2002).
[100] IPCC (2006, v. 4, chap. 2, p. 2.47, Table 2.5).

Biome	Category	Value (Dimensionless)	Phytophysiognomies assessed	References
	OWL	0.539	Sp, Tp, Lb	Barbosa; Fearnside, 2005
Cerrado	FL	0.379	Dm, Ds, Aa, Ab, As, Cm, Cs, Fa, Fb, Fs, Fm, Pa, Pm, Sd, Td, Sa, Ta	Ward *et al.*, 1992; Kauffman *et al.*, 1995; Araujo *et al.*, 1999; Fearnside *et al.*, 1993; 1999; 2001; Carvalho Jr *et al.*, 1995; 1998; 2001; Graça *et al.*, 1999; Balch *et al.*, 2008; Castro; Kauffman, 1998; Balch *et al.*, 2008
	G	0.920	Sg, Tg	Castro; Kauffman, 1998 – Average clean and dirty field
	OWL	0.840	Sp, Tp	Castro; Kauffman, 1998
Atlantic Forest	FL	0.368	Same as Amazon	Same as Amazon- tropical humid forests
	G	0.920	Same as Cerrado	Same as Cerrado
	OWL	0.539	Same as Amazon	Same as Amazon
Caatinga	FL	0.383	Cm, Cs, Fm, Fs, Pa, Sd, Td, Sa, Ta	Castro; Kauffman, 1998
	G	0.840	Same as Other wooded land	Castro; Kauffman, 1998
	OWL	0.840	Same as Cerrado	Castro; Kauffman, 1998
Pampa	FL	0.368	Same as Amazon	Same as Amazon- tropical humid forests
	G	0.944	Eg	Fidelis *et al.*, 2010
	OWL	0.539	Same as Amazon	Same as Amazon
Pantanal	FL	0.379	Same as Cerrado	Same as Cerrado
	G	0.920	Same as Cerrado	Same as Cerrado
	OWL	0.840	Same as Cerrado	Same as Cerrado

Note: FL = Forest Land; G = Grassland; OWL= Other Wooded Land. The acronyms for the vegetation classes are described in Dataframe 7.4.

Table 7.5. Non-CO_2 gas emission factors by category.

Gas	Forest Land	Grassland and Other Wooded Land
	Value (kg/t dry biomass burnt)	
CO	104	65
CH_4	6.8	2
N_2O	0.2	0
NO_x	1.6	4

Source: Based on IPCC (2006).[101]

7.3 Forest Land (CRT 4.A)

This subsector is based on the Food and Agriculture Organization of the United Nations (FAO) concept of forest land, which defines forest land as a minimum area of 0.5 hectares

[101] IPCC (2006, v. 4, chap. 2).

with a canopy above 5 m in height and a canopy cover of 10% or more, or trees capable of reaching these limits *in situ*, not including areas predominantly used for agricultural or urban purposes (FAO, 2012). Both natural and planted forests are considered.

The Forest Land subsector (4.A) is divided into the categories of Forest Land Remaining Forest Land (4.A.1) and Land Converted to Forest Land (4.A.2), which take into account national subdivisions (Dataframe 7.11). CO_2 emissions and removals are linked to the loss or gain of carbon through land use and land-use and land-cover change for all pools. Emissions of CH_4 and N_2O, on the other hand, are associated with the process of converting natural vegetation to forest plantation.

Dataframe 7.11. National subdivision of the Forest Land subsector (4.A).

CATEGORY	DESCRIPTION
Managed Forest Land (MFL)	A natural forest, where human action has not caused significant changes in its characteristics, classified based on the map of past natural vegetation, also with regard to its phytophysiognomy. It is in a protected area (CU or IL) and, therefore, has its CO_2 removals accounted for, based on a scientific survey, when it remains in the same category during the assessed periods.
Unmanaged Forest Land (UFL)	A natural forest, where human action has not caused significant changes in its characteristics, classified based on the map of past natural vegetation, also with regard to its phytophysiognomy. Emissions and removals are only accounted for when there is conversion to anthropogenic use. CO_2 removals are not accounted for when it remains in the same category during the assessed periods.
Secondary Forest (SecF)	Classified based on the map of past natural vegetation and resulting from a process of natural regeneration associated with previous anthropogenic use, for example, crop cultivation or pasture.
Selective Logging (SL)	Identified only in the Amazon biome, it consists of the removal of trees in native forests, which can be associated with the practice of sustainable forest management, regulated and authorized by the competent bodies, as well as the practice of predatory selective logging, which consists of the unsustainable exploration of wood over time and without authorization from the competent bodies.
Forest plantation (FP)	Monoculture planted forests, most of which are made up of exotic species. In the case of Brazil, there is a predominance of *Eucalyptus* spp. and *Pinus* spp, but there are also rubber and teak plantations.

In 2022, the Forest Land subsector (4.A) had a net removal of -312,125 kt CO_2 eq, while in 2020 it was -326,825 kt CO_2 eq. In 2022, net removals from the Forest Land Remaining Forest Land category (4.A.1) (-285,009 kt CO_2 eq) accounted for 91% of net removals in 2022, while the Land Converted to Forest Land category (4.A.2) accounted for 9% (-27,116 kt CO_2 eq) (Figure 7.7).

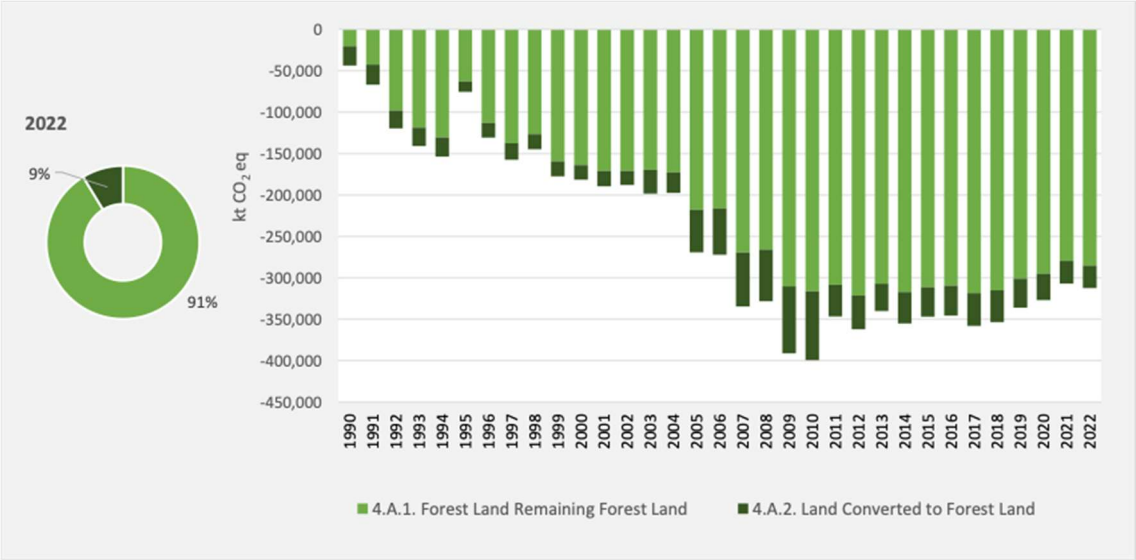


Figure 7.7. Net removals from the Forest Land subsector categories (4.A), in kt CO_2 eq, from 1990 to 2022.

7.3.1 Methodological aspects

CO_2 emissions and removals are the result of the loss or gain of carbon due to changes in land use and land cover, for all pools. CH_4 and N_2O emissions, on the other hand, are associated with the conversion process of converting natural vegetation to forest plantation.

The carbon stocks of natural forests were estimated by forest phytophysiognomy and biome (Table A.VII.2 to Table A.VII.7, Appendix A.VII.3). The factors associated with the emission/removal of CO_2 from natural forests, forests subject to selective logging and forest plantation are shown in Tables A.VII.8, A.VII.12 and A.VII.13 (Appendix A.VII.3), respectively.

Forest plantation

Carbon stocks and carbon gains values from forest plantation in Brazil were adopted for *Eucalyptus* spp., *Pinus* spp. and black wattle (*Acacia mearnsii*) given their economic importance and the availability of information on these species.

The land-use and land-cover maps do not differentiate between the species planted per forest plantation area. Thus, the spatial distribution was based on secondary data, by state. Firstly, a search was carried out on the areas of planted forests for the years of 1994, 2002, 2005 and 2010 on different sources of information (technical reports, yearbooks and other documents). No significant differences were found in the areas of planted forests previously reported in the inventory of the Third National Communication (Brasil, 2016). For this reason, the same values for areas of planted forests were used (Table 7.6).

Table 7.6. Area of planted forests planted with eucalyptus and pine in Brazil used as the basis for the years of 1994, 2002, 2005 and 2010.

Species	Area planted in 1994 (ha)	Area planted in 2002 (ha)	Area planted in 2005 (ha)	Area planted in 2010 (ha)
Eucalyptus	148,004 (87)	1,144,188 (74)	3,462,719 (65)	4,754,334 (73)
Pine	23,067 (13)	392,464 (26)	1,831,485 (35)	1,756,359 (27)
Total	**171,071**	**1,536,652**	**5,294,204**	**6,510,693**

Note: The values in parentheses represent the percentage of area planted with each species.

Source: 1994 (BRASIL, 2004), 2002 (Brasil, 2016), 2005 (ABRAF – Brazilian Association of Planted Forest Producers (Associação Brasileira de Produtores de Florestas Plantadas), 2012) and 2010 (ABRAF, 2011).

This inventory used updated eucalyptus and pine forest plantation data from the inventory of the Fourth National Communication for 2016 (Table 7.7), as well as for the other main species used in forest plantation in Brazil (Table 7.8). The data used here are from the report by the Brazilian Tree Industry (IBA, Indústria Brasileira de Árvores) (IBA, 2017), which shows the areas of planted forests for 15 states in Brazil.

The methodology adopted by IBA was the same for all states and is based on: i) questionnaires answered by companies and state associations affiliated to IBA; ii) official documents and data from government institutions and autonomous entities, such as state departments, institutes, foundations and universities; and iii) contact with companies in the planted tree production chain that are not affiliated to IBA.

Table 7.7. Forest plantation area for all Federative Units (FU)/States in 2016.

FU/State	Area planted (ha)		
	Eucalyptus	Pine	**Total**
Amapá	65,026 (100)	0	**65,026**
Bahia	612,199 (99)	3,301 (1)	**615,500**
Espírito Santo	233,760 (99)	2,500 (1)	**236,260**
Goiás	127,201 (94)	8,500 (6)	**135,701**
Maranhão	221,859 (100)	0	**221,859**
Mato Grosso	185,219 (100)	0	**185,219**
Mato Grosso do Sul	877,795 (99)	5,852 (1)	**883,647**
Minas Gerais	1,390,032 (97)	36,764 (3)	**1,426,796**
Pará	133,996 (100)	0	**133,996**
Paraná	294,050 (30)	672,607 (70)	**966,657**
Piauí	26,068 (100)	0	**26,068**
Rio Grande do Sul	308,178 (63)	184,595 (37)	**492,773**
Santa Catarina	116,240 (18)	545,835 (82)	**662,075**
São Paulo	946,124 (88)	124,179 (12)	**1,070,303**
Tocantins	116,798 (100)	200 (0.0)	**116,998**
Other FUs/States	19,239 (100)	0	**19,239**
Total	5,673,784	1,584,333	**7,258,117**

Source: IBA (2017). The values in parentheses represent the percentage of area planted with each species in the FU/state.

Table 7.8. Total area planted with other species in 2016 in Brazil.

Species	Area planted (ha)
Rubber	229,964 (39)
Acacia	159,877 (27)
Teak	87,502 (15)
Parica	90,047 (15)
Araucaria	11,114 (2)
Populus	4,216 (1)
Other	6,641 (1)
Total	**589,361**

Note: The values in parentheses represent the percentage of area planted with each species.

Source: IBA (2017).

To estimate the carbon from planted forests, the IPCC (2006) equation was used, which suggests using the average productivity of forests in volume as the basis for calculating carbon. In this case, the average annual carbon increase in the biomass of planted forests ($\Delta C_G Ref$) was based on IPCC equation 2.10 (IPCC, 2006),[102] which suggests using the average productivity of forests in volume as the basis for calculating carbon (Equations 7.8 and 7.9).

Dataframe 7.12. Equations for estimating CO_2 stocks and removals in areas of Planted Forest.

Equations	Description	Central equations	Reference
Equation 7.8	Average biomass increase	$G_W = I_V \times D \times BEF$	Adapted from Equation 2.10 (IPCC, 2006, v. 4, chap. 2)
Equation 7.9	Annual carbon increase	$\Delta C_G Ref = G_W \times 0.47 \times (1 + R)$	Adapted from Equation 2.10 (IPCC, 2006, v. 4, chap. 2)
Equation 7.10	Average carbon stock in Planted Forests	$C_{Ref} = \Delta C_G Ref \times {}^{T}/_{2}$	Brasil (2015)

In which:

G_W = annual average increase in above-ground biomass (t dry mass ha^{-1} year^{-1});
I_V = average annual net increase in volume, suitable for industrial processing (m^3 ha^{-1} year^{-1});
D= basic wood density (t dry mass m^3);
BEF = biomass expansion factor for converting the average annual net increment (in volume, m^3 ha^{-1}) to above-ground tree biomass increment (t ha^{-1}) (dimensionless);
$\Delta C_G Ref$ = annual increment previously calculated for each of the two species (t C ha^{-1} year^{-1});
R = root biomass/aerial biomass ratio for each specific species (dimensionless).
C_{Ref} = average carbon stock of planted forests (t C ha^{-1});
$\Delta C_G Ref$ = annual increment previously calculated for each of the two species (t C ha^{-1} year^{-1}); and

[102] IPCC (2006, v. 4, chap. 2, p. 2.15).

T = planting cycle time (year). For the eucalyptus and black wattle plantations it was considered to be a 7-year cycle, and for pine, a 15-year cycle (IBA, 2016).

In this NIR, data collected as part of the Fourth National Communication inventory was used to calculate the average annual carbon increase of the planted forest areas. The parameters of average annual net increment (I_V), basic density (D), root ratio (R) and carbon content are shown in Table 7.9.

Table 7.9. Parameters used to calculate the average annual carbon increase of eucalyptus and pine planted forest areas.

Parameter	Year	Eucalyptus[1]	Pine[1]	Black wattle
Average annual net increment - I_V (m^3 ha^{-1} $year^{-1}$)	1994	28.33[1]	26.25[1]	20.7[6]
	2002	41[2]	36[2]	23.63[7]
	2005	36.7[3]	30.7[3]	23.6
	2010	34.5[4]	33.5[4]	23.6
	2016	35.7[5]	30.5[5]	23.6
Basic density – D (t dry matter m^3)	All	0.425[1]	0.385[1]	0.623[8]
Biomass Expansion Factor – BEF (dimensionless)	All	1.2[1]	1.25[1]	1.8[9]
Root ratio – R (dimensionless)	All	0.35[1]	0.35[1]	0.12[10]
Carbon content (%)	All	0.47[11]	0.47[11]	0.47[11]

Source: Based on [1] Brasil (2004); [2] Brasil (2004); [3] ABRAF (2011); [4] IBA (2016); [5] IBA (2017); [6] Mora (2002); [7] Mochiutti (2007); [8] Gonzaga *et al.* (1982); Schneider *et al.* (2005); Hillig *et al.* (2002); Martinez (2006); [9] Mochiutti (2007); [10] Schumacher *et al.* (2001); Saidelles *et al.* (2009); [11] IPCC (2006).

Based on the $\Delta C_G Ref$ value for each species, the average carbon stock accumulated by the forest plantation in the species cycle was estimated using equation 7.10 (Brasil, 2015, p. 192). The stock was calculated as an average of the cycle ($^{T}/_{2}$) because, as explained above, it is not possible to identify the exact year of planting between the two points in time referring to the years actually mapped for the purposes of the Inventory. The value of the carbon stock from forest plantation (C_{Ref}) of the species over the years, used for the calculations by FU/state, can be seen in Table 7.10.

Table 7.10. Average annual carbon increment ($\Delta C_G Ref$) and average carbon stock (C_{Ref}) values for eucalyptus, pine and black wattle forest plantation for the years of 1994, 2002, 2005, 2010 and 2016.

Years	Eucalyptus		Pine		Black wattle	
	$\Delta C_G Ref$ (t C ha^{-1} year^{-1})	C_{Ref} (t C ha^{-1})	$\Delta C_G Ref$ (t C ha^{-1} year^{-1})	C_{Ref} (t C ha^{-1})	$\Delta C_G Ref$ (t C ha^{-1} year^{-1})	C_{Ref} (t C ha^{-1})
1994	9.17	32.09	8.02	60.12	5.40	18.92
2002	11.91	41.68	9.01	67.56	6.17	21.58
2005	11.16	39.07	10.23	76.72	6.17	21.58
2010	11.16	39.07	10.23	76.72	6.17	21.58
2016	11.55	40.43	9.31	69.85	6.17	21.58

The $\Delta C_G Ref$ and C_{Ref} values for each species were multiplied by the fraction of the planted species area in the FU/state. For 1994, a single value was used for all FUs/states, as statistics on the area of planted forest were not available by FU/state (Table A.VII.13, Appendix A.VII.3). It should be noted that the carbon stock of black wattle was only estimated for the state of Rio Grande do Sul (RS), since this species is only grown commercially in that state.

For Forest plantation remaining as Forest plantation (FP-FP), the value was considered to be nil, i.e., the carbon that is stored in the form of harvested wood products was not accounted for. For more methodological details regarding the estimates, see Section 7.2.

7.4 Cropland (CRT 4.B)

The Cropland subsector (4.B) comprises areas cultivated with temporary, perennial or semi-perennial crops. Also included in this category is land that is left fallow before being cultivated again. This subsector includes the categories of Cropland Remaining Cropland (4.B.1) and Land Converted to Cropland (4.B.2).

Dataframe 7.13. National subdivision of the Cropland subsector (4.B).

CATEGORY	DESCRIPTION
Annual Cropland (AC)	Areas used for crops with an annual production cycle, which culminates in the death of the plant after the harvest. This category includes areas for horticulture and the cultivation of soybeans, rice, beans, corn, cotton, tubers, etc.
Perennial Cropland (PER)	Areas intended for crops that produce over several years, without the need for new planting after harvest. Perennial crops include trees and shrubs, represented mainly by fruit trees, such as citrus, bananas, coconuts, coffee, among others.
Semi-perennial Cropland (SUGARCANE)	In Brazil, this type of crop is represented by sugar cane, which is harvested several times before being planted again. Semi-perennial crops can produce for a period of between five and six years, depending on the cutting management.

The Cropland subsector (4.B) accounted for a net emission of 184,499 kt CO_2 eq in 2022, while in 2020 it was 157,403 kt CO_2 eq (Figure 7.14). In 2022, the subcategories of Forest Land Converted to Cropland (4.B.2.a) and Grassland Converted to Cropland (4.B.2.b) accounted for 108,725 kt CO_2 eq and 75,776 kt CO_2 eq, respectively, of the net emissions from this category. The subcategory of Other Land Converted to Cropland (4.B.2.e) contributed with a removal of -0.8 kt CO_2 eq (Figure 7.8).

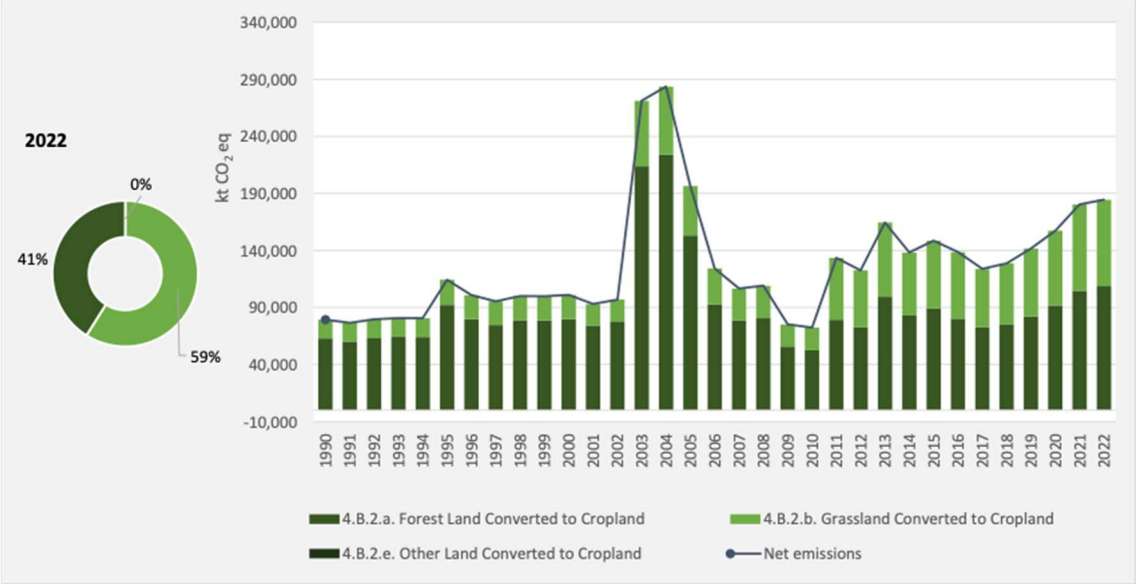


Figure 7.8. Net emissions and removals from the subcategories of the Land Converted to Cropland category (4.B.2) from the Cropland subsector (4.B), in kt CO_2 eq, from 1990 to 2022.

7.4.1 Methodological aspects

Emissions and removals of CO_2 result from the loss or gain of carbon due to changes in land use and land cover, for all pools, while emissions of CH_4 and N_2O are associated with the process of converting natural vegetation to Cropland. The carbon stocks of the natural vegetation classes for each biome are shown in Tables A.VII.2 to A.VII.7 in Appendix A.VII.3.

For the spatialization of the carbon stocks of crops for 1994, 2002, 2005 (only for the Amazon biome) and 2010, we used the proportions, by FU/states, obtained from the daa made available by the IBGE (IBGE, 2018a; IBGE, 2018b). These proportions were multiplied by the emission factors shown in Table A.VII.8 of Appendix A.VII.3. For 2016, this step was not necessary because there was a mapping for the types of crops – annual, semi-perennial and perennial. The final values applied by FU/state are presented for the Amazon biome (Table 7.11) and other biomes (Table 7.12). As the different crops were mapped in 2016, the calculation of the carbon increment between 2010 and 2016 was based on the factors presented in Table A.VII.8 and on the equations shown in Table A.VII.14 of Appendix A.VII.3.

For more methodological details regarding the estimates, see Section 7.2.

Table 7.11. Carbon stock in cropland (CAc) and carbon-stock gain in cropland (ΔCGAc) for the Amazon biome states.

FU/State	CAc 1994 (t C/ha)	CAc 2002 (t C/ha)	CAc 2005 (t C/ha)	CAc 2010 (t C/ha)	ΔCGAc 1994-2002 (t C/ha)	ΔCGAc 2002-2005 (t C/ha)	ΔCGAc 2005-2010 (t C/ha)
Acre	6.52	6.88	6.83	6.75	0.49	0.17	0.25
Amazonas	7.31	7.52	7.30	7.39	0.94	0.30	0.53
Amapá	6.64	6.76	6.77	6.80	0.41	0.16	0.27
Maranhão	6.28	6.30	6.29	6.29	0.09	0.03	0.05
Mato Grosso	6.29	6.25	6.22	6.21	0.05	0.01	0.01
Pará	7.24	7.24	7.14	7.44	0.74	0.25	0.55
Rondônia	7.52	8.71	8.08	7.74	1.77	0.50	0.69
Roraima	6.66	6.73	6.73	7.08	0.39	0.15	0.39
Tocantins	6.40	6.30	6.23	6.22	0.08	0.01	0.02

Table 7.12. Carbon stock in cropland (CAc) and carbon-stock gain in cropland (ΔCGAc) for the Federative Units (FUs/States) in the Cerrado, Atlantic Forest, Caatinga, Pantanal and Pampa biomes.

Biome FU/state	CAc 1994 (t C/ha)	CAc 2002 (t C/ha)	CAc 2010 (t C/ha)	ΔCGAc 1994-2002 (t C/ha)	ΔCGAc 2002-2010 (t C/ha)
Cerrado Biome					
Bahia	9.70	9.68	9.55	3.04	2.96
Federal District	5.77	5.63	5.34	0.41	0.22
Goiás	5.16	5.18	5.14	0.12	0.09
Maranhão	5.31	5.38	5.34	0.25	0.22
Minas Gerais	8.52	9.57	8.75	2.97	2.44
Mato Grosso do Sul	5.05	5.06	5.03	0.04	0.02
Mato Grosso	5.35	5.20	5.09	0.13	0.06
Pará	8.28	8.26	8.90	2.12	2.53
Piauí	7.73	7.62	7.24	1.70	1.46
Paraná	5.48	5.42	5.29	0.27	0.19
Rondônia	9.14	12.79	9.82	5.06	3.14
São Paulo	7.95	7.77	7.09	1.80	1.36
Tocantins	5.67	5.37	5.14	0.24	0.09
Atlantic Forest Biome					
Alagoas	0.64	4.54	4.61	0.19	0.21
Bahia	6.91	9.59	9.44	1.53	1.49
Espírito Santo	15.31	19.63	19.41	4.20	4.15
Goiás	0.23	4.06	4.00	0.06	0.05
Minas Gerais	5.18	9.46	8.45	1.50	1.23
Mato Grosso do Sul	0.07	3.90	3.86	0.02	0.01
Paraíba	2.62	5.70	6.32	0.50	0.66
Pernambuco	1.32	5.28	5.54	0.38	0.45
Paraná	0.70	4.34	4.19	0.14	0.09

Biome FU/state	CAc 1994 (t C/ha)	CAc 2002 (t C/ha)	CAc 2010 (t C/ha)	ΔCGAc 1994-2002 (t C/ha)	ΔCGAc 2002-2010 (t C/ha)
Rio de Janeiro	5.53	8.21	8.40	1.17	1.21
Rio Grande do Norte	6.32	10.39	12.78	1.75	2.38
Rio Grande do Sul	0.47	4.28	4.26	0.12	0.11
Santa Catarina	0.66	4.68	4.73	0.23	0.24
Sergipe	6.34	10.17	8.76	1.69	1.31
São Paulo	4.33	7.23	6.40	0.91	0.68
Caatinga Biome					
Alagoas	1.22	1.43	1.52	0.20	0.22
Bahia	7.68	7.65	7.46	1.60	1.56
Ceará	5.77	6.32	7.68	1.30	1.61
Maranhão	1.03	1.14	1.08	0.13	0.12
Minas Gerais	5.89	7.49	6.25	1.57	1.29
Paraíba	3.26	2.86	3.62	0.52	0.69
Pernambuco	1.92	2.34	2.66	0.40	0.47
Piauí	4.70	4.53	3.96	0.90	0.77
Rio Grande do Norte	7.07	8.63	11.57	1.83	2.49
Sergipe	7.10	8.36	6.62	1.76	1.37
Pantanal Biome					
Mato Grosso do Sul	5.05	5.06	5.03	0.04	0.02
Mato Grosso	5.35	5.20	5.09	0.13	0.06
Pampa Biome					
Rio Grande do Sul	5.32	5.37	5.35	0.24	0.23

7.5 Grassland (CRT 4.C)

The Grassland subsector (4.C) includes natural grasslands, natural and planted pastures, and Other Wooded Land. Grassland is characterized by areas with predominantly herbaceous and shrubby vegetation, where sunlight falls directly on the ground or lower strata, since there is no dense canopy in these environments (IBGE, 2012). The inclusion of Other Wooded Land in this subsector took into account the definition used in the FAO's Forest Resources Assessment (FRA) (2015), which classifies forests as formations that do not fall under the Forest Land subsector, covering more than 0.5 hectares with trees higher than 5 meters and with a canopy cover of 5 to 10%, or with trees capable of reaching these limits, or with a combined cover of shrubs and trees of more than 10%.

This subsector is divided into the Grassland Remaining Grassland (4.C.1) and Land Converted to Grassland (4.C.2) categories. CO_2 emissions and removals are linked to the loss or gain of carbon due to changes in land use and land cover, including soil management, for all pools (living matter above and below ground, dead organic matter, and soil). Degraded Pastures (DP) were mapped in 2016, but CO_2 removals were only accounted for areas converted from uses other than pasture to well-managed pastures, for the entire time series, based on soil organic carbon change factors weighted by pasture quality. With

regard to emissions of CH_4 and N_2O, these are specifically linked to the process of converting natural vegetation to pasture.

Dataframe 7.14. National subdivision of the Grassland subsector.

CATEGORY	DESCRIPTION
Managed Grassland (MG)	Natural grassland, where human action has not caused significant changes to its characteristics, classified based on the previous natural vegetation map. It is in a protected area (CU or IL) and, therefore, has its CO_2 removals accounted for when it remains with the same cover during the assessed periods.
Unmanaged Grassland (UG)	Natural grassland, where human action has not caused significant changes to its characteristics, classified based on the previous natural vegetation map. Emissions and removals are only accounted for when there is conversion to anthropogenic use. CO_2 removals are not accounted for when it remains with the same cover during the assessed periods.
Secondary Grassland (SEcG)	Classified based on the map of past natural vegetation and resulting from a process of natural regeneration associated with previous anthropogenic use, for example, crop cultivation or pasture.
Pasture (P)	Areas destined for grazing, consisting of both grazable fields of native origin (natural pastures) and planted fields (mostly of exotic grass species). The combination of areas (natural and planted) was mainly due to the spectral similarity observed in the satellite images, especially in areas of degraded pasture or with great seasonal variation. In biomes, such as the Pampa and Pantanal, there is extensive use of natural pastures. On the other hand, in biomes such as the Amazon and Cerrado, there is a predominance of cultivated pastures.
Degraded pasture (DP)	These are pasture areas with advanced biological degradation, characterized mainly by the presence of bare soil and low productivity.
Other Managed Wooded Land (OMWL)	Other natural Wooded Land, with an intermediate structure between Forest Land and Grassland, where human action has not caused significant changes in its characteristics. Classified based on the previous natural vegetation map. It is in a protected area (CU or IL) and, therefore, has its CO_2 removals accounted for when it remains in the same category during the assessed periods.
Other Unmanaged Wooded Land (OUWL)	Other natural Wooded Land, with an intermediate structure between Forest Land and Grassland, where human action has not caused significant changes in its characteristics. Classified based on the previous natural vegetation map. Emissions and removals are only accounted for when there is conversion to anthropogenic use. CO_2 removals are not accounted for when it remains in the same category during the assessed periods.
Other Secondary Wooded Land (OSWL)	Classified based on the map of past natural vegetation and resulting from a process of natural regeneration after anthropogenic use, for example, crop cultivation or pasture.

Net CO_2 emissions from the Grassland subsector (4.C) totaled 959,862 kt CO_2 eq in 2022 and 855,213 kt CO_2 eq in 2020, representing a 12% increase over the period. In 2022, the Grassland Remaining Grassland category (4.C.1) accounted for net emissions of 7,243 kt CO_2 eq in this subsector. The Land Converted to Grassland category (4.C.2) emitted 952,620 kt CO_2 eq, of which the Forest Land Converted to Grassland (4.C.2.a) and the Cropland Converted to Grassland (4.C.2.b) subcategories accounted for 949,958 kt CO_2 eq and 2,672 kt CO_2 eq. The Other Land Converted to Grassland subcategory (4.C.2.e) accounted for a net removal of -11 kt CO_2 eq (Figure 7.9).

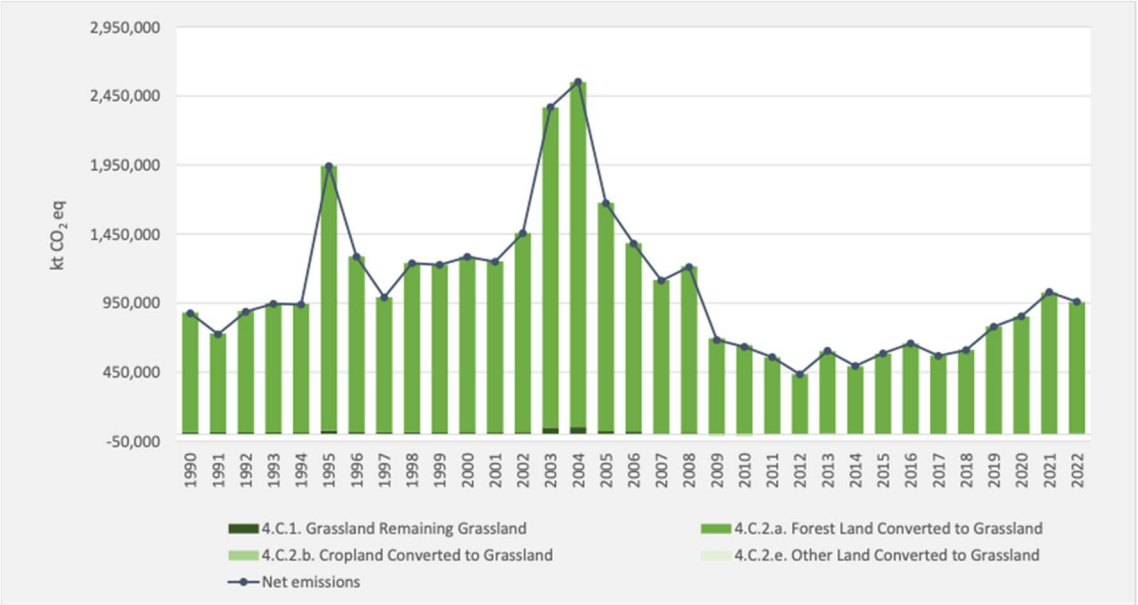


Figure 7.9. Net emissions and removals from categories and subcategories of the Grassland subsector (4.C), in CO_2 eq, from 1990 to 2022.

7.5.1 Methodological aspects

CO_2 emissions and removals are accounted for by carbon loss or gain due to land-use and land-cover change, including soil management, for all pools. Emissions of CH_4 and N_2O were recalculated when natural vegetation was converted to anthropogenic use.

The carbon stocks of the natural formations of Grassland and Other Wooded Land were estimated for the phytophysiognomies of these categories by biome (Tables A.VII.2 to A.VII.7, Appendix A.VII.3), while the carbon stocks and emission factors of pastures are presented in Table A.VII.8. Degraded Pastures (DP) were mapped in 2016, but CO_2 removals were only accounted for areas converted from uses other than pasture to well-managed pastures, for the entire time series, based on soil organic carbon change factors weighted by pasture quality.

It should be noted that the inventory did not detail the types of pasture, which requires the triangulation of more complex methodologies to qualify this analysis. It should be noted that the soil organic carbon change factors were applied considering the proportions per type of pasture per FU/state (planted pasture, natural pasture, improved pasture, moderately degraded pasture). However, this analysis is only considered at the time of the land-use transition. If a pasture remains as pasture, emissions or removals are not taken into account, regardless of the good practices applied, which will be explored in greater depth in the next editions of the Inventory.

For more methodological details regarding the estimates, see Section 7.2.

7.6 Wetlands (CRT 4.D)

The Wetlands subsector (4.D) includes areas of marshes (formation in coastal zones), swamps, peat bogs or natural or artificial, permanent or temporary, stagnant or flowing, fresh, brackish or salty waters (excluding oceans). This subsector comprises the Wetland remaining Wetland (4.D.1) and Land converted to Wetland (4.D.2) categories. Emissions of CO_2, CH_4 and N_2O are linked to the process of converting natural vegetation to reservoir, specifically.

Dataframe 7.15. National subdivision of the Wetlands subsector (4.D).

CATEGORY	DESCRIPTION
Water (W)	Lentic (lakes) and lotic (rivers) natural bodies of water, from spring areas where the watercourses are small, to large rivers, such as the Amazon and São Francisco rivers. These areas are not accounted for as Managed Areas for the purposes of the Inventory, since they are not subject to anthropogenic interference.
Reservoir (Res)	Bodies of water created by anthropogenic action, such as artificial lakes and areas flooded for the construction of hydroelectric dams and human supply.

In 2022, the Wetlands subsector (4.D) accounted for 11,675 kt CO_2 eq of GHG emissions, which came only from the Land converted to Wetland category (4.D.2). In 2020, net emissions from this subsector were 10,601 kt CO_2 eq.

The Forest Land converted to Wetland subcategory (4.D.2.a) accounted for 90% (10,524 kt CO_2 eq) of the net emissions of the Land converted to Wetland category (4.D.2), followed by the Grassland converted to Wetland subcategories (4.D.2.c), which accounted for 9% (1,065 kt CO_2 eq), and Cropland converted to Wetland (4.D.2.b), which accounted for 1% (86 kt CO_2 eq) (Figure 7.10).

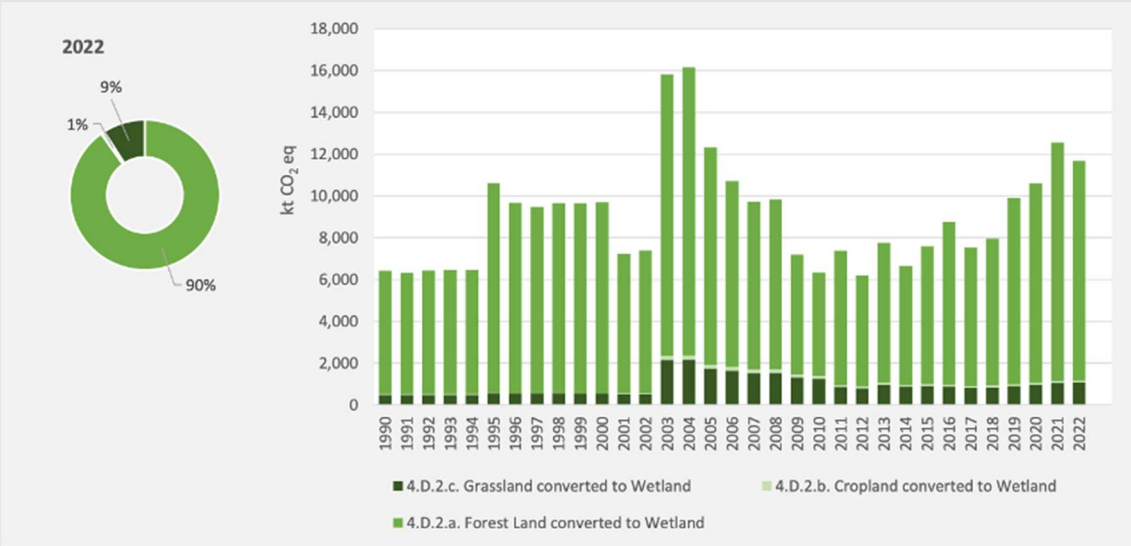


Figure 7.10. Net emissions from the subcategories of the Land converted to Wetland category (4.D.2) of the Wetlands (4.D) subsector, in CO_2 eq, from 1990 to 2022.

7.6.1 Methodological aspects

Emissions of CO_2, CH_4 and N_2O are associated with the natural vegetation conversion process (whose carbon stocks are shown in Tables A.VII.2 to A.VII.7 in Appendix A.VII.3). For more methodological details regarding the estimates, see Section 7.2.

7.7 Settlements (CRT 4.E)

The Settlements subsector (4.E) is characterized by the presence of typical structures for housing (buildings and agglomerations of residences), industrial buildings and routes for the transportation of people and means of transport. This subsector is divided into the categories of Settlements remaining Settlements (4.E.1) and Land Converted to Settlements (4.E.2). Emissions of CO_2, CH_4 and N_2O are specifically linked to the process of converting natural vegetation to Settlements.

In 2022, GHG emissions from the Settlements subsector (4.E) corresponded to 5,670 kt CO_2 eq, originating only from the Land Converted to Settlements category (4.E.2), while in 2020, emissions were 5,008 kt CO_2 eq (Figure 7.11).

The subcategories with the highest representation in 2022 were Forest Land Converted to Settlements (4.E.2.a), which emitted 3,006 kt CO_2 eq and accounted for 53%, and Grassland converted to Settlements (4.E.2.c), which emitted 2,264 kt CO_2 eq and accounted for 40% of the emissions from the Land Converted to Settlements category (4.E.2). The Cropland Converted to Settlements subcategory (4.E.2.b) contributed with the remaining 7%, with emissions of 399 kt CO_2 eq.

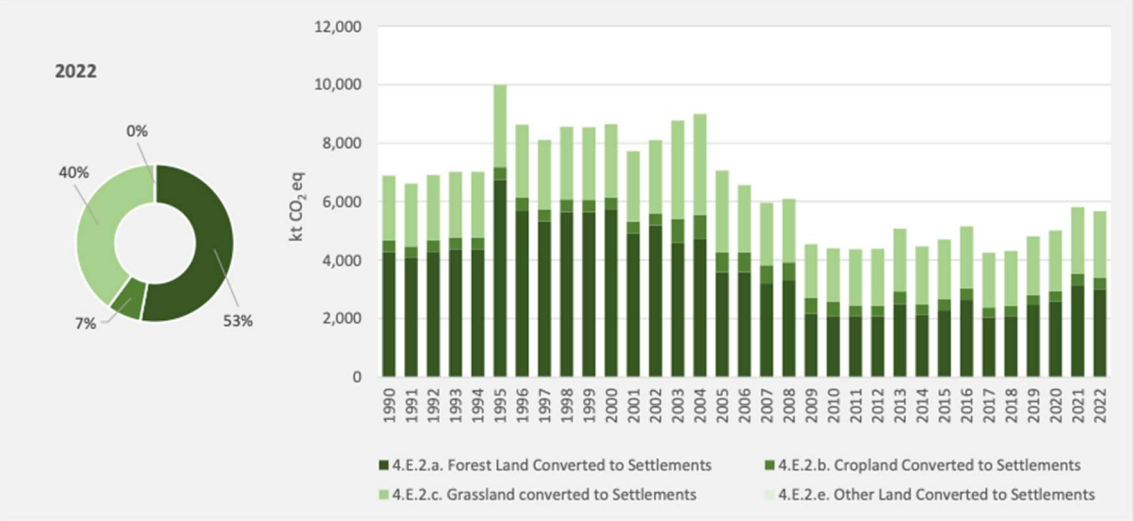


Figure 7.11. Net emissions from the subcategories of the Land converted to Settlements category (4.E.2) of the Settlements (4.E) subsector, in CO_2 eq, from 1990 to 2022.

7.7.1 Methodological aspects

Emissions of CO_2, CH_4 and N_2O are linked to the process of converting natural vegetation (whose carbon stocks are shown in Tables A.VII.2 to A.VII.7 in Appendix A.VII.3) to Settlements. For more methodological details regarding the estimates, see Section 7.2.

7.8 Other Land (CRT 4.F)

The Other Land subsector (4.F) includes natural areas, such as dunes and rock outcrops, and anthropized areas, such as bare soil and mining, according to the subdivisions adopted by the country (Dataframe 7.16). This subsector comprises the categories of Other Land remaining Other Land (4.F.1) and Land Converted to Other Land (4.F.2). Emissions of CO_2, CH_4 and N_2O are linked specifically to the process of converting natural vegetation to mining and bare soil.

Dataframe 7.16. National subdivision of the Other Land subsector (4.F).

CATEGORY	DESCRIPTION
Managed dunes (MD)	Natural areas made up only of sand, with no vegetation cover, located in a protected area (CU or IL).
Unmanaged dunes (UD)	Natural areas made up only of sand, with no vegetation cover, not located in a protected area.
Managed rock outcrop (MRO)	Areas where there is natural exposure of rocks on the surface of the ground, without vegetation cover, located in a protected area (CU or IL).
Unmanaged rock outcrop (URO)	Areas where there is natural exposure of rocks on the surface of the ground, without vegetation cover, not located in a protected area.
Mining (M)	Areas destined for the extraction of minerals for commercial use, characterized mainly by the total removal of native vegetation.
Bare soil (BS)	Areas devoid of native or exotic vegetation cover, subject to erosion and loss of soil fertility due to the action of abiotic agents (such as leaching). Bare soils usually originate from activities such as deforestation and fires.
Areas not observed (NO)	Areas that could not be classified due to the presence of clouds and their shadows, which compromised the analysis of the available satellite images.

In 2022, the subsector emitted 12,620 kt CO_2 eq, from the Land Converted to Other Land category (4.F.2) alone, and emitted 11,740 kt CO_2 eq in 2020.

In 2022, the Forest Land Converted to Other Land subcategory (4.F.2.a) accounted for 95.1% of net emissions in this category (12,010 kt CO_2 eq). The Grassland Converted to Other Land subcategory (4.F.2.c) emitted 4.7% (588 kt CO_2 eq) and the Cropland Converted to Other Land subcategory (4.F.2.b) accounted for only 0.2% (22 kt CO_2 eq) (Figure 7.12).

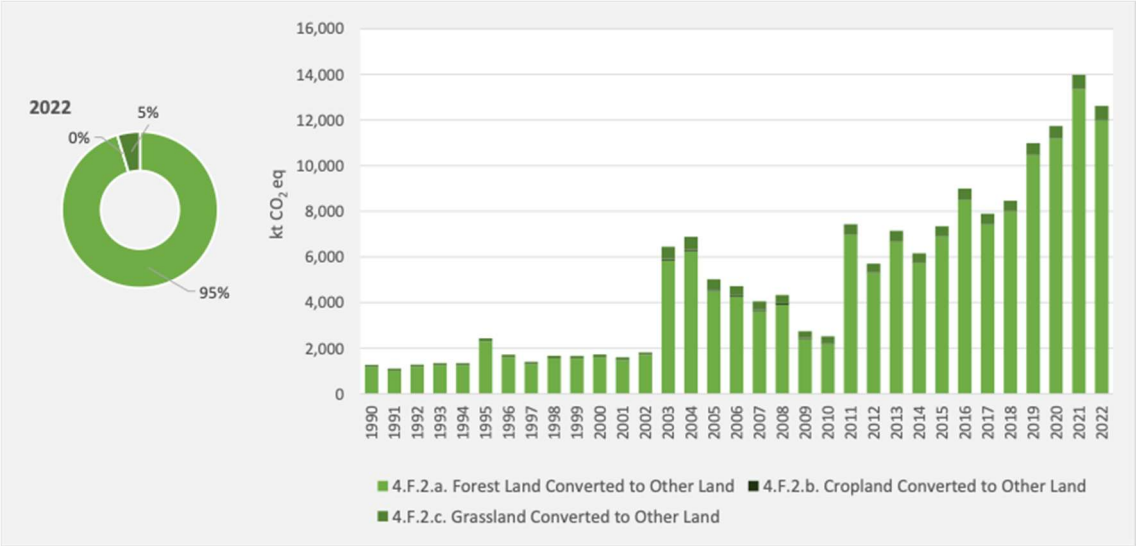


Figure 7.12. Net emissions from the subcategories of the Land Converted to Other Land category (4.F.2) of the Other Land subsector (4.F), in kt CO_2 eq, from 1990 to 2022.

7.8.1 Methodological aspects

Emissions of CO_2, CH_4 and N_2O are associated with the process of converting natural vegetation (whose carbon stocks are shown in Tables A.VII.2 to A.VII.7 in Appendix A.VII.3) to mining and bare soil. For more methodological details regarding the estimates, see Section 7.2.

7.9 Harvested Wood Products (CRT 4.G)

The Harvested Wood Products subsector (4.G) considers CO_2 emissions and removals from products originating from raw materials of planted forests, such as solid wood, panels, paper and paperboard. CO_2 emissions result from the decomposition of these products[103] (accounted for in the consumer country), while CO_2 removals reflect the growth of forest plantation (accounted for in the producer country).

For 2022, the removal corresponding to harvested wood was -624,004 kt CO_2 eq for planted forests, while the gross emission was 567,497 kt CO_2 eq. As a result, the balance of the contribution of Harvested Wood Products was a net removal of -56,507 kt CO_2 eq in 2022 (Figure 7.13).

[103] Non-CO_2 gas emissions associated with the decomposition process are accounted for in the Waste sector (IPCC, 2006, chap. 8).

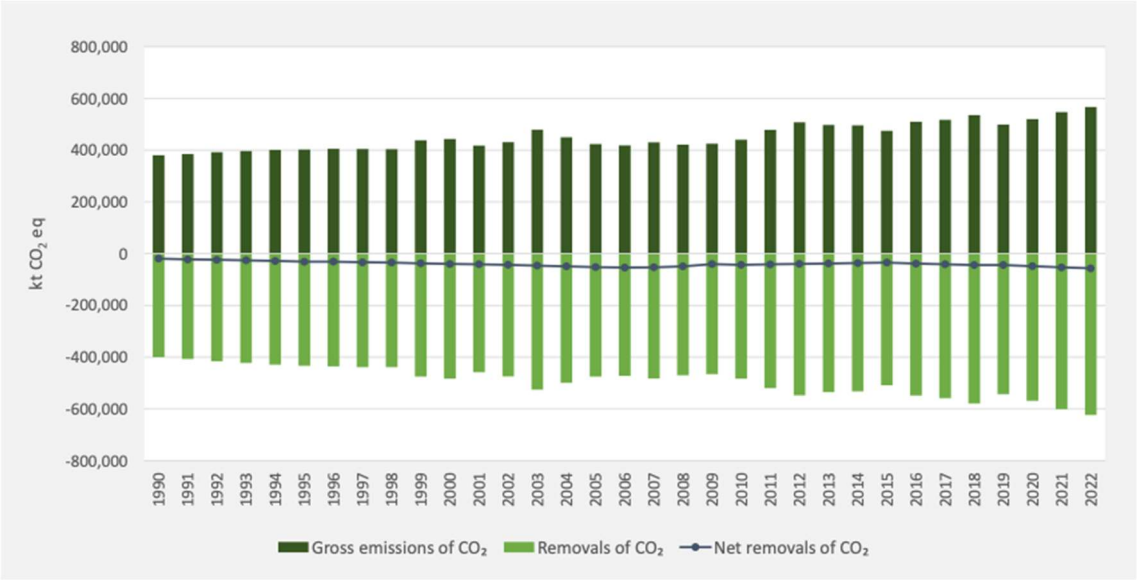


Figure 7.13. Gross emissions, removals and net removals of CO_2 from the Harvested Wood Products subsector (4.G), from 1990 to 2022.

7.9.1 Methodological aspects

According to the IPCC (2006, volume 4, chapter 12) there are several different approaches to the reporting of carbon storage in wood products and its subsequent emission as CO_2, and it is up to the country to decide which approach is most convenient for adoption in the Inventory, according to the characteristics of production, consumption, export and import of harvested wood products.

In view of Brazil's national circumstances as a major exporter of wood and wood products, the estimates for Harvested Wood Products (4.G) were based on the Atmospheric Flow Approach (Tier 1) of the IPCC (IPCC, 2006).[104]

However, in order to meet the transparency criteria of the Paris Agreement (paragraph 56 of Decision 18, CMA1), Brazil also presents the results from the Production approach and the Stock Change Approach as supplementary information, as shown in Table A.VII.28 of this NIR 2024.

For the Atmospheric Flow Approach (Tier 1) used, the carbon flows between the atmosphere and the forest and harvested wood products pools within national borders are estimated. The reporting country includes in its estimate of emissions/removals the value of carbon removals from the atmosphere due to the growth of tree biomass in forests (i.e., net removals taking into account decomposition within forests) and the release of carbon into the atmosphere from the oxidation of the waste of harvested wood products consumed in the country. The release of carbon into the atmosphere from harvested wood products includes the release of carbon from imports into the reporting country.

The system boundary and the carbon pools using the Atmospheric Flow methodology are shown in Figure 7.14. According to the IPCC (IPCC, 2006), national CO_2 emissions are

[104] IPCC (2006, v. 4, chap. 12).

provided by Equation 7.11. As the annual change in the AFOLU carbon stock without harvested wood products is accounted for elsewhere, the contribution of harvested wood products is provided by Equation 7.12 (Dataframe 7.17).

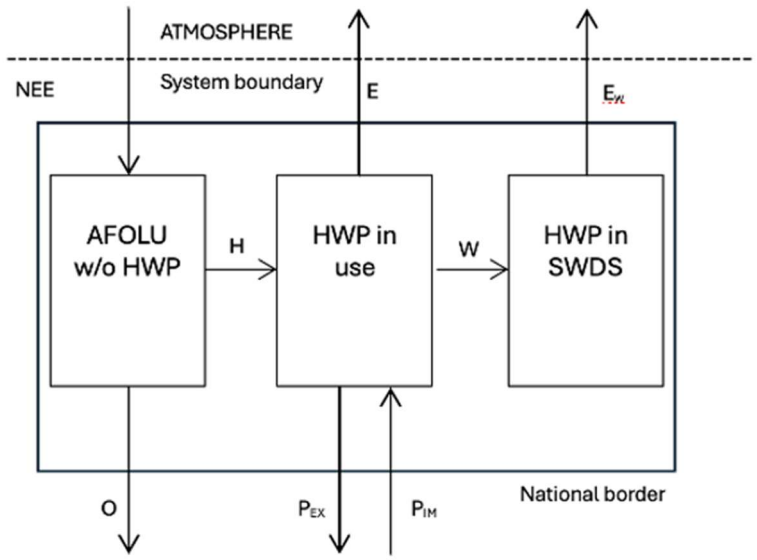


Figure 7.14. System Boundary of the Atmospheric Flow Approach.

Source: IPCC (2006). Notes: AFOLU = Agriculture, Forestry and Other Land Use, HWP = harvested wood products, SWDS = solid waste disposal sites, NEE = net ecosystem exchange of carbon, E = atmospheric carbon emission from HWP in use, EW = atmospheric carbon emission from HWP in SWDS, H = wood harvest for use in HWP (including fuelwood), W = carbon transfer from wood residues in SWDS, PEX = carbon transfer in the form of biomass from exported wood products, PIM = carbon transfer in the form of biomass from imported wood products, O = other possible cross-border carbon transfers from rest of AFOLU (assumed here to be zero).

Dataframe 7.17. Equations for estimating net CO_2 emissions from Harvested Wood Products using the Atmospheric Flow Approach.

Equations	Description	Central equation	Reference
Equation 7.11	CO_2 emissions	$\text{Emissions of } CO_2 \text{ from AFOLU} = -\frac{44}{12} \times (NEE - E - E_w)$ $= -\frac{44}{12} \times (NEE - \uparrow C_{HWP\ DC})$ $= -\frac{44}{12} \times [\Delta(\text{AFOLU without HWP}) + \Delta C_{HWP\ IU_{DC}} + \Delta C_{HWP\ SWDS_{DC}} + P_{EX} - P_{IM}]$ or $= -44/12 \times [\Delta(\text{AFOLU without HWP}) + H - \uparrow C_{HWP\ DC}]$	Equation 12A.3 (IPCC 2006, v. 4, chap. 12)

Equation 7.12	Contribution of net emissions from HWP	$N_{HWP\ AFOLU_{AFA}} = -\frac{44}{12} \times [\Delta C_{HWP\ IU_{DC}} + \Delta\ C_{HWP\ SWDS_{DC}} + P_{EX} - P_{IM} + O] = -44/12 \times [H \times \uparrow C_{HWP\ DC}]$	Equation 12A.4 (IPCC 2006, v. 4, chap. 12)

In which:

$AFOLU$ = Agriculture, Forestry, and Other Land Use;
AFA = Atmospheric Flow approach;
HWP = harvested wood products;
$\Delta(AFOLU\ without\ HWP)$ = annual change in carbon stocks from $AFOLU$ without HWP;
$SWDS$ = solid waste disposal sites;
NEE = net ecosystem exchange of carbon;
H = wood harvesting for use in HWP (including fuelwood);
$\uparrow C_{HWP\ DC} = E + E_W$;
E = carbon emission into the atmosphere from HWP in use;
E_W = carbon emissions into the atmosphere from HWP in $SWDS$;
HWP in use includes all HWP in use consumed in the reporting country and HWP in $SWDS$;
P_{EX} = carbon transfer in the form of biomass from exported wood products;
P_{IM} = carbon transfer in the form of biomass from imported wood products;
$\Delta C_{HWP\ IU_{DC}}$ = annual change in carbon stocks from HWP in use;
$C_{HWP\ SWDS_{DC}}$ = annual change in carbon stocks from HWP in $SWDS$ in which the wood comes from domestic harvesting;
$N_{HWP\ AFOLU_{AFA}}$ = Contribution of net emissions from HWP from AFOLU with the AFA approach;
O = other possible cross-border carbon transfers from rest of AFOLU (assumed here to be zero); and
$\Delta(AFOLU\ without\ HWP)$ = annual change in carbon stocks from $AFOLU$ without HWP.

Default IPCC values (IPCC, 2006)[105] for unit conversion factors (density, carbon fraction and carbon factor) and national production, import and export data from FAOSTAT (FAO, 2024) and their respective residues and park and garden waste were used. All the activity data and intermediate estimates for this subsector are presented in Tables A.VII.23 to A.VII.28 in Appendix A.VII.4.

The data on the quantity of industrial roundwood (in cubic meters) is subdivided into: a) roundwood for the production of wood pulp and particles; b) roundwood for the production of laminates and solid wood; and c) other industrial roundwood.

The estimate of the carbon stored in HWP was carried out separately for "products in use" and solid waste disposal sites (SWDS). The calculations were, therefore, carried out considering Variables 1 and 2 (Dataframe 7.18 and Dataframe 7.19), which are divided into two parts corresponding to storage in products in use and in products in SWDS (IPCC 2006).[106] To obtain the carbon values, the production, import and export of solid wood or paper were converted from cubic meters or tons (air-dried) to tons of carbon (IPCC, 2006).[107]

[105] IPCC (2006, v. 4, chap. 12).
[106] IPCC (2006, v. 4, chap. 12, p. 12.8, Table 12.1).
[107] IPCC (2006, v. 4, chap. 12, p. 12.19, Table 12.4).

Dataframe 7.18. Variables of harvested wood products (HWP) used to estimate their annual CO_2 emissions and removals.

DEFINITION OF VARIABLES	VARIABLE NAME	
	HWP IN PRODUCTS IN USE	HWP IN SWDS
1. Annual change in carbon stocks in a) HWP in use and b) in HWP in solid waste disposal sites in the country, originating from carbon in wood from the domestic consumption of products.	Variable 1A	Variable 1B
ΔCHWP DC = ΔCHWP IU DC + ΔCHWP SWDS DC	ΔCHWP IU DC	ΔCHWP SWDS DC
2. Annual change in carbon stocks in a) HWP in use and b) in HWP in solid waste disposal sites (SWDS) where the products' wood came from domestic harvesting - trees harvested in the reporting country, including HWP exported to other countries.	Variable 2A	Variable 2B
ΔCHWP DH = ΔCHWP IU DH + ΔCHWP SWDS DH	ΔCHWP IU DH	ΔCHWP SWDS DH
3. Carbon in the country's annual HWP imports, including all wood-based material – wood in solid wood products, paper, pulp and recycled paper.	PIM	
4. Carbon in the country's annual HWP exports, including all wood-based material - wood in solid wood products, paper, pulp and recycled paper.	PEX	
5. Carbon in the annual harvest of roundwood for products – wood removed from harvesting sites in the reporting country, including fuelwood.	H	

Note: ΔCHWP DC is the annual release of carbon into the atmosphere from HWP contained in the reporting country. Includes carbon release from all wood harvested and retained in the country and from wood imports into the country, but excluding exports (Gg year^{-1}); 1A. ΔCHWP IU DC is the annual change in carbon stored in HWP that comes from the country's domestic consumption, including imports (Mg C year^{-1}); 1B. ΔC SWDS DC is the annual change in carbon stored in HWP in products in SWDS that comes from the country's domestic consumption of products, including imports (Mg C year^{-1}); ΔCHWP DH is the annual release of carbon into the atmosphere from HWP originating from wood harvested in the reporting country. This includes the carbon release of all wood harvested in the country, including wood that is exported, but excluding imports, (Gg year^{-1}); 2A. ΔC HWP IU DH is the annual change in carbon stored in HWP in products in use that comes from the country's domestic harvest (Mg C year^{-1}); 2B. ΔC SWDS DH is the annual change in carbon stored in HWP in products in SWDS that comes from the country's domestically harvested wood (Mg C year^{-1}).

Dataframe 7.19. Definition of harvested wood products (HWP) variables used to estimate their annual CO_2 emissions and removals.

ANNUAL CHANGE IN CARBON STOCK IN "PRODUCT IN USE" IN THE REPORTING COUNTRY	
Variable 1A	The carbon inflow variable in the product in use is the annual consumption in the reporting country of semi-finished wood products, including sawnwood, wood panels and other solid wood products, paper and paperboard. Consumption is equal to domestic production, plus imports and minus exports (Equation 12.2; IPCC, 2006).[108] The rate at which solid wood or paper is lost from pools in a given year is specified by a constant loss rate (k) and, for convenience, it is also specified by the half-life in years. The half-life of each category of harvested wood products is of 2 years for paper and paperboard products (k = 0.347) and 30 years for solid products and wood panels (k = 0.023) (IPCC, 2006).[109]

[108] IPCC (2006), v. 4, chap. 12, p. 12.11.
[109] IPCC (2006), v. 4, chap. 12, p. 12.17, Table 12.2.

ANNUAL CHANGE IN CARBON STOCK IN "PRODUCT IN USE" IN THE REPORTING COUNTRY	
Annual change in carbon stock in "products in use" where the wood came from harvesting in the reporting country (includes exports).	
Variable 2A	The flow variable for this pool is the production of all wood products harvested in the reporting country, including products exported and kept in use in other countries (Equation 12.3, IPCC 2006).[110]
Annual change in carbon stock in SWDS in the reporting country (1B) and annual change in carbon stock in SWDS, where wood originates from harvesting in the reporting country (2B).	
Variables 1B and 2B	Variable 1B, which is the change in the carbon stock of HWP from domestic consumption disposed of in SWDS of the reporting country, is estimated directly by applying the methods and template spreadsheets of the Waste Sector of the IPCC guidelines (IPCC, 2006).[111] The portion of Variable 1B that is from domestic harvest is approximated by multiplying by the fraction of wood carbon consumed in the country in the current year that came from domestic harvest (Equation 12.4, IPCC, 2006).[112] In order to estimate variable 2B, it is necessary to estimate the domestic harvest portion of variable 1B. Thus, the estimation of Variable 2B is limited only to carbon change in SWDS of domestic origin.

7.10 Quality assurance and quality control

The QA/QC procedures for LULUCF were applied according to the plan described in Section 2.5 of this NIR.

Given the complex process of generating the sector's activity data and in view of the size and regional specificities of the national territory, it is possible to highlight some of the procedures adopted to ensure the quality of the sector's data:

- The definition of carbon stock values and expansion factors for the different pools of each biome prioritized the use of references available in peer-reviewed scientific journals. In rare cases where there was no data published in a scientific journal, references were consulted from the "gray literature" (e.g. dissertations and theses) that were publicly available in well-known databases, such as the Brazilian Digital Library of Theses and Dissertations, coordinated by the Brazilian Institute of Information in Science and Technology (Instituto Brasileiro de Informação em Ciência e Tecnologia);
- A mapping validation committee was set up, made up of experts in each biome with experience in detecting potential points of uncertainty, reviewing previous maps, assisting in the selection of images and during the execution of updated maps;
- Expert consultants for each biome reviewed and updated estimates of biomass, carbon stocks and expansion factors for the different pools;
- The uncertainties related to the estimates were recorded by the experts and consultants responsible for the stages of literature review of the biomass and carbon stock values; and

[110] IPCC (2006, v. 4, chap. 12, p.12.12).
[111] IPCC (2006, v. 5, chap. 3, section 3.2.1.1, p. 3.10 and v. 5, chap. 3, p. 3.23).
[112] IPCC (2006, v. 4, chap. 2, p. 12.14).

- All the land-use and land-cover conversion matrices and greenhouse gas emissions and removals went through a prior review and validation of the results by the validation committee for each biome.

7.11 Assessment of uncertainty, consistency and recalculations of the time series

Uncertainty analysis was carried out using the random sampling methods and techniques described in the 2006 IPCC Guidelines. The uncertainty associated with the sector's emissions is presented in Appendix II.

In this inventory, estimates of the time series were recalculated in relation to the previous inventory (Brasil, 2022). The changes occurred mainly because there was a change in the time series of the secondary data sources used: deforestation data in the Cerrado (Prodes, 2024b) and Pantanal (SOS Pantanal, 2020) biomes, data from the Harvested Wood Products subsector (FAO, 2024) and data on the harvesting of fuelwood and roundwood (IBGE, 2024).

The details of the recalculation will be presented for the entire sector and not necessarily by subsector or category, with the exception of HWP, given the specificities of the LULUCF data, which are related in an integrated way and have a diffuse impact on the results observed.

Impacts of adjustments to the annual deforestation data for the Cerrado and Pantanal biomes

The adjustments resulted from the updating of the data from the time series of annual deforestation in the Cerrado by INPE (INPE, 2024b) and in the Pantanal by SOS Pantanal (SOS Pantanal, 2020).

According to INPE, the changes in the annual deforestation data for the Cerrado were due to the new official delimitation of Brazil's biomes, published by IBGE (IBGE, 2019). Due to these changes, the biggest differences in gross emissions from the Cerrado biome for the inventory's subsectors occurred for the years of 2016 (11.3%), 2018 (10.3%) and 2020 (8.5%) (Figure 7.15).

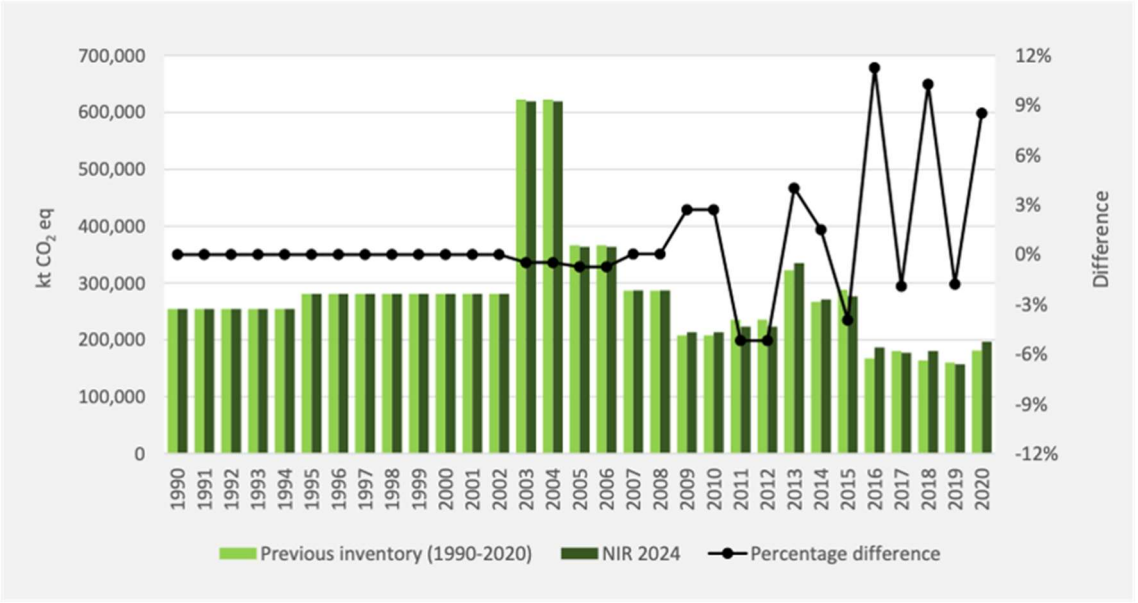


Figure 7.15. Comparison of estimated gross CO_2 emissions from the Forest Land subsectors (4.A). Cropland (4.B) Grassland (4.C), Wetlands (4.D), Settlements (4.E.) and Other Land (4.F) in the Cerrado between inventories.

SOS Pantanal has updated the time series of the annual deforestation data from 2003 to 2019 (SOS Pantanal, 2020). In the previous inventory, the updated values from 2017 to 2020 were used. In the NIR 2024, updated values from 2003 to 2020 were used. As a result, accumulated emissions from 2003 to 2008 were 17% lower than in the previous inventory. The estimates for 2009 and 2010 were significantly higher (192%), while the difference ranged from -16% to 19% for subsequent years up to 2016. From 2017 to 2020, the average difference was 0.04% (Figure 7.16).

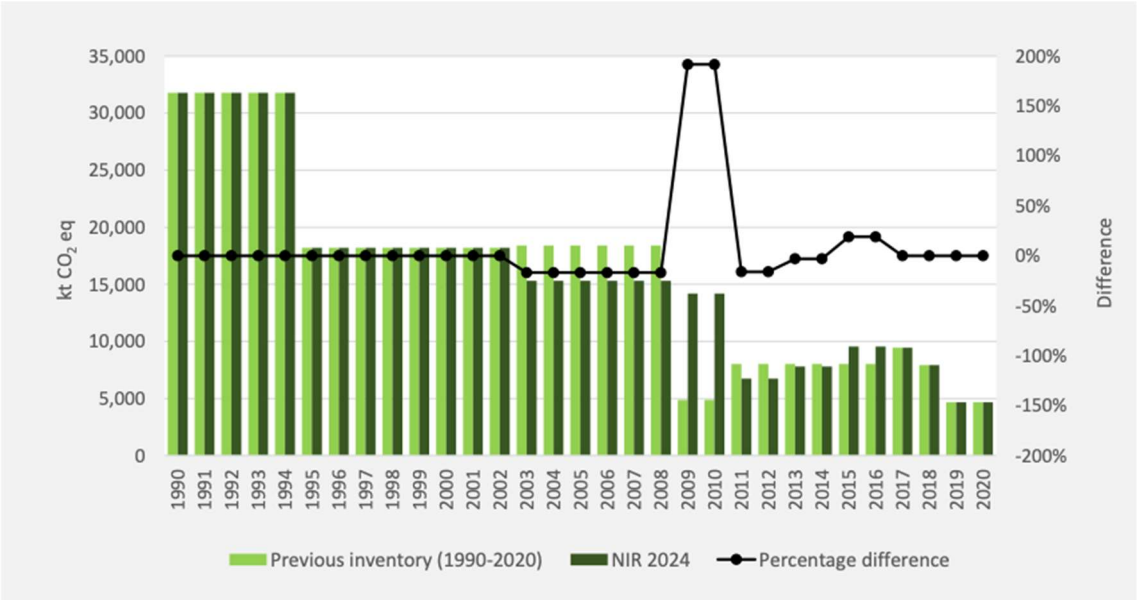


Figure 7.16. Comparison of estimated gross CO_2 emissions from the Forest Land subsectors (4.A). Cropland (4.B) Grassland (4.C), Wetlands (4.D), Settlements (4.E.) and Other Land (4.F) in the Pantanal between inventories.

Harvested Wood Products

The adjustments resulted from the FAO's review of import, export and production data for the Harvested Wood Products subsector for the entire time series (1990-2020) by FAO (FAO, 2024). This directly affected the net removals of CO_2 for the subsector. In the previous inventory (BRASIL, 2022), due to the lack of data for 2019 and 2020, these values were extrapolated by trend based on data from the previous 5 years.

The biggest differences in relation to the previous report occurred between 1990 and 1996, with an average increase of 52% in CO_2 removals, especially in 1990, when there was a 72% increase in removals. From 2003 onwards, removals decreased, especially between 2009 and 2022, when the average reduction in emissions was of 11%. Between 2017 and 2020, a redução média das emissões também foi de 11% (Figure 7.17).

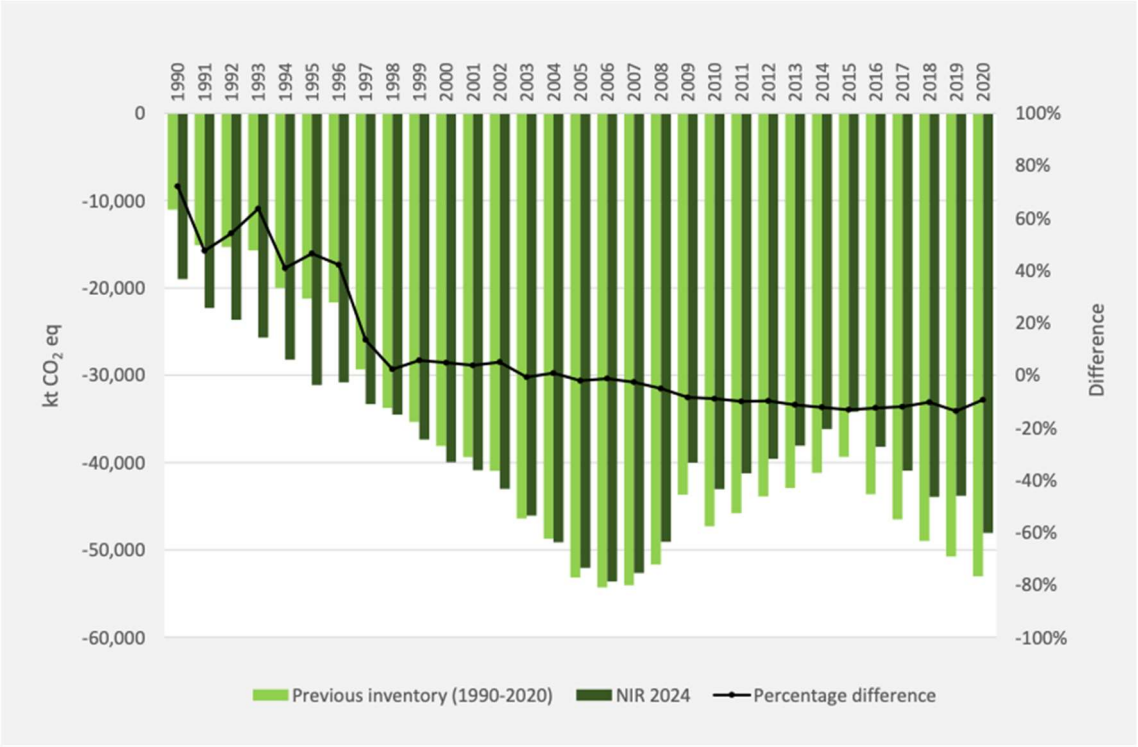


Figure 7.17. Comparison of estimated net CO_2 removals from the Harvested Wood Products sector (4.G) between inventories.

Non-CO_2 Gases

As emissões de gases não-CO_2 foram revisadas em face aos seguintes ajustes:

- Review of gross CO_2 emissions, as described, which directly impacted emissions from 2003 onwards.
- In the previous inventory, due to the lack of data, the fuelwood and roundwood harvesting values for 2019 were replicated for 2020. In addition, there was a change in the values reported by the IBGE for 2019 (IBGE, 2024).

There was no significant difference between the NIR 2024 and the previous inventory for CH_4 emissions in the period from 1990 to 2002, as shown in Figure 7.18. Since 2003, the

difference has varied from -2.3% (2012) to 2.2% (2013). Between 2017 and 2020, it ranged from -1.2% (2017) to 1.2% (2018).

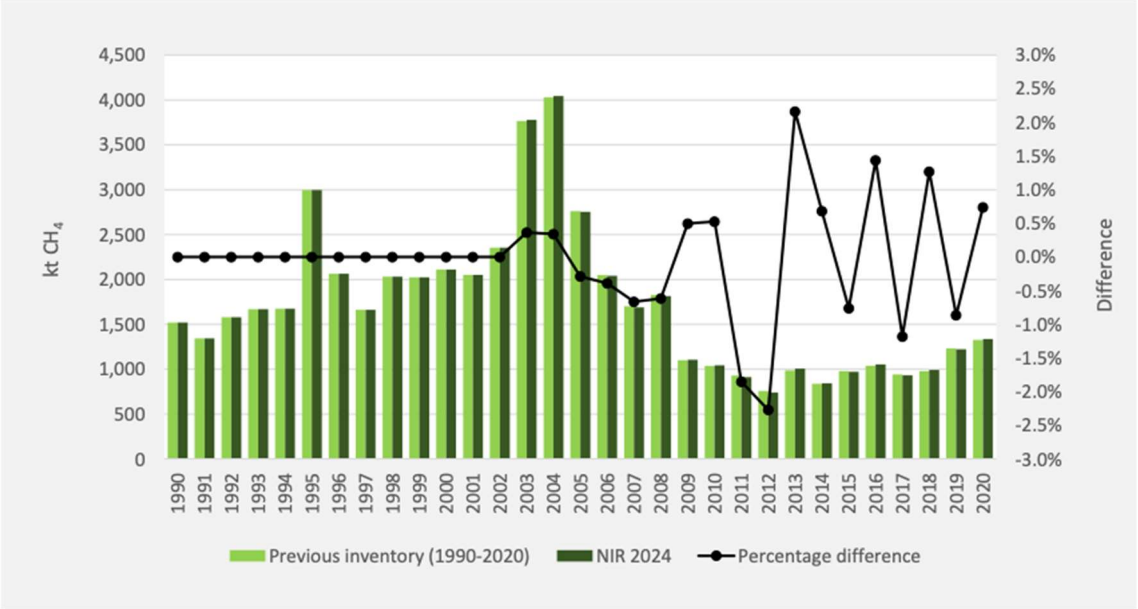


Figure 7.18. Comparison of estimated CH_4 emissions from the Forest Land subsectors (4.A). Cropland (4.B) Grassland (4.C), Wetlands (4.D), Settlements (4.E.) and Other Land (4.F) between inventories.

There was also no significant difference in N_2O emissions from 1990 to 2002, as shown in Figure 7.19. From 2003 to 2020, the difference ranged from -2.9 (2012) to 3.6% (2013). Between 2017 and 2020, the difference was of -1.3% on average.

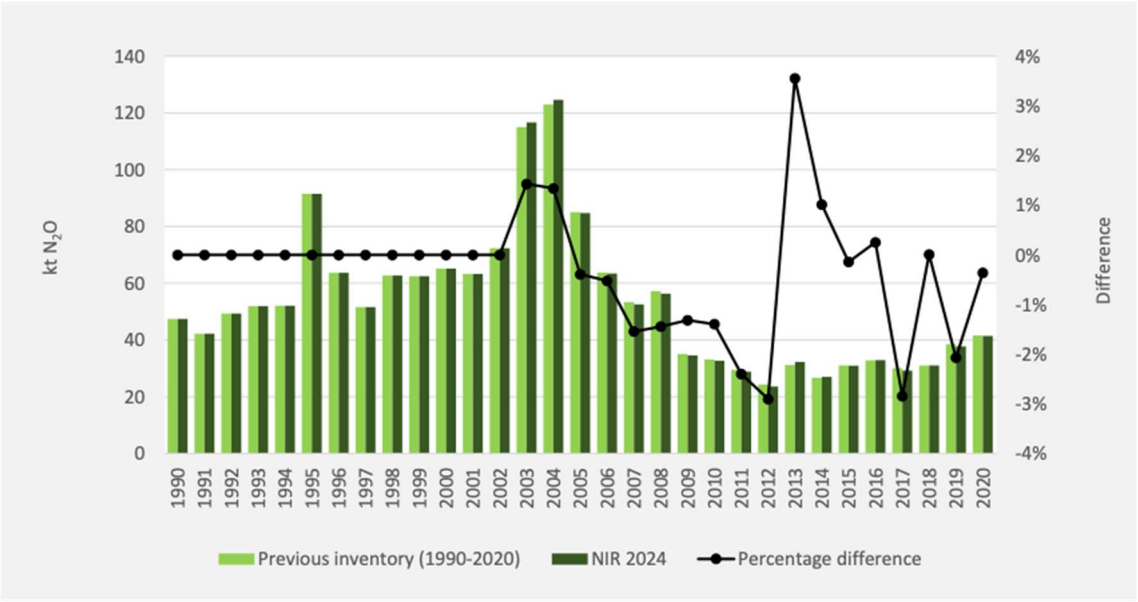


Figure 7.19. Comparison of estimated N_2O emissions from the Forest Land subsectors (4.A). Cropland (4.B) Grassland (4.C), Wetlands (4.D), Settlements (4.E.) and Other Land (4.F) between inventories.

Difference in total net emissions from LULUCF

The aforementioned differences, caused by changes in the secondary databases, resulted in small changes to the net emissions of kt CO_2 eq for LULUCF (considering CO_2, CH_4 and N_2O gases) compared to the previous inventory. From 1990 to 2002, the difference ranged from -1.14 (1993) to -0.07% (1998). Since 2003, the difference has ranged from -5.71% (2012) to 6.93% (2010). From 2017 to 2020, the difference was an average of 2.6% (Figure 7.20).

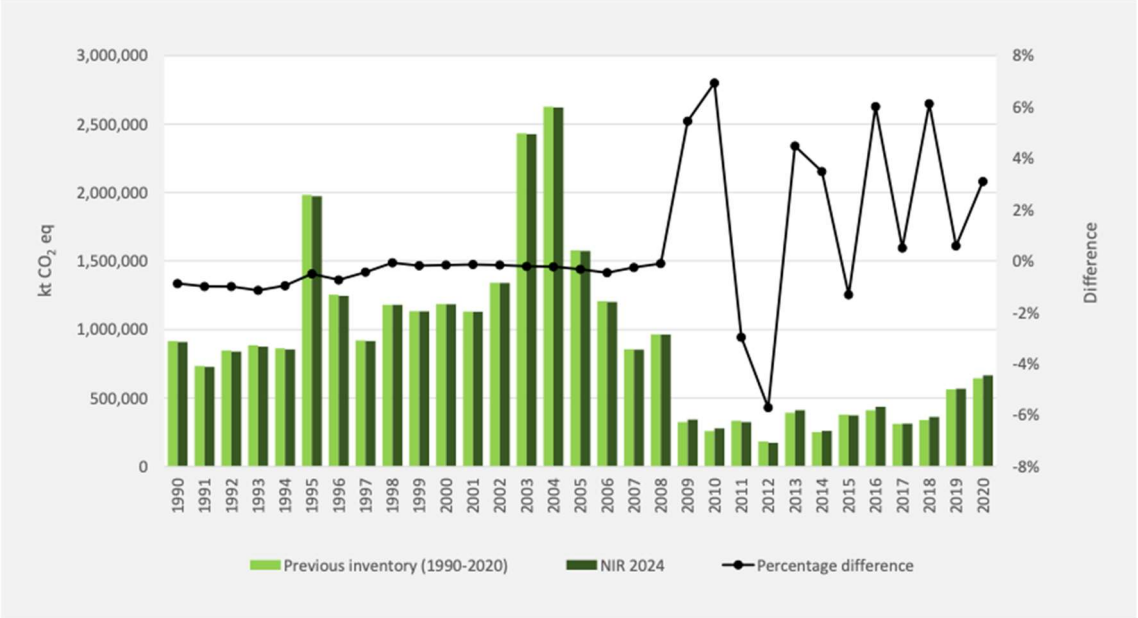


Figure 7.20. Comparison of estimated net CO_2 eq emissions from the Forest Land subsectors (4.A). Cropland (4.B) Grassland (4.C), Wetlands (4.D), Settlements (4.E.) and Other Land (4.F) between inventories.

7.12 Improvement plan

Brazil has made a continuous effort to expand the databases and improve the methodologies for quantifying emissions and removals from the LULUCF sector. Considering the size of the country and the complexity and specificities that are inherent to the estimation of emissions in this sector, it is possible that this could be improved, with a view to improving the accuracy and consistency of the data, as well as providing greater detailing of the results obtained. Thus, Dataframe 7.20 summarizes the potential improvements for possible implementation in future editions.

Dataframe 7.20. Potential improvements applicable to the emissions inventory of the Land Use, Land-Use Change and Forestry (LULUCF) sector.

Sector	Category	Improvement
	General (all categories)	▪ Establish Technical Cooperation Agreements or partnerships to prioritize efforts aimed at reducing uncertainties by obtaining more detailed activity data associated with quantifying emissions from key categories in the sector. ▪ Conduct further studies to estimate emissions from categories not included in the inventory.
4. LULUCF	Subsectors (4.A to 4.F)	▪ Expand the literature review on vegetation carbon stocks and emission and removal factors for native vegetation, especially for key categories and/or for those with greater uncertainty (e.g., removal for primary forests and secondary forests at different succession stages). ▪ Expand the development of national studies and methodologies to ensure the proper accounting of unestimated emissions, such as forest fires in which there is no conversion of land-use and land-cover class. ▪ Conduct further studies to improve the classification of grassland and estimates of emissions and removals from Grassland that remains as Grassland.

8 WASTE (CRT 5)

8.1 Sector overview

The Waste sector covers emissions from the disposal and treatment of solid and liquid waste and includes emissions of CH_4, N_2O and CO_2 from four subsectors, according to the IPCC (2006) methodology[113]: Solid Waste Disposal (5.A), Biological Treatment of Solid Waste (5.B), Incineration and Open Burning of Waste (5.C) and Wastewater Treatment and Discharge (5.D). Emissions from the sector are mainly due to the anaerobic degradation process that occurs when solid waste is finally disposed of in managed waste disposal sites (landfills) or in uncategorized waste disposal sites (controlled landfills and garbage dumps),[114] as well as the discharge of wastewater that has or has not undergone some kind of treatment process.

Emissions from the Waste sector totaled 90,761 kt CO_2 eq in 2022, an increase of 2% compared to 2020. The Solid Waste Disposal subsector (5.A) contributed the most to the sector's emissions in 2022, with 53,421 kt CO_2 eq, or around 59% of the total. Wastewater Treatment and Discharge (5.D) emitted 36,056 kt CO_2 eq in 2022 and accounted for approximately 40% of the sector's total. The other subsectors contributed with a smaller share of emissions.

Figure 8.1 illustrates emissions from the Waste sector by subsector.

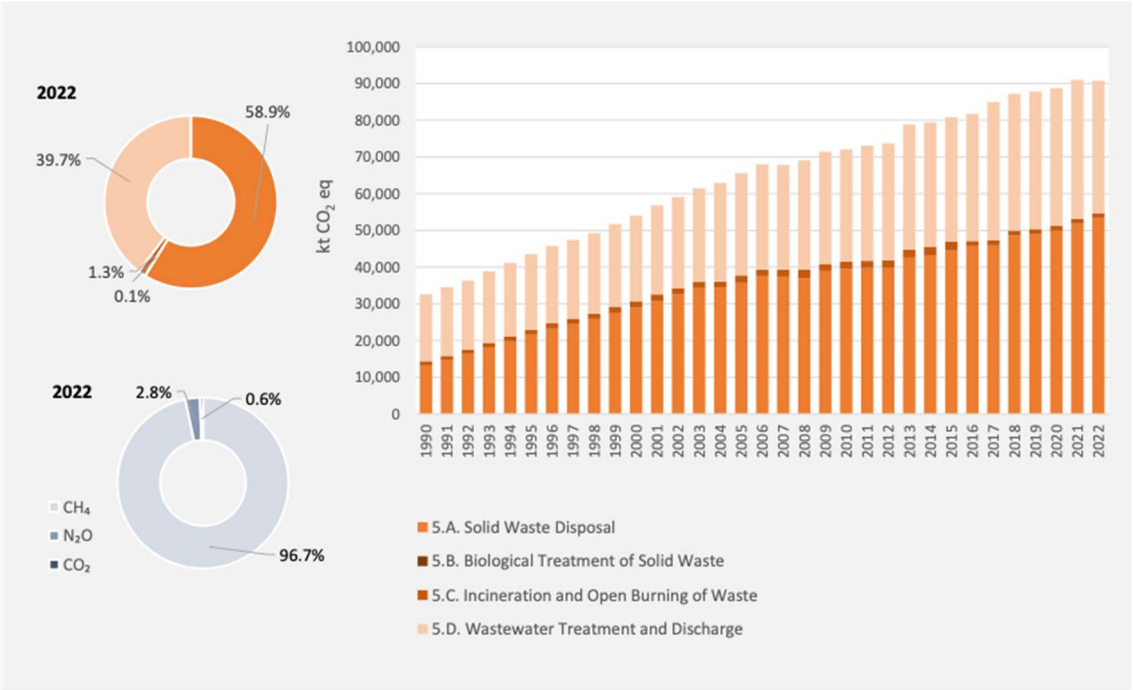


Figure 8.1. Emissions from the Waste sector, in kt CO_2 eq, by subsector, from 1990 to 2022.

[113] Waste (IPCC, 2006, v. 5).
[114] Garbage dumps are commonly called "open dumps" in Brazil.

When evaluating the categories, the ones that contributed the most were Managed Waste Disposal Sites (5.A.1) and Domestic Wastewater Treatment (5.D.1), corresponding to 49% and 33% of total emissions from the Waste sector, respectively.

Emissions from the sector were predominantly of CH_4, with around 97%, resulting from the decomposition of degradable biological matter at solid waste and liquid effluent disposal and treatment sites. Other gases are generated in smaller quantities during the treatment of domestic and industrial effluents, such as N_2O and CO_2, the latter coming from the incineration of solid waste of fossil origin, representing 2.8% and 0.6% in 2022, respectively.

8.2 Methodological aspects

Considering the emission characteristics of the decomposition of organic matter through anaerobic processes and the combustion of waste, emissions of CO_2 and non-CO_2 were included. This second category includes CH_4 and N_2O. Emission estimates were based on the methodology recommended in IPCC (2006), specifically in Volume 5 (Waste). This edition of the inventory revised the data on emitting activities for the entire historical period (1990 to 2020), and inventoried the emissions for the years of 2021 and 2022.

Dataframe 8.1 shows the methodologies, activity data and parameters/factors used in each of the inventoried categories. The Tier 2 methodology was used for the most representative categories, especially for Solid Waste Disposal (5.A), which includes emissions from Managed Waste Disposal Sites (5.A.1) and Uncategorized Waste Disposal Sites (5.A.3).

For emissions from the Biological Treatment of Solid Waste (5.B), Tier 1 was used in the Composting category (5.B.1), as composting activities are not very representative in terms of the final disposal of municipal solid waste. For the Incineration and Open Burning of Waste subsector (5.C), the Tier 2a methodology was used for CO_2 emissions in the Open Burning of Waste category (5.C.2). This methodology used equation 5.2, p. 5.7, Volume 5, Chapter 5 (IPCC, 2006), which requires country-specific activity data on the composition of burnt waste and default data for solid waste parameters. For the other gases and categories in this subsector, the Tier 1 method was applied. As for the Wastewater Treatment and Discharge subsector (5.D), Tier 2 was used for CH_4 and Tier 1 for N_2O.

Population data was applied cross-sectionally in almost all sub-sectors. The information was obtained from the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística) (IBGE) throughout the time series (1990 to 2022), by consulting the following sources: Demographic Censuses (1970; 1980; 1991; 2000; 2010; 2022) (IBGE, 1991b; 2012; 2024b), Population Estimates (1992 to 1995; 1997 to 1999; 2001 to 2009; 2011 to 2021) (IBGE, 2000b; 2023d) and Population Counts (1996 and 2007) (IBGE, 2008a). IBGE is a public institute of the Brazilian federal administration, and is the main provider of geographical and statistical information in the country.

In addition to demographic censuses, other relevant sanitation surveys were also consulted to quantify and categorize the waste generated, collected and disposed of: the Public Cleaning and Garbage Removal Survey (1977; 1980; 1983) (IBGE, 1980a; 1980b; 1988), the data declared annually by municipalities since 2003 through the National Sanitation Information System SNIS (Sistema Nacional de Informações sobre Saneamento) (2003 to 2024) (MCID (Ministry of Cities [Ministério das Cidades]), 2022). We also consulted the

results of the National Household Sample Survey (PNAD, Pesquisa Nacional por Amostra de Domicílios) (1992 to 2015) (IBGE, 2019b; 2019c), and the Continuous Annual National Household Sample Survey (PNADC, Pesquisa Nacional por Amostra de Domicílios Contínua Anual) (2016 to 2022) (IBGE, 2023a), which present data on the population with access to waste collection services. With regard to industrial effluents, based on the identification of the nine industrial activities with the highest share of potentially GHG-generating organic load (BRASIL, 2010; BRASIL, 2015), industrial production data between 1990 and 2022 was collected.

With regard to parameters and emission factors, the gravimetric composition of Municipal Solid Waste (MSW) was obtained from a review of academic literature and states' solid waste plans. Another regionalized factor was climate classification. At the municipal level, the climatic variables of mean annual temperature (MAT), mean annual precipitation (MAP) and potential evapotranspiration (PET) were evaluated, as recommended in the IPCC (2006). The municipal data for these variables was provided by the National Meteorological Institute (INMET, Instituto Nacional de Meteorologia) for the time series from 1970 to 2010, showing the average annual value for each variable in the municipality's time series (Brasil, 2021). Based on the classification of the municipalities, the representativeness of the population living in each climate region in relation to the total population of the Federative Unit (FU) was calculated annually from 1970 to 2022.

With regard to the other emission factors, the factors available in the Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) were adopted. In some subcategories, it was not possible to calculate the emissions, mainly due to the lack of information or to the allocation of the emissions to another sector of the Inventory.

Dataframe 8.1. Methodological levels applied by gas and references of the Waste sector.

			ESTIMATED GASES AND METHODOLOGIES			REFERENCES	
Subsector	**Category**	**Subcategories**	**CO_2**	**CH_4**	**N_2O**	**Activity data**	**Emission factors**
5.A. SOLID WASTE DISPOSAL	5.A.1. Managed Waste Disposal Sites		NA	T2	NA	Population data: Demographic Census (1970; 1980; 1991; 2000; 2010; 2022), Population Estimates (1992 to 1995; 1997 to 1999; 2001 to 2009; 2011 to 2021) and Population Count (1996; 2007) (IBGE, 2010; 2015); Estimated gap for the 1970s and 1980s and 1994, using a degree 2 polynomial model; Public Cleaning and Garbage Removal (IBGE, 1980a; 1980b; 1988); National Sanitation Information System – SNIS (2003 to 2024) (MCID, 2022); National Basic Sanitation Survey – PNSB (Pesquisa Nacional de Saneamento Básico) (IBGE, 1994; 2000a; 2008b; 2017a); National Solid Waste Management Information System – SINIR (Sistema Nacional de Informações sobre a Gestão dos Resíduos Sólidos) (2015); PNAD – National Household Sample Survey (Pesquisa Nacional por Amostra de Domicílios) (1992;1993;1995;1996-1999;2001-2015) (IBGE, 2019b; 2019c) and PNADC (2016; 2017; 2018; 2019; 2022) (IBGE, 2023a); recovered CH_4: Clean Development Mechanism projects (UNFCCC, 2024).	Total population data (urban and rural) with waste collection from the National Sanitation Information System – SNIS (MCID, 2024) and the Brazilian Institute of Geography and Statistics – IBGE (IBGE, 1980; 1983; 2008). Degree 2 polynomial model based on data from IBGE (1980; 1983; 2008) and SNIS (2003 to 2022; MCID, 2018) on the total population served with Municipal Solid Waste (MSW) collection and the mass collected; The type of landfill in each municipality was obtained from information on the final disposal unit of all municipalities in Brazil (MMA – Ministry of the Environment (Ministério do Meio Ambiente), 2024) and the year in which landfills began operating (MCID, 2018); Average municipal data on mean annual temperature (MAT), mean annual precipitation (MAP) and potential evapotranspiration (PET) (INMET, 1970 to 2010); Gravimetric composition: Review of academic literature (scientific articles, congress annals, books and theses) and states' solid waste plans (1963-2018); IPCC (2006, v. 5, chap. 3).
	5.A.2. Unmanaged Waste Disposal Sites		NA	IE	NA		
	5.A.3. Uncategorized Waste Disposal Sites		NA	T2	NA		
5.B. BIOLOGICAL TREATMENT OF SOLID WASTE	5.B.1. Composting		NA	T1	T1	Same as the information for the Solid Waste Disposal subsector (5.A).	IPCC (2006, v. 5, chap. 4)
	5.B.2. Anaerobic Digestion at Biogas Facilities		NO	IE	NA	Energy generation from the flaring of biogas: National Energy Balance (BEN, Balanço Energético Nacional)	IPCC (2006; v. 5, ch. 4, p. 4.6); Emissions in this category are allocated to the Energy sector (1.A) under energy generation from biogas activities.
5.C. INCINERATION	5.C.1. Waste Incineration	5.C.1.a. Biogenic	T1	NA	T1	Quantity of incinerated clinical waste obtained from the population of the	IPCC (2006, v. 5, chap. 5)

			ESTIMATED GASES AND METHODOLOGIES			REFERENCES	
Subsector	Category	Subcategories	CO_2	CH_4	N_2O	Activity data	Emission factors
AND OPEN BURNING OF WASTE		5.C.1.b. Non-biogenic	T1	NA	T1	municipalities served with waste collection and mass collected from the National Basic Sanitation Survey – PNSB (IBGE, 1994; 2000a; 2008b).	IPCC (2006, v. 5, chap. 5)
	5.C.2. Open Burning of Waste		T2a	T1	T1	Population data from the Population Census (1991, 2000, 2010 and 2022); National Household Sample Survey – PNAD (1992;1993;1995;1996-1999; 2001-2015) (IBGE, 2019b; 2019c) and PNADC (2016; 2017; 2018; 2019; 2022) (IBGE, 2023a); (years in between the Census); Gravimetric composition: Review of academic literature (scientific articles, congress annals, books and theses) and states' solid waste plans (1963-2018).	IPCC (2006, v. 5, chap. 5)
5.D. WASTEWATER TREATMENT AND DISCHARGE	5.D.1. Domestic Wastewater Treatment		NA	T2	T1	The states' urban population was estimated annually by simple bivariate linear regression for the years in between the population censuses (IBGE, 1970; 1980; 1991; 2000; 2010; 2022). The rural population was estimated by the difference between the total and the urban population. The treatment system data was obtained from PNAD (1992;1993;1995;1996-1999; 2001-2015) (IBGE, 2019b; 2019c) and PNADC (2016; 2017; 2018; 2019; 2022) (IBGE, 2023a) and the Population Census (1991, 2000; 2010 and 2022). The fraction of the population served with each treatment technology was estimated using data from the National Basic Sanitation Survey – PNSB (IBGE, 2008).	Classification of treatment systems used in Brazil in the PNSB (IBGE, 2000a; 2008b; 2017a), with simple linear interpolation between periods, according to default values (IPCC, 2006) and Von Sperling (2015); Protein consumption from the World Food and Agriculture – Statistical Yearbook (FAO, 2009; 2022; 2023); S-DWW (Andreoli; Von Sperling; Fernandes, 2001); IPCC (2006, v. 5, chap. 5)

Subsector	Category	Subcategories	ESTIMATED GASES AND METHODOLOGIES			REFERENCES	
			CO_2	CH_4	N_2O	Activity data	Emission factors
	5.D.2. Industrial Wastewater Treatment		NA	T2	NE	Industrial production data: Sugar and Alcohol (UNICA – Brazilian Sugarcane Industry Association (União da Indústria de Cana-de-Açúcar) 2024); Raw milk (PPM – Municipal Liverstock Survey (Pesquisa da Pecuária Municipal) IBGE, 2023e); Pasteurized Milk (ABLV – Brazilian Long – Life Milk Association (Associação Brasileira da Indústria de Leite Longa Vida), 2022); Pulp (IBA – Brazilian Tree Industry (Indústria Brasileira de Árvores), 2023); Beer, Poultry slaughtering, cattle and swine slaughtering (PIA – Annual Industrial Survey (Pesquisa Industrial Anual) IBGE, 2021).	Organic load (kg BOD/ton of product): Sugar (CTC – Sugarcane Technology Center (Centro de Tecnologia Canavieira), 1995; Elia Neto *et al*., 2009); Alcohol (Elia Neto *et al*., 2009); Pulp (Michael *et al*., 2015); Raw milk, Pasteurized milk, Beer, Poultry slaughtering, Cattle and Swine slaughtering (Brasil, 2015); S-DWW (Andreoli; Von Sperling; Fernandes, 2001); IPCC (2006, v. 5, chap. 6).

Note: Methodological levels (IPCC, 2006) – T1: Tier 1; T2: Tier 2; T2a (Tier 2a): use country-specific data to estimate the fossil carbon fraction (FCF); T3: Tier 3. Notations: NA (Not applicable) – Activity in a given source/sink category that occurs in the country, but did not result in emissions or removals of a specific gas; IE (Included elsewhere) – Included in another location/category of emissions or removals; NO (Not occurring) – Categories and processes that do not occur in the country; NE (Not estimated) – Activity data and/or emissions by sources and removals by sinks of GHG that have not been estimated, but for which a corresponding activity may occur in the country.

According to IPCC 2006, the description of final disposal sites indicates a classification for landfills (5.A.1 – Managed Waste Disposal Sites), but does not specify a classification for controlled landfills and garbage dumps. Controlled landfills and garbage dumps have been classified as "Uncategorized" (5.A.3), since there are not enough characteristics regarding these sites to allow them to be classified in any other category.

As a result, emissions from solid waste disposal in Brazil that fall under the category of Waste Disposal at Unmanaged Waste Disposal Sites (5.A.2) have been reallocated to category 5.A.3.

Dataframe 8.2 and Dataframe 8.3 show categories that were relocated or could not be estimated in the NIR 2024.

Dataframe 8.2. Categories with values assigned to other categories (IE) in the Waste sector.

IPCC CODES	REALOCATED CATEGORIES	REALLOCATION DESTINATION
5.A.2	Unmanaged Waste Disposal Sites	CH_4 emissions from disposal at Unmanaged Waste Disposal Sites have been reallocated to category 5.A.3.
5.B.2	Anaerobic digestion at biogas facilities	CH_4 emissions generated from anaerobic digestion at biogas facilities are allocated to the Energy sector (1.A). The data source consulted, the National Energy Balance (BEN), only shows total national biogas production, without separating biogas generation by type of facility.

Dataframe 8.3. Categories not estimated (NE) in the Inventory for the Waste sector.

IPCC CODES	CATEGORIES NOT ESTIMATED	NOTES
5.D.2	Industrial Wastewater Treatment	No specific emission factor has been determined to estimate N_2O emissions from the treatment and disposal of industrial effluents.

8.3 Solid Waste Disposal (CRT 5.A)

The Solid Waste Disposal subsector (5.A) only emits CH_4, resulting from the anaerobic degradation process that occurs in the waste over time. Emissions vary according to the size of the population, the amount of waste generated, the gravimetric composition of the waste and the final disposal method. The subsector is subdivided into three categories: Managed Waste Disposal Sites (5.A.1), Unmanaged Waste Disposal Sites (5.A.2) and Uncategorized Waste Disposal Sites (5.A.3).

Emissions associated with Solid Waste Disposal (5.A) totaled 53,421 kt CO_2 eq in 2022, with a 7% increase compared to 2020 (Figure 8.2). Waste disposal at Managed Waste Disposal Sites (5.A.1) accounted for 82.5% of emissions for this subsector in 2022. This increase stems from the increase in the disposal of this waste at landfills, where the emission factor for CH_4 generation is higher than in controlled landfills and garbage dumps.

Emissions at Uncategorized Waste Disposal Sites (5.A.3) represented 17.5% of this subsector's emissions (9,370 kt CO_2 eq) in 2022 and showed a reduction of 24% compared

to 2020. This reduction is due to the increase in disposal at landfills, which consequently reduces the proportion of waste disposed at Unmanaged Waste Disposal Sites and garbage dumps. In qualitative terms of gravimetric composition, "food waste" and "paper and paperboard" were the main components in the generation of CH_4 from the disposal of municipal solid waste, contributing with 61% and 30% of the total emissions generated, respectively.

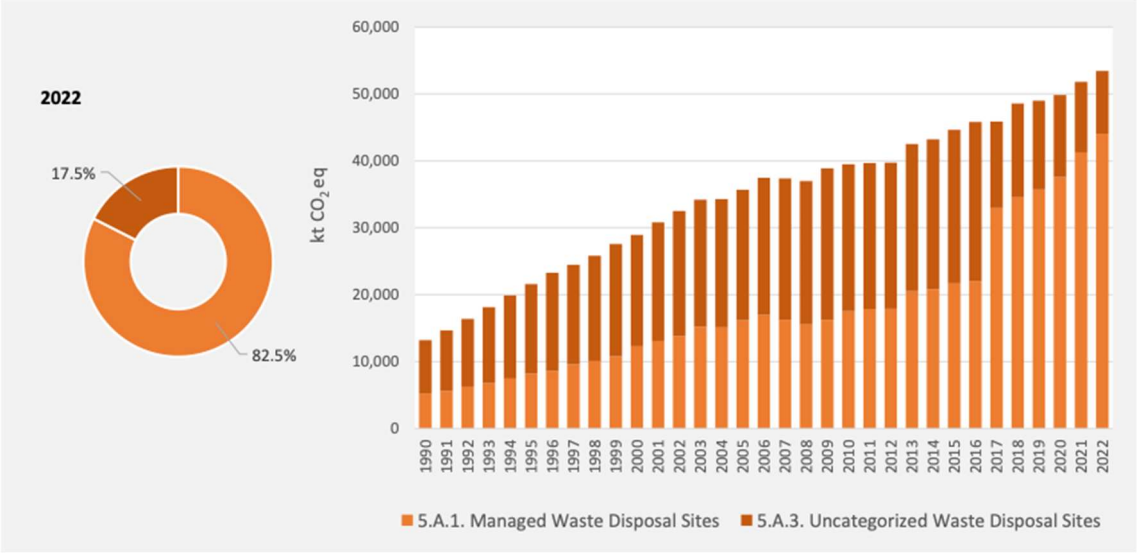


Figure 8.2. Emissions from Solid Waste Disposal (5.A), in kt CO_2 eq by category, from 1990 to 2022.

8.3.1 Methodological aspects

To calculate CH_4 emissions from categories 5.A.1 and 5.A.2 of the Solid Waste Disposal subsector (5.A), equations 8.1 to 8.5 were used, which are shown in Dataframe 8.4, with Tier 2 methodological details. The equations were applied as follows:

- Attainment of the amount of waste collected and disposed of annually;
- Quantification of the fraction of each category of waste based on the gravimetric data;
- Quantification of the fraction of each waste disposal category based on basic sanitation service data;
- Quantification of the mass of degradable carbon for each type of waste and, consequently, the sum of all types results in the mass of degradable carbon accumulated annually;
- Quantification of the mass of degradable carbon that is decomposed annually;
- Quantification of CH_4 generated from the decomposed material;
- Quantification of CH_4 recovered from material burned in CDM projects; and

- Quantification of CH_4 emitted.

Dataframe 8.4. Equations for estimating emissions from the Solid Waste Disposal subsector (5.A).

Equations	GHG	Categories	Central equation	Reference
Equation 8.1	CH_4	5.A.1 5.A.2	$CH_4\ \text{emitted}_{x,T} = \left[\sum_x CH_4\ \text{generated}_{x,T} - R_t\right] * (1 - OX_T)$	Equation 3.1 (IPCC, 2006, v. 5, chap. 3)
Equation 8.2	CH_4	5.A.1 5.A.2	$DDOC_m = W * DOC * DOC_f * MCF$	Equation 3.2 (IPCC, 2006, v. 5, chap. 3)
Equation 8.3	CH_4	5.A.1 5.A.2	$DDOCma_T = DDOCmd_T + (DDOCma_{T-1} * e^{-k})$	Equation 3.4 (IPCC, 2006, v. 5, chap. 3)
Equation 8.4	CH_4	5.A.1 5.A.2	$DDOC_m\ decomp_T = DDOCma_{T-1} * (1 - e^{-k})$	Equation 3.5 (IPCC, 2006, v. 5, chap. 3)
Equation 8.5	CH_4	5.A.1 5.A.2	$CH_4\ \text{generated}_T = DDOC_m\ decomp_T * F * 16/12$	Equation 3.6 (IPCC, 2006, v. 5, chap. 3)

In which:

$CH_4\ emitted_{x,T}$ = quantity of CH_4 emitted in year T (Gg CH_4 . $year^{-1}$);
$CH_4\ generated_{x,T}$ = quantity of CH_4 generated at the final disposal site in year T (Gg CH_4 . $year^{-1}$);
x = type of waste/material;
T = year inventoried;
R_T = CH_4 recovered in year T (Gg CH_4 . $year^{-1}$);
OX_T = oxidation factor in year T;
$DDOC_m$ = mass of decomposable degradable organic carbon (Gg);
W = mass of waste deposited (Gg);
DOC = degradable organic carbon in the year of deposition (Gg C Gg $waste^{-1}$);
DOC_f = DOC that decomposes (fraction);
MCF = CH_4 correction factor for aerobic decomposition in the year of deposition (fraction);
$DDOCma_T$ = DDOCm accumulated in SWDS at the end of year T (Gg);
$DDOCma_{T-1}$ = DDOCm accumulated in the SWDS at the end of year T-1 (Gg);
$DDOCmd_T$ = DDOCm deposited in SWDS in year T (Gg);
k = reaction constant, $k = \frac{\ln(2)}{t_{1/2}}$ ($year^{-1}$),
$t_{1/2}$ = half-life time ($year^{-1}$);
$DDOC_m\ decomp_T$ = degradable organic matter decomposed in year T (Gg);
F = CH_4 (volume) in the landfill gas generated (fraction); and
16/12 = molecular fraction CH_4/C.

Activity data and other parameters

The annual generation of MSW (Mg $year^{-1}$) was obtained from the product of the variables of total population ($inhabitant^{-1}year^{-1}$) and generation *per capita* of MSW (Mg $inhabitant^{-1}year^{-1}$). The total population data ($inhabitant^{-1}$ $year^{-1}$) was obtained from the surveys: Demographic Census (1970; 1980; 1991; 2000; 2010; 2022) (IBGE, 1991b; 2012; 2024b), Population Estimates (1992 to 1995; 1997 to 1999; 2001 to 2009; 2011 to 2021) (IBGE, 2000b; 2023d) and Population Count (1996 and 2007) (IBGE, 2008a). For the missing years in the time series, the total population was estimated by interpolation.

For more information on population estimates, see Box 8.1.

Box 8.1. Updating of population data

The population data in the time series has undergone methodological changes compared to the data used in the calculations in previous reports. For this edition of the NIR, the population data for the missing years (1970s and 1980s; 1990) was recalculated based on the data from the IBGE's Demographic Census (1970; 1980; 1991). The adjusted degree 2 polynomial (quadratic) model was applied to each state. For the years between 1991 and 2022, both census data and official IBGE's estimates were used. It should be noted that population data influences the results of almost all the categories in the Waste sector, and this is one of the main input data. Table 8.1 and Figure 8.3 show a comparison of the population data used to calculate emissions in previous inventories and in this edition (NIR 2024).

Table 8.1. Comparison of population data submitted in previous inventories and in the NIR 2024 after methodological adjustment.

Year	NIR 2024	Previous inventories	Difference
1970	93,130,683	92,685,279	0.481%
1971	95,744,517	95,325,649	0..439%
1972	98,352,372	97,958,846	0.402%
1973	100,954,566	100,584,863	0.368%
1974	103,551,098	103,203,709	0.337%
1975	106,141,962	105,815,380	0.309%
1976	108,727,173	108,419,879	0.283%
1977	111,306,715	111,017,203	0.261%
1978	113,880,596	113,607,354	0.241%
1979	116,448,817	116,190,329	0.222%
1980	119,011,052	118,766,131	0.206%
1981	121,568,267	121,334,759	0.192%
1982	124,119,502	123,896,214	0.180%
1983	126,665,069	126,450,492	0.170%
1984	129.204,980	128,997,598	0.161%
1985	131,739.224	131,537,532	0.153%
1986	134,267,810	134,070,288	0.147%
1987	136,790,730	136,595,870	0.143%
1988	139,307,991	139,114,280	0.139%
1989	141,819,587	141,625,515	0.137%
1990	144,325,525	144,129,578	0.136%
1991	146,825,475	146,626,464	0.136%
1992	149,206,029	149,116,181	0.060%
1993	151,540,595	151,598,720	-0.038%
1994	153,694,445	154,074,083	-0.246%
1995	155,791,127	156,542,276	-0.480%
1996	157,063,306	159,003,289	-1.220%

Year	NIR 2024	Previous inventories	Difference
1997	159,609,584	161,457,133	-1.144%
1998	161,763,775	163,903,804	-1.306%
1999	163,921,311	166,343,298	-1.456%
2000	169,872,854	168,775,619	0.650%
2001	172,385,826	171,200,764	0.692%
2002	174,632,960	173,618,738	0.584%
2003	176,871,437	176,029,536	0.478%
2004	181,581,024	178,433,161	1.764%
2005	184,184,264	180,829,614	1.855%
2006	186,770,562	183,218,889	1.938%
2007	183,879,292	185,600,991	-0.928%
2008	189,612,823	187,975,919	0.871%
2009	191,480,630	190,343,675	0.597%
2010	190,755,799	192,704,254	-1.011%
2011	192,379,287	195,057,662	-1.373%
2012	193,946,886	197,403,891	-1.751%
2013	201,032,714	199,742,955	0.646%
2014	202,768,562	202,074,838	0.343%
2015	204,450,049	204,399,546	0.025%
2016	206,081,432	206,717,082	-0.307%
2017	207,660,929		
2018	208,494,900		
2019	210,147,125		
2020	211,755,692		
2021	213,317,639		
2022	203,080,756		

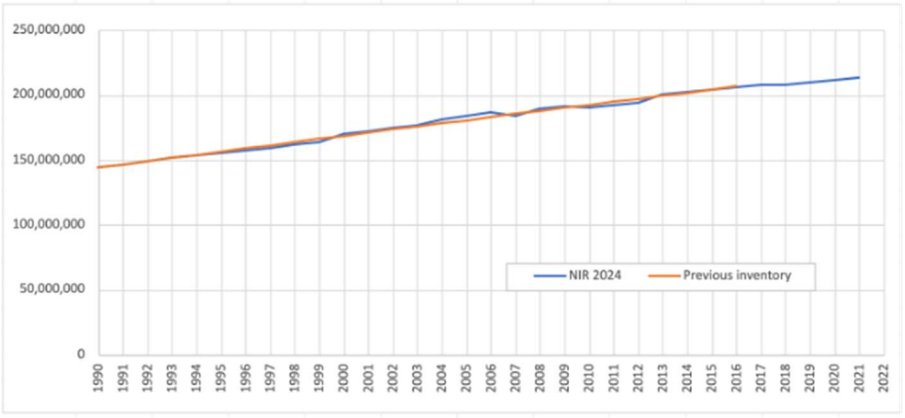


Figure 8.3. Comparison of population data submitted in previous inventories and in the NIR 2024 after methodological adjustment.

Given the lack of official national data on the generation of MSW *per capita* (Mg inhab^{-1} year^{-1}), this variable was calculated based on the ratio of the amount of waste collected and the population served with waste collection annually. The data on the population served with waste collection used to obtain the generation of MSW *per capita* was obtained from the Demographic Census (1980; 1991; 2000) (IBGE, 1991b; 2012; 2024b), and the Public Cleaning and Waste Removal surveys (1977; 1980; 1983) (IBGE, 1980a; 1980b; 1988). For both surveys, the population served with waste collection service was considered to be the total declared urban population. For the years in which data was available from the National Sanitation Information System – SNIS (2003 to 2024) (MCID, 2022), the values for the declaring population served with waste collection service, shown in indicator CO164,[115] were adopted.

The amount of waste collected annually was obtained from the Demographic Census (1980; 1991; 2000) (IBGE, 1991b; 2012; 2024b), and the Public Cleaning and Waste Removal surveys (1977; 1980; 1983) (IBGE, 1980a; 1980b; 1988). For the years with available SNIS data (2003 to 2024) (MCID, 2022), the declared values were adopted in indicator CO119.[116] For the years in which there was no official data on the population served with waste collection service or on the amount of waste collected, the annual MSW generation values were estimated by extrapolation based on a linear trend obtained from the observed data.

The national data on the population served with waste collection service (inhabitants^{-1} year^{-1}) was calculated based on the sum of the amount of waste collected in each state, and was obtained from the National Household Sample Survey (PNAD) (1992 to 2015) (IBGE, 2019b; 2019c), and the Continuous Annual National Household Sample Survey (PNADC) (2016 to 2022) (IBGE, 2023a). This methodological measure aimed to maintain the database for different subcategories, since these same data sources declare the amount of waste burned, as well as the population that is served with waste collection service. For the missing years, the population served with waste collection service was estimated by extrapolation based on a linear trend obtained from the observed data.

Another relevant parameter is the fraction of MSW disposed of at each type of final solid waste disposal site (SWDS), broken down into landfills, unmanaged waste disposal sites, composting and incineration. In order to determine the level of management of Brazilian SWDS between 1970 and 2016, we consulted the mapping of existing landfill sites and the respective dates in which their operation started. Data on the type of final solid waste disposal unit used in each Brazilian municipality was obtained from the National Solid Waste Management Information System – SINIR (Sistema Nacional de Informações sobre a Gestão dos Resíduos Sólidos) (MMA, 2015), through the survey on the Integrated Solid Waste Management Plan – PGIRS (Plano de Gestão Integrada de Resíduos Sólidos), in addition to the Public Cleaning and Garbage Removal surveys (1977; 1980; 1983) (IBGE, 1980a; 1980b; 1988) and the National Basic Sanitation Survey (PNSB) (IBGE, 1994; 2000a; 2008b), which explain the destination fractions of SWDS, composting yards and incinerators (Table 8.2).

[115] SNIS (2003 to 2024) (MCID, 2024), Indicator CO164 – Total population served in the municipality with regular waste collection at least once a week.
[116] SNIS (2003 to 2024) (MCID, 2024), Indicator CO119 – Total amount of Household Solid Waste and Urban Public Waste collected by all agents.

Table 8.2. MSW disposal data from the main Brazilian sanitation surveys.

Year	Garbage dump	Controlled landfill	Landfill	Composting
	fraction			
1983	0.60	0.13	0.26	0.01
1989	0.50	0.22	0.24	0.03
2000	0.31	0.23	0.42	0.04
2008	0.18	0.16	0.66	0.01

Source: Public Cleaning and Garbage Removal (1977; 1980; 1983) (IBGE, 1980a; 1980b); National Basic Sanitation Survey – PNSB (IBGE, 1994; 2000a; 2008b).

In order to annually update the fraction of MSW destined for landfills between 2017 and 2022, the information declared in SNIS indicators UP003[117] and UP025[118] was taken into account (Table 8.3). By cross-referencing this information, it was possible to calculate the fraction of the state's population that disposed of MSW in landfills each year, using the ratio between the population of municipalities with landfills and the total population of the state for the year under review. Thus, the sum of the states' results represented the national emissions. Regarding the composting fractions, the values declared in the 2008 PNSB were maintained.

Table 8.3. Population data regarding solid waste collection and disposal services in landfills in Brazil.

Year	Total population	Population served with waste collection service	Population served with waste disposal in landfills
	inhabitant year^{-1}		
1990	144,325,525	76,499,988	25,879,236
1991	146,825,475	85,480,467	26,282,726
1992	149,206,029	89,943,726	27,855,547
1993	151,540,595	95,700,996	28,551,946
1994	153,694,445	96,606,415	29,514,554
1995	155,791,127	101,448,426	31,316,155
1996	157,063,306	104,838,327	31,894,739
1997	159,609,584	110,681,694	38,045,841
1998	161,763,775	114,399,784	40,098,529
1999	163,921,311	118,066,727	41,837,841
2000	169,872,854	118,967,845	46,154,014
2001	172,385,826	133,948,024	50,897,448
2002	174,632,960	137,820,949	53,160,547
2003	176,871,437	141,683,155	57,434,900
2004	181,581,024	144,167,082	61,496,979
2005	184,184,264	146,684,042	65,469,489
2006	186,770,562	149,877,150	67,324,811
2007	183,879,292	150,701,078	67,436,270
2008	189,612,823	154,798,930	71,462,070

[117] SNIS (2003 to 2024) (MCID, 2024), Indicator UP003 – Type of unit, according to the reporting municipality
[118] SNIS (2003 to 2024) (MCID, 2024), Indicator UP025 – Municipality of origin of the waste

Year	Total population	Population served with waste collection service	Population served with waste disposal in landfills
	inhabitant year^{-1}		
2009	191,480,630	157,365,563	74,234,448
2010	190,755,799	155,122,929	76,831,230
2011	192,379,287	161,027,584	79,866,589
2012	193,946,886	162,399,245	82,552,133
2013	201,032,714	166,846,846	87,439,883
2014	202,768,562	168,901,710	89,147,854
2015	204,450,049	170,185,798	90,452,397
2016	206,081,432	171,439,272	91,348,758
2017	207,660,928	173,555,787	128,855,514
2018	208,494,900	175,172,234	128,471,639
2019	210,147,125	176,951,728	133,723,770
2020	211,755,692	184,850,837	144,137,462
2021	213,317,640	186,869,986	152,984,716
2022	203,080,757	176,908,423	149,095,337

Source: National Sanitation Information System – SNIS (Sistema Nacional de Informações sobre Saneamento) MCID (2018, 2022); IBGE (1994; 2000; 2008; 2019d; 2019e).

Data on the generation and disposal of Clinical Waste (CW) (Mg year^{-1}) was estimated annually for each state between 1990 and 2022, based on data available from the National Basic Sanitation Survey (PNSB) (IBGE, 2000a; 2008b). This survey indicates the municipalities that collect and dispose of CW, and quantify the mass of CW collected municipally (Table 8.4). Since the information on the population that generates CW is not included in the PNSB, an assumption was made that the mass of CW collected is proportional to the population served with the municipality's waste collection service. Therefore, the total population of the municipality was used as the generating population. The CW-generating population of each state (Pop_{CW}) results from the sum of the population of municipalities served with waste collection and disposal.

In order to fill the data gap in the years in which there is no observed data, the annual mass of CW collected in each state ($CW_{collection}$, Mg year^{-1}) was estimated using the product of the population generating CW and the annual *per capita* rate of clinical waste generation obtained in the observed years (2000 and 2008). To that end, we first found the ratio of the total population of the state to the generating population for the years 2000 and 2008, since not all municipalities in the state have CW collection and disposal.

Table 8.4. Total population (Pop_{total}), population served with waste collection (Pop_{CW}), mass collected and disposed of (CW) and mass *per capita* ($CW_{per\ capita}$) of clinical waste collection service (CW) in the states in 2000 and 2008.

UF	^{Pop}total		^{Pop}CW		CW		^{CW}per capita	
	2000	2008	2000	2008	2000	2008	2000	2008
	Inhabitants				Mg		kg inhabitant $^{-1}$	
AC (Acre)	557,882	680,075	383,417	641,120	949	10,447	2.5	16.3
AL (Alagoas)	2,827,856	3,127,560	2,183,662	1,507,318	7,884	35,810	3.6	23.8
AM (Amazonas)	2,817,253	3,341,094	2,035,582	2,843,740	10,403	42,681	5.1	15.0
AP (Amapá)	477,032	613,166	296,194	588,412	14,637	6,065	49.4	10.3
BA (Bahia)	13,085,768	14,502,563	8,886,768	10,015,049	58,437	265,841	6.6	26.5
CE (Ceará)	7,431,597	8,450,528	2,595,639	7,675,549	12,848	126,651	4.9	16.5
DF (Federal District)	2,051,146	2,557,159	2,051,146	2,557,159	9,052	15,453	4.4	6.0
ES (Espírito Santo)	3,097,497	3,453,646	2,710,174	3,242,343	9,125	53,850	3.4	16.6
GO (Goiás)	5,004,196	5,844,995	2,943,483	5,607,237	24,638	105,185	8.4	18.8
MA (Maranhão)	5,657,553	6,305,537	3,090,572	4,634,046	23,871	124,236	7.7	26.8
MG (Minas Gerais)	17,905,135	19,850,060	8,131,828	18,621,298	145,818	416,636	17.9	22.4
MS (Mato Grosso do Sul)	2,078,070	2,336,060	895,568	2,159,647	5,694	60,723	6.4	28.1
MT (Mato Grosso)	2,505,245	2,957,735	1,109,584	2,294,319	8,724	65,912	7.9	28.7
PA (Pará)	6,195,965	7,321,490	4,403,069	5,823,606	14,673	105,435	3.3	18.1
PB (Paraíba)	3,444,794	3,742,604	400,043	2,842,554	5,767	64,925	14.4	22.8
PE (Pernambuco)	7,929,153	8,734,196	4,683,467	7,630,143	30,587	124,730	6.5	16.3
PI (Piauí)	2,843,427	3,119,698	456,914	2,528,992	7,848	75,939	17.2	30.0
PR (Paraná)	9,564,643	10,590,171	3,865,769	9,155,987	34,164	191,917	8.8	21.0
RJ (Rio de Janeiro)	14,392,106	15,872,362	11,904,509	15,711,740	40,552	229,962	3.4	14.6
RN (Rio Grande do Norte)	2,777,509	3,106,436	436,548	2,925,703	17,885	83,144	41.0	28.4
RO (Rondônia)	1,380,952	1,493,565	665,264	1,159,348	6,643	19,385	10.0	16.7
RR (Roraima)	324,397	412,783	308,387	20,657	986	733	3.2	35.5
RS (Rio Grande do Sul)	10,187,842	10,855,228	1,883,922	8,079,147	19,674	187,429	10.4	23.2
SC (Santa Catarina)	5,357,862	6,052,587	2,311,987	5,481,028	17,338	118,626	7.5	21.6
SE (Sergipe)	1,784,829	1,999,374	247,114	1,671,082	5,950	41,770	24.1	25.0

UF	^{Pop}total		^{Pop}CW		CW		^{CW}per capita	
	2000	2008	2000	2008	2000	2008	2000	2008
	Inhabitants				Mg		kg inhabitant $^{-1}$	
SP (São Paulo)	37,035,455	41,011,638	26,285,174	38,217,107	947,759	644,284	36.1	16.9
TO (Tocantins)	1,157,690	1,280,513	658,614	1,125,434	4,563	34,018	6.9	30.2
BR (Brazil)	169,872,854	189,612,823	95,824,398	164,759,765	1,486,469	3,251,787	11.9	21.3

Source: Populations (IBGE, 1991b; 2000b; 2008a, 2012; 2023d; 2024b); PNSB – National Basic Sanitation Survey (Pesquisa Nacional de Saneamento Básico) 3G, 2000a; 2008b).

In order to fill in the gaps in the time series, the fractions of each state observed for the year 2000 were kept in the previous years (1990 to 2000) and the fractions observed in 2008 were kept in the subsequent years (2008 to 2022), and linear interpolation was carried out between the years 2000 and 2008. Finally, once the fraction of the state's population served with CW collection had been obtained, the state's population served with collection service (Pop_{CW}) was calculated for the remaining years. The national results represent the sum of the state populations (Dataframe 8.5).

A similar procedure was adopted to estimate the annual *per capita* rate of CW in each state. The *per capita* CW generation rate observed for each state was calculated as the ratio between the mass collected and the generating population in 2000 and 2008. To fill in the gaps in the time series, the states' rates observed for the year 2000 were kept in the previous years (up to 1990) and the states' rates observed in 2008 were kept in the subsequent years (up to 2016), and linear interpolation was carried out between the years 2000 and 2008.

Table 8.5. Annual amount of clinical waste collected and incinerated in Brazil (1990-2022).

Year	CW collected	CW incinerated
	Mg CW year^{-1}	
1990	1,251,041	125,104
1991	1,272,790	127,279
1992	1,293,529	129,353
1993	1,315,734	131,573
1994	1,335,379	133,538
1995	1,354,523	135,452
1996	1,370,420	137,042
1997	1,394,581	139,458
1998	1,415,109	141,511
1999	1,435,670	143,567
2000*	1,486,463	148,646
2001	1,665,330	166,533
2002	1,852,825	185,283
2003	2,051,295	205,129
2004	2,292,556	229,256
2005	2,522,287	252,229
2006	2,764,145	276,415
2007	2,930,456	293,046
2008*	3,251,785	325,179
2009	3,283,361	328,336
2010	3,270,428	327,043
2011	3,297,866	329,787
2012	3,324,348	332,435
2013	3,445,368	344,537
2014	3,474,554	347,455
2015	3,502,794	350,279
2016	3,530,160	353,016
2017	3,556,624	355,662
2018	3,568,968	356,897
2019	3,596,502	359,650
2020	3,623,348	362,335
2021	3,649,456	364,946
2022	3,484,849	348,485

Note: * Years with values observed in the National Sanitation Survey (IBGE, 2000; 2008); for all other years the values were estimated.

Regarding the generation of Domestic Wastewater Sludge (S-DWW) (Mg BOD year^{-1}), it was considered that the entire mass of wastewater sludge from domestic wastewater treatment generated is deposited in SWDS. The mass of sludge deposited in SWDS is obtained from the calculation of the "organic component removed as S-DWW" in the Domestic Wastewater Treatment subsector (5.D.1).

For the estimates of recovered methane (R) (Mg year^{-1}) we consulted the verification reports of the projects under the Clean Development Mechanism (CDM) for landfill gas flaring

(UNFCCC, 2024).[119] A total of 51 projects in operation between 2003 and 2022 were identified, 37 of which submitted methane recovery monitoring reports, which were taken into account in the calculations for this subsector (Table 8.6).

Table 8.6. Methane recovered in Clean Development Mechanism (CDM) projects in landfills (2003-2022).[a]

UNFCC Project Code	Project (names in English)	Municipality	State	R[b]	
				Mg CH_4	%
4211	Manaus Landfill Gas Project	Manaus	AM	160,294.3	3.75%
52	Salvador da Bahia Landfill Gas Management Project	Salvador	BA	454,947.2	10.65%
893	Canabrava Landfill Gas Project	Salvador	BA	451.7	0.01%
1626	Feira de Santana Landfill Gas Project	Feira de Santana	BA	1,612.0	0.04%
10261	Oeste de Caucaia Landfill Project Activity	Fortaleza	CE	124,911.5	2.92%
137	Brazil MARCA Landfill Gas to Energy Project	Cariacica	ES	4,943.8	0.12%
1491	CTRVV Landfill emission reduction project	Vila Velha	ES	39,941.6	0.93%
8242	CTR Rosario Landfill Gas Project	Rosário	MA	7,352.1	0.17%
3464	Exploitation of the biogas from Controlled Landfill in Solid Waste Management Central – CTRS	Belo Horizonte	MG	35,353.8	0.83%
7110	Uberlândia landfills I and II	Uberlândia	MG	49,112.0	1.15%
9063	MACAÚBAS LANDFILL GAS PROJECT	Sabará	MG	73,655.4	1.72%
888	Aurá Landfill Gas Project	Belém	PA	120,859.7	2.83%
1165	PROBIOGAS-JP – João Pessoa Landfill Gas Project	Joao Pessoa	PB	31,115.0	0.73%
3958	CTR Candeias Landfill Gas Project	Recife	PE	81,773.4	1.91%
8	Brazil NovaGerar Landfill Gas to Energy Project	Nova Iguaçu	RJ	162,781.0	3.81%
6573	Caixa Econômica Federal Solid Waste Management and Carbon Finance Project	São Gonçalo	RJ	168,466.6	3.94%
648	Central de Resíduos do Recreio Landfill Gas Project (CRRLGP)	Minas do Leão	RS	187,388.6	4.39%
9290	ITVR Sao Leopoldo landfill gas project	São Leopoldo	RS	6,895.7	0.16%
1506	Proactiva Tijuquinhas Landfill Gas Capture and Flaring project	Biguaçu	SC	70,785.4	1.66%
9943	Canhanduba Landfill Project	Balneário Camburiú	SC	4,501.0	0.11%
91	Landfill Gas to Energy Project at Lara Landfill, Mauá, Brazil	Mauá	SP	89,931.9	2.10%
27	Onyx Landfill Gas Recovery Project – Trémembé, Brazil	Tremembé	SP	18,801.7	0.44%
165	ESTRE's Paulínia Landfill Gas Project (EPLGP)	Paulínia	SP	385,305.7	9.02%
171	Caieiras landfill gas emission reduction	Caieiras	SP	701,877.1	16.43%
164	Bandeirantes Landfill Gas to Energy Project (BLFGE)	São Paulo	SP	295,233.3	6.91%
226	Anaconda Landfill Gas Project	Santa Isabel	SP	3,132.6	0.07%
373	São João Landfill Gas to Energy Project (SJ)	São Paulo	SP	140,572.5	3.29%
1179	Embralixo/Araúna – Bragança Landfill Gas Project	Bragança Paulista	SP	15,675.6	0.37%
1636	Alto-Tietê landfill gas capture project	Itaquaquecetuba	SP	20,696.6	0.48%
1133	Terrestre Ambiental Landfill Gás Project	Santos	SP	28,072.6	0.66%
911	ESTRE Itapevi Landfill Gas Project (EILGP)	Itapevi	SP	41,513.9	0.97%
1134	ESTRE Pedreira Landfill Gás Project (EPLGP)	Tremembé	SP	258,238.7	6.04%
1247	URBAM/ARAUNA – Landfill Gas Project (UALGP)	São José dos Campos	SP	54,562.1	1.28%
5947	CTL Landfill Gas Project	São Paulo	SP	354,573.8	8.30%
8751	Proactiva CGA Iperó Landfill Gas to Energy Project	Iperó	SP	1,025.0	0.02%
6553	CGR Guatapara Landfill Project	Guatapará	SP	50,694.6	1.19%

[119] UNFCCC, 2024. Methodologies (ACM0001, ACM0002, AM0002, AM0003, AM0011) under the Clean Development Mechanism (CDM) of the Kyoto Protocol. Link to projects' search: https://cdm.unfccc.int/Projects/projsearch.html

UNFCC Project Code	Project (names in English)	Municipality	State	R[b]	
				Mg CH_4	%
7799	Projeto de Gás de Aterro TECIPAR – PROGAT	Santana de Parnaíba	SP	25,923.3	0.61%
TOTAL OF RECOVERED METHANE Mg CH_4 (2003-2022)				**4,272,973**	**100%**

Note: [a] 2021-2022 values were estimated with linear extrapolation over the last 5 years; [b] Recovered Methane (R): accumulated value since the start of the project's operation (UNFCCC, 2024).

For the years of 2021 and 2022, when the methane recovery projects did not report data and the deadline for closing the projects is after 2022, the recovered methane emissions were estimated, where necessary, up to the deadline of December 2022. In order to extrapolate recoveries, projects were selected which complied with the methodologies related to recovery in landfills (ACM0001, ACM0002, AM0002, AM0003, AM0011), which provided for credit periods with a closing date after 2022, and which presented at least three years of observed data over the last five years. The projects with codes 64 and 373 (Table 8.6), presented observed data for 2021; thus, only the 2022 removals were extrapolated. For projects 1506, 1247, 1491 and 3464, with closing dates between the first and last day of the year, removals were accounted for in proportion to the days of operation. Projects 6553 and 8751 presented constant values that were maintained for estimating methane recovery (2021-2022).

As a result, it was estimated that 336.2 kt of CH_4 were recovered from landfills in 2022, which contributed to a 15% reduction in the subsector's total emissions (Figure 8.4).

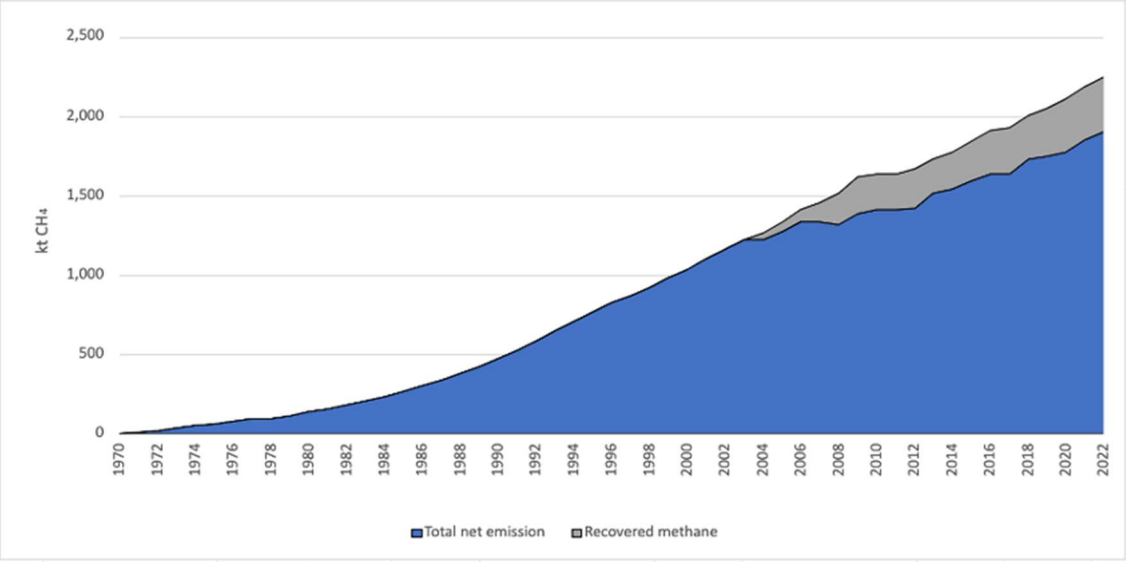


Figure 8.4. Total emissions from the Solid Waste Disposal subsector (5.A), considering emissions avoided by methane recovered in CDM projects.

The main parameters and emission factors applied in this subsector are related to the type of waste, the type of final disposal and the climate characteristics of the disposal region. The composition of the waste sent to SWDS indicates the fraction of degradable organic carbon (DOC) that can be decomposed and transformed into CH_4. The DOC value is the

product of the gravimetric composition (percentage of paper, textiles, food waste, wood, pruning waste, disposable diapers, rubber and leather, glass, metal, plastic, other, etc.) and the mass of carbon contained in each fraction (Dataframe 8.5).

Dataframe 8.5. Equation for estimating the fraction of degradable organic carbon (DOC).

Equations	GHG	Categories	Central equation	Reference
Equation 8.6	CO_2	5.A.1 5.A.2	$DOC = \sum_i (DOC_i * W_i)$	Equation 3.7 (IPCC, 2006, v. 5, chap. 3)

In which:

DOC = degradable organic carbon in the year of deposition (Gg C Gg waste^{-1});
DOC_i = degradable organic carbon in the year of deposition in each waste category i (Gg C Gg waste^{-1});
W_i = gravimetric proportion by waste category i (fraction); and
i = waste category.

For other emission factors, the default values suggested in the IPCC Guidelines were applied, such as for the carbon content of each gravimetric fraction of MSW (IPCC, 2006; v. 5, chap. 2, p. 2.14, Table 2.4), by type of waste, including specific values for the disposal of domestic wastewater sludge (S-DWW) based on the mass of BOD disposed of and on clinical waste (CW) (IPCC, 2006; v. 5, chap. 2, p. 2.16, Table 2.6). Due to the lack of national data on the fraction of decomposable degradable organic carbon (DOC_f) (IPCC, 2006; v. 5, chap. 3, p. 3.13), the default value of 0.5 for developing countries was used. For the same reason, the values of 0.5 for the fraction of CH_4 in landfill gas (F) (IPCC, 2006; v. 5, chap. 3, p. 3.15) and zero for the oxidation factor (OX) were determined (IPCC, 2006; v. 5, chap. 3, p. 3.15, Table 3.2). Two OX values are presented in the 2006 IPCC Guidelines, zero and 0.1. The latter is only recommended for very well-managed sites, where the waste is covered daily with material that allows the oxygenation and oxidation of CH_4, or air is injected into the surface layers, which does not happen in Brazil.

The values for the gravimetric composition of MSW were compiled from academic literature (scientific articles, congress annals, books and theses) and states' solid waste plans. The set of information consulted covered the period between 1963 and 2018, totaling 520 municipal observations distributed among 92 references (Brasil, 2015). Based on the average data observed in the literature, the municipal series of gravimetric composition were linearly interpolated, the average weighted by the population of the respective municipalities in each year was calculated for each of the levels (state, regional and national), and the gravimetric composition referring to the lowest hierarchical level available in each year was selected for each state. Thus, when there was an observation for the state in the year assessed, the average value was used (FU – Federal Unit – State). If there was no average value for the state in the year assessed, the average value for the demographic region (RE – regional) was used. As there was no average data for the demographic region in the year assessed, the national average value (BR – national) was used (Table 8.7). Given the lack of data for more recent years, in order to determine the gravimetric compositions between 2017 and 2022, the state proportions of each category of waste determined for 2016 were maintained.

Table 8.7. Gravimetric composition of MSW in Brazilian states between 1970 and 2016. Average (min-max).

State	Paper	Textiles	Food Waste	Wood	Pruning waste	Disposable diapers	Rubber and Leather	Plastics	Other
	Percentage (%)								
AC	22.5 (10.0 – 33.7)	1.2 (0 – 2.6)	45.2 (19.1 – 58.7)	2.0 (0 – 4.6)	0.4 (0 – 1.9)	0.1 (0 – 1.1)	0.6 (0 – 1.7)	9.9 (1.5 – 18.0)	18.1 (7.7 – 39.8)
AL	19.3 (6.2 – 33.7)	1.8 (0 – 3.2)	46.4 (19.1 – 72.7)	1.5 (0 – 4.6)	0.4 (0 – 1.9)	-	0.4 (0 – 1.2)	10.2 (1.5 – 21.4)	19.7 (10.6 – 36.1)
AM	22.7 (10.0 – 33.7)	1.3 (0 – 2.6)	45.0 (19.1 – 58.7)	2.1 (0.1 – 4.6)	0.4 (0 – 1.9)	0.1 (0 – 1.1)	0.6 (0 – 1.7)	10.0 (1.5 – 18.5)	17.9 (7.7 – 39.8)
AP	22.4 (10.0 – 33.7)	1.2 (0 – 2.6)	45.1 (19.1 – 58.7)	2.0 (0 – 4.6)	0.4 (0 – 1.9)	0.1 (0 – 1.1)	0.6 (0 – 1.7)	9.8 (1.5 – 18.0)	18.4 (7.7 – 39.8)
BA	19.1 (5.3 – 33.7)	1.8 (0 – 4.2)	46.0 (19.1 – 72.7)	1.2 (0 – 4.6)	0.4 (0 – 1.9)	0.7 (0 – 6.5)	0.4 (0 – 1.5)	10.4 (1.5 – 21.7)	19.8 (8.9 – 36.1)
CE	19.1 (2.4 – 33.7)	1.6 (0 – 4.2)	46.0 (19.1 – 72.7)	1.2 (0 – 4.6)	0.6 (0 – 1.9)	0.3 (0 – 3.4)	0.4 (0 – 0.9)	9.6 (1.5 – 16.4)	21.0 (10.6 – 43.6)
DF	21.8 (11.7 – 33.7)	1.7 (0.1 – 3.6)	37.7 (19.1 – 51.3)	1.7 (0.1 – 4.6)	-	-	1.2 (0.1 – 2.6)	3.8 (0.2 – 7.5)	31.6 (24.3 – 36.6)
ES	22.0 (10.7 – 33.7)	1.2 (0 – 2.5)	47.7 (19.1 – 63.4)	1.1 (0 – 4.6)	0.6 (0 – 2.2)	0.1 (0 – 1.1)	0.3 (0 – 1.2)	10.2 (1.5 – 20.9)	16.5 (8.0 – 36.1)
GO	21.1 (4.5 – 33.7)	2.0 (0 – 5.9)	40.2 (19.1 – 68.2)	1.7 (0 – 4.6)	0.1 (0 – 1.1)	0.1 (0 – 2.7)	1.1 (0 – 2.6)	6.1 (0.2 – 16.4)	27.3 (5.9 – 37.4)
MA	18.9 (5.8 – 33.7)	1.6 (0 – 4.2)	47.0 (19.1 – 76.2)	1.1 (0 – 4.6)	0.6 (0 – 1.9)	0.4 (0 – 3.4)	0.4 (0 – 0.9)	9.7 (1.5 – 16.4)	20.2 (5.9 – 36.1)
MG	20.8 (8.8 – 33.7)	1.1 (0 – 2.0)	49.0 (19.1 – 68.1)	0.9 (0 – 4.6)	0.7 (0 – 4.5)	0.1 (0 – 1.1)	0.2 (0 – 0.6)	9.2 (1.5 – 20.9)	18.2 (3.4 – 41.7)
MS	20.3 (11.4 – 33.7)	2.0 (0 – 4.7)	44.8 (19.1 – 66.4)	1.6 (0 – 4.6)	0.1 (0 – 0.9)	0.1 (0 – 0.8)	1.0 (0 – 2.6)	7.8 (0.2 – 18.4)	22.1 (1.8 – 38.0)
MT	21.0 (10.7 – 33.7)	3.1 (0 – 12.1)	35.5 (19.1 – 51.3)	1.9 (0 – 4.6)	0.8 (0 – 6.0)	-	1.1 (0 – 2.6)	7.9 (0.2 – 16.7)	28.4 (7.2 – 47.1)
PA	22.1 (4.0 – 33.7)	1.2 (0 – 2.6)	44.8 (19.1 – 58.7)	1.9 (0 – 4.6)	0.4 (0 – 1.9)	0.1 (0 – 1.1)	0.6 (0 – 1.7)	9.7 (1.5 – 18.0)	19.3 (7.7 – 43.2)
PB	18.9 (3.7 – 33.7)	1.7 (0 – 5.9)	46.7 (19.1 – 72.7)	1.2 (0 – 4.6)	0.5 (0 – 1.9)	0.7 (0 – 7.9)	0.4 (0 – 0.9)	9.4 (0 – 24.8)	20.3 (8.1 – 39.3)
PE	19.6 (6.2 – 33.7)	1.4 (0 – 4.2)	47.9 (19.1 – 72.7)	1.1 (0 – 4.6)	0.5 (0 – 1.9)	0.2 (0 – 3.4)	0.3 (0 – 0.7)	8.8 (1.5 – 16.4)	20.0 (10.6 – 36.1)
PI	19.1 (6.2 – 33.7)	1.7 (0 – 4.2)	46.1 (19.1 – 72.7)	1.2 (0 – 4.6)	0.6 (0 – 1.9)	0.4 (0 – 3.4)	0.4 (0 – 0.9)	9.8 (1.5 – 16.4)	20.5 (10.6 – 36.1)
PR	18.2 (8.6 – 33.7)	1.8 (0 – 4.3)	43.1 (19.1 – 67.1)	1.0 (0 – 4.6)	1.2 (0 – 11.9)	0.8 (0 – 8.4)	0.8 (0 – 2.8)	10.1 (1.5 – 18.2)	23.2 (12.0 – 40.1)
RJ	27.0 (11.1 – 44.0)	1.8 (0 – 4.3)	41.0 (0 – 61.4)	1.6 (0 – 7.1)	2.0 (0 – 5.9)	0.1 (0 – 1.1)	0.4 (0 – 1.0)	11.7 (1.5 – 21.1)	14.4 (5.1 – 50.0)
RN	19.0 (5.1 – 33.7)	1.9 (0 – 4.2)	42.0 (19.1 – 72.7)	1.2 (0 – 4.6)	1.6 (0 – 10.6)	0.2 (0 – 3.4)	0.4 (0 – 0.7)	9.9 (1.5 – 16.4)	23.7 (10.6 – 41.9)
RO	22.4 (10.0 – 33.7)	1.2 (0 – 2.6)	45.2 (19.1 – 58.7)	2.0 (0 – 4.6)	0.4 (0 – 1.9)	0.1 (0 – 1.1)	0.6 (0 – 1.7)	10.0 (1.5 – 18.0)	18.1 (7.7 – 39.8)
RR	22.5 (10.0 – 33.7)	1.2 (0 – 2.6)	45.0 (19.1 – 58.7)	2.0 (0 – 4.6)	0.4 (0 – 1.9)	0.1 (0 – 1.1)	0.6 (0 – 1.7)	10.0 (1.5 – 19.0)	18.2 (7.7 – 39.8)
RS	18.5 (10.0 – 33.7)	2.6 (0.1 – 8.5)	42.6 (19.1 – 58.4)	1.1 (0 – 4.6)	0.9 (0 – 11.9)	0.6 (0 – 8.4)	0.7 (0 – 2.8)	9.5 (1.5 – 20.9)	23.7 (9.0 – 40.1)
SC	19.9 (11.2 – 33.7)	2.1 (0.4 – 4.3)	40.7 (19.1 – 59.3)	1.1 (0.1 – 4.6)	1.8 (0 – 11.9)	1.3 (0 – 8.4)	1.0 (0.1 – 2.8)	10.9 (1.5 – 18.1)	21.3 (8.5 – 40.1)
SE	19.1 (6.2 – 33.7)	1.9 (0 – 9.1)	46.2 (19.1 – 72.7)	1.1 (0 – 4.6)	0.6 (0 – 1.9)	0.4 (0 – 3.4)	0.4 (0 – 0.9)	10.0 (1.5 – 18.5)	20.3 (4.8 – 36.1)
SP	19.1 (9.2 – 30.5)	1.6 (0 – 9.7)	50.0 (31.0 – 68.8)	1.0 (0 – 4.3)	0.1 (0 – 1.6)	0.1 (0 – 5.2)	0.2 (0 – 0.9)	11.1 (1.5 – 21.7)	16.8 (2.2 – 37.6)
TO	22.4 (6.9 – 33.7)	1.2 (0 – 2.6)	45.5 (19.1 – 79.6)	1.9 (0 – 4.6)	0.4 (0 – 1.9)	0.1 (0 – 1.1)	0.6 (0 – 1.7)	10.0 (1.5 – 25.2)	17.9 (4.0 – 39.8)

Note: The values shown are those observed and estimated based on national literature as described in the text.

Different values of the methane generation rate constant (k) are associated with the composition of the waste and the temperature and humidity regime of the region in which the SWDS is located. No national k values were identified. Therefore, the default average values corresponding to the decay of the gravimetric fractions of MSW and the average composition of CW and S-DWW in the different climate regions were used, as shown in Table 8.8 (IPCC, 2006, v. 5, chap. 2, p. 3.17, Table 3.3).

Table 8.8. Default values recommended for methane generation rate (k).

Decomposition speed	Type of waste	Temperate		Tropical	
		Dry	Humid	Dry	Humid
Slow	Paper and Paperboard	0.04	0.06	0.045	0.07
	Textiles	0.04	0.06	0.045	0.07
	Wood	0.02	0.03	0.025	0.035
	Rubber and Leather	0.02	0.03	0.025	0.035
Moderate	Pruning waste	0.05	0.10	0.065	0.17
	Diapers	0.05	0.10	0.065	0.17
Fast	Food Waste	0.06	0.185	0.085	0.40
	S-DWW	0.06	0.185	0.085	0.40
Mix	MSW	0.05	0.09	0.065	0.17
	ISW-CW	0.05	0.09	0.065	0.17

Source: Prepared based on IPCC 2006, v. 5, chap. 3, p. 3.17, Table 3.3.

The classification of the climate region of the Brazilian municipalities was carried out by evaluating the climate variables of mean annual temperature (MAT), mean annual precipitation (MAP) and potential evapotranspiration (PET), as recommended in the 2006 IPCC Guidelines. The municipal data for these variables was obtained for the time series from 1970 to 2010. For the classification, only the average value of each variable of the municipality's time series was used (Brasil, 2015). Based on the classification of the municipalities, the representativeness of the population living in each climate region in relation to the total population of the state was calculated annually, from 1970 to 2022. This calculation must be carried out since the municipalities have different population growth rates, so that each year they represent a different share of the total population (Table A.VIII.1, Appendix VIII).

The methane correction factor (MCF) is associated with the quality of the operation of the final disposal site. The better the management, the greater the capacity to promote anaerobiosis and, consequently, the generation and emission of CH_4 (IPCC, 2006, v. 5, ch. 3, item 3.2.3, table. 3.1). The description of final disposal sites (SWDS) indicates a classification for landfills (Managed – anaerobic), but does not specify a classification for controlled landfills and garbage dumps. Therefore, controlled landfills and garbage dumps have been classified as "Uncategorized", since there are not enough characteristics regarding these sites to allow them to be classified in any other category. Therefore, only Managed Waste Disposal Sites (landfills) with an MCF of 1 and Uncategorized Waste Disposal Sites (controlled landfills and garbage dumps) with an MCF of 0.6 were considered to exist in Brazil (IPCC, 2006; v. 5, ch. 3, Table 3.1, p. 3.14) (Table A.VIII.2, Appendix VIII).

8.3.2 Quality assurance and quality control

The QA/QC procedures adopted for the subsector of Solid Waste Disposal (5.A) are described in section 2.5 of this document.

8.3.3 Assessment of uncertainty, consistency and recalculations of the time series

An uncertainty analysis was carried out using the Monte Carlo methods and techniques described in the 2006 IPCC Guidelines. The uncertainty associated with CH_4 emissions from Solid Waste Disposal (5.A) is presented in Appendix II.

The process of updating the National Inventory of the Waste sector considered the revision of the time series of activity data, a process that resulted in adjustments, albeit small ones, to the emission estimates for the Solid Waste Disposal categories (5.A). In short, the following were re-assessed:

- *Population data (1970-2016):* The population data was reviewed and a new quadratic regression model was applied to estimate the total states' populations for the years in which there was no official observed or estimated data (1971-1979; 1981-1990) from IBGE;
- *Population served with waste collection (missing years):* Based on the data observed in the PNAD/PNADC, estimates were made using simple linear regression between 1970-2022; and
- *Methane recovery (2003-2022):* The methane reductions reported between 2003 and 2020 in CDM projects were updated (UNFCCC, 2024). As mentioned above, methane recoveries for the years of 2021 and 2022 were estimated using linear extrapolation based on the data observed in previous years.

Comparing the consolidated results of the previous Inventory with the one carried out for this NIR 2024, the largest proportion of adjustments is seen in 2020 with a 13% difference between estimated emissions. This adjustment is related to the updating of CDM projects values, especially in 2020. The estimated GHG emissions between 2017 and 2020 for the Waste sector in Brasil (2022) were not obtained from emitting activity data, but from extrapolating the values of the last five years (2012-2016) submitted in the Fourth National Communication (Brasil, 2021). Between 2017 and 2020, the average adjustment in aggregate emissions was 10%, and in the period from 1990 to 2020 it was 6%, thus demonstrating the consistency of the sector's time series. Among all the years in the time series, the main factor influencing the differences between the publications is related to the recalculation of population values and, above all, the updating of CH_4 recovery values in CDM projects (Figure 8.5).

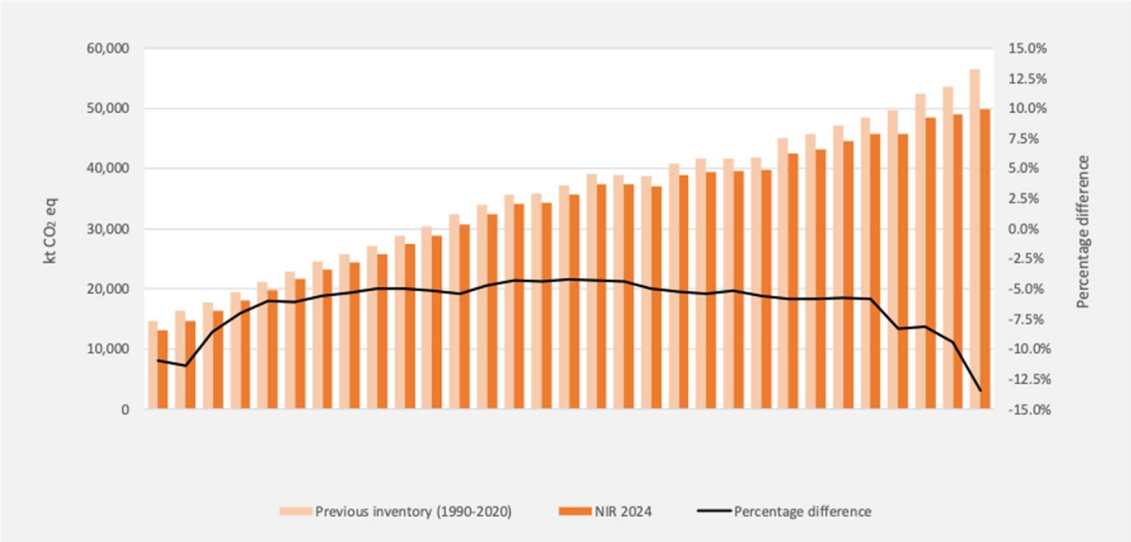


Figure 8.5. Comparison of estimated emissions from the Solid Waste Disposal subsector (5.A) between the inventories.

8.3.4 Improvement plan

The systematic preparation of national GHG inventories has allowed us to gain knowledge that enables us to propose measures aimed at improving the results of the Inventory, in particular of Solid Waste Disposal (5.A).

Dataframe 8.6 summarizes the potential improvements to be implemented in future editions of this subsector's inventory.

Dataframe 8.6. Improvements potentially applicable to future editions of the emissions inventory for the Solid Waste Disposal subsector (5.A).

Subsector	Category	Improvement
	General (all categories)	▪ Establish partnerships with institutions responsible for managing data from the National Sanitation Information System (SNIS) in order to assess the possibility of proposing metrics and data quality standards that meet the methodological requirements of Tier 2 with regard to the collection of municipal data on solid waste generation, collection and disposal; ▪ Expand studies to explore the information available in the database of the National Solid Waste Management Information System (SINIR+ (Sistema Nacional de Informações sobre a Gestão dos Resíduos Sólidos)) and at other institutions, with a view to analyzing the feasibility of using this data in emissions calculations for future inventories, with the inclusion of information on the disposal of industrial waste; ▪ Establish partnerships with educational and research institutions with a view to mapping municipal climate data that influences solid waste degradation; ▪ Establish Technical Cooperation Agreements or partnerships to promote the production and collection of new data on the gravimetric composition of municipal solid waste, with the aim of determining new categories based on different waste generation profiles, based on economic and social data, as well as municipal political and administrative divisions; ▪ Establish Technical Cooperation Agreements or partnerships to promote the production and collection of data to characterize the types of solid waste disposal into the four standard categories (Managed – anaerobic;

Subsector	Category	Improvement
		Managed-semi-anaerobic; Unmanaged deep (>5m); and Unmanaged shallow (<5m)).
5.A. SOLID WASTE DISPOSAL	5.A.1. Managed waste disposal sites	▪ Expand studies to explore quantitative data on the mass of waste disposed of in landfills and on the *per capita* generation obtained from the National Sanitation Information System (SNIS) database; ▪ Promote a dialogue with companies that have CDM projects to access key parameters for calculating emissions/obtaining methane capture estimates.
	5.A.3. Uncategorized waste disposal sites	▪ Expand studies to explore the database of the National Sanitation Information System (SNIS) in order to identify indicators that signal the closure of uncategorized waste disposal sites over the years of the time series.

8.4 Biological Treatment of Solid Waste (CRT 5.B)

The Biological Treatment of Solid Waste category (5.B) accounts for CH_4 and N_2O emissions associated with the aerobic composting process, which is related to the quantity, type and composition of the organic waste deposited. It is subdivided into Composting (5.B.1) and Anaerobic Digestion at Biogas Facilities (5.B.2).

In Brazil, energy generation from biogas flaring is declared in the National Energy Balance and its emissions are accounted for in the Energy sector (CRT 1). However, the generation sources are not segregated, preventing the tracking of emissions resulting exclusively from the biological treatment of anaerobic digestion at biogas facilities. For flares, according to the IPCC (2006) assumption, CO_2 emissions are of biogenic origin and CH_4 and N_2O emissions are small and do not need to be estimated.

Emissions from category 5.B.1 of composting of municipal solid waste were estimated at 61 kt CO_2 eq in 2022, which reflected a 3% reduction compared to 2020 (Figure 8.6). CH_4 and N_2O emissions represented 64% and 36% of total emissions in 2022, respectively.

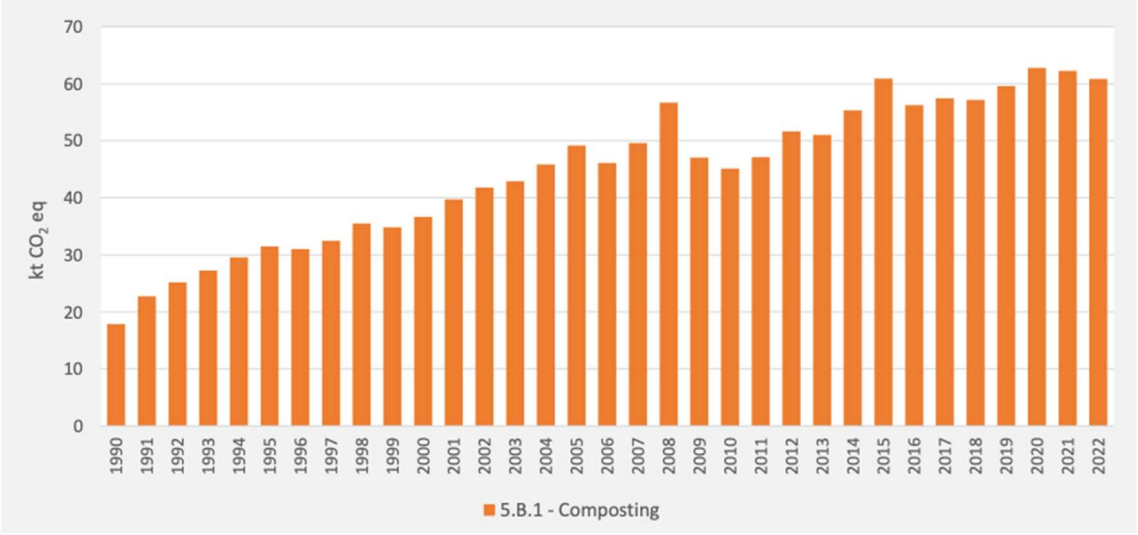


Figure 8.6. Emissions from the Biological Treatment of Solid Waste (5.B), in kt CO_2 eq by category, from 1990 to 2022.

8.4.1 Methodological aspects

In order to calculate emissions of CH_4 and N_2O from the Biological Treatment of Solid Waste subsector (5.B), Equations 8.7 and 8.8 were used, as shown in Dataframe 8.7, with Tier 1 methodological details.

The equations were applied as follows:

- Quantification of waste collected and disposed of annually;
- Quantification of the fraction of the organic waste category, using gravimetry;
- Quantification of the mass of organic waste treated by the biological treatment of composting; and
- Quantification of CH_4 and N_2O emitted by multiplying the quantity of waste by the respective emission factors.

Dataframe 8.7. Equations for estimating emissions from the Biological Treatment of Solid Waste subsector (5.B).

Equations	GHG	Categories	Central equation	Reference
Equation 8.7	CH_4	5.B.1	$CH_4\ \text{emitted}_T = \sum_i (M * \ EF_{CH4}) * 10^{-3} - R$	Equation 4.1 (IPCC, 2006, v. 5, chap. 4)
Equation 8.8	N_2O	5.B.1	$N_2O\ \text{emitted}_T = \sum_i (M * \ EF_{N2O}) * 10^{-3}$	Equation 4.2 (IPCC, 2006, v. 5, chap. 4)

In which:

$CH_4\ \text{emitted}_T$ = quantity of CH_4 emitted in year T (Gg CH_4 . $year^{-1}$);
$N_2O\ \text{emitted}_T$ = quantity of N_2O emitted in year T (Gg N_2O . $year^{-1}$);
M = mass of organic waste treated by the biological treatment of composting (Gg . $year^{-1}$);
EF = emission factors for composting treatment (g CH_4 kg^{-1} waste treated / g N_2O kg^{-1} waste treated); and
R = total quantity of CH_4 recovered in year T (Gg CH_4 . $year^{-1}$).

Activity data and other parameters

In order to estimate the mass of organic waste sent for composting, the annual values for the mass of MSW collected each year ($MSW_{collected}$, Mg $year^{-1}$) were obtained from the product of the population served with MSW collection and the daily rate *per capita* of MSW generation.[120] The organic fraction present in the MSW mass was calculated based on the gravimetric fractions of food waste and pruning waste. With regard to the values of the gravimetric compositions for the years between 2017 and 2022, the states' proportions of each category of waste determined for 2016 were maintained.

Based on the data on the final destination of MSW presented in the National Basic Sanitation Survey PNSB (IBGE, 1994; 2000a; 2008b), the national average composting fraction of 1% was considered. This percentage was applied to the mass of organic waste

[120] References and methodology for calculating population data and per capita generation rates are described in section 8.3.1. Methodological aspects of the Solid Waste Disposal subsector.

to calculate the mass of composted waste. The emissions of CH_4 and N_2O are the result of the product between the composted mass of MSW and their respective default emission factors (Dataframe 8.8).

Dataframe 8.8. Emission factors of the biological treatment of solid waste.

Categories	Parameter	Emission factors	Reference
5.B.1	EF CH_4	$4.0 \frac{g}{kg\ MSW}$	Table 4.1 (IPCC, 2006, v. 5, chap.4)
5.B.1	EF N_2O	$0.24 \frac{g}{kg\ MSW}$	Table 4.1 (IPCC, 2006, v. 5, chap.4)

8.4.2 Quality assurance and quality control

The QA/QC procedures adopted for the subsector of Biological Treatment of Solid Waste (5.B) are described in section 2.5 of this document.

8.4.3 Assessment of uncertainty, consistency and recalculations of the time series

An uncertainty analysis was carried out using the Monte Carlo methods and techniques described in the 2006 IPCC Guidelines. The uncertainty associated with CH_4 and N_2O emissions from Biological Treatment of Solid Waste (5.B) is presented in Appendix II.

The process of updating the National Inventory considered the revision of the time series of activity data, a process that resulted in adjustments, albeit small ones, to the emission estimates for the Biological Treatment of Solid Waste categories (5.B). In short, the following were re-assessed:

- *Population data (1990-2016):* Revision of the total number of inhabitants and adjustment of the data on inhabitants served with waste collection service were also adjusted; both descriptions are included in the recalculations item for subsector 5.A; and
- *Gravimetric composition (2017-2022):* The gravimetric composition values from 2016 were maintained.

Comparing the consolidated results of the previous Inventory with the one carried out for this NIR 2024, the largest proportion of adjustments is seen in 2018 with a 21% difference between estimated emissions. The estimated GHG emissions between 2017 and 2020 for the Waste sector in Brasil (2022) were not obtained from emitting activity data, but from extrapolating the values of the last five years (2012-2016) submitted in the Fourth National Communication (Brasil, 2021). Between 2017 and 2020, the average adjustment in aggregate emissions was of 19%, and in the period from 1990 to 2020, it was of 8%, thus demonstrating the consistency of the sector's time series (Figure 8.7).

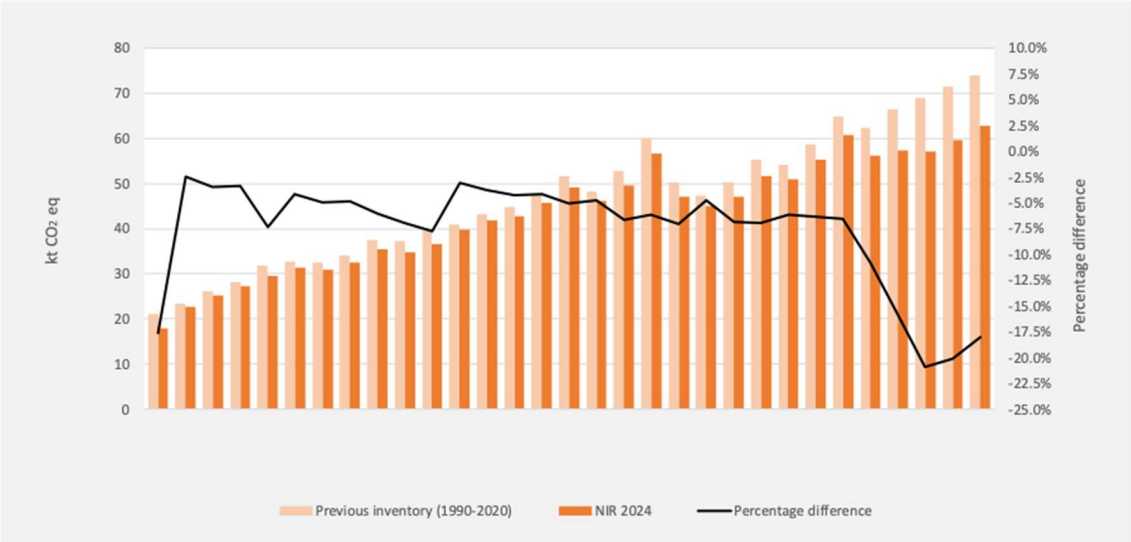


Figure 8.7. Comparison of estimated emissions from the Biological Treatment of Solid Waste subsector (5.B) between inventories.

8.4.4 Improvement plan

The systematic preparation of national GHG inventories has allowed us to gain knowledge that enables us to propose measures aimed at improving the results of the Inventory, in particular of Biological Treatment of Solid Waste (5.B).

Dataframe 8.9 summarizes the potential improvements to be implemented in future editions of this subsector's inventory.

Dataframe 8.9. Improvements potentially applicable to future editions of the emissions inventory for the Biological Treatment of Solid Waste subsector (5.B).

Subsector	Category	Improvement
	General (all categories)	▪ Establish Technical Cooperation Agreements or partnerships to promote the production and collection of new data on the gravimetric composition of municipal solid waste, with the aim of determining new categories based on different waste generation profiles, based on economic and social data, as well as municipal political and administrative divisions.
5.B. BIOLOGICAL TREATMENT OF SOLID WASTE	5.B.1 Composting	▪ Establish Technical Cooperation Agreements or partnerships with institutions responsible for managing data from the National Sanitation Information System (SNIS) in order to encourage the mapping of information regarding municipal solid waste composting practices; ▪ Expand studies to explore the information available in the database of the National Solid Waste Management Information System (SINIR+ (Sistema Nacional de Informações sobre a Gestão dos Resíduos Sólidos)) and in other databases, with a view to analyzing the feasibility of using this data in emissions calculations for future inventories, including information on municipal solid waste composting and on industrial activities; ▪ Establish partnerships with public-private institutions to assess the feasibility of obtaining data from composting projects.

Subsector	Category	Improvement
	5.B.2. Anaerobic Digestion at Biogas Facilities	▪ Establish partnerships with institutions that operate biogas production facilities in order to assess the possibility of quantifying production from the anaerobic treatment of solid waste.

8.5 Incineration and Open Burning of Waste (CRT 5.C)

The Incineration and Open Burning of Waste subsector (5.C) includes emissions of CH_4, N_2O and CO_2 resulting from the waste burning process. Emissions vary according to the type of burning, which can take place in a controlled or uncontrolled manner, and are also influenced by population characteristics, the amount of waste generated and the gravimetric composition of the waste burned. The category covers Waste Incineration (5.C.1) and Open Burning of Waste (5.C.2).

Emissions from this subsector amounted to 1,224 kt CO_2 eq in 2022, 90% of which came from the Open Burning of Waste category (5.C.2) (1,107 kt CO_2 eq). There was an 8% decrease in emissions in this category compared to 2020, mainly due to the increase in plastic recycling during this period, which led to a smaller increase in fossil carbon burned (Brasil, 2021). Emissions from Waste Incineration (5.C.1) amounted to 117 kt CO_2 eq in 2022, or 10% of the category. In 2022, the subsector's emissions of CH_4, N_2O and CO_2 represented 52%, 7% and 41% respectively (Figure 8.8).

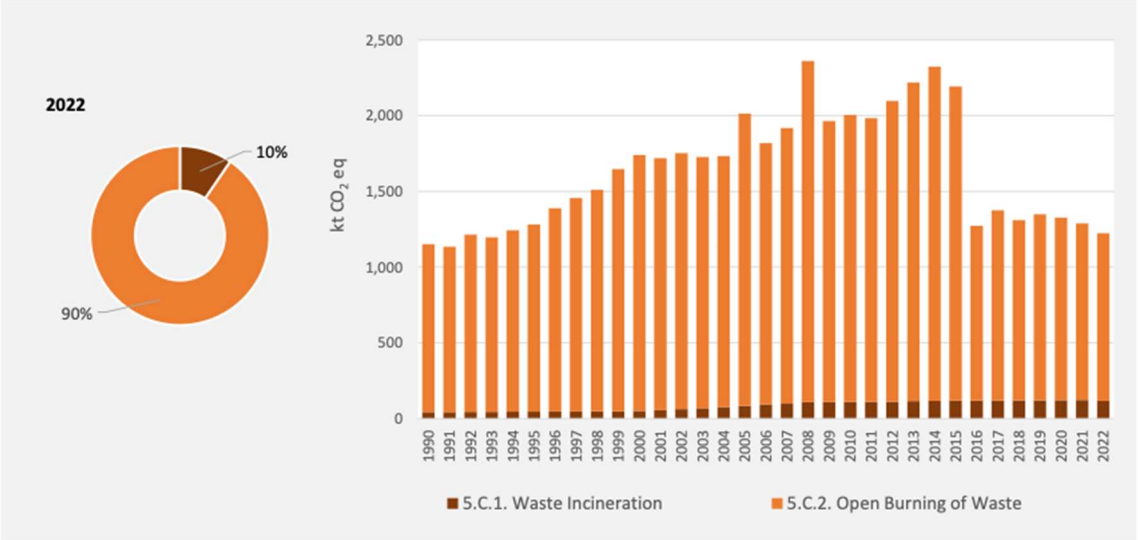


Figure 8.8. Emissions from the Incineration and Open Burning of Waste (5.C), in kt CO_2 eq by category, from 1990 to 2022.

8.5.1 Methodological aspects

In order to calculate CO_2, CH_4 and N_2O emissions from the Incineration and Open Burning of Waste subsector (5.C), equations 8.9 to 8.16 were used, shown in Dataframe 8.10, with Tier 1 and Tier 2a methodological details. The equations were applied as follows:

- Attainment of the amount of waste collected and disposed of annually (MSW);
- Attainment of the amount of clinical waste generated annually (CW);

- Quantification of waste burned;
- Quantification of waste incinerated; and
- Quantification of CO_2, CH_4 and N_2O emissions from categories 5.C.1 and 5.C.2.

Dataframe 8.10. Equations for estimating emissions from the Incineration and Open Burning of Waste subsector (5.C).

Equations	GHG	Categories	Central equation	Reference
Equation 8.9	CO_2	5.C.1	$CO_2\ \text{emitted}_{\text{incineration T}} = \sum_i (SW_i * \ dm_i * CF_i * FCF_i * OF_i) * 44/12$	Equation 5.1 (IPCC, 2006, v. 5, chap. 5)
Equation 8.10	CO_2	5.C.2	$CO_2\ \text{emitted}_{\text{burning T}} = MSW * \sum_j (WF_j * \ dm_j * CF_j * FCF_j * OF_j) * 44/12$	Equation 5.2 (IPCC, 2006, v. 5, chap. 5)
Equation 8.11	CH_4	5.C.2	$CH_4\ \text{emitted}_{\text{burning T}} = \sum_i (IW_i * \ EF_i) * 10^{-6}$	Equation 5.4 (IPCC, 2006, v. 5, chap. 5)
Equation 8.12	N_2O	5.C.1 5.C.2	$N_2O\ \text{emitted}_{\text{incineration or burning T}} = \sum_i (IW_i * \ EF_i) * 10^{-6}$	Equation 5.5 (IPCC, 2006, v. 5, chap. 5)
Equation 8.13	CO_2	5.C.2	$MSW_B = P * P_{frac} * MSW_P * B_{frac} * 365 * 10^{-6}$	Equation 5.7 (IPCC, 2006, v. 5, chap. 5)
Equation 8.14	CO_2	5.C.2	$dm = \sum_i (WF_i * \ dm_i)$	Equation 5.8 (IPCC, 2006, v. 5, chap. 5)
Equation 8.15	CO_2	5.C.2	$CF = \sum_i (WF_i * \ CF_i)$	Equation 5.9 (IPCC, 2006, v. 5, chap. 5)
Equation 8.16	CO_2	5.C.2	$FCF = \sum_i (WF_i * \ FCF_i)$	Equation 5.10 (IPCC, 2006, v. 5, chap. 5)

In which:

CO_2 emitted from incineration $_T$ = amount of CO_2 emitted from incineration in year T (Gg CO_2 . year^{-1});
SW_i = mass of type i solid waste (as wet weight) incinerated (Gg . year^{-1});
dm_i = dry mass of waste (as wet weight) incinerated (fraction);
CF_i = carbon fraction in the dry mass (fraction);
FCF_i = fossil carbon fraction in the total carbon content (fraction);
OF_i = oxidation factor (fraction);
44/12 = conversion factor from C to CO_2;
i = type of waste incinerated (municipal solid waste; industrial solid waste; wastewater sludge; clinical waste; hazardous waste);
CO_2 emitted from burning $_T$ = amount of CO_2 emitted from burning in year T (Gg CO_2 . year^{-1});
MSW = mass of municipal solid waste as wet weight incinerated or open-burned (Gg . year^{-1});
WF_j = Gravimetric fraction of MSW waste type/component j (as wet weight, open-burned);
dm_j = dry mass of component j of open-burned MSW (fraction);
CF_j = carbon fraction in the dry mass (total carbon content) of component j (fraction);

FCF_j = fraction of fossil carbon in the total carbon content of component j (fraction);
OF_j = oxidation factor (fraction);
j = component of open-burned MSW, such as paper/paperboard, food waste, wood, pruning and garden waste, disposable diapers, rubber and leather, plastics, metal, glass, other inert waste;
CH_4 emitted from burning $_T$ = amount of CH_4 emitted from burning in year T (Gg CH_4 . $year^{-1}$);
IW_i = mass of solid waste of type i incinerated or burned (Gg . $year^{-1}$);
EF_i = N_2O emission factor for waste type i (kg N_2O Gg^{-1} waste);
10^{-6} = conversion factor from kg to Gg;
N_2O emitted from incineration or burning $_T$ = amount of N_2O emitted from incineration or burning in year T (Gg N_2O . $year^{-1}$);
MSW_B = total mass of open-burned MSW (Gg $year^{-1}$);
P = population (inhabitants);
P_{frac} = fraction of the population that carries out burning (fraction);
MSW_P = waste generation per inhabitant (kg $inhabitant^{-1}$. day^{-1});
B_{frac} = fraction of the mass of waste that is burned in relation to the total mass of waste that is treated (fraction);
365 = number of days in the year (days);
dm = total dry mass of MSW (Gg);
CF = total carbon of MSW (Gg); and
FCF = total fossil carbon of MSW (Gg).

Activity data and other parameters

The annual generation of solid clinical waste (Mg CW $year^{-1}$) was obtained for each state from the data available from the PNSB (IBGE, 1994; 2000a; 2008b). For the data gap between the years (1990-1999/2001-2007/2009-2022), data on the population served with CW collection and disposal was estimated. Firstly, we found the ratio of the total population of the state to the population served with CW collection for the years of 2000 and 2008, since not all municipalities are served with CW collection and disposal. For the years before 2000 and after 2008, the ratios found for these two years were maintained, respectively. Between 2000 and 2008, values were estimated using simple linear interpolation.

The same procedure was used to estimate the annual *per capita* rate of CW (Mg CW $inhabitant^{-1}$ $year^{-1}$) in each state. The *per capita* rate observed for each state was calculated as the ratio between the mass collected and the population served with CW collection in 2000 and 2008. Based on the rate observed in these two years, for the years before 2000 (1990-1999) and after 2008 (2009-2022), the *per capita* values for CW found for these two years were maintained, respectively. Linear estimates were made between 2000 and 2008 (2001-2007). With the exception of the years of 2000 and 2008, the annual mass of CW collected in each state was estimated using the product of the population served with CW collection and the *per capita* annual rate.[121]

The average incineration fraction of 10% was found based on the CW disposal data contained in the PNSB (IBGE, 1994; 2000a; 2008b). This fraction was applied to the mass of CW collected annually to calculate the mass of CW incinerated.

In Brazil, the practice of open burning of waste is still used, especially by the population that is not served by the selective waste collection system. Within the scope of this NIR 2024, the mass of open-burned MSW (Mg $year^{-1}$) was considered to be the fraction of MSW

[121] References and the methodology for calculating the generation of solid clinical waste (CW) are described in section 8.3.1.

generated by the population that is not collected by the municipality and is not buried for the period between 1990 and 2016. With regard to the fraction of burned waste (B_{frac}), the average default value of 0.6 was used (IPCC, 2006).

Information on the population that burns MSW is available in three Brazilian statistics: the National Household Sample Survey (PNAD), the Continuous National Household Sample Survey (PNADC) and the Census, all carried out by the IBGE. In the PNAD, information on the population that burns MSW is aggregated with information on the population that buries MSW. In the Census and in the PNADC, the information is disaggregated, showing both the fraction of the population that burns, exclusively, and the fraction that buries its waste. Therefore, the population fractions identified in the surveys that only record the number of inhabitants who burn waste (Census, 1991; 2000; 2010; 2022 and PNADC, 2017; 2021) were replicated for the years in which there were only surveys with aggregate population values for inhabitants who burn and bury waste (PNAD, between the years of 1989-2015).

In order to quantify the population that burns waste for the years between 1990 and 2016 in the time series, we first obtained the fraction of the population that carries out burning in each state, using the ratio between the population that burns and the population that burns and buries MSW for the Census years (1991, 2000 and 2010). To fill the gaps in the time series, the states' fractions of the population that burns MSW observed for 1991 were kept in 1990; the states' rates observed in 2010 were kept in subsequent years (up to 2016); and linear interpolation was carried out between 1991 and 2010. The second step was to calculate the population that burns waste, the result of the product between the population that burns and buries waste observed in the PNAD and the fractions of the population that burns waste. The population that burns waste was, therefore, calculated using the ratio between the population that burns MSW and the total population in each state, for the respective years that were assessed (Table A.VIII.3, Appendix VIII).

In order to obtain the population data between 2017 and 2022, the data available in the PNADC (2017-2019) (IBGE, 2023a) and in the 2022 Census were taken into account. For 2020 and 2021, the values were obtained by interpolating the states' results between 2019 and 2022. Although the 2006 IPCC Guidelines also include the spontaneous combustion or the deliberate burning of waste in garbage dumps (IPCC, 2006), this national information is non-existent and was, therefore, not taken into account.

With regard to the Waste Incineration category (5.C.1), all the parameters and emission factors used are default values from the IPCC (2006), since there is no national data on the gravimetric composition or the concentration of carbon (C) in clinical waste fractions. For the Open Burning of Waste category (5.C.2), average default values for dry mass (dm_i), total carbon (CF_i) and fossil carbon (FCF_i) were used for each MSW gravimetric fraction (IPCC, 2006; v. 5, chap. 2, table 2.4, p. 2.14) (Dataframe 8.11). Please note that the categories in this subsector follow the Tier 2a methodological description, as it considers national data regarding the gravimetric composition of solid waste, even though the emission factors are all IPCC default values.

Dataframe 8.11. Emission factors of the Incineration and Open Burning of Waste.

Categories	Parameter	Emission factors	Reference
5.C.1	Dry matter as wet weight	$0.35\ \frac{\text{Kg DM}}{\text{kg Waste}}$	Table 2.6 (IPCC, 2006, v. 5, chap.2)
5.C.1	Total C as dry weight	$0.60\ \frac{\text{Kg C}}{\text{kg Waste}}$	Table 5.2 (IPCC, 2006, v. 5, chap.5)
5.C.1	Fraction of fossil C in total C	$0.40\ \frac{\text{Kg C}_{\text{fossil}}}{\text{kg C}_{\text{total}}}$	Table 5.2 (IPCC, 2006, v. 5, chap.5)
5.C.1	Oxidation factor	1	Table 5.2 (IPCC, 2006, v. 5, chap.5)
5.C.1	EF CH_4	$0\ \frac{\text{Kg CH}_4}{\text{Gg MSW}}$	Table 5.3 (IPCC, 2006, v. 5, chap.5)
5.C.1	EF N_2O	$100\ \frac{\text{kg N}_2\text{O}}{\text{Gg MSW}}$	Table 5.6 (IPCC, 2006, v. 5, chap.5)
5.C.2	EF CH_4	$6.5\ \frac{\text{Kg CH}_4}{\text{Mg MSW}}$	Page 5.20 (IPCC, 2006, v. 5, chap.5)
5.C.2	EF N_2O	$0.15\ \frac{\text{g N}_2\text{O}}{\text{Mg MSW}}$	Table 5.6 (IPCC, 2006, v. 5, chap.5)

8.5.2 Quality assurance and quality control

The QA/QC procedures adopted for the subsector of Incineration and Open Burning of Waste (5.C) are described in section 2.5 of this document.

8.5.3 Assessment of uncertainty, consistency and recalculations of the time series

An uncertainty analysis was carried out using the Monte Carlo methods and techniques described in the 2006 IPCC Guidelines. The uncertainty associated with CO_2, CH_4 and N_2O emissions from Incineration and Open Burning of Waste (5.C) is presented in Appendix II.

The process of updating the Inventory considered the revision of the time series of activity data, a process that resulted in adjustments, albeit small ones, to the emission estimates for the Incineration and Open Burning of Waste categories (5.C). In short, the following were re-assessed:

- *Mass of CW (1990-2022):* adjustment of the time series of the mass of CW collected and incinerated based on updated population values; and
- *Mass of open-burned waste (2020-2021):* Linear interpolation based on data from the PNADC and the Census.

Comparing the consolidated results of the previous Inventory with the one carried out for this NIR 2024, the largest proportion of adjustments is seen in 2020 with an 18% difference between estimated emissions. The estimated GHG emissions between 2017 and 2020 for the Waste sector in Brasil (2022) were not obtained from emitting activity data, but from extrapolating the values of the last five years (2012-2016) submitted in the Fourth National Communication inventory (Brasil, 2021). Between 2017 and 2020, the average adjustment in aggregate emissions was of 6%, and in the period from 1990 to 2020, it was of 1%, thus demonstrating the consistency of the sector's time series (Figure 8.9).

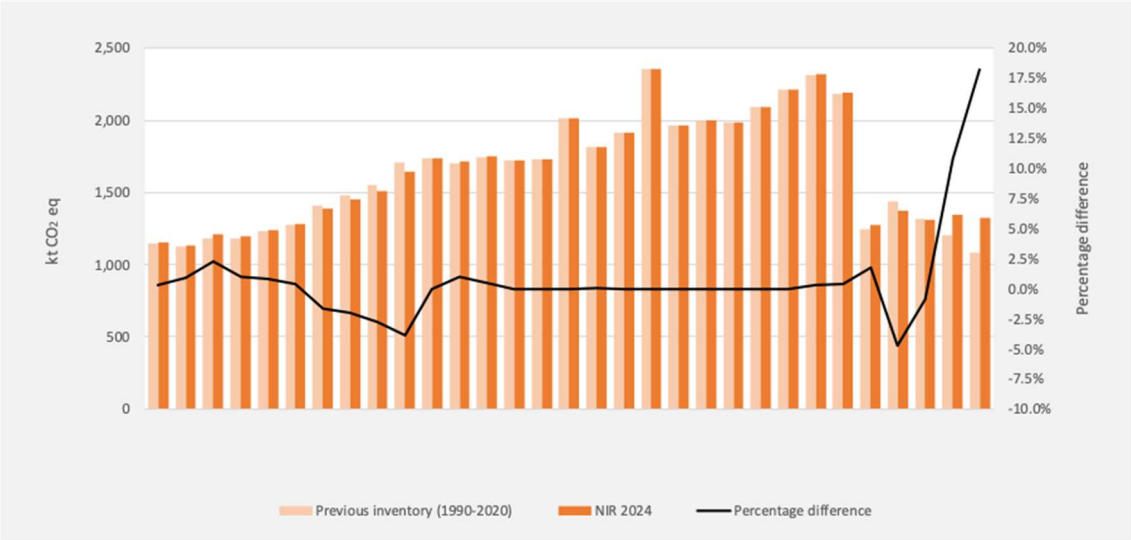


Figure 8.9. Comparison of estimated emissions from the Incineration and Open Burning of Waste subsector (5.C) between inventories.

8.5.4 Improvement plan

The systematic preparation of national GHG inventories has allowed us to gain knowledge that enables us to propose measures aimed at improving the results of the Inventory, in particular of Incineration and Open Burning of Waste (5.C).

Dataframe 8.12 summarizes the potential improvements to be implemented in future editions of this subsector's inventory.

Dataframe 8.12. Improvements potentially applicable to future editions of the emissions inventory for the Incineration and Open Burning of Waste subsector (5.C).

Subsector	Category	Improvement
5.C. INCINERATION AND OPEN BURNING OF WASTE	General (all categories)	▪ Establish Technical Cooperation Agreements or partnerships to promote the production and collection of new data on the gravimetric composition of municipal solid waste, with the aim of determining new categories based on different waste generation profiles, based on economic and social data, as well as municipal political and administrative divisions.
	5.C.1. Waste Incineration	▪ Expand studies to explore the information available in the database of the National Solid Waste Management Information System (SINIR+ (Sistema Nacional de Informações sobre a Gestão dos Resíduos Sólidos)) and in other databases, with a view to analyzing the feasibility of using this data in emissions calculations for future inventories, including information on the disposal of industrial waste.
	5.C.2. Open Burning of Waste	▪ Expand studies to assess the feasibility of updating the gravimetric compositions of open-burned waste, as well as characterizing the population that carries out this practice.

8.6 Wastewater Treatment and Discharge (CRT 5.D)

The Wastewater Treatment and Discharge subsector (5.D) accounts for emissions of CH_4 and N_2O. Methane is emitted in anaerobic environments and emissions are related to the amount of degradable organic matter present in the effluent, as well as the temperature of the site and the type of treatment used. In turn, nitrous oxide emissions are associated with the degradation of nitrogen present in the effluent, through the process of nitrification and denitrification. The emissions category is subdivided into Domestic Wastewater Treatment (5.D.1) and Industrial Wastewater Treatment (5.D.2).

Emissions from Wastewater Treatment and Discharge (5.D) were estimated at 36,056 kt CO_2 eq in 2022, a 4% reduction compared to 2020. The Domestic Wastewater Treatment category (5.D.1) was the most representative, with emissions of 30,210 kt CO_2 eq, or 84% of the emissions from this subsector (Figure 8.10). For the Industrial Wastewater Treatment category (5.D.2), emissions in 2022 were estimated at 5,846 kt CO_2 eq (16% of the subsector), also with a 4% reduction compared to 2020.

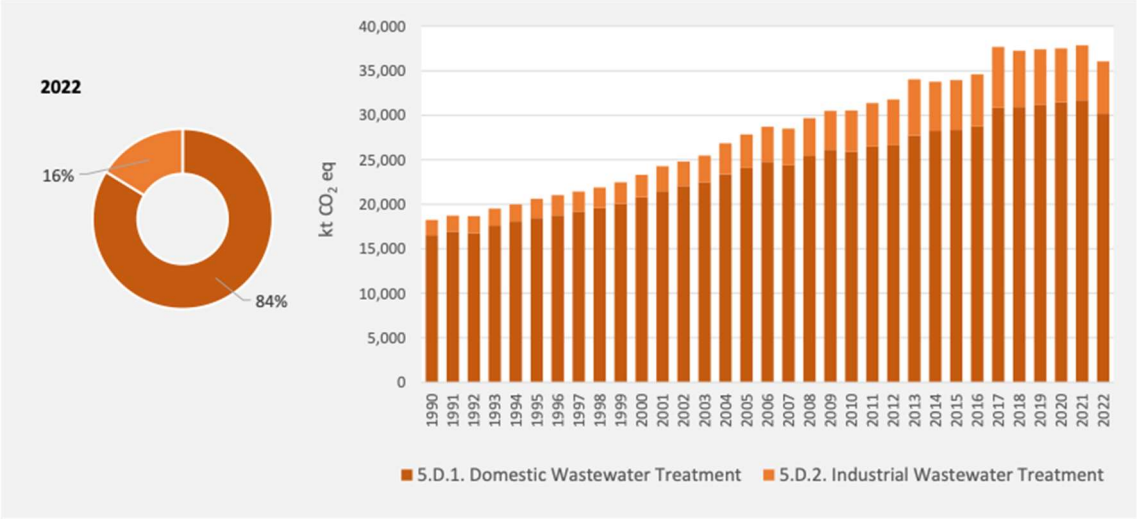


Figure 8.10. Emissions from Wastewater Treatment and Discharge (5.D), in kt CO_2 eq by category, from 1990 to 2022.

8.6.1 Methodological aspects

To calculate CH_4 and N_2O emissions from the Wastewater Treatment and Discharge subsector (5.D), equations 8.17 to 8.24 were used, as shown in Dataframe 8.13, with Tier 1 and Tier 2 methodological details.

The equations were applied as follows:

- Attainment of the rate of domestic effluent that is collected and treated;
- Attainment of the fractions of the types of domestic effluent treatment systems;
- Quantification of domestic effluent;
- Quantification of CH_4 and N_2O emissions from domestic effluent;

- Attainment of the industrial productions that account for emissions from industrial effluent treatment and discharge;
- Attainment of the fraction of the types of effluent treatment systems by type of industrial activity;
- Quantification of industrial effluent; and
- Quantification of CH_4 emissions from industrial effluent.

Dataframe 8.13. Equations for estimating emissions from the Wastewater Treatment and Discharge subsector (5.D).

Equations	GHG	Categories	Central equation	Reference
Equation 8.17	CH_4	5.D.1	$CH_4\ \text{emitted domestic effluent}_T = \left[\sum_{i,j}(U_i * T_{i,j} * EF_j)\right] * (TOW - S) - R$	Equation 6.1 (IPCC, 2006, v. 5, chap. 6)
Equation 8.18	CH_4 and N_2O	5.D.1	$EF_j\ \text{domestic effluent} = B_0 * MCF_j$	Equation 6.2 (IPCC, 2006, v. 5, chap. 6)
Equation 8.19	CH_4	5.D.1	$TOW\ \text{domestic} = P * BOD * 0.001 * I * 365$	Equation 6.3 (IPCC, 2006, v. 5, chap. 6)
Equation 8.20	CH_4	5.D.2	$CH_4\ \text{emitted industrial effluent}_T = \sum_{i,j}(TOW_k - S_k) * EF_k - R_k)$	Equation 6.4 (IPCC, 2006, v. 5, chap. 6)
Equation 8.21	CH_4	5.D.2	$EF_j\ \text{industrial effluent} = B_0 * MCF_j$	Equation 6.5 (IPCC, 2006, v. 5, chap. 6)
Equation 8.22	CH_4	5.D.2	$TOW\ \text{industrial} = P_k * W_k * DQO_k$	Equation 6.6 (IPCC, 2006, v. 5, chap. 6)
Equation 8.23	N_2O	5.D.1	$N_2O\ \text{emitted}_T = N_{Effluent} * EF_{Effluent} * 44/28$	Equation 6.7 (IPCC, 2006, v. 5, chap. 6)
Equation 8.24	N_2O	5.D.1	$N_{Effluent} = (P * Protein * F_{NPR} * F_{NON-CON} * F_{IND-COM}) - N_{sludge}$	Equation 6.8 (IPCC, 2006, v. 5, chap. 6)

In which:

$CH_4\ emitted_T$ = amount of CH_4 emitted from domestic effluents in year T (Gg CH_4 . $year^{-1}$);
TOW = total mass of organic matter in domestic/industrial wastewater in the year inventoried (kg BOD . $year^{-1}$);
S = organic component removed in the form of sludge in the year inventoried (kg BOD . $year^{-1}$);
U_i = population in income group i in the year inventoried (fraction);
T_{ij} = degree of use of treatment system/discharge system or pathway j, for each fraction of income group i in the year inventoried (fraction);
i = income group, rural or urban (fraction);
j = type of treatment/discharge system or pathway (fraction);
EF_j = effluent emission factor (kg CH_4 kg^{-1} BOD);
R = mass of CH_4 recovered in year T (kg CH_4 . $year^{-1}$);
P = population (inhabitants);
BOD = country-specific BOD *per capita* (g BOD . $inhab^{-1}$. day^{-1});
0.001 = conversion from g to kg of BOD;
I = correction factor for additional discharge of industrial BOD into the wastewater collection system;
B_0 = maximum CH_4 production capacity (kg CH_4 kg^{-1} BOD);
MCF_j = CH_4 correction factor;
k = industrial sector;
S_k = organic component removed from the sludge in the inventoried year (kg COD $year^{-1}$);

EF_k = emission factor of industry k for each treatment/system used in the inventoried year (kg CH_4 kg^{-1} COD);
P_k = total industrial production for industry of sector i (Mg $year^{-1}$);
W_k = effluent generated (m^3 . Mg product);
COD_k = chemical oxygen demand (kg COD m^{-3});
N_2O emitted $_T$ = amount of N_2O emitted from the treatment of domestic effluent in year T (Gg N_2O . $year^{-1}$);
$N_{Effluent}$ = nitrogen from the effluent discharged into the aquatic environment (kg N . $year^{-1}$);
$EF_{Effluent}$ = N_2O emission factor of the discharged wastewater (kg N_2O . kg^{-1} N);
44/28 = conversion factor from kg N_2O-N to kg N_2O;
P = population (inhabitants);
Protein = annual protein consumption *per capita* (kg . $inhab^{-1}$. $year^{-1}$);
F_{NPR} = fraction of nitrogen in protein, default = 0.16 (kg N . kg^{-1} protein);
$F_{NON-CON}$ = factor for non-consumed protein added to wastewater;
$F_{IND-CON}$ = factor for commercial and industrial protein co-discharged in the collection system; and
N_{Sludge} = nitrogen removed via sludge (kg N . $year^{-1}$).

Activity data and other parameters

In Brazil, not all the sewage (wastewater) generated is collected and not all the sewage collected is treated in treatment plants. Thus, in order to meet the variables required by the models in the IPCC (2006), it is necessary to transform the raw data into variables that can be used to calculate emissions.

The first stage consists in estimating the fraction of the total population's income group variable (U_i, in which **i** is the income group). This variable expresses fractions of population arrangements within the total population. In the second stage, the degree of use of the treatment, discharge route or system is estimated for each income group (T_{ij}, in which i is the income group and **j** is the treatment, system or discharge route). This variable demonstrates the representativeness of each treatment or discharge route/system within each population arrangement.

The volume of sewage collected and treated can be seen in the PNSB (IBGE, 1994; 2000a; 2008b; 2017a; 2017b; 2017c) and in the National Water Agency's Sewage Atlas (ANA – National Water Agency (Agência Nacional de Águas), 2013). The treatment fraction of the sewage collected was obtained based on the ratio between the volume of sewage collected and the volume of sewage treated, obtained from the PNSB and the National Water Agency's Sewage Atlas (ANA, 2013). For the years in which there was no observed data, the fractions were estimated using linear interpolation between the observed data for 1989, 2000, 2008, 2013 and 2017.

Protein consumption *per capita* (PTN) (kg PTN $inhab^{-1}$ $year^{-1}$) was obtained annually from data made available by the FAO (2009, 2022, 2023) for Brazil, and when there was no observed data, the values were estimated using linear interpolation considering the entire time series (1990-2022). The CH_4 (MCF) conversion factor for collected and treated sewage is classified according to the treatment system observed in the PNSB (IBGE, 1994; 2000a; 2008b; 2017a; 2017b; 2017c). Firstly, weighted MCF was calculated for each observation, and, then, based on that, a linear estimate of the weighted MCF was carried out between the years of 1989, 2000, 2008 and 2017, with the latter observation being used annually until 2022.

The total organic load (kg BOD $year^{-1}$) generated by the population was calculated according to the population of the state in the year inventoried, the country-specific BOD

per capita (g $inhab^{-1}d^{-1}$) and the potential share of industrial waste in the domestic collection system.

The annual data on the resident population in the Brazilian states for the period between 1990 and 2016 are the same as those already described for subsector 5.A. The BOD *per capita* used was 54 g $inhab^{-1}$ d^{-1}, which follows NBR (Brazilian Regulatory Standard [Norma Brasileira Regulamentadora]) standard 12.209/2011 for sanitary sewage treatment plant projects (ABNT – Brazilian Association of Technical Standards (Associação Brasileira de Normas Técnicas), 2011). Since it was not possible to identify the share of industrial wastewater discharged into the domestic wastewater collection system, the default value of 1.0 of the correction factor for additional industrial discharge was used (IPCC, 2006).

National statistics do not include the economic arrangement of the population (low and high income) for the classification of income groups as described in the 2006 IPCC Guidelines. Therefore, it was only possible to disaggregate the use according to urban and rural population arrangements. Based on this organization, the fraction of population arrangements was obtained using the ratio between the urban population and the total population (POP_{urb}) and the ratio between the rural population and the total population (POP_{rural}) for each state, annually, from 1990 to 2022. The final rural population (POP_{rural}) was obtained from the difference between POP_{total} and POP_{urb}.

It was necessary to annually estimate the distribution of the population in urban and rural areas for the years between population censuses. The model adjusted for all the states was a simple bivariate linear regression, which estimates the population through the direct ratio between this population and the year and the total population. However, for the year 2022, the fraction of the urban population of each state was replicated with the same value as the fraction for the year of 2021. This measure was necessary because in some states, when the regression statistical model was applied, the rural population values turned out to be negative, where, actually, the minimum value is zero.

The degree of use of the treatment, discharge route or system for each income group (T_{ij}, in which i is the income group and j is the treatment, system or discharge route) demonstrates the representativeness of each treatment or discharge route/system within each population arrangement. The data observed are the urban and rural population served with a wastewater collection system, septic tanks, latrines (identified by the IBGE as "other") and with direct discharge into water bodies (identified by the IBGE as "none"), from the PNAD (1992 and 1993, 1995 to 1999, 2001 to 2009 and 2011 to 2015) (IBGE, 2019b; 2019c) and the Census (1991, 2000 and 2010). In order to fill the data gaps (1990, 1994), a single independent regression model was adjusted for each variable (Wastewater collection system, Latrine, Other, and None) from the data observed in the PNAD and Census (Figure 8.11). For the years between 2016 and 2022, the last observed value of the fractions of each type of treatment in relation to the urban and rural population in each state was maintained.

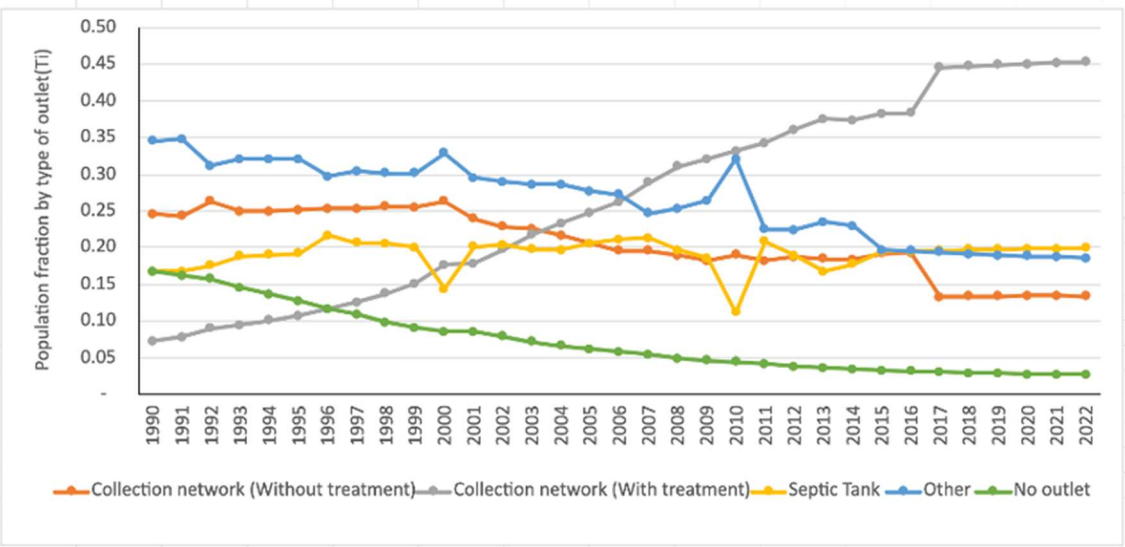


Figure 8.11. Degree of use of the treatment system or discharge pathway for each group (Tij) in Brazil, between 1990 and 2022.

According to the expert panel of the Third National Communication inventory (BRASIL, 2016), anaerobic reactors invariably contain burners for the gas generated and, so, the CH_4 produced in these systems is partially destroyed, with the efficiency of CH_4 destruction being approximately of 50%. The estimate of recovered methane (R) (kg CH_4 $year^{-1}$) was calculated based on maintaining these assumptions, considering only the CH_4 generated in anaerobic reactors, both in domestic and industrial wastewater treatment processes.

With regard to the organic component removed as sludge (S-DWW) (Kg BOD $year^{-1}$), it was considered that the mass of sludge generated in treatment plants is normally removed from the treatment system and sent for final disposal. Therefore, the organic load related to sludge is subtracted from the total affluent organic load, thus being disregarded in the calculation of CH_4 emissions in this category. In Brazil, sewage sludge is mainly disposed of in landfills and garbage dumps. To this end, the organic load removed in the form of sludge is, then, counted as a source of organic matter in the Solid Waste Disposal subsector (5.A). The sludge removed from the treatment system was calculated based on the sludge generation factors per unit of BOD treated in each treatment technology, as shown in Table 8.9.

Table 8.9. Organic load of sludge (S) produced in different wastewater treatment technologies.

Treatment technology	Organic load generated (kg BOD sludge kg^{-1} BOD affluent)
Facultative lagoon	0.107
Anaerobic lagoon	0.158
Complete-mix aerated lagoon	0.058
Septic tank	0.126
High load biological filter	0.316
Conventional activated sludge	0.340
UASB anaerobic reactor	0.073

Source: Adapted from Andreoli, Von Sperling; and Fernandes (2001).

As with domestic effluent, emissions from industrial effluents come from anaerobic degradation. The organic matter present in these effluents is expressed in terms of Chemical Oxygen Demand (COD), and the organic fraction present in these effluents varies according to the products and processes involved. The same plant includes several different types of effluents that require different types of treatment.

Data from activities that generate effluents with the highest organic loads were prioritized, maintaining the industrial sectors that were considered in the Inventory of the Fourth National Communication (Brasil, 2021), since they still represent the largest share of pollution load and there has been no introduction of new industrial sectors in the Brazilian economy (IBGE, 2019c). Nine main industries that generate large quantities of effluents were identified: sugar, raw milk, alcohol, paper and pulp, beer, poultry slaughtering, cattle slaughtering, swine slaughtering and pasteurized milk.

Based on the identification of the nine industrial activities with the highest contribution of organic load that can generate GHGs (Brasil, 2010; Brasil, 2015), data on industrial production (P_i) (Mg year^{-1}) between 1990 and 2022 was collected (Table 8.10). The time series for sugar and alcohol production was obtained from the Brazilian Sugarcane and Bioenergy Industry Association (UNICA, União da Indústria de Cana-de-Açúcar). Historical data on raw milk production was obtained from the IBGE's Municipal Livestock Survey (PPM, Pesquisa da Pecuária Municipal), and on pasteurized milk from the statistical reports of ABLV – Brazilian Long-Life Milk Association (Associação Brasileira da Indústria de Leite Longa Vida). Pulp production information was collected in IBA (2023). The annual production of beer (Classes of industrial activities and products: 1113.2020), poultry (Classes of industrial activities and products: 1012.2030, 1012.2040), cattle (Classes of industrial activities and products: 10.112.020, 1011.2030, 1011.2080, 1011.2100, 1011.2120, 1011.2130), and swine (Classes of industrial activities and products: 1012.2010, 1012.2020, 1012.2070, 1012.2080, 1012.2110, 1012.2120, 1012.2130) slaughtering, was obtained from the IBGE's Annual Industrial Survey (PIA).

Table 8.10. Annual industrial production (Pi) in Brazil between 1990 and 2022.

Year	Sugar	Alcohol	Raw milk	Pasteurized milk	Pulp	Beer	Poultry slaughtering	Cattle slaughtering	Swine slaughtering
	kt								
1990	7,214	9,647	14,948	4,184	4,351	3,813	1,605	2,836	730
1991	7,365	9,319	15,562	3,867	4,778	3,947	1,801	2,921	812
1992	8,530	10,295	16,289	3,445	5,302	4,082	1,911	3,062	893
1993	9,264	9,492	16,090	2,793	5,471	4,216	2,074	3,124	885
1994	9,162	9,138	16,289	2,977	5,829	4,350	2,196	2,829	855
1995	12,652	10,319	17,002	3,251	5,936	8,175	2,318	2,534	825
1996	13,513	10,205	19,108	2,926	6,201	8,084	2,439	2,239	794
1997	14,828	11,649	19,263	2,343	6,331	8,228	2,561	1,944	764
1998	14,887	12,475	19,292	2,043	6,687	8,668	2,683	1,649	734
1999	18,024	11,230	19,680	1,754	7,209	8,665	2,993	1,782	1,200
2000	19,388	10,507	20,400	1,682	7,463	9,178	3,317	2,164	673
2001	16,198	8,571	21,166	1,486	7,412	9,297	4,216	3,178	1,223
2002	19,218	9,336	22,335	1,527	8,021	9,095	4,518	4,252	1,088
2003	22,567	10,215	22,966	1,589	9,069	8,603	4,822	4,812	1,436

Year	Sugar	Alcohol	Raw milk	Pasteurized milk	Pulp	Beer	Poultry slaughtering	Cattle slaughtering	Swine slaughtering
	kt								
2004	24,919	11,925	24,226	1,641	9,620	9,456	5,102	6,871	1,794
2005	26,685	12,453	25,409	1,600	10,352	10,035	6,412	6,145	2,887
2006	25,823	12,803	26,211	1,662	11,180	10,791	6,561	6,448	3,096
2007	29,988	14,440	26,974	1,765	11,998	11,683	7,734	6,614	3,489
2008	31,026	18,230	28,468	1,852	12,697	12,409	7,960	6,767	3,822
2009	31,049	22,275	30,016	1,847	13,315	12,695	8,223	6,526	4,052
2010	32,956	20,790	31,698	1,744	14,164	13,168	8,609	7,446	4,076
2011	38,006	22,154	33,123	1,677	13,922	13,978	9,881	8,774	3,850
2012	35,925	18,355	33,338	1,476	13,977	14,463	9,712	10,771	3,871
2013	38,246	18,796	35,351	1,383	15,127	13,832	9,593	18,021	4,063
2014	37,594	22,235	36,248	1,259	16,465	14,703	10,373	10,989	4,259
2015	35,571	23,048	35,717	1,129	17,370	14,505	10,733	10,802	4,834
2016	33,837	24,466	34,758	1,140	18,773	14,118	11,709	12,044	5,626
2017	38,734	22,056	34,379	1,156	19,527	13,949	13,642	15,744	8,503
2018	38,608	22,553	34,993	1,125	21,085	15,581	13,380	13,265	6,333
2019	29,053	26,797	35,988	1,115	19,691	17,565	10,408	13,383	5,942
2020	29,606	28,807	36,447	1,084	21,000	16,298	12,106	10,126	7,251
2021	41,503	26,303	36,309	954	22,500	17,239	12,724	9,969	7,727
2022	34,992	24,101	35,717	904	25,000	18,315*	11,520*	8,091*	6,961*

Source: Sugar and Alcohol (UNICA, 2024); Raw Milk (PPM – IBGE, 2023e); Pasteurized Milk, (ABLV, 2022); Pulp (IBA, 2023); Beer, Poultry slaughtering, Cattle slaughtering and Swine slaughtering (PIA – IBGE, 2021). Notes: * values estimated with linear progression based on the results of the last 5 years by type of industrial production.

One of the main activity data required to estimate category 5.D.2 emissions is degradable organic matter in industrial wastewater (TOW) (kg BOD year^{-1}), which is generated by the most relevant industrial sectors (Figure 8.13). It was calculated based on the P_i and the organic load (CO_i) (Mg DBO Mg^{-1} product) generated per unit of product. The organic load is the product of the volume of wastewater generated per unit of product (W_i) (m^3 Mg^{-1} product) and the concentration of carbonaceous material contained in the wastewater (COD_i) (kg COD m^{-3}).

Data on the generation of organic load per unit of product is scarce, since it varies significantly throughout the production stages, as well as in relation to the different production technologies employed. The same values used in Brasil (2021) were applied to this inventory, as shown in Table 8.11.

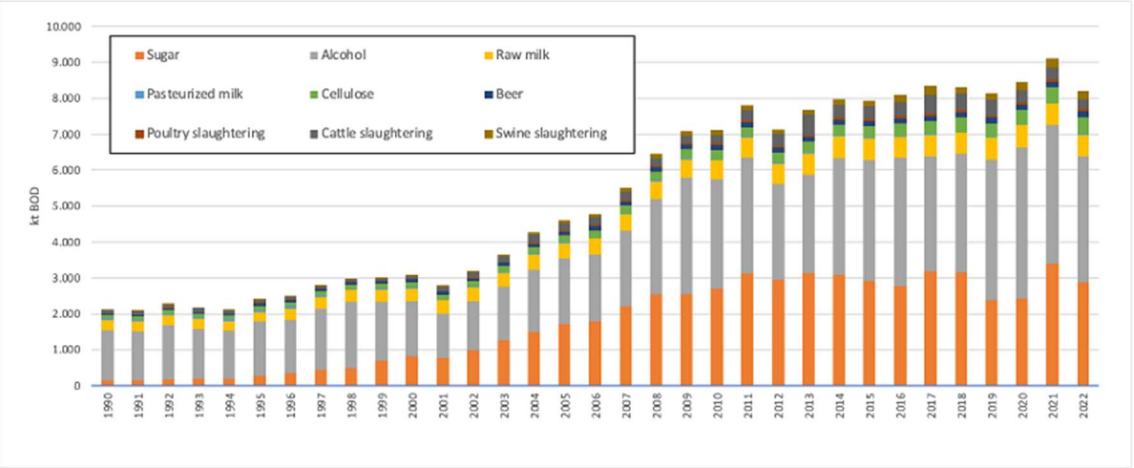


Figure 8.12. Degradable organic matter (TOW) present in industrial wastewater in Brazil, annually, between 1990 and 2022.

Table 8.11. Organic load (kg BOD/ton of product) of wastewater from the industrial sectors assessed.

Sector	Organic Load (kg BOD Mg^{-1} product)
Sugar (1990-1995)	21
Sugar (2008-2016)	82
Alcohol	146
Raw milk	17
Pasteurized milk	17
Pulp	19
Beer	9
Poultry slaughtering	6
Cattle slaughtering	33
Swine slaughtering	33

Source: Sugar (CTC, 1995; Elia Neto *et al.*, 2009); Alcohol (Elia Neto *et al.*, 2009); Pulp (Michael *et al.*, 2015); Raw milk, Pasteurized milk, Beer, Poultry slaughtering, Cattle slaughtering and Swine slaughtering (Brasil, 2015).

Unlike the sludge from domestic wastewater treatment, in which all of it is sent to SWDS due to the waste's pathogenic potential, the sludge from industrial wastewater treatment can be reused (applied directly to the soil as fertilizer), recycled (composted) or sent directly to SWDS. Since it was not possible to establish the fractions sent to each destination, the organic load of the sludge remained in the calculation of this category, i.e., the organic component removed as sludge (S) from industrial effluents is nil. According to IPCC (2006), whenever the organic component present in sludge is removed from wastewater treatment, it must be accounted for in another sector (IPCC, 2006). When it is not possible to remove the sludge, it must be accounted for in the sector of origin (IPCC, 2006).

The methane correction factor (MCF) variable represents the CH_4 generation capacity of each treatment system. The systems that are solely anaerobic have a greater capacity to generate CH_4 and high MCF values. On the other hand, systems that use forced aeration,

such as activated sludge, due to the high oxygen pressure on the effluent, have a low CH_4 generation capacity and have the lowest MCF values among the potentially existing treatment solutions. It was, therefore, necessary to estimate the fraction of sewage treated by each type of treatment in order to calculate the weighted MCF, which considers the contribution of all the systems used in the state, weighted by the corresponding population served.

Information on sewage collection and treatment systems used in Brazilian states is available in the editions of the PNSB (IBGE, 1994; 2000a; 2008b; 2017a; 2017b; 2017c). In the 1989 edition (IBGE, 1994), the data was aggregated by state; in the 2000, 2008 and 2017 editions, the survey was refined and the data was disaggregated to the municipal level. However, the classification used was qualitative, related to the presence or absence of a certain type of treatment and the number of districts in the municipality that were served by each type of treatment.

In order to obtain the fraction of sewage treated by treatment technology, based on qualitative data from the PNSB, i.e., the presence or absence of technology, an assumption had to be adopted. It was considered that only one of the various technologies declared by the municipality would be responsible for treating all the sewage. This distinction was made by means of hierarchical classification, in which, in the presence of a technology with the highest rank in the hierarchy, it is considered to be the only type of treatment in that municipality, regardless of whether it is combined with another one. The hierarchy was organized based on knowledge of the main system arrangements in Brazil and considers the treatment stage with the highest organic load removal. Thus, whenever there was an anaerobic reactor treatment, which is the highest treatment in the proposed hierarchy, the other types of treatment employed in the municipality were ignored and the sewage was considered to be treated entirely by that treatment. Once the municipalities that employed reactor treatment had been grouped, they were removed from the set and a new grouping was made for the next hierarchical level, which in this case is activated sludge, and this selection was carried out to the last hierarchical level (Table 8.12).

Table 8.12. Domestic wastewater treatment systems (DWW) and associated MCF.

Hierarchical level	Treatment system	Classification*	MCF**
1	Anaerobic reactor	Anaerobic	0.8
2	Activated sludge	Aerobic	0.1
3	Biological filter	Aerobic	0.3
4	Oxidation value	Aerobic	0.3
5	Anaerobic lagoon	Anaerobic	0.8
6	Aerobic lagoon	Aerobic	0.3
7	Facultative lagoon	Aerobic	0.3
8	Septic tank in residential condominiums	Latrine	0.5
9	Other	Latrine	0.5

Source: Prepared based on *Von Sperling (2015). ** Adapted from IPCC (2006), Table 6.3, v. 5, ch. 6, p. 6.13.

The fraction of the population served with each type of treatment in the state was calculated as the ratio between the population served with that treatment and the sum of the populations of all the treatments. The data gaps between the PNSBs were filled by linear interpolation, and the value observed in 2017 was maintained until 2022. Based on the

representativeness of the treatment systems observed and their respective MCF, it was possible to calculate the weighted MCF for each state and each year.

Since the occurrence of food waste in sewage is incipient in Brazil, the default adjustment factor for non-consumed protein (FNON_CON) used was that of a system without food waste disposal, with a value of 1.1 (IPCC, 2006). In order to determine the fraction of N in protein (FNPR), the default value of 0.16 kg N kg^{-1} protein was used (IPCC, 2006).

For the N_2O emission factor ($EF_{EFFLUENT}$), the default value of 0.005 kg N_2O-N kg^{-1} N (IPCC, 2006) was used. For the maximum production capacity of CH_4 (B_O), the default value of 0.6 kg CH_4 kg^{-1} BOD was used (IPCC, 2006). With regard to the CH_4 correction factor (MCF) of industrial wastewater, the MCF values per type of industrial production listed in Brasil (2015) were maintained (Table 8.13). To convert the volumes of alcohol, milk (raw and pasteurized) and beer, the densities of 809.25 kg/m^3 (Sindipetroleo – Mato Grosso State Petroleum Products Retail Trade Union (Sindicato do Comércio Varejista de Derivados de Petróleo do Estado de Mato Grosso)), 2013), 1,032.00 kg/m^3 (VENTURINI; SARCINELLI; and SILVA, 2007) and 1,017.10 kg/m^3 (Carvalho; Zambiazi, 2011) were applied, respectively.

Table 8.13. Methane correction factor (MCF) and fraction of wastewater treated by type of technology used.[a]

Type of treatment /disposal	MCF[a]	Sugar	Alcohol	Raw milk	P* milk	Pulp	Beer	Poultry s**	Cattle s**	Swine s**
		Fraction of wastewater treated by type of technology								
Soil[b]	-	1.00	1.00	-	-	-	-	-	-	-
Anaerobic lagoon	0.80	-	-	0.11	0.13	0.03	0.03	0.11	0.11	0.11
Facultative lagoon[c]	0.50	-	-	0.11	0.13	0.03	0.03	0.11	0.11	0.10
Aerobic lagoon	0.10	-	-	0.10	0.12	0.08	0.04	0.11	0.11	0.10
Anaerobic reactor	0.80	-	-	0.09	0.15	-	0.48	0.07	0.10	0.14
Activated sludge	0.10	-	-	0.09	0.15	0.72	0.20	0.30	0.20	0.23
Aerobic secondary and tertiary treatment[d]	0.30	-	-	-	0.02	-	0.02	0.00	0.02	0.02
Discharged into bodies of water	0.10	-	-	0.50	0.30	0.15	0.20	0.30	0.35	0.30
WEIGHTED MCF	**-**	**-**	**-**	**0.284**	**0.352**	**0.128**	**0.473**	**0.270**	**0.295**	**0.319**

Note: [a] The fractions of each treatment used in the industrial sectors were obtained through a panel of experts from the Third National Communication Inventory (Brasil, 2016; Reference Report, Waste Treatment sector, Table 38, p. 55); except for the sugar and alcohol industries, updated to Elia Neto *et al*, 2009; [b] Emissions resulting from the disposal of effluents on the soil for fertilization purposes should be accounted for in the Agriculture sector; [c] This category is not described in the 2006 IPCC Guidelines. Since this is a mixed treatment, half aerobic and half anaerobic, the MCF for this treatment was obtained from the average value between the MCF values described for aerobic (0.1) and anaerobic (0.8) treatments; [d] MCF values for aerobic treatment in poorly managed units, according to the IPCC (2006); * P = Pasteurized; ** S = Slaughtering.

All effluents from sugarcane mills, regardless of the production stage (sugarcane washing, cooling, equipment cleaning, among others) or the type of product generated (sugar or

ethanol), are disposed of on the soil for fertirrigation purposes or simply as waste (ELIA NETO et al., 2009). Therefore, 100% of the wastewater from the sugar and alcohol industries was considered as being disposed of on the soil. Based on the representativeness of the treatment systems observed and their respective MCF, it was possible to calculate the weighted MCF for each year. For the years of 1990, 2005 and 2010, the observed MCF values were used, based on input from experts in previous editions of the National Inventories. For the years between 1990 and 2010, the MCF values were estimated by simple linear interpolation for each type of industrial production. Between 2011 and 2022, the values obtained in 2010 were replicated (Table A.VIII.4, Appendix VIII).

8.6.2 Quality assurance and quality control

The QA/QC procedures adopted for the subsector of Wastewater Treatment and Discharge (5.D) are described in section 2.5 of this document.

8.6.3 Assessment of uncertainty, consistency and recalculations of the time series

An uncertainty analysis was carried out using the Monte Carlo methods and techniques described in the 2006 IPCC Guidelines. The uncertainty associated with CH_4 and N_2O emissions from Wastewater Treatment and Discharge (5.D) is presented in Appendix II.

The process of updating the National Inventory considered the revision of the time series of activity data, a process that resulted in adjustments, albeit small ones, to the emission estimates for the Wastewater Treatment and Discharge categories (5.D). In short, the following were re-assessed:

- As a result of the recalculation of total populations, urban and rural populations were also recalculated for the years of 1971-1979; 1981-1990; 1992-1999; 2001-2009; 2001-2016. A new linear regression model was determined which considered the observed urban and rural populations from the 1970, 1980, 1991, 2000 and 2010 censuses. This same model was used to estimate the populations for the years of 2017-2021. The urban and rural population data for 2022 followed the same state rates identified in the previous year, since the application of the model resulted in negative values in some states;

- Data on domestic wastewater treatment from the latest update of the 2017 National Basic Sanitation Survey was included in the calculations; and

- The following were updated: sugar and alcohol production data (UNICA, 2024); raw milk data updated between 2017 and 2022 based on the municipal livestock survey (PPM), made available by the IBGE (IBGE, 2023e); pulp based on data from the Brazilian Tree Industry for 2020, 2021 and 2022 (IBA, 2023); poultry, cattle and swine slaughtering (IBGE, 2019a). To obtain the production of beer and animal slaughtering, due to the lack of data available for 2022, a linear progression was made considering the values observed in the Annual Industrial Survey (PIA) for the period of 2017-2021.

Comparing the consolidated results of the previous Inventory with the one carried out for this NIR 2024, the largest proportion of adjustments is seen in 2017 with a 12% difference

between estimated emissions. The estimated GHG emissions between 2017 and 2020 for the Waste sector in Brasil (2022) were not obtained from emitting activity data, but from extrapolating the values of the last five years (2012-2016) submitted in the Fourth National Communication (Brasil, 2021). Between 2017 and 2020, the average adjustment in aggregate emissions was of 11%, and in the period from 1990 to 2020, it was of 2%, thus demonstrating the consistency of the sector's time series (Figure 8.13).

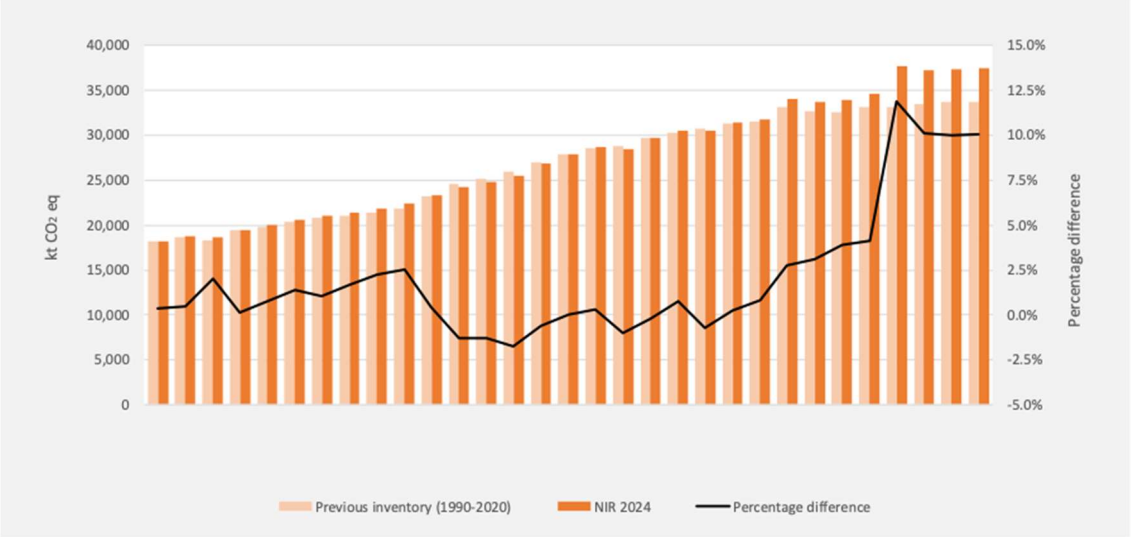


Figure 8.13. Comparison of estimated emissions from the Wastewater Treatment and Discharge subsector (5.D) between the inventories.

8.6.4 Improvement plan

The systematic preparation of national GHG inventories has allowed us to gain knowledge that enables us to propose measures aimed at improving the results of the Inventory, in particular of Wastewater Treatment and Discharge (5.D).

Dataframe 8.14 summarizes the potential improvements to be implemented in future editions of this subsector's inventory.

Dataframe 8.14. Improvements potentially applicable to future editions of the emissions inventory for the Wastewater Treatment and Discharge subsector (5.D).

Subsector	Category	Improvement
	General (all categories)	▪ Establish Technical Cooperation Agreements or partnerships with public-private institutions to assess the feasibility of obtaining more detailed data on the characteristics of effluent treatment systems, both domestic and industrial.

Subsector	Category	Improvement
5.D. WASTEWATER TREATMENT AND DISCHARGE	5.D.1. Domestic Wastewater Treatment	▪ Establish partnerships with educational and research institutions with a view to mapping municipal climate data that influence the treatment of domestic effluents; ▪ Establish Technical Cooperation Agreements or partnerships with institutions responsible for managing data from the National Sanitation Information System (SNIS) with a view to promoting the alignment of the metrics and data quality standards that meet the methodological requirements of Tier 2 with regard to the collection of municipal data on wastewater treatment and discharge.
	5.D.2. Industrial Wastewater Treatment	▪ Establish partnerships with public-private institutions to encourage studies to characterize the efficiency of anaerobic reactors by type of industrial production, update the CH_4 (MCF) correction factor, and generate production and effluent generation data by type of industrial activity.

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APPENDIX I. KEY CATEGORY ANALYSIS

A key category is one that is prioritized in the inventory system because it has a significant influence on greenhouse gas emissions and removals in absolute terms, trend terms, or both. Identifying the main categories in national inventories allows the limited resources available for preparing inventories to be prioritized, ideally with a view to improving methodologies and data for the categories with the greatest impact in terms of GHG. In addition, they serve to select the use of higher tier methods for accounting for emissions and removals (Tier 2 and Tier 3), and guide specific quality control and quality assurance (QA/QC) procedures.

Brazil identified the key categories for the inventory using Tier 1 level and trend assessments, as recommended in the IPCC (2006, v. 1, chap. 4)[122] and adopted by the Modalities, Procedures and Guidelines (MPGs) of Article 13 of the Paris Agreement. This approach identifies the sources, which, when combined, contribute to 95% of total emissions, or 95% of the inventory trend in absolute terms.

When the LULUCF sector is considered in the analysis, the Land Converted to Grassland, Forest Land Remaining Forest Land and Road Transportation are the most significant key categories. The full results of the analysis of the main source are reported in Table A.I.1 and Table A.I.3.

When the LULUCF sector is excluded from the analysis, the most significant key categories are Road Transportation, Enteric Fermentation (female beef cattle over 2 years old, not confined) and Enteric Fermentation (cattle between 1 and 2 years old). The results of this last analysis are shown in Table A.I.2 and Table A.I.4.

[122] General Guidance and Reporting, Methodological Choice and Identification of Key Categories (IPCC, 2006, v. 1, chap. 4).

Table A.I.1. Key categories for Brazil's NIR 2024, Tier 1 methodology, including LULUCF – Level Assessment.

IPCC Category Code	IPCC Category	GHG	Value in estimated year (kt CO_2 eq)	Absolute value in estimated year (kt CO_2 eq)	Level assessment (%)	Cumulative total (%)
4.C.2	Land Converted to Grassland	CO_2	908,386	908,386	0.33	0.33
4.A.1	Forest Land Remaining Forest Land	CO_2	-287,645	287,645	0.10	0.43
1.A.3.b	Road transportation	CO_2	194,411	194,411	0.07	0.50
4.B.2	Land Converted to Cropland	CO_2	179,798	179,798	0.06	0.56
3.A.1.a.iii	Enteric Fermentation (Female beef cattle > 2 years old, not confined)	CH_4	114,634	114,634	0.04	0.61
3.A.1.a.vi	Enteric Fermentation (Cattle > 1 year < 2 years old)	CH_4	91,451	91,451	0.03	0.64
3.A.1.a.ii	Enteric Fermentation (Male beef cattle > 2 years old, not confined)	CH_4	77,097	77,097	0.03	0.67
1.A.2	Manufacturing Industries and Construction	CO_2	66,427	66,427	0.02	0.69
4.G	Harvested Wood Products	CO_2	-56,507	56,507	0.02	0.71
1.A.1	Energy Industries	CO_2	54,357	54,357	0.02	0.73
3.D.1.c	Animal Manure Deposited by Grazing Animals (Direct emissions, soils)	N_2O	51,940	51,940	0.02	0.75
5.A	Solid Waste Disposal	CH_4	53,421	53,421	0.02	0.77
3.A.1.a.v	Enteric Fermentation (Cattle < 1 year old)	CH_4	49,305	49,305	0.02	0.79
2.C.1	Iron and Steel Production	CO_2	47,372	47,372	0.02	0.80
1.A.4	Other Sectors	CO_2	41,055	41,055	0.01	0.82
4.C.2	Land Converted to Grassland	CH_4	34,601	34,601	0.01	0.83
5.D	Wastewater Treatment and Discharge	CH_4	33,654	33,654	0.01	0.84
3.D.1.d	Crop Residues (Direct emissions, soils)	N_2O	30,564	30,564	0.01	0.85
4.A.2	Land Converted to Forest Land	CO_2	-27,198	27,198	0.01	0.86
3.G	Liming	CO_2	27,087	27,087	0.01	0.87
3.B	Manure Management	CH_4	24,868	24,868	0.01	0.88
2.A.1	Cement Production	CO_2	24,625	24,625	0.01	0.89
3.A.1.b.ii	Enteric fermentation (Dairy cows, low production)	CH_4	22,068	22,068	0.01	0.90
3.D.1.a	Inorganic N Fertilizers (Direct emissions, soils)	N_2O	21,771	21,771	0.01	0.91

IPCC Category Code	IPCC Category	GHG	Value in estimated year (kt CO_2 eq)	Absolute value in estimated year (kt CO_2 eq)	Level assessment (%)	Cumulative total (%)
3.D.2.b	Nitrogen Leaching and Run-off (Indirect emissions)	N_2O	20,986	20,986	0.01	0.91
3.A.1.b.i	Enteric fermentation (Dairy cows, high production)	CH_4	17,981	17,981	0.01	0.92
1.B.2.a	Oil and natural gas and other emissions from energy production – Oil	CO_2	16,001	16,001	0.00	0.92
3.A.1.a.i	Enteric Fermentation (Bulls > 2 years old)	CH_4	12,543	12,543	0.01	0.93
3.D.2.a	Atmospheric Deposition (Indirect emissions)	N_2O	12,324	12,324	0.00	0.93
4.F.2	Land Converted to Other Land	CO_2	12,062	12,062	0.00	0.94
3.C	Rice Cultivation	CH_4	11,901	11,901	0.00	0.94
4.D.2	Land Converted to Wetland	CO_2	11,178	11,178	0.00	0.95
4.C.2	Land Converted to Grassland	N_2O	9,632	9,632	0.00	0.95

Table A.I.2. Key categories for Brazil's NIR 2024, Tier 1 methodology, excluding LULUCF – Level Assessment.

IPCC Category Code	IPCC Category	GHG	Emission in 2022 (kt CO_2 eq)	Absolute emission in 2022 (kt CO_2 eq)	Level assessment (%)	Cumulative total (%)
1.A.3.b	Road transportation	CO_2	194,411	194,411	0.16	0.16
3.A.1.a.iii	Enteric Fermentation (Female beef cattle > 2 years old, not confined)	CH_4	114,634	114,634	0.09	0.25
3.A.1.a.vi	Enteric Fermentation (Cattle > 1 year < 2 years old)	CH_4	91,451	91,451	0.07	0.32
3.A.1.a.ii	Enteric Fermentation (Male beef cattle > 2 years old, not confined)	CH_4	77,097	77,097	0.06	0.39
1.A.2	Manufacturing Industries and Construction	CO_2	66,427	66,427	0.05	0.44
1.A.1	Energy Industries	CO_2	54,357	54,357	0.04	0.49
5.A	Solid Waste Disposal	CH_4	53,421	53,421	0.04	0.53
3.D.1.c	Animal Manure Deposited by Grazing Animals (Direct emissions, soils)	N_2O	51,940	51,940	0.04	0.57
3.A.1.a.v	Enteric Fermentation (Cattle < 1 year old)	CH_4	49,305	49,305	0.04	0.61
2.C.1	Iron and Steel Production	CO_2	47,372	47,372	0.04	0.65
1.A.4	Other Sectors	CO_2	41,055	41,055	0.03	0.68
5.D	Wastewater Treatment and Discharge	CH_4	33,654	33,654	0.03	0.71
3.D.1.d	Crop Residues (Direct emissions, soils)	N_2O	30,564	30,564	0.02	0.73
3.G	Liming	CO_2	27,087	27,087	0.02	0.76
3.B	Manure Management	CH_4	24,868	24,868	0.02	0.78
2.A.1	Cement Production	CO_2	24,625	24,625	0.02	0.80
3.D.1.a	Inorganic N Fertilizers (Direct emissions, soils)	N_2O	21,771	21,771	0.02	0.81
3.A.1.b.ii	Enteric fermentation (Dairy cows, low production)	CH_4	22,068	22,068	0.02	0.83
3.D.2.b	Nitrogen Leaching and Run-off (Indirect emissions)	N_2O	20,986	20,986	0.02	0.85
3.A.1.b.i	Enteric fermentation (Dairy cows, high production)	CH_4	17,981	17,981	0.01	0.86
1.B.2.a	Oil and natural gas and other emissions from energy production – Oil	CO_2	16,001	16,001	0.01	0.88
3.A.1.a.i	Enteric Fermentation (Bulls > 2 years old)	CH_4	12,543	12,543	0.01	0.89
3.D.2.a	Atmospheric Deposition (Indirect emissions)	N_2O	12,324	12,324	0.01	0.90
3.C	Rice Cultivation	CH_4	11,901	11,901	0.01	0.91

IPCC Category Code	IPCC Category	GHG	Emission in 2022 (kt CO_2 eq)	Absolute emission in 2022 (kt CO_2 eq)	Level assessment (%)	Cumulative total (%)
1.A.4	Other Sectors	CH_4	9,080	9,080	0.01	0.91
2.F.1	Refrigeration and Air Conditioning	HFCs	8,768	8,768	0.01	0.92
1.A.3.a.ii	Domestic Aviation	CO_2	8,452	8,452	0.01	0.93
3.A.4	Enteric fermentation (Other animals)	CH_4	7,504	7,504	0.01	0.93
3.A.1.a.iv	Enteric Fermentation (Confined cattle)	CH_4	7,221	7,221	0.01	0.94
2.B.8	Petrochemical and Carbon Black Production	CO_2	6,348	6,348	0.01	0.94
2.A.2	Lime production	CO_2	5,924	5,924	0.00	0.95
3.D.1.b	Organic N Fertilizers (Direct emissions)	N_2O	4,620	4,620	0.00	0.95

Table A.I.3. Key categories for Brazil's NIR 2024, Tier 1 methodology, including LULUCF – Trend Assessment.

IPCC Category Code	IPCC Category	GHG	Emission in base year (kt CO_2eq)	Emission in current year (kt CO_2eq)	Trend assessment (%)	Contribution to trend (%)	Cumulative total (%)
4.C.2	Land Converted to Grassland	CO_2	812,119	908,386	0.24	0.34	0.34
4.A.1	Forest Land Remaining Forest Land	CO_2	-22,641	-287,645	0.15	0.21	0.55
1.A.3.b	Road transportation	CO_2	72,062	194,411	0.05	0.06	0.61
3.A.1.b.ii	Enteric fermentation (Dairy cows, low production)	CH_4	48,875	22,068	0.03	0.05	0.66
4.B.2	Land Converted to Cropland	CO_2	75,950	179,798	0.03	0.05	0.71
5.A	Solid Waste Disposal	CH_4	13,186	53,421	0.02	0.03	0.73
4.G	Harvested Wood Products	CO_2	-18,984	-56,507	0.01	0.02	0.75
4.C.2	Land Converted to Grassland	CH_4	812,119	908,386	0.01	0.02	0.77
3.A.1.b.i	Enteric fermentation (Dairy cows, high production)	CH_4	521	17,981	0.01	0.01	0.79
3.D.1.a	Inorganic N Fertilizers (Direct emissions, soils)	N_2O	3,245	21,771	0.01	0.01	0.80
3.A.1.a.vi	Enteric Fermentation (Cattle > 1 year < 2 years old)	CH4	66,477	91,451	0.01	0.01	0.82
1.A.1	Energy Industries	CO_2	23,707	54,357	0.01	0.01	0.83
3.A.1.a.iii	Enteric Fermentation (Female beef cattle > 2 years old, not confined)	CH_4	63,046	114,634	0.01	0.01	0.84
3.G	Liming	CO_2	9,141	27,087	0.01	0.01	0.85
3.D.1.d	Crop Residues (Direct emissions, soils)	N_2O	12,101	30,564	0.01	0.01	0.86
4.A.2	Land Converted to Forest Land	CO_2	-23,497	-27,198	0.01	0.01	0.87
4.F.2	Land Converted to Other Land	CO_2	-18,984	-56,507	0.01	0.01	0.88
2.F.1	Refrigeration and air conditioning	HFCs	-	8,768	0.01	0.01	0.88
3.A.1.a.v	Enteric Fermentation (Cattle < 1 year old)	CH_4	35,571	49,305	0.00	0.01	0.89
1.A.2	Manufacturing Industries and Construction	CO_2	36,470	66,427	0.00	0.01	0.90
4.C.2	Land Converted to Grassland	N_2O	10,245	9,632	0.00	0.01	0.90
2.A.1	Cement Production	CO_2	11,062	24,625	0.00	0.01	0.91
1.A.4	Other Sectors	CH_4	9,559	9,080	0.00	0.01	0.91
5.D	Wastewater Treatment and Discharge	CH_4	16,950	33,654	0.00	0.01	0.92
3.D.1.c	Animal Manure Deposited by Grazing Animals (Direct emissions, soils)	N_2O	35,815	51,940	0.00	0.01	0.92

IPCC Category Code	IPCC Category	GHG	Emission in base year (kt CO_2eq)	Emission in current year (kt CO_2eq)	Trend assessment (%)	Contribution to trend (%)	Cumulative total (%)
1.B.2.a	Oil and natural gas and other emissions from energy production – Oil	CO_2	6,191	16,001	0.00	0.00	0.93
3.A.1.a.iv	Enteric fermentation (Other animals > 2 years old, confined)	CH_4	1,038	7,221	0.00	0.00	0.93
3.D.2.b	Nitrogen Leaching and Run-off (Indirect emissions)	N_2O	9,636	20,986	0.00	0.00	0.94
4.E.2	Land Converted to Settlements	CO_2	6,711	5,552	0.00	0.00	0.94
3.A.4	Enteric fermentation (Other animals)	CH_4	7,869	7,504	0.00	0.00	0.95

Table A.I.4. Key categories for Brazil's NIR 2024, Tier 1 methodology, excluding LULUCF – Trend Assessment.

IPCC Category Code	IPCC Category	GHG	Emission in base year (kt CO_2eq)	Emission in current year (kt CO_2eq)	Trend assessment (%)	Contribution to trend (%)	Cumulative total (%)
3.A.1.b.ii	Enteric fermentation (Dairy cows, low production)	CH_4	48,875	22,068	0.10	0.16	0.16
1.A.3.b	Road transportation	CO_2	72,062	194,411	0.09	0.16	0.32
5.A	Solid Waste Disposal	CH_4	13,186	53,421	0.04	0.07	0.39
3.A.1.a.vi	Enteric Fermentation (Cattle > 1 year < 2 years old)	CH_4	66,477	91,451	0.04	0.07	0.46
3.A.1.b.i	Enteric fermentation (Dairy cows, high production)	CH_4	521	17,981	0.03	0.04	0.51
3.D.1.a	Inorganic N Fertilizers (Direct emissions, soils)	N_2O	3,245	21,771	0.02	0.04	0.54
3.A.1.a.v	Enteric Fermentation (Cattle < 1 year old)	CH_4	35,571	49,305	0.02	0.04	0.58
3.D.1.c	Animal Manure Deposited by Grazing Animals (Direct emissions, soils)	N_2O	35,815	51,940	0.02	0.03	0.61
3.A.1.a.ii	Enteric Fermentation (Male beef cattle > 2 years old, not confined)	CH_4	49,192	77,097	0.02	0.03	0.64
1.A.1	Energy Industries	CO_2	23,707	54,357	0.02	0.03	0.67
3.G	Liming	CO_2	9,141	27,087	0.02	0.03	0.70
2.F.1	Refrigeration and Air Conditioning	HFCs	-	8,768	0.01	0.02	0.72
3.D.1.d	Crop Residues (Direct emissions, soils)	N_2O	12,101	30,564	0.01	0.02	0.74
1.A.4	Other Sectors	CH_4	9,559	9,080	0.01	0.02	0.76
1.A.4	Other Sectors	CO_2	26,728	41,055	0.01	0.02	0.78
3.A.4	Enteric fermentation (Other animals)	CH_4	7,869	7,504	0.01	0.02	0.79
3.A.1.a.iv	Enteric fermentation (Other animals > 2 years old, confined)	CH_4	1,038	7,221	0.01	0.01	0.81
3.C	Rice Cultivation	CH_4	9,271	11,901	0.01	0.01	0.82
1.B.2.a	Oil and natural gas and other emissions from energy production – Oil	CO_2	6,191	16,001	0.01	0.01	0.83
2.A.1	Cement Production	CO_2	11,062	24,625	0.01	0.01	0.84
2.B.3	Adipic Acid Production	N_2O	2,286	1	0.01	0.01	0.85
2.C.3	Aluminum Production	PFCs	2,296	277	0.01	0.01	0.86
3.D.2.b	Nitrogen Leaching and Run-off (Indirect emissions)	N_2O	9,636	20,986	0.01	0.01	0.87
3.H	Urea Application	CO_2	631	4,397	0.00	0.01	0.88

IPCC Category Code	IPCC Category	GHG	Emission in base year (kt CO_2eq)	Emission in current year (kt CO_2eq)	Trend assessment (%)	Contribution to trend (%)	Cumulative total (%)
3.B	Manure Management	CH_4	15,500	24,868	0.00	0.01	0.89
1.A.3.b	Road transportation	N_2O	745	4,493	0.00	0.01	0.89
3.A.1.a.i	Enteric Fermentation (Bulls > 2 years old)	CH_4	8,641	12,543	0.00	0.01	0.90
5.D	Wastewater Treatment and Discharge	CH_4	16,950	33,654	0.00	0.01	0.91
1.A.3.d.ii	Domestic Navigation	CO_2	3,484	3,519	0.00	0.01	0.92
1.A.3.b	Road transportation	CH_4	1,872	1,083	0.00	0.01	0.92
3.A.2	Enteric Fermentation (Sheep)	CH_4	2,807	3,012	0.00	0.01	0.93
1.A.3.e	Other Transportation	CO_2	-	2,024	0.00	0.00	0.93
1.A.5	Other (Not specified elsewhere)	CO_2	1,612	1,111	0.00	0.00	0.94
2.C.1	Iron and Steel Production	CO_2	27,091	47,372	0.00	0.00	0.94
3.F	Field Burning of Agricultural Residues	CH_4	1,109	279	0.00	0.00	0.94
1.B.2.a	Oil and natural gas and other emissions from energy production – Oil	CH_4	1,156	3,762	0.00	0.00	0.95

APPENDIX II. ASSESSMENT OF UNCERTAINTY

For this inventory, in order to calculate the uncertainties of the activity data and emission factors, the error propagation method (Approach 1) was used at national level for all sectors, with the exception of the Waste sector, which used the Monte Carlo method (Approach 2), given the possibility of detailing the various parameters involved in this estimate.

The total uncertainty of the Inventory was obtained by analyzing the uncertainties of all the estimated gases, and not just of the three most relevant ones – CO_2, CH_4 and N_2O -, which made up 99.5% of the total emissions in kt CO_2 eq in 2022. The uncertainty of total net emissions in 2022 is 20.3%, and the uncertainty introduced in the trend of total net emissions has been assessed at 9.8% (Table A.II.1).

Table A.II.1. Summary of NIR 2024 uncertainties by category, gas and total, in 2022.

CATEGORIES	GAS	EMISSION IN 1990 (kt CO_2eq)	EMISSION IN 2022 (kt CO_2eq)	COMBINED UNCERTAINTY (2022)	TREND UNCERTAINTY IN EMISSIONS
1.A. FUEL COMBUSTION ACTIVITIES	CO_2	170,856	374,317	3.0%	0.7%
1.A. FUEL COMBUSTION ACTIVITIES	CH_4, N_2O	16,305	21,309	2.1%	0.0%
1.B. FUGITIVE EMISSIONS	CO_2, CH_4, N_2O	9,096	22,824	2.6%	0.0%
2. IPPU	CO_2	48,558	91,483	2.6%	0.2%
2. IPPU	CH_4, N_2O	4,262	1,321	0.9%	0.0%
2. IPPU	HFCs, PFC, SF_6	4,050	9,512	0.9%	0.0%
3. AGRICULTURE	CO_2, CH_4, N_2O	394,743	622,014	21.9%	11.2%
4. LAND USE, LAND-USE CHANGE AND FORESTRY	CO_2, CH_4, N_2O	908,066	805,694	52.9%	0.6%
5. WASTE	CO_2, CH_4, N_2O	32,596	90,761	10.3%	0.0%
TOTAL		**1,588,532**	**2,039,236**	**20.3%**	**9.8%**
TOTAL INVENTORY UNCERTAINTY (2022)		**20.3%**			

The calculated ranges are consistent with the typical ranges of uncertainty expected for each sector, as identified in IPCC (2006).

Table A.II.2. Data used and estimate of total uncertainty and trend uncertainty of the NIR 2024.

IPCC Category	Gas	Emissions and Removals (1990)	Emissions and Removals (2022)	Uncertainty of activity data	Uncertainty in the emission factors	Combined uncertainty	Contribution to variance by category in 2022	Type A Sensitivity	Type B Sensitivity	Trend uncertainty in the emission introduced by the emission factor	Trend uncertainty in the emission introduced by activity data	Uncertainty introduced by the trend in national emissions
		kt CO_2 eq	kt CO_2 eq	%	%	%		%	%			
1.A. Fuel Combustion Activities	CO_2	170,856	374,317	3	2	3	0.0000	0.0975	0.2356	0.16%	1.00%	0.01%
1.A. Fuel Combustion Activities	CH_4	12,597	12,108	3	68	68	0.0000	0.0026	0.0076	0.17%	0.03%	0.00%
1.A. Fuel Combustion Activities	N_2O	3,707	9,201	3	34	34	0.0000	0.0028	0.0058	0.10%	0.02%	0.00%
1.A.1. Energy Industries	CO_2	23,707	54,357	-	-	-	-	0.0151	0.0342	0.00%	0.00%	0.00%
1.A.1. Energy Industries	CH_4	696	934	-	-	-	-	0.0000	0.0006	0.00%	0.00%	0.00%
1.A.1. Energy Industries	N_2O	906	1,275	-	-	-	-	0.0001	0.0008	0.00%	0.00%	0.00%
1.A.2. Manufacturing Industries and Construction	CO_2	36,470	66,427	-	-	-	-	0.0123	0.0418	0.00%	0.00%	0.00%
1.A.2. Manufacturing Industries and Construction	CH_4	458	996	-	-	-	-	0.0003	0.0006	0.00%	0.00%	0.00%
1.A.2. Manufacturing Industries and Construction	N_2O	705	1,693	-	-	-	-	0.0005	0.0011	0.00%	0.00%	0.00%
1.A.3. Transport	CO_2	82,338	211,367	-	-	-	-	0.0665	0.1331	0.00%	0.00%	0.00%
1.A.3. Transport	CH_4	1,884	1,098	-	-	-	-	0.0008	0.0007	0.00%	0.00%	0.00%
1.A.3. Transport	N_2O	973	4,913	-	-	-	-	0.0023	0.0031	0.00%	0.00%	0.00%
1.A.4. Other Sectors	CO_2	26,728	41,055	-	-	-	-	0.0042	0.0258	0.00%	0.00%	0.00%
1.A.4. Other Sectors	CH_4	9,559	9,080	-	-	-	-	0.0020	0.0057	0.00%	0.00%	0.00%
1.A.4. Other Sectors	N_2O	1,118	1,320	-	-	-	-	0.0001	0.0008	0.00%	0.00%	0.00%
1.A.5. Other (Not specified elsewhere)	CO_2	1,612	1,111	-	-	-	-	0.0006	0.0007	0.00%	0.00%	0.00%
1.A.5. Other (Not specified elsewhere)	CH_4	1	0	-	-	-	-	0.0000	0.0000	0.00%	0.00%	0.00%
1.A.5. Other (Not specified elsewhere)	N_2O	7	0	-	-	-	-	0.0000	-	0.00%	0.00%	0.00%
1.B. Fugitive Emissions from Fuels	CO_2	6,191	16,876	-	-	-	-	0.0056	0.0106	0.00%	0.00%	0.00%

IPCC Category	Gas	Emissions and Removals (1990)	Emissions and Removals (2022)	Uncertainty of activity data	Uncertainty in the emission factors	Combined uncertainty	Contribution to variance by category in 2022	Type A Sensitivity	Type B Sensitivity	Trend uncertainty in the emission introduced by the emission factor	Trend uncertainty in the emission introduced by activity data	Uncertainty introduced by the trend in national emissions
		kt CO_2 eq	kt CO_2 eq	%	%	%		%	%			
1.B. Fugitive Emissions from Fuels	CH_4	2,890	5.885	-	-	-	-	0.0014	0.0037	0.00%	0.00%	0.00%
1.B. Fugitive Emissions from Fuels	N_2O	15	64	-	-	-	-	0.0000	0.0000	0.00%	0.00%	0.00%
1.B.1. Solid fuels	CH_4	1,558	1,508	-	-	-	-	0.0003	0.0009	0.00%	0.00%	0.00%
1.B.2. Oil and Natural Gas	CO_2	6,191	16,876	5	63	63	0.0000	0.0056	0.0106	0.35%	0.08%	0.00%
1.B.2. Oil and Natural Gas	CH_4	1,332	4,377	5	63	63	0.0000	0.0017	0.0028	0.11%	0.02%	0.00%
1.B.2. Oil and Natural Gas	N_2O	15	64	5	63	63	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2.A. Mineral Industry	CO_2	15,170	32,993	-	-	-	-	0.0085	0.0208	0.00%	0.00%	0.00%
2.A.1. Cement Production	CO_2	11,062	24,625	2	2	3	0.0000	0.0066	0.0155	0.01%	0.04%	0.00%
2.A.2. Lime production	CO_2	3,502	5,924	10	2	10	0.0000	0.0009	0.0037	0.00%	0.05%	0.00%
2.A.3. Glass production	CO_2	145	266	20	5	20.6	0.0000	0.0001	0.0002	0.00%	0.00%	0.00%
2.A.4. Other process uses of carbonates	CO_2	462	2,179	20	5	20.6	0.0000	0.0010	0.0014	0.00%	0.04%	0.00%
2.B. Chemical industry	CO_2	3,875	6,557	-	-	-	-	0.0010	0.0041	0.00%	0.00%	0.00%
2.B. Chemical industry	CH_4	148	287	-	-	-	-	0.0001	0.0002	0.00%	0.00%	0.00%
2.B. Chemical industry	N_2O	2,865	176	-	-	-	-	0.0022	0.0001	0.00%	0.00%	0.00%
2.B. Chemical industry	HFCs	1,491	0	-	-	-	-	0.0012	-	0.00%	0.00%	0.00%
2.B.1. Ammonia production	CO_2	286	168	5	10	11.2	0.0000	0.0001	0.0001	0.00%	0.00%	0.00%
2.B.2. Nitric acid production	N_2O	479	175	5	5	7.1	0.0000	0.0003	0.0001	0.00%	0.00%	0.00%
2.B.3. Adipic acid production	N_2O	2,286	1	5	5	7.1	0.0000	0.0018	0.0000	0.01%	0.00%	0.00%
2.B.4. Caprolactam, glyoxal and glyoxylic acid production	N_2O	100	0	5	-	5.0	-	0.0001	-	0.00%	0.00%	0.00%
2.B.5. Carbide production	CO_2	0	42	5	5	7.1	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2.B.8. Petrochemical and carbon black production	CO_2	3,589	6,348	5	10	11.2	0.0000	0.0011	0.0040	0.01%	0.03%	0.00%

IPCC Category	Gas	Emissions and Removals (1990)	Emissions and Removals (2022)	Uncertainty of activity data	Uncertainty in the emission factors	Combined uncertainty	Contribution to variance by category in 2022	Type A Sensitivity	Type B Sensitivity	Trend uncertainty in the emission introduced by the emission factor	Trend uncertainty in the emission introduced by activity data	Uncertainty introduced by the trend in national emissions
		kt CO_2 eq	kt CO_2 eq	%	%	%		%	%			
2.B.8. Petrochemical and carbon black production	CH_4	148	287	5	15	15.8	0.0000	0.0001	0.0002	0.00%	0.00%	0.00%
2.B.9. Fluorochemical production	HFCs	1,491	0	5	-	5.0	-	0.0012	-	0.00%	0.00%	0.00%
2.C. Metal Industry	CO_2	28,992	51,091	-	-	-	-	0.0087	0.0322	0.00%	0.00%	0.00%
2.C. Metal Industry	CH_4	1,054	726	-	-	-	-	0.0004	0.0005	0.00%	0.00%	0.00%
2.C. Metal Industry	N_2O	195	132	-	-	-	-	0.0001	0.0001	0.00%	0.00%	0.00%
2.C. Metal Industry	PFCs	2,296	277	-	-	-	-	0.0017	0.0002	0.00%	0.00%	0.00%
2.C. Metal Industry	SF_6	135	0	-	-	-	-	0.0001	-	0.00%	0.00%	0.00%
2.C.1. Iron and steel production	CO_2	27,091	47,372	-	5	5.0	0.0000	0.0079	0.0298	0.04%	0.00%	0.00%
2.C.1. Iron and steel production	CH_4	1,047	726	-	120	120.0	0.0000	0.0004	0.0005	0.05%	0.00%	0.00%
2.C.1. Iron and steel production	N_2O	195	132	-	120	120.0	0.0000	0.0001	0.0001	0.01%	0.00%	0.00%
2.C.2 Ferroalloys production	CO_2	122	646	5	10	11.2	0.0000	0.0003	0.0004	0.00%	0.00%	0.00%
2.C.2 Ferroalloys production	CH_4	6	0	5	25	25.5	-	0.0000	-	0.00%	0.00%	0.00%
2.C.3. Aluminum Production	CO_2	1,574	1,256	3	5	5.8	0.0000	0.0005	0.0008	0.00%	0.00%	0.00%
2.C.3. Aluminum Production	PFCs	2,296	277	3	20	20.2	0.0000	0.0017	0.0002	0.03%	0.00%	0.00%
2.C.4. Magnesium production	CO_2	29	148	3	5	5.8	0.0000	0.0001	0.0001	0.00%	0.00%	0.00%
2.C.4. Magnesium production	SF_6	135	0	3	-	3.0	-	0.0001	-	0.00%	0.00%	0.00%
2.C.7. Other (non-ferrous metals, except aluminum and magnesium)	CO_2	176	1,668	3	5	5.8	0.0000	0.0009	0.0011	0.00%	0.00%	0.00%
2.D. Non-Energy Products from Fuels and Solvent Use	CO_2	520	843	3	5	5.8	0.0000	0.0001	0.0005	0.00%	0.00%	0.00%
2.E. Electronics Industry	PFCs	0	0	-	-	-	-	0.0000	0.0000	0.00%	0.00%	0.00%
2.E. Electronics Industry	HFCs	0	1	-	-	-	-	0.0000	0.0000	0.00%	0.00%	0.00%

IPCC Category	Gas	Emissions and Removals (1990)	Emissions and Removals (2022)	Uncertainty of activity data	Uncertainty in the emission factors	Combined uncertainty	Contribution to variance by category in 2022	Type A Sensitivity	Type B Sensitivity	Trend uncertainty in the emission introduced by the emission factor	Trend uncertainty in the emission introduced by activity data	Uncertainty introduced by the trend in national emissions
		kt CO_2 eq	kt CO_2 eq	%	%	%		%	%			
2.F. Product Uses as Substitutes for Ozone Depleting Substances	HFCs	0	8,891	-	-	-	-	0.0056	0.0056	0.00%	0.00%	0.00%
2.F.1. Refrigeration and air conditioning	HFCs	0	8,768	10	-	10.0	0.0000	0.0055	0.0055	0.00%	0.08%	0.00%
2.F.2. Foam Blowing Agents	HFCs	0	33	10	-	10.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2.F.3. Fire protection	HFCs	0	70	10	-	10.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2.F.4. Aerosols	HFCs	0	19	10	-	10.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2.G. Other Product Manufacture and Use	SF_6	128	343	20	-	20.0	0.0000	0.0001	0.0002	0.00%	0.01%	0.00%
3.A. Enteric fermentation	CH_4	284,981	404,062	-	-	-	-	0.0240	0.2544	0.00%	0.00%	0.00%
3.A.1. Cattle	CH_4	273,361	392,302	15	19	24.2	0.0022	0.0260	0.2470	0.49%	5.24%	0.28%
3.A.2. Sheep	CH_4	2,807	3,012	15	30	33.5	0.0000	0.0004	0.0019	0.01%	0.04%	0.00%
3.A.3. Swine	CH_4	943	1,243	15	30	33.5	0.0000	0.0000	0.0008	0.00%	0.02%	0.00%
3.A.4. Other animals	CH_4	7,869	7,504	15	30	33.5	0.0000	0.0016	0.0047	0.05%	0.10%	0.00%
3.B. Manure Management	CH_4	15,500	24,868	-	-	-	-	0.0031	0.0157	0.00%	0.00%	0.00%
3.B. Manure Management	N_2O	2,301	4,145	-	-	-	-	0.0007	0.0026	0.00%	0.00%	0.00%
3.B.1. Cattle	CH_4	6,950	11,837	15	17	22.7	0.0000	0.0018	0.0075	0.03%	0.16%	0.00%
3.B.1. Cattle	N_2O	827	1,032	15	36	39.0	0.0000	0.0000	0.0006	0.00%	0.01%	0.00%
3.B.2. Sheep	CH_4	95	113	15	35	38.1	0.0000	0.0000	0.0001	0.00%	0.00%	0.00%
3.B.3. Swine	CH_4	7,532	11,529	15	35	38.1	0.0000	0.0012	0.0073	0.04%	0.15%	0.00%
3.B.3. Swine	N_2O	338	728	15	40	42.7	0.0000	0.0002	0.0005	0.01%	0.01%	0.00%
3.B.4. Other animals	CH_4	922	1,389	15	35	38.1	0.0000	0.0001	0.0009	0.00%	0.02%	0.00%
3.B.4. Other animals	N_2O	90	237	15	40	42.7	0.0000	0.0001	0.0001	0.00%	0.00%	0.00%
3.B.5. Indirect N_2O Emissions	N_2O	1,046	2,148	20	100	102.0	0.0000	0.0005	0.0014	0.05%	0.04%	0.00%
3.C. Rice cultivation	CH_4	9,271	11,901	20	40	44.7	0.0000	0.0000	0.0075	0.00%	0.21%	0.00%

IPCC Category	Gas	Emissions and Removals (1990)	Emissions and Removals (2022)	Uncertainty of activity data	Uncertainty in the emission factors	Combined uncertainty	Contribution to variance by category in 2022	Type A Sensitivity	Type B Sensitivity	Trend uncertainty in the emission introduced by the emission factor	Trend uncertainty in the emission introduced by activity data	Uncertainty introduced by the trend in national emissions
		kt CO_2 eq	kt CO_2 eq	%	%	%		%	%			
3.C.1. Irrigated	CH_4	9,271	11,901	-	-	-	-	0.0000	0.0075	0.00%	0.00%	0.00%
3.D. Agricultural soils	N_2O	71,071	145,078	-	-	-	-	0.0339	0.0913	0.00%	0.00%	0.00%
3.D.1. Direct N_2O emissions from managed soils	N_2O	55,496	111,768	15	80	81.4	0.0020	0.0255	0.0704	2.04%	1.49%	0.06%
3.D.2. Indirect N_2O emissions from managed soils	N_2O	15,575	33,310	20	100	102.0	0.0003	0.0084	0.0210	0.84%	0.59%	0.01%
3.F. Field Burning of Agricultural Residues	CH_4	1,109	279	10	30	31.6	0.0000	0.0007	0.0002	0.02%	0.00%	0.00%
3.F. Field Burning of Agricultural Residues	N_2O	739	198	10	50	51.0	0.0000	0.0005	0.0001	0.02%	0.00%	0.00%
3.F.1. Sugar cane	CH_4	1,004	279	-	-	-	-	0.0006	0.0002	0.00%	0.00%	0.00%
3.F.1. Sugar cane	N_2O	713	198	-	-	-	-	0.0005	0.0001	0.00%	0.00%	0.00%
3.F.2. Cotton	CH_4	105	0	-	-	-	-	0.0001	-	0.00%	0.00%	0.00%
3.F.2. Cotton	N_2O	26	0	-	-	-	-	0.0000	-	0.00%	0.00%	0.00%
3.G. Liming	CO_2	9,141	27,087	20	30	36.1	0.0000	0.0097	0.0171	0.29%	0.48%	0.00%
3.H. Urea Application	CO_2	631	4,397	3	5	5.8	0.0000	0.0023	0.0028	0.01%	0.01%	0.00%
4.A. Forest Land	CO_2	-46,138	-314,842	6	12	13.4	0.0004	0.1610	0.1982	1.93%	1.68%	0.07%
4.A. Forest Land	CH_4	1,928	2,106	6	29	29.6	0.0000	0.0002	0.0013	0.01%	0.01%	0.00%
4.A. Forest Land	CO_2	544	612	6	50	50.4	0.0000	0.0001	0.0004	0.00%	0.00%	0.00%
4.A.1. Forest Land Remaining Forest Land	CO_2	-22,641	-287,645	-	-	-	-	0.1628	0.1811	0.00%	0.00%	0.00%
4.A.1. Forest Land Remaining Forest Land	CH_4	1,915	2,062	-	-	-	-	0.0002	0.0013	0.00%	0.00%	0.00%
4.A.1. Forest Land Remaining Forest Land	N_2O	533	574	-	-	-	-	0.0001	0.0004	0.00%	0.00%	0.00%
4.A.2. Land Converted to Forest Land	CO_2	-23,497	-27,198	-	-	-	-	0.0019	0.0171	0.00%	0.00%	0.00%
4.A.2. Land Converted to Forest Land	CH_4	13	44	-	-	-	-	0.0000	0.0000	0.00%	0.00%	0.00%
4.A.2. Land Converted to Forest Land	N_2O	11	38	-	-	-	-	0.0000	0.0000	0.00%	0.00%	0.00%

IPCC Category	Gas	Emissions and Removals (1990)	Emissions and Removals (2022)	Uncertainty of activity data	Uncertainty in the emission factors	Combined uncertainty	Contribution to variance by category in 2022	Type A Sensitivity	Type B Sensitivity	Trend uncertainty in the emission introduced by the emission factor	Trend uncertainty in the emission introduced by activity data	Uncertainty introduced by the trend in national emissions
		kt CO_2 eq	kt CO_2 eq	%	%	%		%	%			
4.B. Cropland	CO_2	75,950	179,798	10	43	44.1	0.0015	0.0518	0.1132	2.23%	1.60%	0.08%
4.B. Cropland	CH_4	2,506	3,517	10	34	35.4	0.0000	0.0002	0.0022	0.01%	0.03%	0.00%
4.B. Cropland	N_2O	848	1,185	10	49	50.0	0.0000	0.0001	0.0007	0.00%	0.01%	0.00%
4.B.2. Land Converted to Cropland	CO_2	75,950	179,798	-	-	-	-	0.0518	0.1132	0.00%	0.00%	0.00%
4.B.2. Land Converted to Cropland	CH_4	2,506	3,517	-	-	-	-	0.0002	0.0022	0.00%	0.00%	0.00%
4.B.2. Land Converted to Cropland	N_2O	848	1,185	-	-	-	-	0.0001	0.0007	0.00%	0.00%	0.00%
4.C. Grassland	CO_2	828,009	914,227	6	41	41.4	0.0345	0.0931	0.5755	3.82%	4.88%	0.38%
4.C. Grassland	CH_4	37,754	35,353	6	39	39.5	0.0000	0.0083	0.0223	0.32%	0.19%	0.00%
4.C. Grassland	N_2O	11,065	10,282	6	48	48.4	0.0000	0.0025	0.0065	0.12%	0.05%	0.00%
4.C.1. Grassland Remaining Grassland	CO_2	15,890	5,841	-	-	-	-	0.0092	0.0037	0.00%	0.00%	0.00%
4.C.1. Grassland Remaining Grassland	CH_4	949	752	-	-	-	-	0.0003	0.0005	0.00%	0.00%	0.00%
4.C.1. Grassland Remaining Grassland	CO_2	820	650	-	-	-	-	0.0003	0.0004	0.00%	0.00%	0.00%
4.C.2. Land Converted to Grassland	CO_2	812,119	908,386	-	-	-	-	0.0840	0.5718	0.00%	0.00%	0.00%
4.C.2. Land Converted to Grassland	CH_4	36,805	34,601	-	-	-	-	0.0080	0.0218	0.00%	0.00%	0.00%
4.C.2. Land Converted to Grassland	N_2O	10,245	9,632	-	-	-	-	0.0022	0.0061	0.00%	0.00%	0.00%
4.D. Wetlands	CO_2	6,158	11,178	6	32	32.6	0.0000	0.0021	0.0070	0.07%	0.06%	0.00%
4.D. Wetlands	CH_4	197	385	6	34	34.5	0.0000	0.0001	0.0002	0.00%	0.00%	0.00%
4.D. Wetlands	N_2O	57	112	6	49	49.4	0.0000	0.0000	0.0001	0.00%	0.00%	0.00%
4.D.2. Land Converted to Wetland	CO_2	6,158	11,178	-	-	-	-	0.0021	0.0070	0.00%	0.00%	0.00%
4.D.2. Land Converted to Wetland	CH_4	197	385	-	-	-	-	0.0001	0.0002	0.00%	0.00%	0.00%

IPCC Category	Gas	Emissions and Removals (1990) kt CO_2 eq	Emissions and Removals (2022) kt CO_2 eq	Uncertainty of activity data %	Uncertainty in the emission factors %	Combined uncertainty %	Contribution to variance by category in 2022	Type A Sensitivity %	Type B Sensitivity %	Trend uncertainty in the emission introduced by the emission factor	Trend uncertainty in the emission introduced by activity data	Uncertainty introduced by the trend in national emissions
4.D.2. Land Converted to Wetland	N_2O	57	112	-	-	-	-	0.0000	0.0001	0.00%	0.00%	0.00%
4.E. Settlements	CO_2	6,711	5,552	13	32	34.5	0.0000	0.0019	0.0035	0.06%	0.06%	0.00%
4.E. Settlements	CH_4	141	90	13	34	36.4	0.0000	0.0001	0.0001	0.00%	0.00%	0.00%
4.E. Settlements	N_2O	44	28	13	49	50.7	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
4.E.2. Land Converted to Settlements	CO_2	6,711	5,552	-	-	-	-	0.0019	0.0035	0.00%	0.00%	0.00%
4.E.2. Land Converted to Settlements	CH_4	141	90	-	-	-	-	0.0001	0.0001	0.00%	0.00%	0.00%
4.E.2. Land Converted to Settlements	N_2O	44	28	-	-	-	-	0.0000	0.0000	0.00%	0.00%	0.00%
4.F. Other Land	CO_2	1,226	12,062	6	32	32.6	0.0000	0.0066	0.0076	0.21%	0.06%	0.00%
4.F. Other Land	CH_4	38	435	6	34	34.5	0.0000	0.0002	0.0003	0.01%	0.00%	0.00%
4.F. Other Land	N_2O	11	124	6	49	49.4	0.0000	0.0001	0.0001	0.00%	0.00%	0.00%
4.F.2. Land Converted to Other Land	CO_2	1,226	12,062	-	-	-	-	0.0066	0.0076	0.00%	0.00%	0.00%
4.F.2. Land Converted to Other Land	CH_4	38	435	-	-	-	-	0.0002	0.0003	0.00%	0.00%	0.00%
4.F.2. Land Converted to Other Land	N_2O	11	124	-	-	-	-	0.0001	0.0001	0.00%	0.00%	0.00%
4.G. Harvested Wood Products	CO_2	-18,984	-56,507	50	35	61.0	0.0003	0.0202	0.0356	0.71%	2.52%	0.07%
5.A. Solid Waste Disposal	CH_4	13,186	53,421	-	15	15.0	0.0000	0.0230	0.0336	0.34%	0.00%	0.00%
5.A.1. Managed Waste Disposal Sites	CH_4	5,229	44,051	-	-	-	-	0.0235	0.0277	0.00%	0.00%	0.00%
5.A.3. Uncategorized Waste Disposal Sites	CH_4	7,957	9,370	-	-	-	-	0.0005	0.0059	0.00%	0.00%	0.00%
5.B. Biological Treatment of Solid Waste	CH_4	11	39	-	38	38.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
5.B. Biological Treatment of Solid Waste	N_2O	6	22	-	37	37.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
5.B.1. Composting	CH_4	11	39	-	-	-	-	0.0000	0.0000	0.00%	0.00%	0.00%

IPCC Category	Gas	Emissions and Removals (1990)	Emissions and Removals (2022)	Uncertainty of activity data	Uncertainty in the emission factors	Combined uncertainty	Contribution to variance by category in 2022	Type A Sensitivity	Type B Sensitivity	Trend uncertainty in the emission introduced by the emission factor	Trend uncertainty in the emission introduced by activity data	Uncertainty introduced by the trend in national emissions
		kt CO_2 eq	kt CO_2 eq	%	%	%		%	%			
5.B.1. Composting	N_2O	6	22	-	-	-	-	0.0000	0.0000	0.00%	0.00%	0.00%
5.C. Incineration and Open Burning of Waste	CO_2	535	504	-	44	44.0	0.0000	0.0001	0.0003	0.01%	0.00%	0.00%
5.C. Incineration and Open Burning of Waste	CH_4	536	630	-	31	31.0	0.0000	0.0000	0.0004	0.00%	0.00%	0.00%
5.C. Incineration and Open Burning of Waste	N_2O	80	90	-	36	36.0	0.0000	0.0000	0.0001	0.00%	0.00%	0.00%
5.C.1. Waste Incineration	CO_2	39	107	-	-	-	-	0.0000	0.0001	0.00%	0.00%	0.00%
5.C.1. Waste Incineration	N_2O	3	9	-	-	-	-	0.0000	0.0000	0.00%	0.00%	0.00%
5.C.2. Open Burning of Waste	CO_2	496	397	-	-	-	-	0.0002	0.0002	0.00%	0.00%	0.00%
5.C.2. Open Burning of Waste	CH_4	536	630	-	-	-	-	2.0000	0.0004	0.00%	0.00%	0.00%
5.C.2. Open Burning of Waste	N_2O	77	81	-	-	-	-	0.0000	0.0001	0.00%	0.00%	0.00%
5.D Wastewater Treatment and Discharge	CH_4	16,950	33,654	-	14	14.0	0.0000	0.0075	0.0212	0.10%	0.00%	0.00%
5.D Wastewater Treatment and Discharge	N_2O	1,291	2,402	-	28	28.0	0.0000	0.0005	0.0015	0.01%	0.00%	0.00%
5.D.1. Domestic Wastewater Treatment	CH_4	15,242	27,808	-	-	-	-	0.0052	0.0175	0.00%	0.00%	0.00%
5.D.1. Domestic Wastewater Treatment	N_2O	1,291	2,402	-	-	-	-	0.0005	0.0015	0.00%	0.00%	0.00%
5.D.2. Industrial Wastewater Treatment	CH_4	1,708	5,846	-	-	-	-	0.0023	0.0037	0.00%	0.00%	0.00%
TOTAL		**1,588,532**	**2,039,236**				**0.0414**					**0.0096**
					Percentage of uncertainty in inventory total		**20.3%**				**Trend Uncertainty**	**9.8%**

APPENDIX III. DESCRIPTION OF THE REFERENCE APPROACH AND ITS COMPARISON WITH THE SECTORAL APPROACH

In order to calculate CO_2 emissions in the Energy sector using the Reference approach, the IPCC (2006, v. 2, chap. 6), was used. This methodology refers to the presentation of an overview of emissions from the burning of fossil fuels. Energy sources are separated by physical state of the primary product, and basically correspond to Oil, its derivatives and Natural Gas Liquids (liquids), Mineral Coal (solids) and Natural Gas (gaseous). The methodology does not distinguish energy use between the different source categories, which requires the use of the Sectoral approach (as indicated in Chapter 4 of this document).

In the Reference approach, emissions from fuel combustion are calculated based on aggregate data on fuel supply in a given economy, based on the concept of apparent consumption. In this concept, the imports of primary and secondary fuels are added to the production of primary fuels and the exports of primary and secondary fuels, bunkers and stock changes are subtracted. Based on this result, CO_2 emissions are estimated based on the carbon content of the fuels.

The data used to determine the apparent consumption of energy inputs, the basis for calculating CO_2 emissions, was obtained from the National Energy Balance (BEN, Balanço Energético Nacional), using the expanded BEN Matrix (EPE – Energy Research Office (Empresa de Pesquisa Energética), 2023). To estimate apparent consumption, equation 6.2 on page 6.6 of Chapter 6 of Volume 2 of the IPCC (2006).

With regard to production data, the IPCC accounts for natural gas liquids (NGL) in the Liquid Fossil category and dry natural gas (DNG) as the only source in the Gaseous Fossil category. This distinction, however, is not reflected in BEN, given that there is a significant indication of wet natural gas consumption in Brazil. Adaptations are therefore needed to make the IPCC consistent with BEN. The inventory accounts for wet natural gas (produced) and dry natural gas (imported) in the Gaseous Fossil category, and keeps natural gas liquids (NGL) in the Liquid Fossil category.

For sugar cane by-products, the values for the production of the following fuels were obtained from BEN: Bagasse, Sugarcane Juice and Molasses – the last two, although they are not fuels, are used as inputs for ethanol production.

For the accounting of other energy sources, considered in the "other BEN primary sources" category, the "other fossil primary sources" – excluding industrial gases because it constitutes double counting, and considering only waste for the cement industry (tires, hospital waste and other waste burned in cement kilns) – and the "other renewable primary sources" – including vegetable oils, biogas and biomass (vegetable waste) – subcategories were included in the accounting.

The values for bunker were obtained from BEN for the years from 1990 to 2022.

With regard to exports and imports, secondary sources are of interest to the Reference approach when they are imported, exported or have stock variations. It was necessary to subtract from imports the percentages relating to the imports of methanol and MTBE for addition to Hydrous Ethanol and Gasoline, respectively, from 1990 to 1995. Since 1996, these additives have no longer been imported.

The carbon contents used in this Inventory are those recommended by the IPCC (2006). In the case of wet natural gas, the dry natural gas factor was adopted, since it is not provided for in the IPCC.

The calculation of the amount of carbon excluded followed the IPCC (2006). The values relating to feedstocks and non energy products were deducted from the calculations based on BEN, which accounts for them as "non-energy consumption". For fuels used as reducers, the values attributed by the Useful Energy Balance (BEU, Balanço de Energia Útil) as being for "direct heating" in the "pig iron and steel", "ferroalloys" and "non-ferrous" sectors, referring to other bituminous coals, charcoal, coal coke and petroleum coke, were deducted from the calculations.

The table below shows the results of annual emissions and the difference (%) between the Reference approach and the Sectoral approach.

Table A.III.1 Results of annual emissions between the Reference approach and the Sectoral approach.

Year	Reference Approach (kt CO_2)	Sectoral Approach (kt CO_2)	Difference (%)
1990	174,697	170,856	2.25
1991	180,552	174,530	3.45
1992	184,171	179,832	2.41
1993	190,501	185,033	2.96
1994	199,495	193,480	3.11
1995	213,954	210,029	1.87
1996	232,839	226,661	2.73
1997	246,978	241,644	2.21
1998	256,452	248,249	3.30
1999	264,585	257,247	2.85
2000	266,758	263,366	1.29
2001	279,446	270,664	3.24
2002	273,967	267,971	2.24
2003	264,383	261,198	1.22
2004	280,315	276,075	1.54
2005	285,261	281,048	1.50
2006	288,392	287,021	0.48
2007	301,577	300,178	0.47
2008	319,733	318,588	0.36
2009	304,380	301,945	0.81
2010	344,436	339,460	1.47
2011	356,328	354,216	0.60
2012	386,688	385,814	0.23
2013	420,907	416,786	0.99
2014	444,453	440,670	0.86
2015	419,704	416,579	0.75
2016	382,936	384,118	-0.31
2017	396,044	391,894	1.06
2018	375,686	369,152	1.77
2019	370,609	368,224	0.65
2020	346,069	348,751	-0.77
2021	399,208	393,734	1.39
2022	373,647	374,317	-0.18

APÊNDICE IV. ADDITIONAL DESCRIPTIONS FOR THE ENERGY SECTOR

This appendix details the methodological procedures, statistical adjustments, data and parameters used to measure emissions from the Energy sector in the NIR 2024. The methodology adopted follows the guidelines outlined in IPCC (2006), especially in Chapters 2 to 5 of Volume 2.

Implicit emission factors by gases in the Road Transportation subcategory

Table A.IV.1. Implicit emission factors for CO_2 (kg/TJ).

Year	Type A gasoline	Hydrous ethanol	Anhydrous ethanol	Mineral diesel	Biodiesel	CNG
1990	72,243	70,770	70,770	74,070	0	54,278
1991	72,038	70,770	70,770	74,070	0	54,278
1992	72,251	70,770	70,770	74,070	0	54,278
1993	71,569	70,770	70,770	74,070	0	54,278
1994	71,962	70,770	70,770	74,070	0	54,278
1995	71,803	70,770	70,770	74,070	0	54,278
1996	69,303	70,770	70,770	74,070	0	54,278
1997	69,303	70,770	70,770	74,070	0	54,278
1998	69,303	70,770	70,770	74,070	0	54,278
1999	69,303	70,770	70,770	74,070	0	54,278
2000	69,303	70,770	70,770	74,070	0	54,278
2001	69,303	70,770	70,770	74,070	0	54,278
2002	69,303	70,770	70,770	74,070	0	54,256
2003	69,303	70,770	70,770	74,070	0	54,256
2004	69,303	70,770	70,770	74,070	0	54,256
2005-2022	69,303	70,770	70,770	74,070	70,770	54,256

Table A.IV.2. Implicit emission factors for N_2O (kg/TJ).

Year	Type C gasoline	Hydrous ethanol	CNG	Mineral diesel
1990	1.5	2.4	0.1	2.7
1991	1.5	2.4	0.1	2.7
1992	1.5	2.4	0.1	2.7
1993	1.5	2.4	0.1	2.6
1994	2.0	2.5	0.1	2.7
1995	2.8	2.6	0.1	2.6
1996	3.6	2.6	0.1	2.6
1997	4.4	2.6	0.1	2.6
1998	4.9	2.6	0.1	2.6
1999	5.4	2.6	0.1	2.7
2000	5.7	2.6	0.1	2.7
2001	6.1	2.7	0.1	2.7
2002	6.4	2.7	0.1	2.7
2003	6.5	2.8	0.1	2.7
2004	6.7	3.0	0.1	2.7
2005	6.8	3.5	0.1	2.7
2006	6.7	3.7	0.1	2.7
2007	6.8	4.0	0.1	2.7
2008	6.9	4.8	0.1	2.7
2009	6.9	5.0	0.1	2.7
2010	7.0	5.4	0.1	2.7
2011	7.1	5.6	0.1	2.7
2012	7.1	5.6	0.1	2.7
2013	7.3	5.8	0.1	2.7
2014	7.4	5.9	0.1	2.8
2015-2022	7.5	6.1	0.1	2.8

Table A.IV.3. Implicit emission factors for CH_4 (kg/TJ).

Year	Type C gasoline	Hydrous ethanol	CNG	Mineral diesel
1990	127.2	93.4	0.5	5.1
1991	124.5	92.8	0.5	5.1
1992	121.0	90.9	0.5	5.1
1993	113.2	88.0	0.5	5.1
1994	104.3	86.0	0.5	5.1
1995	93.7	85.3	0.5	5.0
1996	85.0	84.9	0.5	5.0
1997	76.7	84.7	0.5	5.0
1998	69.1	84.6	0.5	5.0
1999	64.3	84.3	0.5	5.0
2000	59.6	83.8	0.5	5.0
2001	55.4	83.2	0.5	5.0
2002	52.1	81.9	0.5	5.0
2003	48.4	79.8	0.5	5.1
2004	45.6	75.0	0.5	5.0
2005	43.0	66.5	0.5	5.0
2006	39.8	61.4	0.5	5.1
2007	38.1	56.0	0.5	5.1
2008	36.0	41.3	0.5	5.0
2009	33.6	35.7	0.5	5.1
2010	30.3	30.0	0.5	5.1
2011	27.0	27.2	0.5	5.1
2012	23.9	27.3	0.5	5.1
2013	21.7	24.5	0.5	5.1
2014	19.6	22.7	0.5	5.1
2015	18.5	19.4	0.5	5.1
2016-2022	17.2	19.9	0.5	5.2

Table A.IV.4. Implicit emission factors for CO (kg/TJ).

Year	Type C gasoline	Hydrous ethanol	CNG	Mineral diesel
1990	10,866.4	6,937.1	1.3	147.4
1991	10,525.3	6,966.8	1.3	147.9
1992	10,151.0	6,867.2	1.3	148.2
1993	9,474.9	6,644.6	1.3	147.9
1994	8,585.7	6,451.0	1.3	147.7
1995	7,402.7	6,360.7	1.3	146.9
1996	6,410.1	6,333.4	1.3	146.5
1997	5,563.1	6,321.5	1.3	145.8
1998	4,881.1	6,300.1	1.3	146.7
1999	4,452.1	6,262.3	1.3	147.6
2000	4,039.8	6,215.9	1.3	147.7
2001	3,670.8	6,153.0	1.3	147.6
2002	3,369.8	6,026.4	1.3	144.7
2003	3,061.6	5,839.7	1.3	141.0
2004	2,822.3	5,415.6	1.3	135.2
2005	2,604.4	4,675.5	1.3	130.7
2006	2,350.7	4,236.8	1.3	126.8
2007	2,190.7	3,766.9	1.3	122.8
2008	2,034.4	2,518.5	1.3	118.0
2009	1,873.9	2,064.8	1.3	114.7
2010	1,679.4	1,602.7	1.3	108.9
2011	1,482.7	1,347.6	1.3	103.7
2012	1,295.8	1,353.5	1.3	97.3
2013	1,165.2	1,151.6	1.3	88.8
2014	1,050.8	1,031.9	1.3	81.6
2015	989.0	805.4	1.3	77.3
2016-2022	926.6	858.3	1.3	74.9

Table A.IV.5. Implicit emission factors for NO_x (kg/TJ).

Year	Type C gasoline	Hydrous ethanol	CNG	Mineral diesel
1990	418.0	491.3	0.7	833.3
1991	428.5	490.2	0.7	835.3
1992	430.7	482.4	0.7	836.7
1993	417.7	469.4	0.7	834.3
1994	399.5	459.4	0.7	830.3
1995	367.1	454.7	0.7	825.0
1996	339.5	453.6	0.7	821.5
1997	312.3	453.4	0.7	817.6
1998	286.9	453.3	0.7	822.0
1999	271.3	452.6	0.7	825.7
2000	254.7	451.1	0.7	816.6
2001	238.9	448.5	0.7	797.2
2002	224.9	441.3	0.7	775.7
2003	208.8	430.0	0.7	760.6
2004	195.8	402.2	0.7	736.1
2005	183.9	352.8	0.7	713.9
2006	168.3	322.9	0.7	691.4
2007	159.6	287.8	0.7	665.7
2008	150.1	196.4	0.7	636.9
2009	138.9	160.9	0.7	616.2
2010	127.4	125.2	0.7	589.3
2011	115.2	105.4	0.7	565.3
2012	102.6	105.1	0.7	532.8
2013	93.7	89.6	0.7	489.6
2014	85.9	80.2	0.7	452.5
2015	81.3	63.0	0.7	429.9
2016-2022	77.0	66.6	0.7	417.6

Table A.IV.6. Implicit emission factors for NMVOC (kg/TJ).

Year	Type C gasoline	Hydrous ethanol	CNG	Mineral diesel
1990	2,165.3	1,350.3	0.1	53.1
1991	2,085.9	1,340.7	0.1	53.2
1992	2,007.1	1,312.0	0.1	53.3
1993	1,870.4	1,266.9	0.1	53.2
1994	1,686.5	1,227.4	0.1	53.0
1995	1,450.8	1,207.9	0.1	52.6
1996	1,244.4	1,201.9	0.1	52.4
1997	1,065.0	1,199.5	0.1	52.2
1998	929.8	1,196.0	0.1	52.5
1999	844.3	1,190.0	0.1	52.7
2000	761.9	1,182.0	0.1	52.6
2001	688.4	1,171.1	0.1	52.1
2002	628.5	1,148.2	0.1	50.9
2003	567.8	1,114.2	0.1	49.3
2004	520.0	1,037.8	0.1	46.9
2005	478.3	900.0	0.1	44.8
2006	430.0	815.9	0.1	42.8
2007	401.2	730.6	0.1	40.7
2008	372.7	496.4	0.1	37.9
2009	342.3	406.8	0.1	35.3
2010	309.6	316.9	0.1	32.4
2011	276.2	268.4	0.1	29.6
2012	243.1	268.8	0.1	26.9
2013	219.3	229.9	0.1	24.1
2014	198.3	206.8	0.1	21.8
2015	185.6	164.2	0.1	20.3
2016-2022	173.5	173.1	0.1	19.4

Implicit emission factors by gases in the Domestic Aviation subcategory

Tables A.IV.7 and A.IV.8 show the implicit emission factors per GHG modeled in the Domestic Aviation category (1.A.3.d) for aviation kerosene and aviation gasoline. The implicit factors for the years from 2017 to 2022 repeated the 2016 results.

Table A.IV.7. Implicit emission factors (kg/TJ) for aviation kerosene in the Domestic Aviation subcategory (1.A.3.d).

Year	CO_2	CH_4	N_2O	CO	NO_x	NMVOC
1990-2004	71,500	0.03	1.97	51.23	65.70	9.87
2005	73,131	0.03	1.97	51.23	65.70	9.87
2006	73,131	0.03	1.97	47.72	65.09	8.30
2007	73,131	0.03	1.97	42.45	66.11	5.45
2008	73,131	0.03	1.97	38.08	66.36	4.20
2009	73,131	0.03	1.97	38.02	67.20	3.77
2010	73,131	0.03	1.97	38.19	65.63	3.97
2011	73,131	0.03	1.98	38.91	64.75	4.04
2012	73,131	0.03	1.98	39.49	64.81	4.16
2013	73,131	0.03	1.98	39.10	65.62	4.24
2014	73,131	0.03	1.98	39.95	65.74	4.42
2015	73,131	0.03	1.98	39.16	65.31	4.25
2016-2022	73,131	0.03	1.98	38.83	63.61	4.31

Table A.IV.8. Implicit emission factors (kg/TJ) for aviation gasoline in the Domestic Aviation subcategory (1.A.3.d).

Year	CO_2	CH_4	N_2O
1990-2022	70,000	0.50	2.00

Summary of the Energy sector inventory databases

Dataframe A.IV.1 summarizes the main data used, as well as the data sources adopted in the Energy sector inventory.

Dataframe A.IV.1. Summary of the methodology used to calculate emissions from the Energy sector.

Data	Unit	Origin
National carbon intensity, by mode	kg/t-km or kg/pass-km	Brasil (2020) and Anac – National Civil Aviation Agency (Agência Nacional de Aviação Civil) (2020)
National energy consumption, by economy sector and mode	toe, joule, Wh	EPE – Energy Research Office (Empresa de Pesquisa Energética) (2023) and ANP – National Agency of Petroleum, Natural Gas and Biofuels (Agência Nacional do Petróleo, Gás Natural e Biocombustíveis) (2024)
National energy intensity, by mode	kJ/t-km, kJ/pass-km	Estimated based on Abraciclo – Brazilian Association of Motorcycle, Moped, Scooter, Bicycle and Similar Manufacturers (Associação Brasileira dos Fabricantes de Motocicletas, Ciclomotores, Motonetas, Bicicletas e Similares) (2023), Anfavea – National Association of Automotive Vehicle Manufacturers (Associação Nacional dos Fabricantes de Veículos Automotores) (2022), Fenabrave – National Federation of Motor Vehicle Distribution (Federação Nacional da Distribuição de Veículos Automotores) (2022) and Senatran – National Traffic Office (Secretaria Nacional de Trânsito, (2022)
Vehicle fleet by model year	Vehicle	
Infrastructure extension by mode	Km	Briand *et al*., (2023), Briand *et al*., (2024), ANAC – National Civil Aviation Agency (Agência Nacional de Aviação Civil) (2024), ANTAQ – National Agency for Waterway Transportation (Agência Nacional de Transportes Aquaviários) (2023), ANPtrilhos – National Association of Rail Passenger Carriers (Associação Nacional dos Transportadores de Passageiros sobre Trilhos) (2021), EPL (2021) and ANTT – National Land Transport Agency (Agência Nacional de Transportes Terrestres) (2021)
Transport activity by mode	t-km, pass-km	
Freight mode split by mode	%	
Passenger mode split by mode	%	
Total freight transported by mode	T	
Total passengers transported by mode	Pass	
Emission factor per gas	kg/l, g/km, g/day, t/TJ	CETESB – State of São Paulo Environmental Company (Companhia Ambiental do Estado de São Paulo) (2023), IPCC (2006), MMA – Ministry of the Environment (Ministério do Meio Ambiente) (2014), EMEP – European Monitoring and Evaluation Programme/EEA – EEA – European Environment Agency (2013; 2017), Brasil (2020) and ANAC (2020)

Data	Unit	Origin
Implicit emission factor per gas	kg/TJ	Brasil (2020)
Conversion factor by energy source	toe, joule, etc.	ANP (2020) and EPES (2021) and Brasil (2020)
Density by energy source	t/m^3	
Composition by energy source	% of blend	
Calorific value by energy source	kcal/kg	
Licensing by model year	Vehicle	Abraciclo (2023), Anfavea (2022), Fenabrave (2022) and Senatran (2022)
Energy efficiency by model year	km/l	CETESB (2023), IBTS – Brazilian Institute for Sustainable Transportation (Instituto Brasileiro de Transporte Sustentável) (2019) and MMA (2014)
TKM by model year	km/year	
Average occupancy by model year	t/vehicle	NTU – National Association of Urban Transport Companies (Associação Nacional das Empresas de Transportes Urbanos) (2023), IBTS (2019) and ANTP – National Association of Public Transportation (Associação Nacional de Transportes Públicos) (2018)
Average capacity per model year	pass/vehicle	
Average distance per trip by model year	km/trip	
Run-of-Mine (ROM)	T	Siecesc – Coal Extraction Industry Union of the State of Santa Catarina (Sindicato Indústria de Extração Carvão Estado SC)/Abcm – Brazilian Mineral Coal Association (Associação Brasileira do Carvão Mineral) (2023)
Production, refining and transportation of oil derivatives	m^3	ANP (2024) and Petrobras (2024)

APPENDIX V. ADDITIONAL DESCRIPTIONS FOR THE INDUSTRIAL PROCESSES AND PRODUCT USE SECTOR

Activity data and other parameters (2.A.4.a. Ceramics)

Table A.V.1. Suitable energy for the Ceramics subcategory, according to the National Energy Balance, after converting values to the energy unit (ktoe).

Energy: Ceramics	2005	2006	2007	2008	2009	2010	2011	2012	2013
Fossil energy (ktoe)	1,405	1,472	1,644	1,728	1,700	1,838	1,963	1,951	2,016
Biomass energy (ktoe)	1,746	1,794	1,920	2,174	2,134	2,334	2,449	2,521	2,697
Electricity (ktoe)	270	276	284	298	301	319	342	359	380
Total energy	**3,420**	**3,542**	**3,848**	**4,200**	**4,136**	**4,491**	**4,754**	**4,831**	**5,094**
Energy: Ceramics	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Fossil energy (ktoe)	2,005	1,926	1,833	1,834	1,740	1,746	1,534	1,761	1,674
Biomass energy (ktoe)	2,724	2,373	2,136	2,136	2,111	2,137	1,905	2,034	1,980
Electricity (ktoe)	377	339	322	322	318	322	287	321	313
Total energy	**5,105**	**4,637**	**4,291**	**4,293**	**4,170**	**4,205**	**3,726**	**4,116**	**3,966**

Sources: Based on EPE (2023).

Table A.V.2. Ratio between production and energy (t/toe).

Brazil	2005	2006	2007	2008	2009	2010	2011	2012
Ceramics production(kt)	19,816	23,786	24,155	27,196	26,488	29,768	32,222	33,017
Energy (ktoe)	3,420	3,542	3,848	4,200	4,136	4,491	4,754	4,831
Production/energy ratio (t/toe)	5.79	6.72	6.28	6.47	6.41	6.63	6.78	6.83
Brazil	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Ceramics production (kt)	35,146	39,407	37,022	35,390	32,024	33,655	36,957	33,262
Energy (ktoe)	5,094	5,105	4,637	4,291	4,293	4,170	4,205	3,726
Production/energy ratio (t/toe)	6.90	7.72	7.98	8.25	7.46	8.07	8.79	8.93

Sources: Based on EPE (2023).

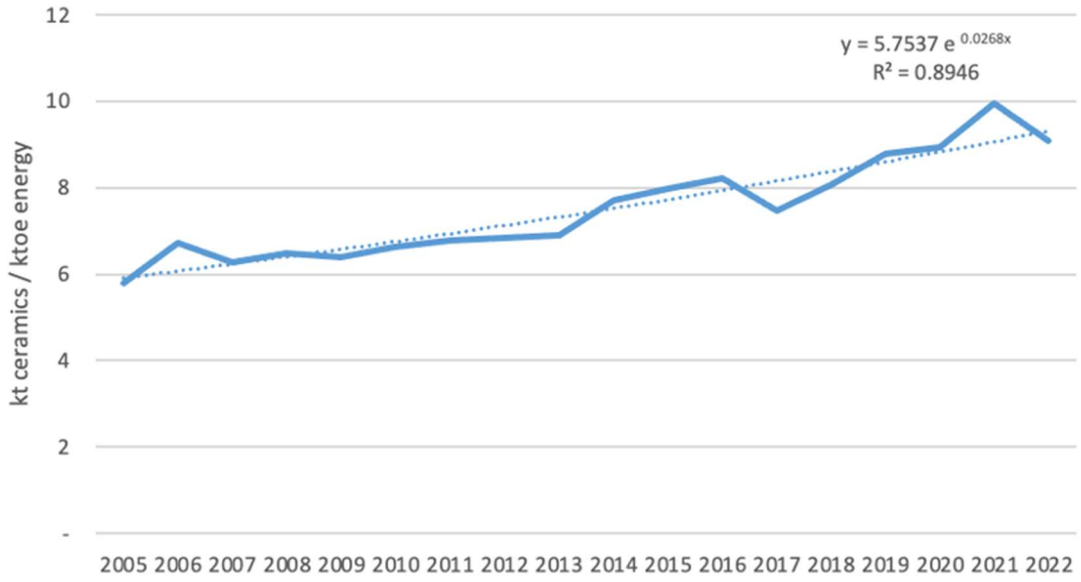


Figure A.V.1. Ratio of ceramics production to energy consumption, 2005 to 2016.

Table A.V.3. Average distribution of ceramics production, in terms of mass, for IBGE – Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística) codes, between 2005-2022.

Code	Average share (2005-2022)
2341.2025	0.06%
2341.2040	6.13%
2342.2010	0.00%
2342.2030	40.60%
2342.2040	1.66%
2342.2045	0.85%
2342.2050	14.37%
2342.2065	33.84%
2342.2080	0.21%
2349.2010	0.04%
2349.2030	0.17%
2349.2045	0.01%
2349.2050	0.43%
2349.2080	0.31%
2349.2090	0.12%
2349.2100	0.01%
2349.2110	1.18%
Total	100.0%

Dataframe A.V.1. Product categories grouped according to SIDRA-Automatic Recovery System (Sistema de Recuperação Automática)/IBGE codes.

Categories	Code/Product
Red ceramics	• 2342.2050 Ceramic roof tiles. • 2342.2065 Perforated bricks, beam covers and other ceramic bricks for construction, except refractory bricks. • 2342.2080 Ceramic pipes, tubes, gutters and other plumbing fittings. • 2341.2025 Bricks, tiles and other ceramic articles of siliceous fossil meals or of similar siliceous earths. • 2341.2040 Refractory bricks, tiles and similar refractory ceramic articles, for use in the construction of furnaces, kilns, equipment for the metal, chemical, ceramics and glass industries, etc., other than those of siliceous fossil meals or siliceous earths • 2342.2010 Ceramic chimneypieces, architectural ornaments, etc. • 2349.2010 Ceramic appliances and articles for technical uses; ceramic containers for rural uses and for transportation or packaging.
Ceramic tiles	• 2342.2030 Glazed ceramic floor or wall tiles. • 2342.2040 Unglazed ceramic floor or wall tiles. • 2342.2045 Ceramic tiles, mosaic cubes and similar articles, whether or not glazed.
Tableware	• 2349.2030 Ceramic articles, other than porcelain, for tableware or kitchenware. • 2349.2045 Ceramic or porcelain articles. • 2349.2050 Porcelain articles for tableware or kitchenware. • 2349.2080 Ceramic statuettes and other ornaments. • 2349.2090 Ceramic insulators for electrical purposes. • 2349.2100 Ceramic insulating fittings or tubes for electrical machines, appliances or installations, with or without metal parts.
Sanitary ware	• 2349.2110 Ceramic or porcelain sinks, baths, bidets and similar sanitary ware (Thousand units).

Table A.V.4. Emission factors from Ceramics, by Federative Unit (FU)/State.

FU/State	Number of studies	FU/State Average	Average by region used	Final emission factor, with 10% increase
		(t CO_2/t clay)		(t CO_2/t produced)
Rondônia	-	-	0.0364	0.0400
Acre	-	-		0.0400
Amazonas	-	-		0.0400
Roraima	-	-		0.0400
Pará	-	-		0.0400
Amapá	-	-		0.0400
Tocantins	-	-		0.0400
Maranhão	-	-	0.0364	0.0400
Piauí	-	-		0.0400
Ceará	-	-		0.0400
Rio Grande do Norte	3	0.0285		0.0400
Paraíba	1	0.0249		0.0400
Pernambuco	1	0.1034		0.0400
Alagoas	-	-		0.0400
Sergipe	1	0.0056		0.0400
Bahia	4	0.0194		0.0400
Minas Gerais	-	-	0.0207	0.0228
Espírito Santo	1	0.0081		0.0228
Rio de Janeiro	4	0.0229		0.0228
São Paulo	11	0.0312		0.0228
Paraná	1	0.0191	0.0147	0.0162
Santa Catarina	3	0.0103		0.0162
Rio Grande do Sul	-	-		0.0162
Mato Grosso do Sul	2	0.0199	0.0199	0.0218
Mato Grosso	-	-		0.0218
Goiás	-	-		0.0218
Distrito Federal (Federal District)	-	-		0.0218

Source: Based on BA (Oliveira, 2011; Prado, 2011; Cabral *et al.*, 2008); ES (Savazzini *et al.*, 2016); MS (Rodrigues *et al.*, 1999; Rodrigues *et al.*, 1999); PB (Lima *et al.*, 2016); PE (Silva, 2008); PR (Cabral *et al.*, 2008); RJ (Cabral *et al.*, 2008; Pereira *et al.*, 2011; Prado, 2011; Sousa, 2008); RN (Silveira *et al.*, 2002; Silveira *et al.*, 2000; Vieira, 2007); SC (Cabral *et al.*, 2008; Grun, 2007); SE (Prado, 2011); SP (Motta *et al.*, 2004; Motta *et al.*, 1993; Prado, 2011; Senna, 2003; Cabral *et al.*, 2008; Rrocha *et al.*, 2009)..

Activity data and other parameters (2.C.1. Iron and Steel)

Table A.V.5. Inputs (feedstocks) considered in the sintering process, from 1990 to 2006.

Inputs (feedstocks)	Unit.	1990	1991	1992	1993	1994	1995	1996	1997	1998
Anthracite consumed in sintering	t	236,984	240,904	252,008	309,143	333,750	343,681	348,076	403,584	407,777
Blast furnace gas consumed in sintering	dam^3	67,146	65,891	69,022	71,260	70,985	68,269	67,839	62,009	69,661
Coke grinder consumed in sintering	t	797,477	810,011	841,851	770,098	796,803	792,093	811,921	818,553	728,285
Coke grinder purchased for sintering	t	137,331	142,807	132,405	125,115	124,325	154,395	157,040	164,726	145,528
Dolomite consumed in sintering	t	738,755	817,630	910,966	917,925	944,943	948,723	953,461	1,006,033	1,029,194
Limestone consumed in sintering	t	1,721,406	1,781,280	1,706,998	1,747,713	1,775,770	1,795,098	1,891,772	2,015,264	2,163,959

Source: Based on IABr (2020) and Brasil (2021c).

Cont. Inputs (feedstocks) considered in the sintering process, from 1990 to 2006.

Inputs (feedstocks)	Unit.	1999	2000	2001	2002	2003	2004	2005	2006
Anthracite consumed in sintering	t	256,268	360,219	447,043	455,172	472,008	571,128	589,539	610,314
Blast furnace gas consumed in sintering	dam^3	98,356	97,145	96,802	96,621	96,691	100,148	95,574	96,583
Coke grinder consumed in sintering	t	734,406	754,612	676,456	758,011	686,082	721,172	681,303	615,855
Coke grinder purchased for sintering	t	165,239	112,469	110,589	128,208	149,134	126,764	128,059	121,945
Dolomite consumed in sintering	t	649,441	675,179	652,169	736,798	881,498	1,073,626	1,087,213	342,032
Limestone consumed in sintering	t	2,062,636	2,316,250	2,147,678	2,088,993	2,112,337	1,897,896	1,708,708	2,335,625

Source: Based on IABr (2020) and Brasil (2021c).

Table A.V.6. Inputs (feedstocks) considered in the blast furnace and steelmaking process, from 1990 to 2006.

Inputs (feedstocks)	Unit.	1990	1991	1992	1993	1994	1995	1996	1997	1998
EAF coal consumed in electric steelworks	t	6,251	4,431	5,321	5,538	4,578	4,592	4,827	5,805	6,310
Electrode consumed in steelworks	t	8,259	7,195	7,886	8,415	10,293	10,351	10,079	10,971	9,756
PCI coal consumed in blast furnaces	t	193,125	208,394	212,533	237,286	184,342	606,198	610,153	915,943	1,670,352
Metallurgical coke consumed in steelworks	t	5,095	6,571	7,059	7,792	6,252	5,925	6,522	7,117	6,682
Dolomite consumed in steelworks	t	107,009	105,908	112,186	122,384	123,764	103,466	114,254	127,763	425,471
EAF carbon load consumed in steelworks	t	1,606	1,400	1,499	1,520	1,681	1,415	1,374	1,564	1,343
Limestone consumed in blast furnaces	t	37,544	38,942	40,046	41,454	41,356	37,231	36,551	41,777	340,748
Metallurgical coke consumed blast furnaces	t	7,138,979	7,822,997	7,985,095	7,994,908	8,134,998	8,492,380	7,926,205	8,155,267	8,163,025
Petroleum coke consumed in blast furnaces/steelworks	t	40,230	36,025	39,015	41,359	45,263	41,771	78,582	121,036	117,602
Scrap consumed in steelworks	t	3,620,468	3,308,554	3,636,891	3,922,095	4,038,513	3,729,537	3,904,408	4,284,810	4,091,948

Source: Based on IABr (2020) and Brasil (2021c).

Cont. Inputs (feedstocks) considered in the blast furnace and steelmaking process, from 1990 to 2006.

Inputs (feedstocks)	Unit.	1999	2000	2001	2002	2003	2004	2005	2006
EAF coal consumed in electric steelworks	t	7,664	9,240	11,027	9,821	8,893	10,775	11,712	9,729
Electrode consumed in steelworks	t	11,791	12,093	12,195	12,417	14,147	14,704	14,050	13,762
PCI coal consumed in blast furnaces	t	1,796,046	2,602,499	2,511,391	2,686,231	3,083,960	3,302,543	3,117,343	2,947,835
Metallurgical coke consumed in steelworks	t	9,393	12,203	13,874	14,337	14,581	13,158	17,606	7,221
Dolomite consumed in steelworks	t	454,760	144,562	515,229	519,146	546,515	569,867	520,755	445,859
EAF carbon load consumed in steelworks	t	1,284	1,798	1,750	1,485	1,291	1,221	490	232
Limestone consumed in blast furnaces	t	352,025	387,728	356,795	313,503	714,689	827,001	743,526	495,914
Metallurgical coke consumed blast furnaces	t	7,158,653	7,913,756	7,547,307	8,441,420	8,540,356	8,378,568	8,048,581	7,565,814
Petroleum coke consumed in blast furnaces/steelworks	t	319,755	368,585	419,903	475,475	488,021	361,228	504,376	517,036
Scrap consumed in steelworks	t	4,887,503	4,868,754	5,249,134	5,433,776	6,001,644	6,316,687	6,130,313	5,987,101

Source: Based on IABr (2020) and Brasil (2021c).

Table A.V.7. Outputs (products), from 1990 to 2006.

Outputs (products)	Unit.	1990	1991	1992	1993	1994	1995	1996	1997	1998
Steel produced	t	20,340,285	22,034,354	23,219,442	24,393,896	24,763,661	24,471,142	24,644,098	25,528,912	24,897,079
Special steel produced	t	473,936	437,650	485,321	495,594	572,314	504,055	524,517	582,495	474,592
Blast furnace gas produced	dam^3	3,919,134	3,959,490	3,994,196	4,221,138	4,175,954	4,458,751	4,193,411	4,295,815	4,583,476

Source: Based on IABr (2020) and Brasil (2021c).

Cont. Outputs (products), from 1990 to 2006.

Outputs (products)	Unit.	1999	2000	2001	2002	2003	2004	2005	2006
Steel produced	T	25,619,009	28,148,004	27,167,793	29,853,921	31,246,573	32,234,486	31,024,817	29,969,603
Special steel produced	T	522,466	509,891	466,224	550,769	597,720	722,388	625,387	638,887
Blast furnace gas produced	dam^3	4,603,372	4,440,565	4,378,615	4,424,304	4,580,110	4,867,612	4,764,691	5,391,177

Source: Based on IABr (2020) and Brasil (2021c).

Activity data and other parameters (2.F. Product Uses as Substitutes for Ozone Depleting Substances)

Table A.V.8. Production, imports and exports of domestic refrigerators, 1998 to 2022.

Year	Production	Import	Export
1998	4,519,252	77,824	271,862
1999	5,323,553	52,787	358,193
2000	3,788,110	56,635	472,713
2001	4,813,446	24.454	505,731
2002	4,187,791	19,598	505,619
2003	4,849,912	17,624	1,304,124
2004	5,419,834	9,145	1,645,032
2005	5,296,945	2,416	1,181,629
2006	6,128,610	49,521	1,072,231
2007	7,318,636	81,259	950,856
2008	6,694,221	90,707	792,990
2009	7,599,290	72,950	523,802
2010	7,817,150	131,248	507,717
2011	7,970,792	173,332	321,418
2012	8,281,551	228,254	275,723
2013	9,095,266	193,832	391,394
2014	7,701,615	221,093	544,038
2015	6,909,817	241,894	233,833
2016	9,451,000	117,408	214,466
2017	5,694,000	158,549	210,730
2018	6,074,000	168,996	144,925
2019	6,675,000	297,836	189,624
2020	6,312,000	337,503	140,075
2021	6,155,000	529,396	210,804
2022	6,530,000	421,654	170,514

Source: Based on IBGE (2024b) and MDIC (2024). Unit: units.

Table A.V.9. Production, imports and exports of commercial freezers, 1998 to 2022.

Year	Production	Import	Export
1998	55,580	264	64,210
1999	12,656	6,235	69,010
2000	918,109	629	88,552
2001	88,118	1,711	55,715
2002	38,612	56	37,063
2003	23,009	55	62,471
2004	191,620	54	105,040
2005	67,876	63	100,380
2006	191,397	292	106,384
2007	426,927	362	105,691
2008	401,604	1,231	96,757
2009	442,011	1,991	60,083
2010	161,388	5,185	70,971
2011	447,748	3,002	65,527
2012	617,446	26,388	52,489
2013	481,146	87,263	49,413
2014	673,799	36,683	43,965
2015	546,249	50,682	40,515
2016	323,743	19,038	45,486
2017	542,136	58,430	62,117
2018	251,044	65,895	43,920
2019	195,714	70,159	36,008
2020	241,594	109,165	29,058
2021	100,674	247,814	76,450
2022	127,794	191,214	54,744

Source: Based on IBGE (2024b) and MDIC (2024). Unit: units.

Table A.V.10. Production, imports and exports of display cases and cold rooms, 1998 to 2022.

Year	Production	Import	Export
1998	360,875	38,011	6,224
1999	308,366	12,859	7,613
2000	142,867	6,947	17,800
2001	139,653	4,254	21,349
2002	245,386	8,462	15,368
2003	210,955	880	110,720
2004	216,625	884	258,710
2005	461,141	7,804	169,033
2006	414,331	25,419	60,269
2007	566,429	48,355	86,990
2008	536,628	102,202	34,229
2009	250,830	60,430	23,206
2010	572,698	154,332	22,646
2011	562,430	201,806	20,988
2012	436,709	108,742	14,707
2013	463,800	69,498	19,459
2014	751,482	49,292	40,387
2015	615,326	51,287	19,824
2016	445,271	33,582	16,873
2017	373,651	49,624	51,109
2018	546,036	65,984	46,587
2019	593,126	49,707	25,184
2020	604,253	62,477	30,546
2021	807,455	115,219	35,106
2022	862,655	65,272	25,632

Source: Based on IBGE (2024b) and MDIC (2024). Unit: units.

Table A.V.11. Production, imports and exports of cooling units for water, juice and drinking fountains, 1998 to 2022.

Year	Production	Import	Export
1998	136,289	1,166	11,713
1999	168,258	1,389	16,671
2000	212,178	3,652	24,287
2001	479,853	2,416	23,116
2002	356,391	1,150	22,549
2003	266,734	914	18,885
2004	247,003	17,890	22,737
2005	340,474	31,756	27,508
2006	649,225	36,706	21,435
2007	183,633	98,288	24,392
2008	140,328	125,646	21,681
2009	140,328	146,503	21,830
2010	407,573	215,736	31,368
2011	649,989	417,342	16,870
2012	420,917	344,832	12,644
2013	324,369	652,146	14,853
2014	339,267	485,683	13,318
2015	481,826	428,600	15,322
2016	188,589	218,369	12,315
2017	231,753	230,219	11,042
2018	172,907	209,830	10,887
2019	162,247	230,408	9,105
2020	510,761	362,227	9,419
2021	122,511	360,193	13,419
2022	275,847	145,633	13,000

Source: Based on IBGE (2024b) and MDIC (2024). Unit: units.

Table A.V.12. Split Air conditioning production and sales, 2010 to 2022.

Year	Production	Sales
2010	1,178,098	2,350,000
2011	2,689,808	2,650,000
2012	2,934,307	3,200,000
2013	3,406,022	3,500,000
2014	4,634,309	3,900,000
2015	4,978,510	4,250,000
2016	1,524,945	3,750,000
2017	3,036,056	3,490,336
2018	3,218,330	3,011,693
2019	4,229,189	4,173,733
2020	5,240,047	5,335,773
2021	5,878,534	5,591,649
2022	4,330,630	4,742,549

Table A.V.13. VRF production and installed capacity (TR), 2010 to 2022.

Year	Production	Sales
2010	62,201	62,201
2011	58,766	120,967
2012	91,476	212,443
2013	128,175	340,618
2014	183,712	524,330
2015	127,562	651,892
2016	131,841	783,733
2017	130,391	914,124
2018	157,512	1,071,636
2019	172,791	1,244,426
2020	161,905	1,406,331
2021	181,495	1,587,827
2022	192,385	1,780,212

Source: Based on Abrava (2022).

Table A.V.14. Production and installed capacity of chillers, 1998 to 2022.

Year	Production	Installed capacity
1996	91,020	387,616
1997	121,180	508,796
1998	133,730	642,526
1999	126,830	769,356
2000	171,403	940,759
2001	168,757	1,109,516
2002	116,427	1,225,943
2003	143,559	1,369,501
2004	147,452	1,516,954
2005	149,678	1,666,632
2006	176,827	1,843,459
2007	185,449	2,000,192
2008	192,135	2,157,797
2009	166,920	2,279,337
2010	202,407	2,447,389
2011	233,703	2,638,872
2012	292,521	2,881,663
2013	288,944	3,116,892
2014	283,750	3,339,302
2015	195,526	3,489,706
2016	171,983	3,625,754
2017	170,091	3,795,845
2018	205,470	4,001,315
2019	225,401	4,226,716
2020	211,201	4,437,917
2021	236,756	4,674,672
2022	250,961	4,925,634

Source: Based on IBGE (2024b) and MDIC (2024). Unit: units.

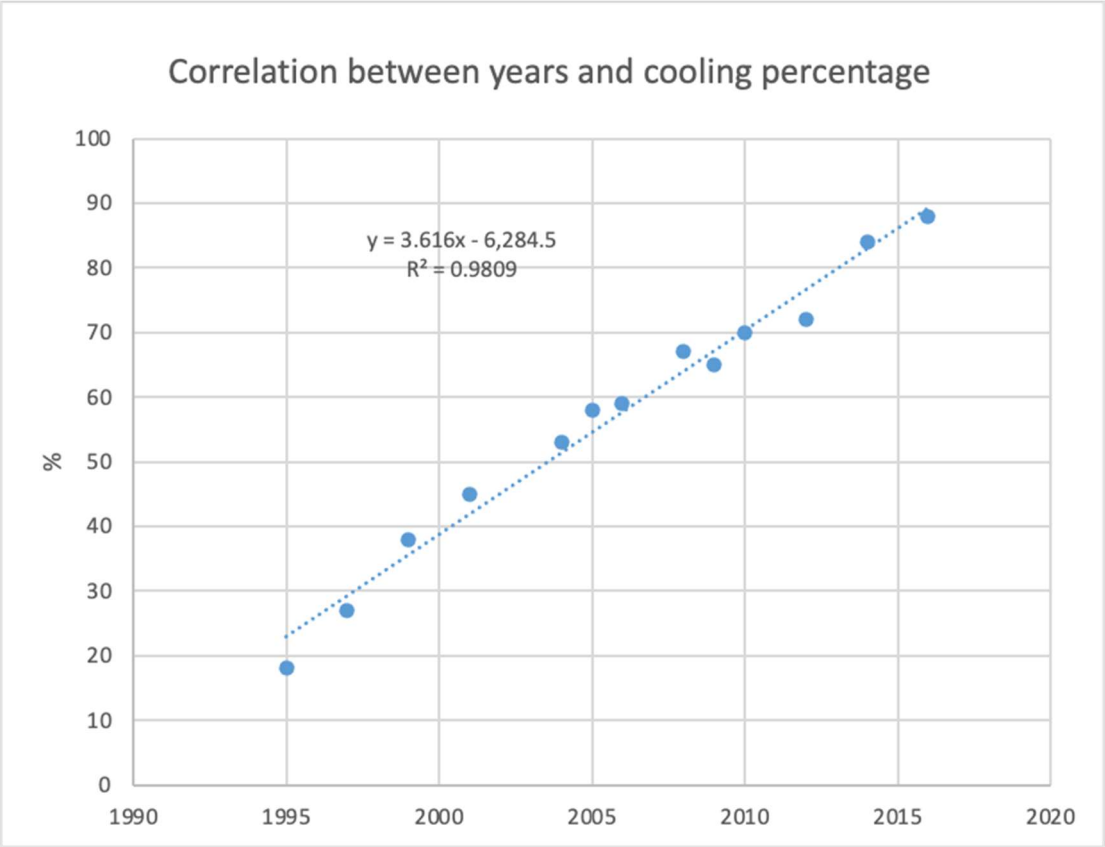


Figure A.V.2. Estimated progression for the number of vehicles produced with air conditioning.

Activity data and other parameters (2.G. Other Product Manufacture and Use)

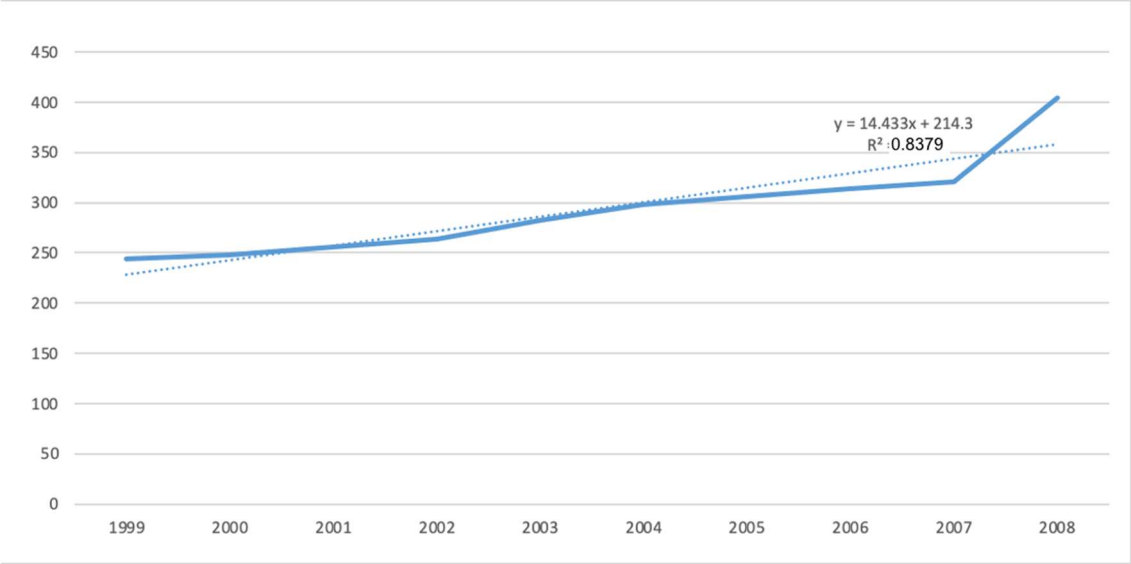


Figure A.V.3. Evolution of the installed capacity of SF_6 and trendline coefficients from 1999 to 2008.

APPENDIX VI. ADDITIONAL DESCRIPTIONS FOR THE AGRICULTURE SECTOR

Enteric Fermentation

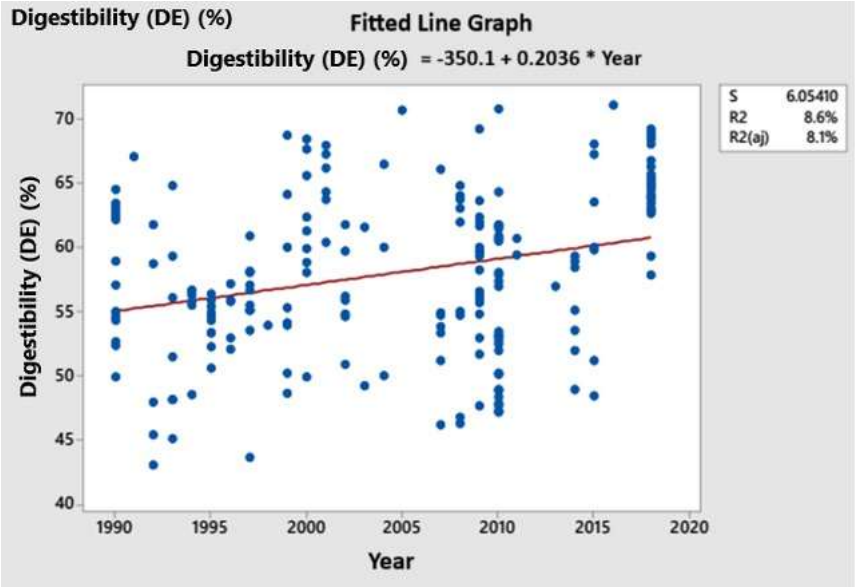


Figure A.VI.1. Ratio between the digestibility (%) of the dry matter of tropical forage plants and the assessed years.

Based on the linear regression model, the averages of the digestibility factor were calculated for each year, and, then, the average was obtained as a function of the assessed periods. Considering the scarcity of publications with information on the digestibility of forage plants in some regions, it was decided to use the national average value for all the regions in the country.

The linear increase in digestibility over the years is a strong indication of the increased intensification of production systems within cattle farming, i.e., an increase in productivity, also pointing to an improvement in the quantity and quality of pastures in Brazil.

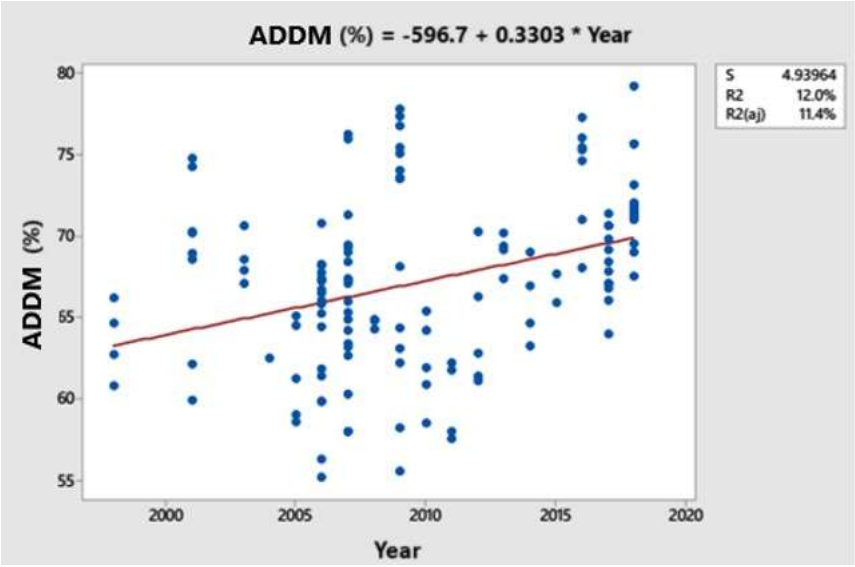


Figure A.VI.2. Ratio between apparent dry matter digestibility (ADDM) of cows' diets and the assessed years.

Manure Management

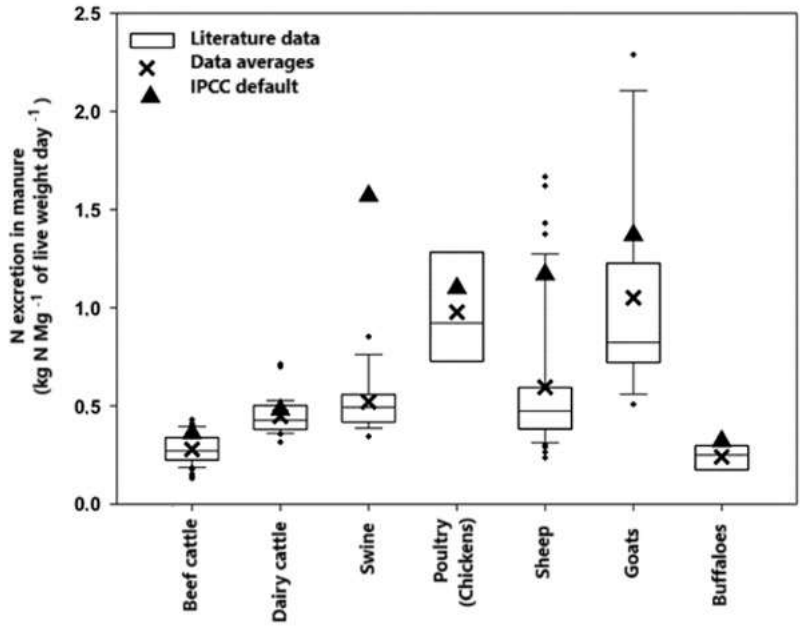


Figure A.VI.3. Box-plot of N excretion rate data (kg N Mg^{-1} of animal live weight day^{-1}) for different herd species calculated based on scientific publications, including average data and the IPCC (2006) default excretion rate.

Table A.VI.1. Definition of climate ranges and compensated average temperature for the Brazilian FUs/states between 1990-2009 and 2010-2016.

1990 – 2009				2010 to 2016		
Region	**FU/State**	**Climate**	**Compensated average temperature**	**FU/State**	**Climate**	**Compensated average temperature**
North	Rondônia***	hot	26	Rondônia	hot	26
	Acre	hot	26	Acre	hot	26
	Amazonas	hot	27	Amazonas	hot	28
	Roraima	hot	28	Roraima	hot	28
	Pará	hot	27	Pará	hot	27
	Amapá	hot	27	Amapá	hot	28
	Tocantins	Hot	27	Tocantins	hot	28
Northeast	Maranhão	hot	27	Maranhão	hot	27
	Piauí	hot	27	Piauí	hot	28
	Ceará	hot	27	Ceará	hot	27
	Rio Grande do Norte	hot	26	Rio Grande do Norte	hot	27
	Paraíba	hot	27	Paraíba	hot	27
	Pernambuco	hot	26	Pernambuco	hot	26
	Alagoas*	hot	26	Alagoas*	hot	26
	Sergipe	hot	26	Sergipe	hot	27
	Bahia*	hot	26	Bahia*	hot	26
Southeast	Minas Gerais	temperate	22	Minas Gerais	temperate	22
	Espírito Santo	temperate	25	Espírito Santo	temperate	25
	Rio de Janeiro	temperate	25	Rio de Janeiro	temperate	25
	São Paulo	temperate	20	São Paulo	temperate	21
South	Paraná	temperate	18	Paraná	temperate	18
	Santa Catarina	temperate	21	Santa Catarina	temperate	21
	Rio Grande do Sul	temperate	20	Rio Grande do Sul	temperate	20
Central-west	Mato Grosso do Sul	temperate	22	Mato Grosso do Sul	temperate	22
	Mato Grosso*	hot	27	Mato Grosso*	hot	27
	Goiás	temperate	24	Goiás	temperate	25
	Distrito Federal (Federal District)	temperate	21	Distrito Federal (Federal District)	temperate	22

Note: *In addition to the INMET– National Institute of Meteorology (Instituto Nacional de Meteorologia) source, data from Alvares *et al*. (2013) was used to classify the climate of these FUs/states. **based on climatological standards for the period: 1990-2009 and 2010-2016 (INMET, 2018). *** For the state of Rondônia (RO), the data was obtained from the Institute of Forestry Research and Studies (Instituto de Pesquisas e Estudos Florestais) database (www.ipef.br/geodatabase), assuming an average compensated temperature value of 26°C for this state for the years from 1990 to 2016.

According to Table A.VI.1, the states of Amazonas, Amapá, Tocantins, Piauí, Rio Grande do Norte, Sergipe, São Paulo, Goiás and the Federal District had a 1°C increase in the average compensated temperature between the two assessed periods. This small change in temperature affects the percentage in the specific methane conversion factor of each manure management system per FU/state, which reflects in the maximum methane production capacity for manure produced per animal category. The database for the period from 1990 to 2009 was adjusted in accordance with this modification addressed in the IPCC (2006) methodology.

Table A.VI.2. National poultry population broken down by species and categories.

Year	Laying hens	Chicks, male and female broilers, and roosters	Quails
	No. of heads		
1990	104,583,810	372,065,924	2,464,016
1991	200,544,113	393,848,481	2,542,093
1992	204,160,371	435,464,988	2,488,172
1993	202,091,623	452,826,963	2,417,950
1994	207,539,242	473,548,803	2,424,280
1995	188,367,357	541,163,942	2,939,376
1996	178,527,564	549,558,943	4,219,887
1997	179,628,673	580,992,997	4,303,237
1998	175,851,681	589,370,346	4,707,143
1999	180,194,312	624,381,496	4,837,506
2000	183,494,626	659,245,547	5,775,181
2001	190,233,644	692,654,775	6,045,342
2002	180,427,006	703,718,166	5,575,068
2003	183,799,736	737,523,096	5,980,474
2004	184,786,319	759,512,029	6,243,202
2005	186,573,334	812,467,900	6,837,767
2006	191,622,110	819,893,591	7,207,830
2007	197,618,060	930,040,524	7,586,732
2008	207,711,504	990,992,544	8,976,816
2009	208,871,491	1,021,215,181	11,485,093
2010	210,761.060	1,028,151,477	12,992,269
2011	216,219,543	1,051,989,862	15,567,634
2012	213,230,493	1,032,038,992	16,436,164
2013	219,681,760	1,026,956,193	18,171,955
2014	223,913,652	1,096,835,749	20,332,003
2015	221,985,987	1,104,466,708	18,971,342
2016	217,878,734	1,129,747,458	13,809,820
2017	240,892,112	1,185,767,321	16,208,058
2018	244,864,094	1,220,782,600	16,844,423
2019	247,556,293	1,210,140,243	17,419,818
2020	252,772,110	1,225,652,251	16,455,799
2021	253,397,268	1,274,634,417	15,278,109
2022	259,452,999	1,326,594,876	14,028,550

Source: Based on IBGE (2018; 2024a).

Agricultural Soils

- Cultivation of Organic Soils (F_{OS})

Table A.VI.3. Estimate of the total area of organic soils in Brazil.

FU/State	Area
	ha
Tocantins	95,664.60
North	**95,664.60**
Maranhão	10,575.47
Piauí	11,944.06
Rio Grande do Norte	2,184.25
Paraíba	1,298.84
Pernambuco	2,905.17
Alagoas	68.52
Sergipe	2,275.83
Bahia	63,134.50
Northeast	**94,386.64**
Minas Gerais	23,417.14
Espírito Santo	11,134.13
Rio de Janeiro	44,419.15
São Paulo	166,666.57
Southeast	**245,636.99**
Paraná	118,478.07
Santa Catarina	64,080.48
Rio Grande do Sul	106,418.66
South	**288,977.21**
Mato Grosso do Sul	45,053.03
Mato Grosso	175,685.25
Goiás	13,189.29
Distrito Federal (Federal District)	-
Central-West	**233,927.57**
Brazil	**958,593.01**

Source: Based on the soils map of Brazil (IBGE, 2018).

- Crop residues and pasture renewal (FCR)

The *FracNew* parameter was used fractionally only for pasture renewal, whose parameters for estimation are shown in Table A.VI.4. As discussed earlier, *FracNew* is equal to 0.1, which means that 10% of the pasture area is renewed every year, i.e., the entire pasture area in the country is renewed every 10 years on average.

Table A.VI.4. Summary of the parameters used to calculate FCR in pasture renewal.

Biome	C in total pasture biomass	Rbg-bio	Nag	Nbg	AGDM	BGDM
	tonC/ha	kgMS/kgMS	kgN/kg	kgN/kg	kg/ha	kg/ha
Amazon	6.84	1	0.010	0.006	8.54	8.54
Cerrado	7.57	1	0.007	0.006	9.46	9.46
Caatinga	1.19	1	0.007	0.006	1.49	1.49
Pantanal	7.57	1	0.010	0.006	9.46	9.46
Pampa	7.57	1	0.010	0.006	9.46	9.46
Atlantic Forest	7.57	1	0.010	0.006	9.46	9.46

Note: Rbg-bio: Ratio between dry matter of below-ground residues and dry matter of above-ground biomass; Nag: N content in above-ground residues; Nbg: N content in below-ground residues; AGdm: dry matter of above-ground biomass; BGdm: dry matter of below-ground residues. Source: Brasil (2016); Carvalho *et al*. (1991); Oliveira *et al*. (2004); Piccolo *et al*. (2005); Santos *et al*. (2007); Fabrice *et al*. (2014).

- Dry matter fraction in grains (DRY)

Based on data from the Ministry of Agriculture, Livestock and Supply (MAPA, Ministério da Agricultura, Pecuária e Abastecimento) established in different Ordinances (1976, 1983, 1988)[123] and Normative Ruling (2008), standards were established for the moisture content of commercialized grains. For soybeans, corn and beans, the maximum limits are 14%, while for rice and wheat they are 13%. In general, the moisture content of grains considered in studies of these crops is 13%. Thus, a grain dry matter fraction (DRY) of 0.87 was considered for these crops.

- Ratio of dry residue to dry harvested product (Rag) and N fractions in the residues of the above-ground portion and roots (Nag)

The values of above-ground residues deposited on the soil due to harvested production were the same as those used since the Third National Communication Inventory (BRASIL, 2016), with supplementation from national literature. Likewise, the N content in the dry matter of the above-ground residues was defined. In addition, national studies were used to define the fraction of N in the dry matter of roots and the ratio of the dry matter of the roots produced to the total dry mass of the above-ground portion, including the products to be harvested. Table A.VI.5 shows the parameters used to calculate the FCR of above-ground residues of the crops that were included in the estimate of N_2O emissions. In the column identified as R_{ag}, where the value is the default value, it means that the calculation of the residue on the soil (*AGdm*) was carried out using default values from the IPCC (2006), based on the linear regression whose *AGdm* value is obtained directly in relation to the productivity and the product's dry matter fraction. In all cases, *FracNew*, which is the fraction of the area that is renewed annually, is equal to 1. Even considering that only part of the area occupied by sugar cane is completely renewed each year, it was assumed that after harvesting, the roots are renewed.

[123] Ordinances: nº. 845, of November 8, 1976; nº. 262, of November 23, 1983; nº. 269, of November 17, 1988, for soybeans, corn and rice, respectively, and Normative Ruling nº. 12, of March 28, 2008, for beans.

Table A.VI.5. Summary of the parameters used to calculate the FCR of crop residues.

Parameter	Rag	Nag	Nbg	Rbg-bio	Frac dm	Rbg-bio*	AGdm intercept	AGdm slope
	kgMS/kgMS	kgN/kgMS	kgN/kgMS	kgMS/kgMS	kgMS/kgMS	kgMS/kgMS (Mato Grosso do Sul)		
Rice	0.9901	0.0092	0.0073	0.263	-	-	-	-
Sugar cane	-	0.006	0.006	0.1	0.28			
Beans	1.49	0.018	0.011			0.206		
Cassava	0.49	0.014		0	0.38			
Corn	1.492	0.007	0.014	-		0.208		
Soybeans	1.977	0.009	0.015			0.11		
Wheat	1.74	0.004	0.011			0.207		
Pineapple	2.75	0.012	0.014	0.18	0.13	-		
Cotton	0.025		0.014	0.2	0.92		1.54	1.07
Garlic	0.31	0.05	0.014	0.05	0.62		-	-
Peanut	-	0.04		NA	0.93		1.54	1.07
Oats		0.009	0.014	0.25	0.85		0.89	0.91
Sweet potato		0.023	0.014	0.2	0.17		1.06	0.1
Potato		0.016	0.014	0.2	0.15		1.06	0.1
Onion	0.23	0.05	0.014	0.05	0.2			
Rye	-	0.005	0.011	NA	0.87		0.88	1.09
Barley		0.014	0.014	0.22	0.087		0.59	0.98
Peas		0.026	0.008	0.19	0.87		0.85	1.13
Broad beans		0.027	0.008	0.19	0.87		0.85	1.13
Tobacco	0.38	-	-	-	0.83		-	-
Sunflower		0.012	0.009	0.22	0.88		0.88	1.09
Jute	0.24	0.021	0.016	0.56	0.87		-	-
Linen	0.24	0.021	0.016	0.56	0.87			
Mallow	0.89	0.016	0.016	0.18	0.84			
Castor beans	4.18	0.015	0.033	0.2	0.91			
Watermelon	1.23	0.029	0.014	0.01	0.1			
Melon	1.23	0.021	0.014	0.01	0.09			
Rami	1.56	0.016	0.016	0.12	0.93			
Sorghum	-	0.008	0.006	NA	0.87		1.33	0.88
Tomato	0.81	0.025	0.014	0.02	0.1		-	-
Triticale	1.74	0.016	0.007	0.065	0.86			

Note: Rag: Ratio of dry matter of the above-ground portion to product's dry matter; Nag: N content in above-ground residues; Nbg: N content in below-ground residues; Rbg-bio: Ratio of dry matter of below-ground residues to dry matter of the biomass of the above-ground portion; Rbg-bio*: Ratio of root dry matter to dry matter of the above-ground biomass deducted from the dry matter of the harvested product; Fracdm: Dry matter fraction of the harvested product; AGdm intercept and AGdm slope correspond to the parameters of the linear functions for estimating the amount of dry matter in the above-ground portion of the crop.

- Mineralization of N due to loss of C from the soil (F_{SOM})

In cases where the variation in soil C stocks implied a loss, the amount of mineralized N was estimated by multiplying the R factor, which is the opposite of the soil's C/N ratio. Based on data obtained from the literature, the C/N ratios were grouped by biome and into subgroups of uses called "native vegetation", "pastures" and "crops". The statistical analysis of the data showed differences between biomes, with the Cerrado being significantly different from the

other ones ($p<0.05$).[124] Based on the results, except for the Cerrado biome, where use with pastures or crops results in a C/N ratio of 15, a C/N ratio of 12 was defined for all biomes, regardless of soil use, and native vegetation has a C/N ratio of 14, as shown in Figure A.VI.4.

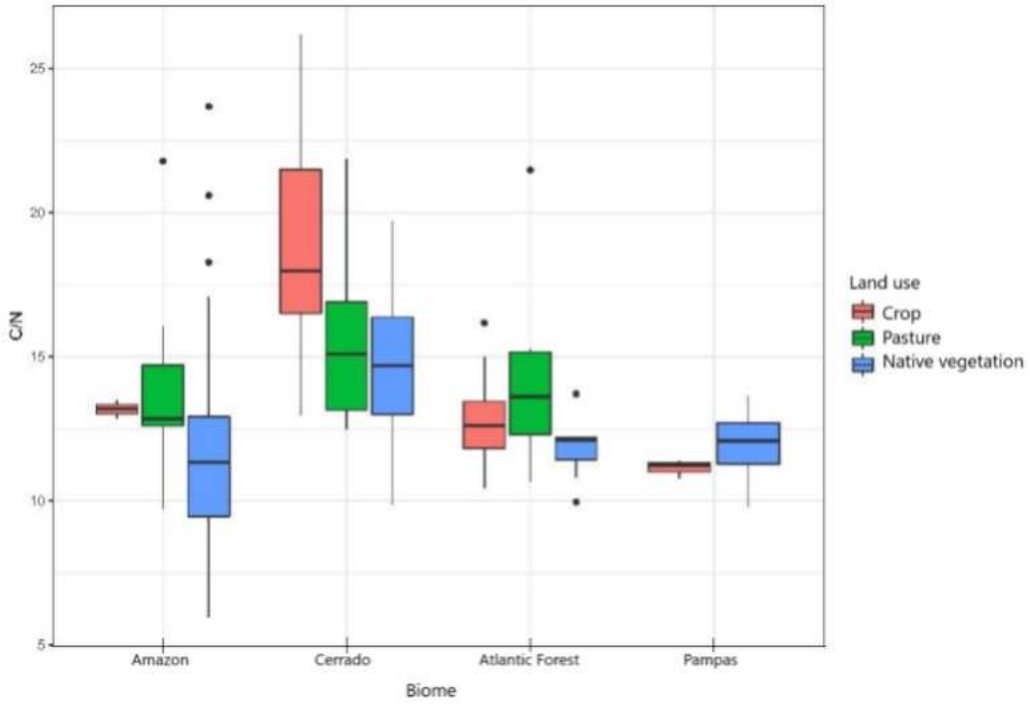


Figure A.VI.4. Box-plot with C/N ratio data grouped by biome and soil use.

Table A.VI.6. Amount of C accumulated (negative number) or lost (positive number) from the soil (0-30 cm) for each FU/state as a function of land use and land-use change between the years of 1994, 2002, 2010 and 2016.

State (FU)	Change in C stocks (t C)		
	1994-2002	2002-2010	2010-2016
Rondônia	85,801	45,416	33,833
Acre	-517,200	-104,009	-139,197
Amazonas	-244,659	-67,325	76,800
Roraima	2,069,163	2,557,451	1,001,403
Pará	-476,234	-178,452	573,094
Amapá	-2,958,809	6,044	1,930,468
Tocantins	-432,232	-330,071	-86,619
Maranhão	137,509	203,374	109,927
Piauí	224,985	-299,113	373,050
Ceará	-109,036	-15,156	26,316
Rio Grande do Norte	1,016,369	1,757,042	1,094,213
Paraíba	212,861	275,082	209,169
Pernambuco	325,409	496,033	378,829
Alagoas	-238,907	-12,952	-109,110

[124] This difference may be due to the occurrence of natural fires , and even anthropogenic fires, in the biome during the dry season, leaving a relatively high content of charcoal fragments in the soil and, therefore, showing a high C/N ratio.

State (FU)	Change in C stocks (t C)		
	1994-2002	2002-2010	2010-2016
Sergipe	1,205,938	3,112,538	1,350,364
Bahia	-5,519,411	-1,886,615	758,457
Minas Gerais	188,936	476,358	126,916
Espírito Santo	261,823	386,634	-75,391
Rio de Janeiro	59,727	179,191	97,134
São Paulo	544,871	1,530,459	953,780
Paraná	563,896	836,190	133,444
Santa Catarina	1,181,783	1,773,286	447,033
Rio Grande do Sul	172,501	274,826	237,944
Mato Grosso do Sul	-79,217	238,675	1,346,833
Mato Grosso	78,079	-279,798	2,817,948
Goiás	163,838	836,340	147,076
Distrito Federal (Federal District)	3,341	29,525	10,173

Source: Based on Brasil (2020).

Indirect N_2O Emissions

Table A.VI.7. Months that make up the rainy seasons in each FU/state for calculating the water balance.

Region	FU/State	Months that make up the rainy season											
North	AM (Amazonas)	Jan	Feb	Mar	Apr	May	Jun	Oct	Nov	Dec	-	-	-
	AP (Amapá)	Jan	Feb	Mar	Apr	May	Jun	Jul	Dec	-	-	-	-
	RR (Roraima)	Apr	May	Jun	Jul	Aug	Sep	-	-	-	-	-	-
	RO (Rondônia)	Jan	Feb	Mar	Apr	Oct	Nov	Dec	-	-	-	-	-
	TO (Tocantins)	Jan	Feb	Mar	Apr	Oct	Nov	Dec	-	-	-	-	-
	AC (Acre)	Jan	Feb	Mar	Apr	Oct	Nov	Dec	-	-	-	-	-
	PA (Pará)	Jan	Feb	Mar	Apr	May	Dec	-	-	-	-	-	-
Northeast	MA (Maranhão)	Jan	Feb	Mar	Apr	May	Dec	-	-	-	-	-	-
	CE (Ceará)	Jan	Feb	Mar	Apr	May	-	-	-	-	-	-	-
	PI	Jan	Feb	Mar	Apr	May	-	-		-	-	-	-
	BA (Bahia)	Jan	Feb	Mar	Apr	May	Jun	Nov	Dec	-	-	-	-
	RN (Rio Grande do Norte)	Feb	Mar	Apr	May	Jun		-	-	-	-	-	-
	PB (Paraíba)	Feb	Mar	Apr	May	Jun	Jul	-	-	-	-	-	-
	PE (Pernambuco)	Feb	Mar	Apr	May	Jun	Jul	-	-	-	-	-	-
	AL (Alagoas)	Mar	Apr	May	Jun	Jul	Aug	-	-	-	-	-	-
	SE (Sergipe)	Mar	Apr	May	Jun	Jul	Aug	-	-	-	-	-	-
Central-West	GO	Jan	Feb	Mar	Apr	Oct	Nov	Dec	-	-	-	-	-
	DF (Federal District)	Jan	Feb	Mar	Apr	Oct	Nov	Dec	-	-	-	-	-
	MT (Mato Grosso)	Jan	Feb	Mar	Apr	Oct	Nov	Dec	-	-	-	-	-
	MS (Mato Grosso do Sul)	Jan	Feb	Mar	Apr	May	Oct	Nov	Dec	-	-	-	-
Southeast	RJ (Rio de Janeiro)	Jan	Feb	Mar	Apr	Sep	Oct	Nov	Dec	-	-	-	-
	MG (Minas Gerais)	Jan	Feb	Mar	Oct	Nov	Dec	-	-	-	-	-	-
	ES (Espírito Santo)	Jan	Feb	Mar	Apr	Oct	Nov	Dec	-	-	-	-	-
	SP (São Paulo)	Jan	Feb	Mar	Apr	Oct	Nov	Dec	-	-	-	-	-
South	PR (Paraná)	Jan	Feb	Mar	Apr	May	Sep	Oct	Nov	Dec	-	-	-
	RS (Rio Grande do Sul)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	SC (Santa Catarina)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Source: Based on data from INMET (2019).

Field Burning of Agricultural Residues

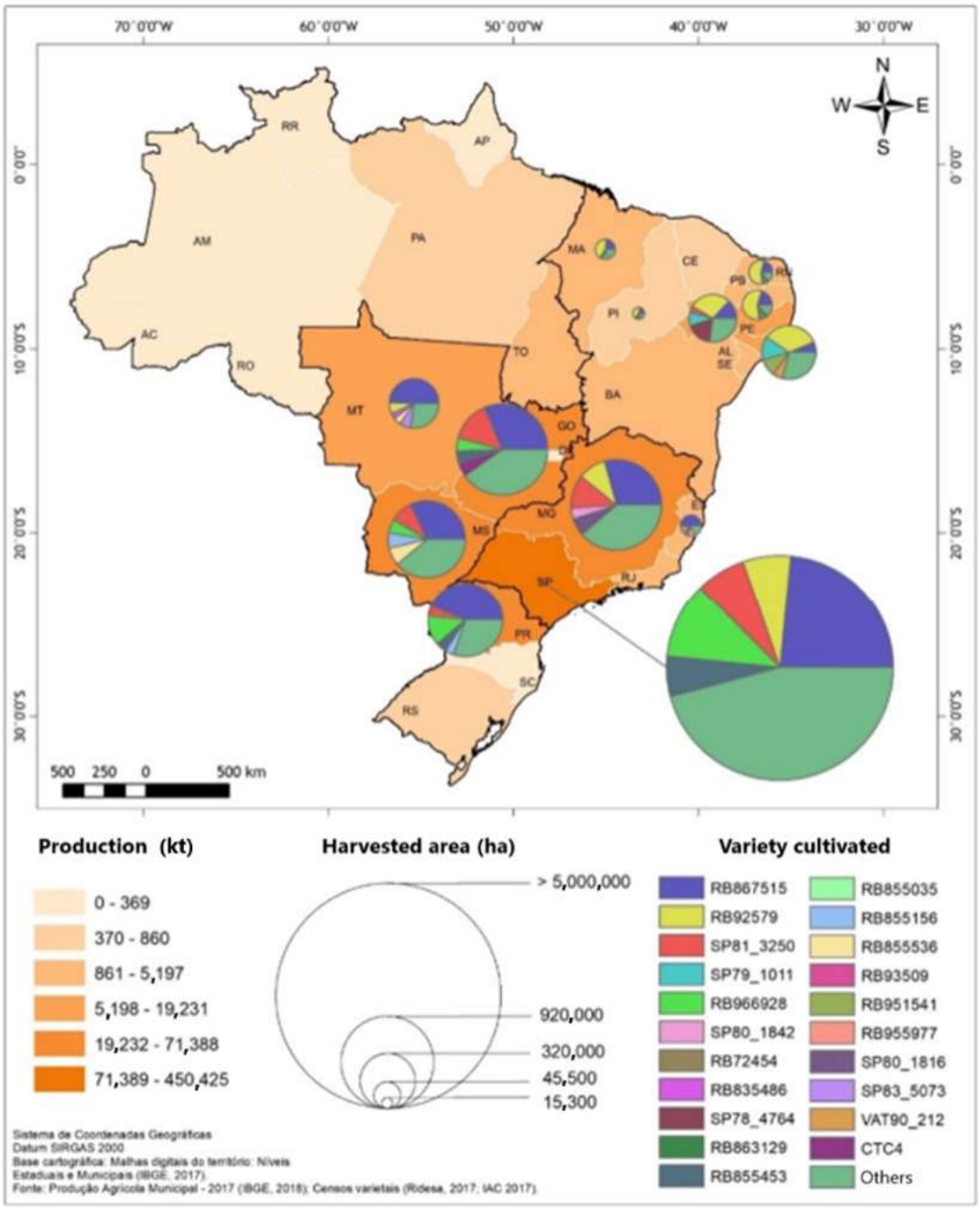


Figure A.VI.5. Proportion of varieties grown in the Federative Units/states recorded in the varietal censuses.

Source: Braga *et al*., 2017; RIDESA, 2018).

Table A.VI.8. Percentage of manually-harvested sugar cane by FU/State.

FU/State	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
AC (Acre)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
AL (Alagoas)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
AM (Amazonas)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
AP (Amapá)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
BA (Bahia)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
CE (Ceará)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
DF (Federal District)	0.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
ES (Espírito Santo)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
GO (Goiás)	75.6%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
MA (Maranhão)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
MG (Minas Gerais)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
MS (Mato Grosso do Sul)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
MT (Mato Grosso)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
PA (Pará)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
PB (Paraíba)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
PE (Pernambuco)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
PI (Piauí)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
PR (Paraná)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
RJ (Rio de Janeiro)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
RN (Rio Grande do Norte)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
RO (Rondônia)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
RR (Roraima)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
RS (Rio Grande do Sul)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
SC (Santa Catarina)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
SE (Sergipe)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
SP (São Paulo)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	90.0%	82.2%	80.0%	77.7%	69.5%
TO (Tocantins)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Cont. Percentage of manually-harvested sugar cane by FU/State.

FU/State	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
AC (Acre)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	0.0%	100.0%	100.0%
AL (Alagoas)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	97.5%	91.8%	93.7%	86.0%	84.9%
AM (Amazonas)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	20.0%	38.5%	36.3%	37.0%	14.6%
AP (Amapá)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BA (Bahia)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.1%
CE (Ceará)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	63.9%	64.4%	33.9%
DF (Federal District)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ES (Espírito Santo)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	87.3%	88.3%	77.7%	80.7%	60.5%
GO (Goiás)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	68.5%	51.2%	35.4%	24.2%	20.4%
MA (Maranhão)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	89.6%	74.8%
MG (Minas Gerais)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	80.6%	62.5%	52.5%	38.5%	26.8%
MS (Mato Grosso do Sul)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	80.0%	65.7%	36.7%	19.4%	10.1%
MT (Mato Grosso)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	66.7%	53.7%	42.7%	35.7%	24.9%
PA (Pará)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	63.0%	60.0%	50.0%	30.0%	30.0%
PB (Paraíba)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	92.4%	88.6%
PE (Pernambuco)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.7%	99.8%	99.7%	98.6%	98.4%
PI (Piauí)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
PR (Paraná)	100.0%	100.0%	100.0%	100.0%	90.0%	90.0%	89.6%	81.6%	73.1%	58.0%	51.7%
RJ (Rio de Janeiro)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	92.9%	89.0%	73.3%	87.4%	81.3%
RN (Rio Grande do Norte)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	79.7%	80.2%	67.9%	54.0%	50.9%
RO (Rondônia)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	40.0%	30.0%	30.5%
RR (Roraima)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RS (Rio Grande do Sul)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
SC (Santa Catarina)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SE (Sergipe)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
SP (São Paulo)	71.0%	72.0%	74.0%	72.0%	72.0%	65.5%	67.0%	52.4%	41.4%	37.3%	27.8%
TO (Tocantins)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	65.0%	64.0%	50.0%	0.0%	0.0%

Cont. Percentage of manually-harvested sugar cane by FU/State.

FU/State	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
AC (Acre)	100.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AL (Alagoas)	82.4%	84.3%	82.2%	77.6%	81.9%	80.1%	80.1%	80.1%	80.1%	80.1%	80.1%
AM (Amazonas)	4.5%	4.9%	1.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AP (Amapá)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
BA (Bahia)	88.6%	97.1%	96.4%	91.4%	88.8%	88.7%	88.7%	88.7%	88.7%	88.7%	88.7%
CE (Ceará)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
DF (Federal District)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ES (Espírito Santo)	49.4%	36.6%	35.0%	29.7%	39.2%	26.2%	26.2%	26.2%	26.2%	26.2%	26.2%
GO (Goiás)	16.5%	12.1%	15.6%	8.2%	4.1%	4.2%	4.2%	4.2%	4.2%	4.2%	4.2%
MA (Maranhão)	71.0%	47.1%	53.8%	52.9%	45.9%	56.5%	56.5%	56.5%	56.5%	56.5%	56.5%
MG (Minas Gerais)	19.7%	20.0%	15.2%	2.0%	3.0%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
MS (Mato Grosso do Sul)	12.8%	0.1%	9.2%	4.2%	0.2%	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%
MT (Mato Grosso)	22.1%	20.0%	12.8%	2.3%	7.5%	8.3%	8.3%	8.3%	8.3%	8.3%	8.3%
PA (Pará)	18.5%	7.8%	7.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PB (Paraíba)	87.8%	88.0%	88.3%	79.7%	70.4%	75.9%	75.9%	75.9%	75.9%	75.9%	75.9%
PE (Pernambuco)	98.3%	98.9%	99.3%	96.0%	98.1%	96.3%	96.3%	96.3%	96.3%	96.3%	96.3%
PI (Piauí)	100.0%	100.0%	100.0%	100.0%	91.6%	90.3%	90.3%	90.3%	90.3%	90.3%	90.3%
PR (Paraná)	40.9%	34.7%	27.2%	25.4%	13.4%	13.9%	13.9%	13.9%	13.9%	13.9%	13.9%
RJ (Rio de Janeiro)	66.6%	28.3%	34.5%	71.5%	72.5%	55.8%	55.8%	55.8%	55.8%	55.8%	55.8%
RN (Rio Grande do Norte)	44.5%	39.6%	40.0%	46.6%	44.8%	47.1%	47.1%	47.1%	47.1%	47.1%	47.1%
RO (Rondônia)	30.5%	19.6%	8.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RR (Roraima)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RS (Rio Grande do Sul)	100.0%	30.1%	9.3%	19.4%	17.5%	18.2%	18.2%	18.2%	18.2%	18.2%	18.2%
SC (Santa Catarina)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SE (Sergipe)	100.0%	100.0%	100.0%	84.5%	88.5%	93.8%	93.8%	93.8%	93.8%	93.8%	93.8%
SP (São Paulo)	22.3%	18.7%	14.9%	5.5%	5.5%	4.1%	4.1%	4.1%	4.1%	4.1%	4.1%
TO (Tocantins)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Source: Based on Conab – Brazil's National Supply Company (Companhia Nacional de Abastecimento) (2018) and Packer *et al*. (2015).

APPENDIX VII. ADDITIONAL DESCRIPTIONS FOR THE LAND USE, LAND-USE CHANGE AND FORESTRY SECTOR

A.VII.1. Mapping of land use and land cover and generation of land-use and land-cover matrices

The mapping of land use and land cover was obtained from the visual interpretation of a mosaic of satellite images of the national territory. Each homogeneous portion of the territory was manually vectorized and associated with one of the land-use categories/subcategories defined in Dataframe 7.4 (see Section 7.2.1), generating land-use and land-cover maps for the assessed years. Details of this procedure are provided below.

Image attainment and storage period

The specific validation committees for each biome in the inventory of the Fourth National Communication were responsible for defining, based on the availability of cloud-free images, the priority and auxiliary periods for obtaining images from medium spatial resolution orbital sensors, especially from the Landsat series satellites (Dataframe A.VII.1).

Dataframe A.VII.1. Priority and auxiliary period established by the validation committees for the attainment of medium spatial resolution orbital sensor images.

Biomes	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Amazon												
Cerrado												
Atlantic Forest												
Caatinga												
Pampa												
Pantanal												

Priority Period

Auxiliary period

Auxiliary period (NE, the coast of Santa Catarina and Vale do Ribeira)

Image selection

The images were selected primarily from the repositories of the United States Department of Agriculture (USDA) and the European Space Agency (ESA) via Google Earth Engine (GEEng). In some cases, where the images were not available for download on GEEng, a direct search was carried out in the USDA and ESA repositories and in the image catalog of the Image Generation Division (DGI, Divisão de Geração de Imagens) of the National Institute for Space Research (INPE, Instituto Nacional de Pesquisas Espaciais).

To download the images, images from the *Landsat* series and the MSI/Sentinel 2A and 2B sensor were intelligently searched for and obtained, with the option of filters for dates and periods, percentage of cloud cover and image quality indicators. In cases where cloud-free

images were not found in the priority and auxiliary periods and additional images were needed to correctly identify summer crops, images from the years of 2015 (last three months) and 2017 (first three months) were selected. In addition, for the critical cases in which cloud-free images were not found in 2015 and 2017, multi-temporal mosaics were made up of cloud-free pixels taken from images of the priority and auxiliary periods and from the aforementioned months of 2015 and 2017 (Figure A.VII.1).

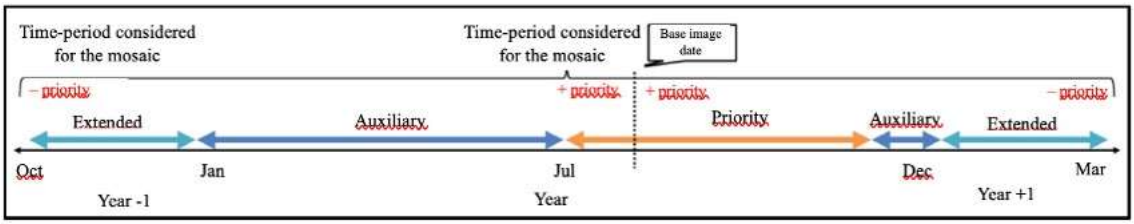


Figure A.VII.1. Theoretical scheme for composing cloud-free mosaics from pure pixel selection.

The mosaics were created at GEEng and consisted of selecting the image with the lowest incidence of clouds (defined as the "base image"), taking into account the priority and auxiliary periods indicated by each validation committee. Next, the selection of cloud-free pixels also considered the extended period, adopting the images from the dates closest to the "base image" as priorities. Figure A.VII.2 illustrates the result of the orbit/point (OP) mosaic construction process (at the right-hand side) compared to a single image (at the left-hand side).

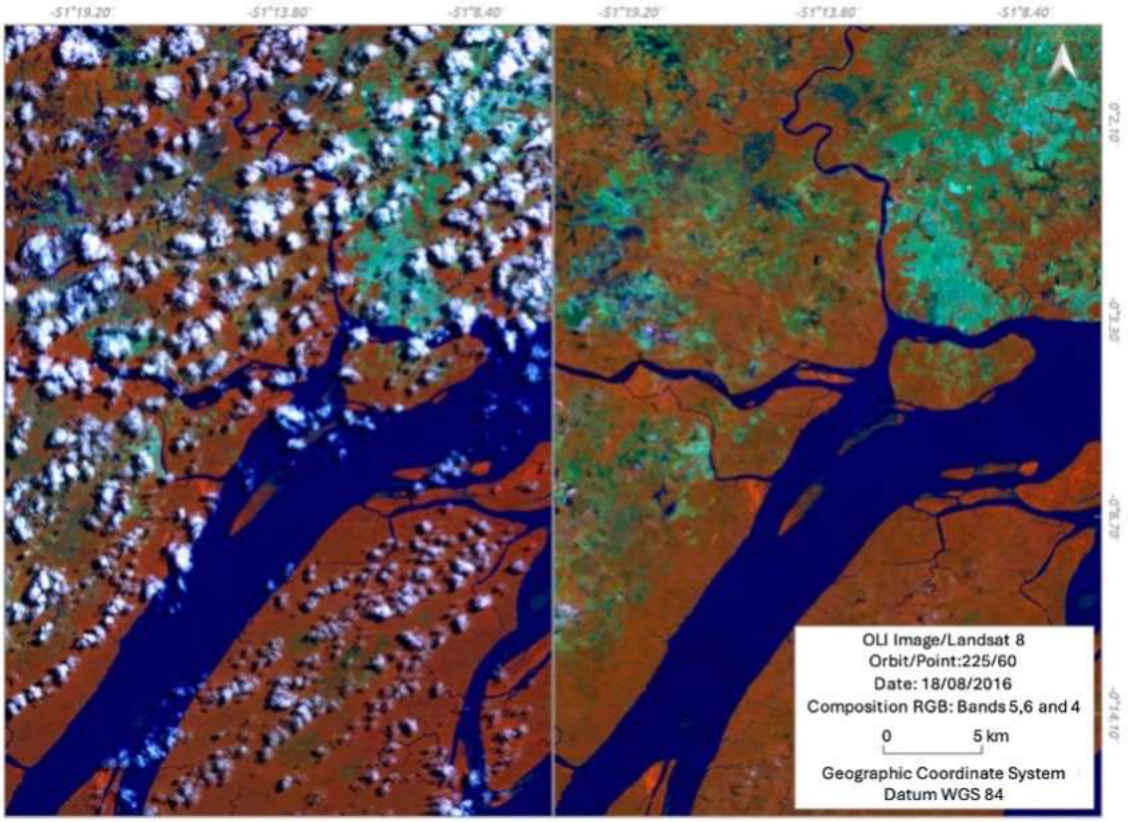


Figure A.VII.2. OLI/Landsat image (R5G6B4) obtained on August 18, 2016 (at the left-hand side) compared to the multi-temporal mosaic construction of OP 225/60 (at the right-hand side).

For the Atlantic Forest biome, images were selected from the priority and auxiliary periods of 1994, 2002, 2010 and 2016, following the same rules and periods mentioned above. Due to the lack of cloud-free images, it was also necessary to create multi-temporal mosaics, especially for the years of 2002 and 1994, when there were fewer sensors in orbit.

Image processing

To help identify the targets, the interpreters used secondary data, such as high spatial resolution images from Google Earth, time series of images from the MODIS sensor available on the SATVeg platform[125] and data from other monitoring programs, such as Prodes[126], TerraClass[127] and MapBiomas[128], among others. It should be noted that the secondary products were only used for consultation purposes and were not incorporated into the mapping, with the exception of the data available from Agrosatélite[129], which were incorporated when they met the quality criteria of the Fourth National Communication inventory (for example, the sugar cane crop maps from Canasat[130]).

Mapping of land use and land cover in 2016

The land-use and land-cover mapping for 2016 was based on the 2010 land-use and land-cover map. The 2016 map was drawn up based on the interpretation of orbital sensor images obtained as described in the previous section. For the Atlantic Forest, it was identified that the accuracy of the previous mappings was low and it was necessary to process the entire series of maps, i.e., 1994, 2002, 2010 and 2016, based on an alternative methodology detailed below.

The classes on the 2016 map were: a) Cropland (C); b) Perennial (PER); c) Sugarcane (SUGARCANE); d) Pasture (P); e) Forest Plantation (FP); f) Managed Forest Land (MFL); g) Unmanaged Forest Land (UFL; h) Secondary Forest (SecF); i) Managed Grassland (MG); j) Unmanaged Grassland (UG); k) Secondary Grassland (SecG); l) Other Managed Wooded Land (OMWL); m) Other Unmanaged Wooded Land (OUWL); n) Other Secondary Wooded Land (OSWL); o) Settlements (S); p) Rivers and Lakes (W); q) Reservoirs (Res); r) Managed Dunes (MD); s) Unmanaged Dunes (UD); t) Managed Rock Outcrop (MRO); u) Unmanaged Rock Outcrop (URO); v) Mining (Min); w) Bare Soil (BS); x) Not Observed (NO). Additionally, for the Amazon and Cerrado biomes, the Degraded Pasture (DP) class was taken into account. Specifically for the Amazon biome, the Selective Logging (SL) class was also considered. Compared to previous inventories, the SUGARCANE, PER, MD, UD MRO and URO and DP classes were quantified for the first time.

[125] Available at: www.satveg.cnptia.embrapa.br/satveg/login.html.
[126] Available at: www.obt.inpe.br/.
[127] Available at: www.terraclass.gov.br/
[128] Available at: https://brasil.mapbiomas.org/.
[129] It should be noted that Agrosatélite was the company hired by the MCTI – Ministry of Science, Technology and Innovations (Ministério da Ciência, Tecnologia e Inovações) to carry out the mapping.
[130] Available at: https://agrosatelite.com.br/cases/#canasat.

All data editing and auditing was carried out in the PostgreSQL/PostGIS geographic/relational database environment, integrated with the QGIS Geographic Information System, used as a digital interface for manipulation, vectorization and mapping. The steps in the mapping process are shown in Figure A.VII.3. Several auxiliary bases were used during the mapping stage as a reference for the interpreters: TerraClass 2013 (INPE/FIP (Forest Investment Program)/UFG (Federal University of Goiás [Universidade Federal de Goiás]); Global Forest Watch 2013 (GFW); Mineral Extraction 2017 (IBGE); DETER – Real-Time Deforestation Detection System in the Legal Amazon Region (Sistema de Detecção do Desmatamento na Amazônia Legal em Tempo Real) 2018 (INPE/FIP/UFG); Municipal Livestock Survey (PPM, Pesquisa da Pecuária Municipal) 2010 and 2016 (IBGE); Municipal Agricultural Production (PAM, Produção Agrícola Municipal) 2010 and 2016 (IBGE); Indigenous Lands 2016 (FUNAI – National Indian Foundation (Fundação Nacional do Índio), 2018); Conservation Units 2016 (ICMBio – Chico Mendes Biodiversity Conservation Institute (Instituto Chico Mendes de Conservação da Biodiversidade), 2018); Urbanized Areas 2015 (IBGE); and Settlements 2016 (Incra – National Institute for Rural Settlement and Agrarian Reform (Instituto Nacional de Colonização e Reforma Agrária)).

The minimum mapping area was 6.25 ha. To ensure the quality of the final product at a scale of 1:250,000, the interpreter identified and classified the polygons at an approximate scale of 1:125:000.

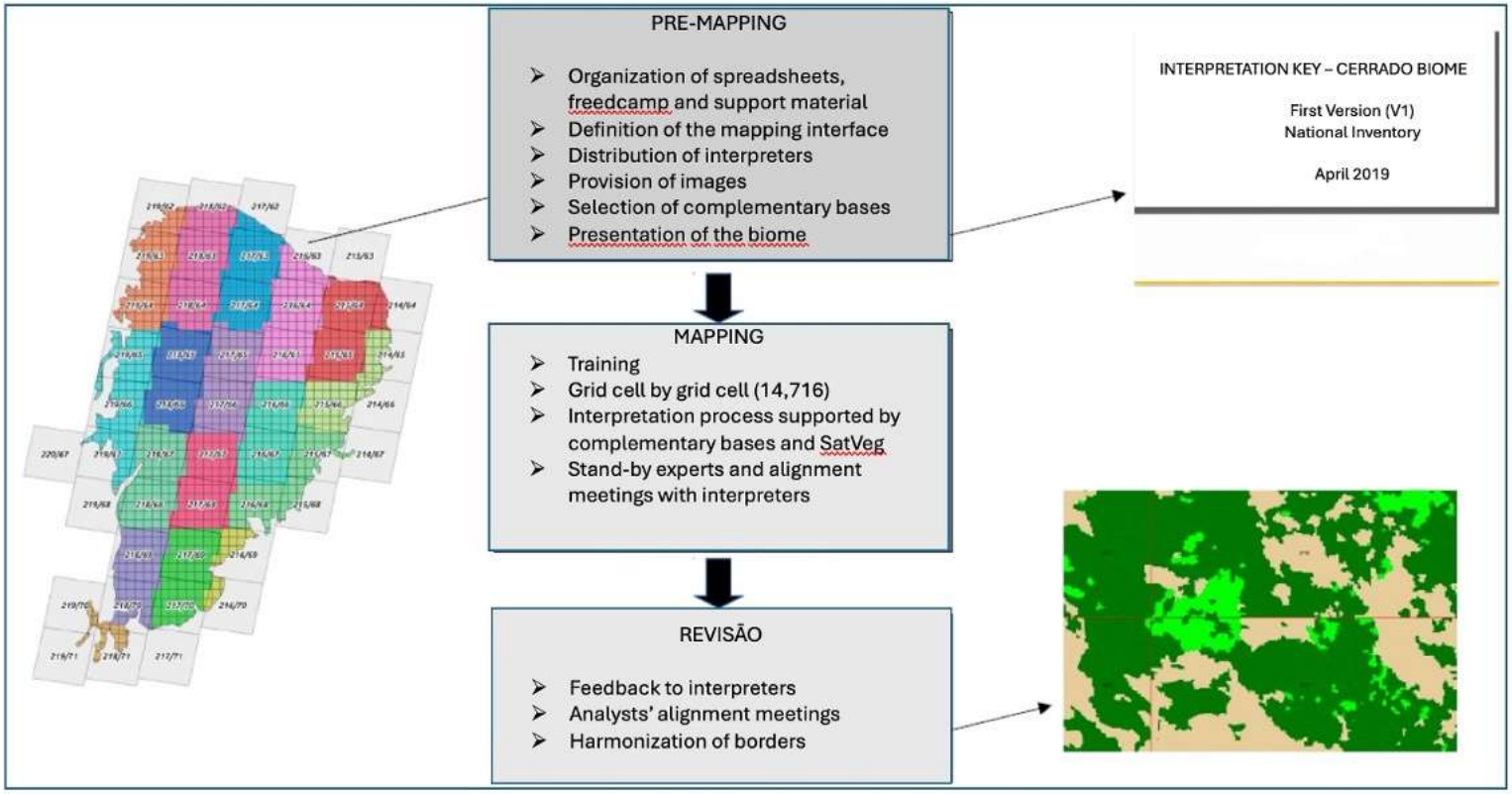


Figure A.VII.3. Illustrative chart showing all the stages, from pre-processing and mapping to review, of the 2016 land-use and land-cover mapping.

Thematic classes

Indirect classes

The MFL, UFL, MG, OMWL, OUWL, MD, UD, MRO, URO classes were created based on two intersection processes. Initially, the interpreter identified areas of native vegetation, regardless of their size, rock outcrops, dunes and water in the orbital sensor images and classified them as Native Vegetation (NATV). The resulting thematic map was intersected with the past natural vegetation map and, then, the NATV class was temporarily converted to FL, G, OWL, D and RO, according to the thematic class contained in the past natural vegetation map. Next, there was a new intersection between the land-use and land-cover map resulting from the previous stage and the map of protected areas, i.e., Conservation Units (CU) and Indigenous Lands (IL), to classify them as Managed (inside CU and IL) and Unmanaged (outside IL and CU) and assign them to the thematic classes of MFL, UFL, MG, UG, OMWL, OUWL, MD, UD, MRO and URO.

The mapping of the Secondary Forest (SecF), Secondary Grassland (SecG) and Other Secondary Wooded Land (OSWL) classes was carried out through visual interpretation of images from 2016, based on the areas belonging to the anthropogenic use classes on the 2010 map for the Amazon, Caatinga, Cerrado, Pampa and Pantanal biomes and on the 1994 map for the Atlantic Forest biome. Improbable conversions were not allowed. In order to correctly discriminate between SecF, SecG and OSWL areas, the map of past natural vegetation was used.

Classes resulting from image interpretation

The mapping of the Forest Plantation (FP) class included the large forest massifs of the main species used in forest plantation, such as eucalyptus, pine, rubber tree and teak. Eucalyptus and pine are dominant in the FP class and are less complex to identify and map (with the exception of some areas in the middle of native forest on slopes). Rubber tree areas show a variation in spectral response throughout the year due to the loss of leaves in the dry season, so mapping was based on images from both periods (i.e., with and without leaves). The FP class from the 2010 map was used as a starting point for the process of identifying the areas from 2016. In addition, searches were carried out in the public mapping databases for planted forests (http://data.globalforestwatch.org/), Agrosatélite databases and secondary data from the IBA – Brazilian Tree Industry (Indústria Brasileira de Árvores).[131]

The mapping of the Pasture (P) class took into account the high inherent complexity of Brazilian pastures due to regional and management aspects (such as, the diversity of management techniques, variation in soil and climate conditions and variety of species). As for the Degraded Pasture (DP) class in the Amazon and Cerrado biomes, auxiliary data from the Google Earth catalog was used to help with mapping and with the potential identification of areas with more advanced biological degradation. The starting point for mapping the P class was the 2010 pasture mapping, aided by other reference mappings, such as the 2014 Amazon TerraClass, the 2013 Cerrado TerraClass, the LAPIG/UFG mappings, MapBiomas, Agrosatélite proprietary mappings, among others.

Mapping of the Cropland (C) class consisted of breaking down the following subclasses: large-scale annual crops (i.e., soybeans, corn 1st harvest and cotton 1st harvest); 2)

[131] Available at: https://iba.org/.

perennial crops (coffee, citrus, cocoa); and 3) semi-perennial crops (sugar cane). The mapping was carried out by visually interpreting images from the harvest and off-season periods, taking into account the aspects duly explored in the various characteristics of agricultural crops, supported by: a) digital image processing with segmentation and object-based classification (GEOBIA), specifically for the Atlantic Forest; b) multitemporal analysis of MODIS image series; and c) previous mapping by Agrosatélite (i.e., Canasat and annual crops in the Cerrado and the Amazon biomes).

The Settlement (S) class was mapped using visual interpretation of images from 2016, with a focus on mapping the expansion of the urban area, taking the 2010 mapping as a starting point. Other reference maps, such as those provided by the IBGE's continuous mapping (1:250,000), were used as auxiliary data for mapping the S class.

The mapping of the Rivers and Lakes (W) class was done by visually interpreting the 2016 images obtained in different seasons, in order to identify the expansion and/or retraction of rivers and lakes, based on the 2010 mapping. The interpreting work took into account the seasonality of this type of target in order to avoid inconsistent conversions, which were identified and duly adjusted by the interpreters.

The Reservoirs (Res) class was mapped by visually interpreting the images from 2016 in order to identify the expansion and/or shrinkage of the reservoirs, based on the 2010 mapping. Additional data obtained from the public databases of the federal and state governments was also used to identify the locations of hydroelectric plants and dams installed between 2010 and 2016.

The classes of mining, dunes, rock outcrops and bare soil were mapped using visual interpretation of images from 2016, based on the 2010 mapping, taking into account the characteristics of each of these targets.

The mapping of the Not Observed (NO) class includes only the areas not observed due to the persistent occurrence of clouds and/or cloud shadows or of relief in the images from 2016 (considering the extended period). In order to minimize the occurrence of this class, several images were used from the different satellite/sensor sets available for 2016. This practice substantially increased the chances of obtaining cloud-free mosaics, allowing valid land-use data to be generated for practically the entire Brazilian territory.

The Selective Logging (SL) class was mapped using the methodology proposed by Imazon - Amazon Institute for Mankind and the Environment (Instituto do Homem e Meio Ambiente da Amazônia) (Souza Jr., 2005), extracting the soil, photosynthetically active vegetation and shadow fractions using the Linear Spectral Mixture Model (LSMM) implemented in GEEng. A band ratio was, then, applied between the soil fraction and the vegetation fraction, in order to highlight the differences between the forest with and without selective logging. The first stage of this classification was to assess whether the areas identified as SL on the 2010 map were still under this type of management. The UFL and MFL areas were, then, assessed in order to identify new SL areas using the products derived from the LSMM. Throughout this stage, auxiliary data was used, particularly from the Brazilian Forest Service, for example, the boundaries of federal forest management concession areas.

Specificities of the interpretation process by biome

Amazon

In the processing stage prior to the mapping of the Amazon and Cerrado biomes, the Prodes' polygons accumulated for the period from 2011 to 2016, whenever they overlapped with the

NATV class, were incorporated into the mapping. Subsequently, based on the interpretation of the images, whether or not they corresponded to clear-cut areas, the polygons were assigned one of the thematic classes provided for in the inventory. In addition, in order to increase the accuracy of the classes referring to agricultural crops (C and PER), the grain crop map from Agrosatélite – 2010/11 and 2016/17 Harvests (Rudorff *et al.*, 2015) and the map of perennial crops from Embrapa [Brazilian Agricultural Research Corporation (Empresa Brasileira de Pesquisa Agropecuária)] Amazônia Oriental were incorporated into the base map.

Except for emissions from selective logging, emissions from forest degradation (e.g. fire on forest and non-forest areas) have not been quantified in the context of the Fourth National Communication inventory. In areas where no fire scars were identified, but where there had in fact been a change in land use and cover, the polygons were kept as native vegetation.

Cerrado

The Cerrado biome is characterized by the presence of natural fires, and this natural dynamic was taken into account to avoid the mistaken conversion of natural areas to other anthropogenic uses. Data from Prodes Cerrado[132] was used as support.

As in the Amazon, the Prodes deforestation polygons accumulated between 2011 and 2017 that overlapped with the NATV class were incorporated into the map without an assigned class, forcing the interpreters to check all the polygons in order to assign the inventory classes.

Another peculiarity of the mapping of the Cerrado biome was the incorporation of Agrosatélite's proprietary databases, such as the map of sugar cane cultivation – 2018 Harvest – Canasat Project (Rudorff et al., 2010), and the map of grain crops – 2016/17 Harvest Project (Rudorff et al., 2015). A total of 24,282,550 ha were included, equivalent to 11.9% of the Cerrado biome area, of which 9.2% refers to the C class, from the grain crop map; and 2.7% refers to the SUGARCANE class, from the sugar cane cultivation map.

As in the Pampa and Pantanal biomes, the Cerrado biome has native pastures with grazing which are preserved. Thus, the presence of paddocks, livestock support structures and cattle trampling paths, among others, were considered key elements for identifying native pastures with grazing. In addition, the degraded pasture (DP) class was also mapped. A large portion of the degraded pasture areas was classified as natural vegetation in previous inventories, as they were areas with old use and occupation and apparently already abandoned in the first version of the National Inventory (base year of 1994).

A previous analysis of the evolution of the C and P classes from 1994 to 2010 showed that there was an overestimation of the C area in 1994, 2002 and 2010, to the detriment of the P class. This was mainly due to images acquired in the dry season (April-August) identifying areas of bare soil or dry vegetation, such as cropland areas. To solve this problem, we used the pasture class data from MapBiomas,[133] on which an intersection analysis of the maps was carried out by the external validation committee.

Caatinga

The seasonal dynamics of the Caatinga vegetation in response to low rainfall is a complicating factor when interpreting images from orbital sensors, as is the variation in soil and climate characteristics (Pacheco *et al.*, 2006; Bezerra *et al.*, 2014). In addition, the

[132] Available at: https://terrabrasilis.dpi.inpe.br/app/map/deforestation
[133] Available at: https://mapbiomas.org.

extreme droughts that occurred between 2012 and 2017 (Martins *et al*., 2017) led to changes in the response patterns of the images when compared between 2010 and 2016, as in several cases the same target showed different spectral response patterns.

Also in this context, for the Reservoir class, there was a reduction in the level of large reservoirs, giving way to cropland and/or pasture (Figure A.VII.4). The conversion from Res to C and P is improbable, but it has been maintained to take into account the reality of the biome.



Figure A.VII.4. High spatial resolution image available on Google Earth of a reservoir in the municipality of Hidrolândia (CE – state of Ceará) in 2010 (left) and 2016 (right). The highlighted areas, submerged in 2010, were under crop cultivation and grazing in 2016.

Nas áreas agrícolas fora dos perímetros de irrigação onde foram evidenciados indícios de manejo agrícola (isto é, solo arado), mas as culturas agrícolas não prosperaram devido à ausência de chuvas, optou-se por classificá-las como pastagens. Essa escolha foi embasada nas características do manejo agrícola da região, que intercala a criação de ovinos e caprinos como uma opção de geração de renda nos períodos prolongados de estiagem.

Pampa

The Pampa biome, despite being one of Brazil's smallest biomes, has a great diversity of land use and land cover. The eastern part of the biome is characterized by the presence of family farming, with small properties and diversified agricultural production. Many of these areas were already classified as pasture by previous inventories and were converted to the cropland class, which better represents the region.

The pasture class (P) is known to be one of the most difficult to map in the Pampa biome, using medium spatial resolution images. This is because it is difficult to distinguish between planted and natural pastures and those with or without grazing. Past mapping has essentially classified natural pastures as P, regardless of their use (with or without grazing). To avoid a large thematic conversion between 2010 and 2016, we opted to maintain a conservative approach without attesting to non-existent conversions. As the Pampa has natural landscapes of grassland with grazing, the conversion of natural vegetation to pasture was only attested when the comparison of the 2010 and 2016 images indicated clear management of the area, and it was necessary to consider, in addition to the spectral response, other elements of visual interpretation, such as the context, shape, texture, and size of the polygons identified and the permanent presence of production infrastructure, such as dams and water tanks for the cattle, roads, trampling marks on trails traced by the herd, paddocks and drinking troughs.

Fallow land in agricultural areas and the integration of agriculture and livestock in rice production areas is a characteristic of land use in the Pampa biome. To this end, time series

of vegetation cover (Enhanced Vegetation Index – EVI) were used to analyze the history of the areas in order to classify them correctly: when they were still active, the crops were classified as cropland.

Due to the extensive production of livestock and rice, there is a large number of small reservoirs in this biome, which serve as drinking troughs for livestock or for irrigation by flooding of rice cultivation areas. These small reservoirs were mapped as P and Water (W) on the base map, so they were mapped as Res. It was necessary to check the entire series of previous maps to avoid including false conversions in the final biome map (Figure A.VII.5).

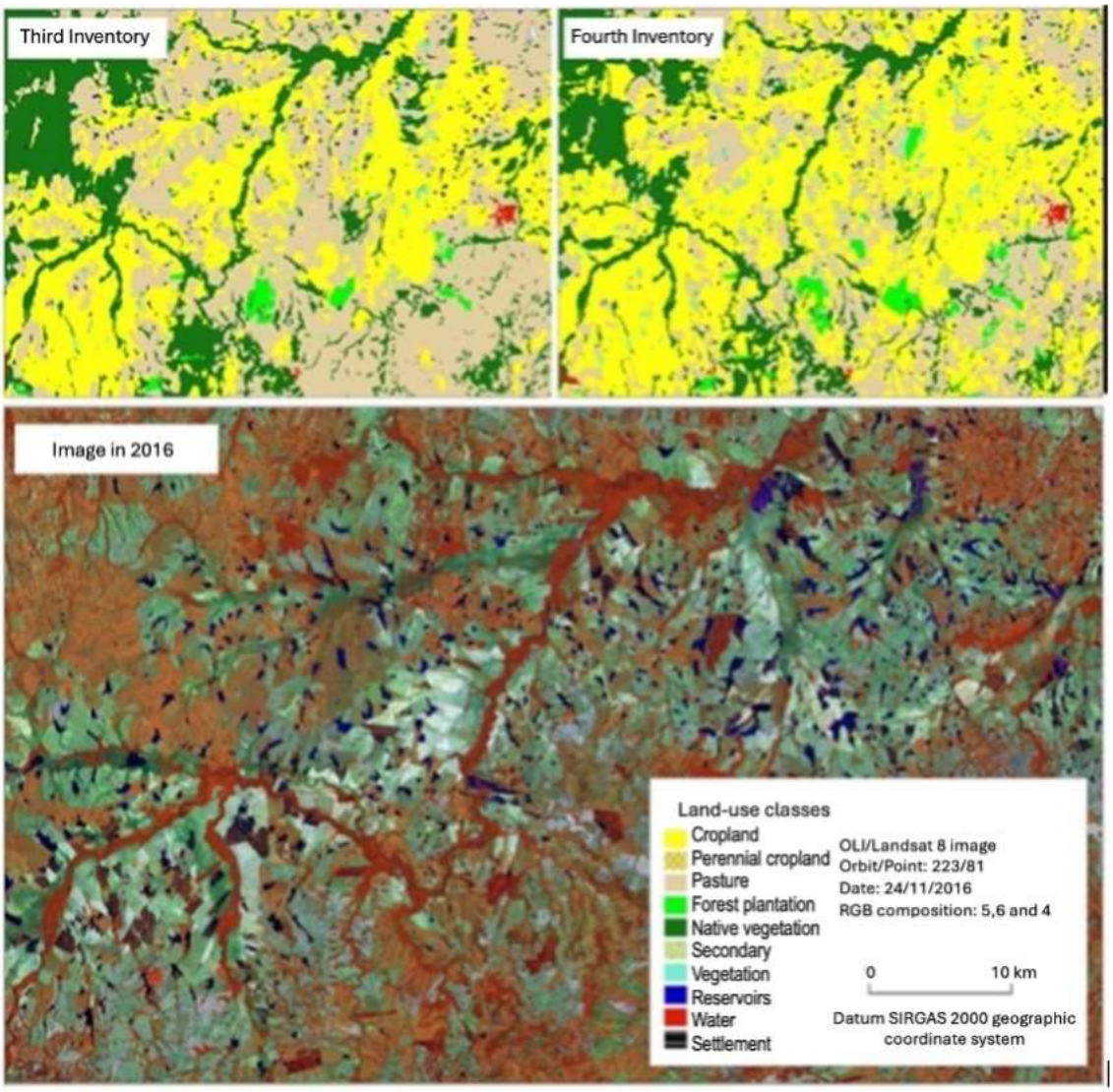


Figure A.VII.5. Map of 2016 pre-correction of reservoirs (top), post-correction (middle) and on OLI/*Landsat* image (bottom).

Pantanal

In the Pantanal, as in the Pampa, it is difficult to distinguish between native and planted pastures, with and without grazing, based on the interpretation of medium spatial resolution orbital sensor images. Besides the additional aforementioned aspects, which help to distinguish between these classes, the seasonal flooding of many of the pasture areas made it possible to assign these areas to the NATV class.

Atlantic Forest

Based on the assessment made by the biome expert, who was a member of the external mapping validation committee, that the accuracy of the previous maps of the Atlantic Forest did not meet the desirable standards, the need to improve the 1994, 2002 and 2010 maps was ascertained. A new mapping methodology for the biome was proposed, covering all four periods (1994, 2002, 2010 and 2016). In general terms, the methodology adopted comprises an object-oriented segmentation stage of an OLI/*Landsat* image obtained in 2016, a semi-automatic classification and, finally, a visual interpretation of the image used in the segmentation and additional images for thematic adjustments. The new mapping for the Atlantic Forest was carried out as detailed below.

Mapping of 1994, 2002, 2010 and 2016 for the Atlantic Forest

The 2016 map was drawn up using a hybrid mapping model based on two stages. The first one is a computational stage consisting of the segmentation and classification of orbital images from the OLI/Landsat-8 satellite, obtained for the year of 2016. The second stage consists of the visual interpretation of images and screen vectorization, carried out by interpreters on the image used for segmentation, and other images obtained in the priority and auxiliary periods.

For the segmentation and automatic classification stage, in addition to the basic image segmentation parameters (size, shape and similarity), complementary data produced by institutions with notable expertise in their respective study topics (such as Landsat 8, MapBiomas, FDBS, GFW, IBGE, ANA and Agrosatélite) were used.

The segmentation process was carried out using ENVI EX Vs. 5.1 software, and the output data was generated in vector format. The classification process was carried out using class modeling with the application of functions based on hierarchical rules, taking into account the image's spectral information and the percentage coverage of features contained in the thematic maps.

After editing the maps, an intersection was made with the past natural vegetation map in order to convert the NATV and SecV classes to Forest Land (FL), Grassland (G) or Other Wooded Land (OWL), and the Other class to Dunes (D) or Rock Outcrop (RO). Subsequently, a new intersection was made with the map of protected areas, with the aim of assigning the suffixes M (for managed areas) and U (for Unmanaged areas) to the Forest Land, Grassland and Other Wooded Land classes).

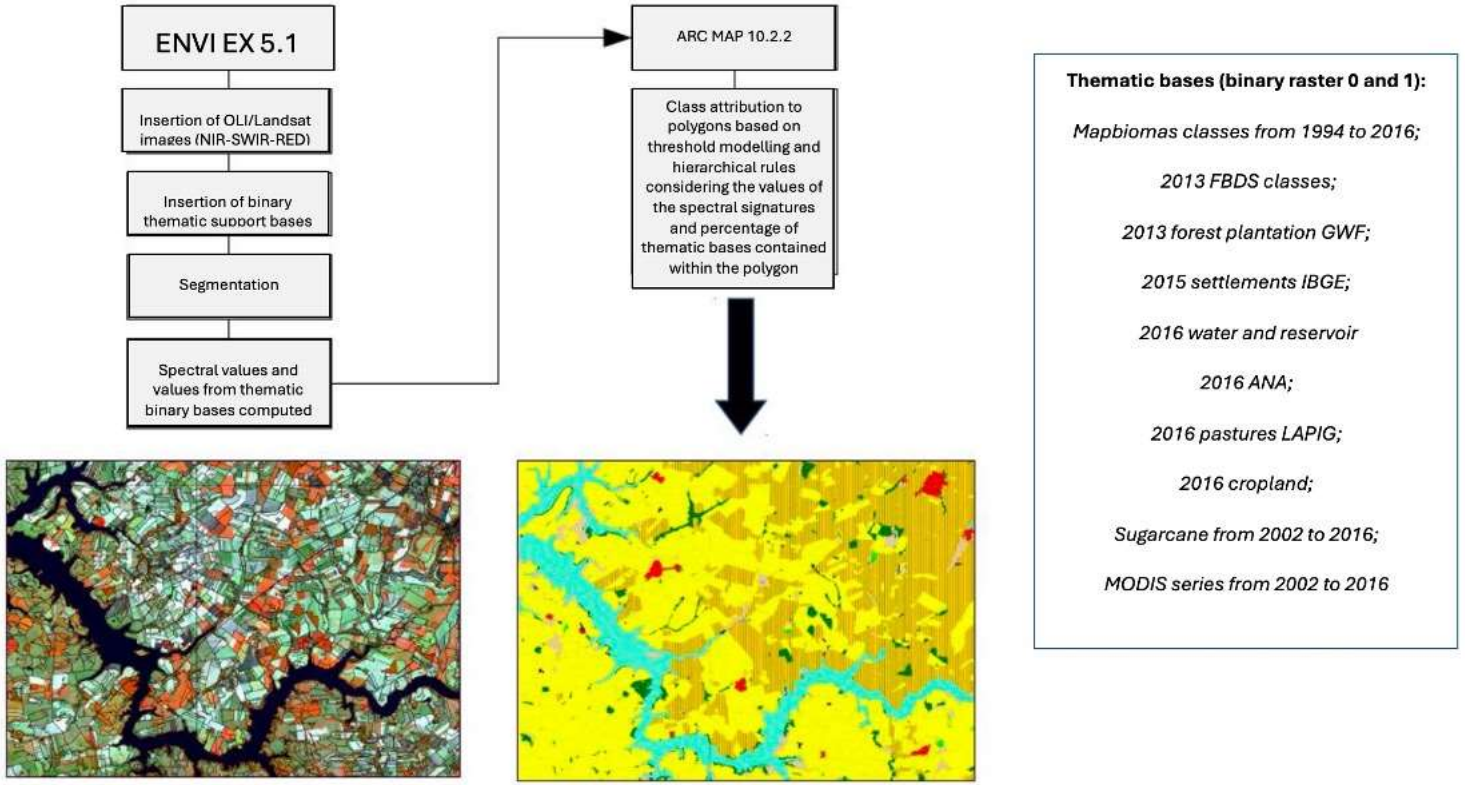


Figure A.VII.6. Chart illustrating the stages of segmentation and automatic classification of the Atlantic Forest biome.

Land-use and land-cover maps generated for all Brazilian biomes

Below are the mosaics built from the selected and processed images that resulted in the land-use and land-cover maps for Brazil and for all biomes for the years of 1994, 2002, 2005 (only for the Amazon biome), 2010 and 2016.

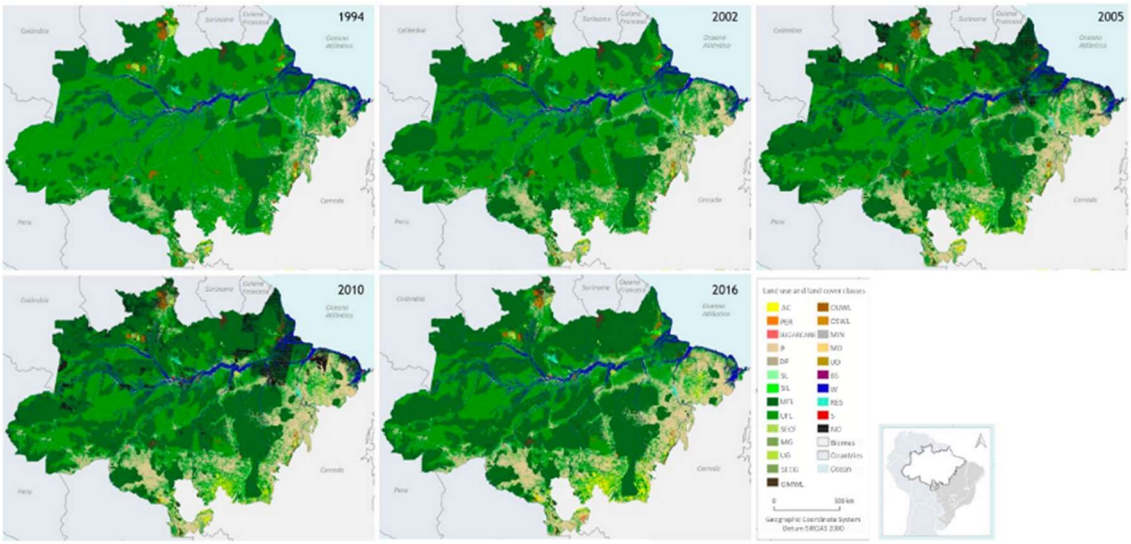


Figure A.VII.7. Land-use and land-cover maps of the Amazon biome for the years of 1994, 2002, 2005, 2010 and 2016. In 2016, the PER, SUGARCANE, DP, MD and UD classes were mapped for the first time.

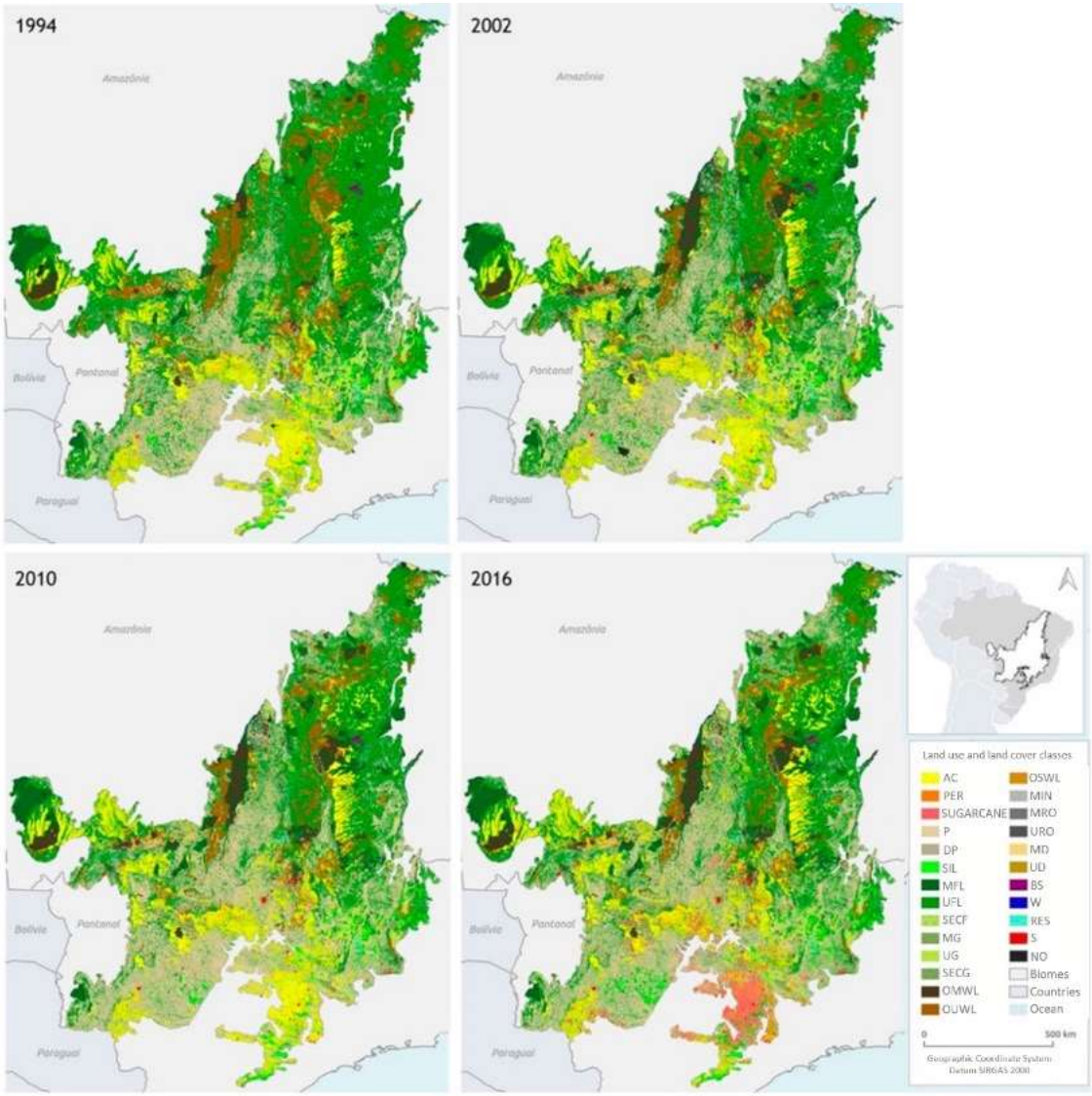


Figure A.VII.8. Land-use and land-cover maps of the Cerrado biome for the years of 1994, 2002, 2010 and 2016. In 2016, the PER, SUGARCANE, DP, MRO, URO, MD and UD classes were mapped for the first time.

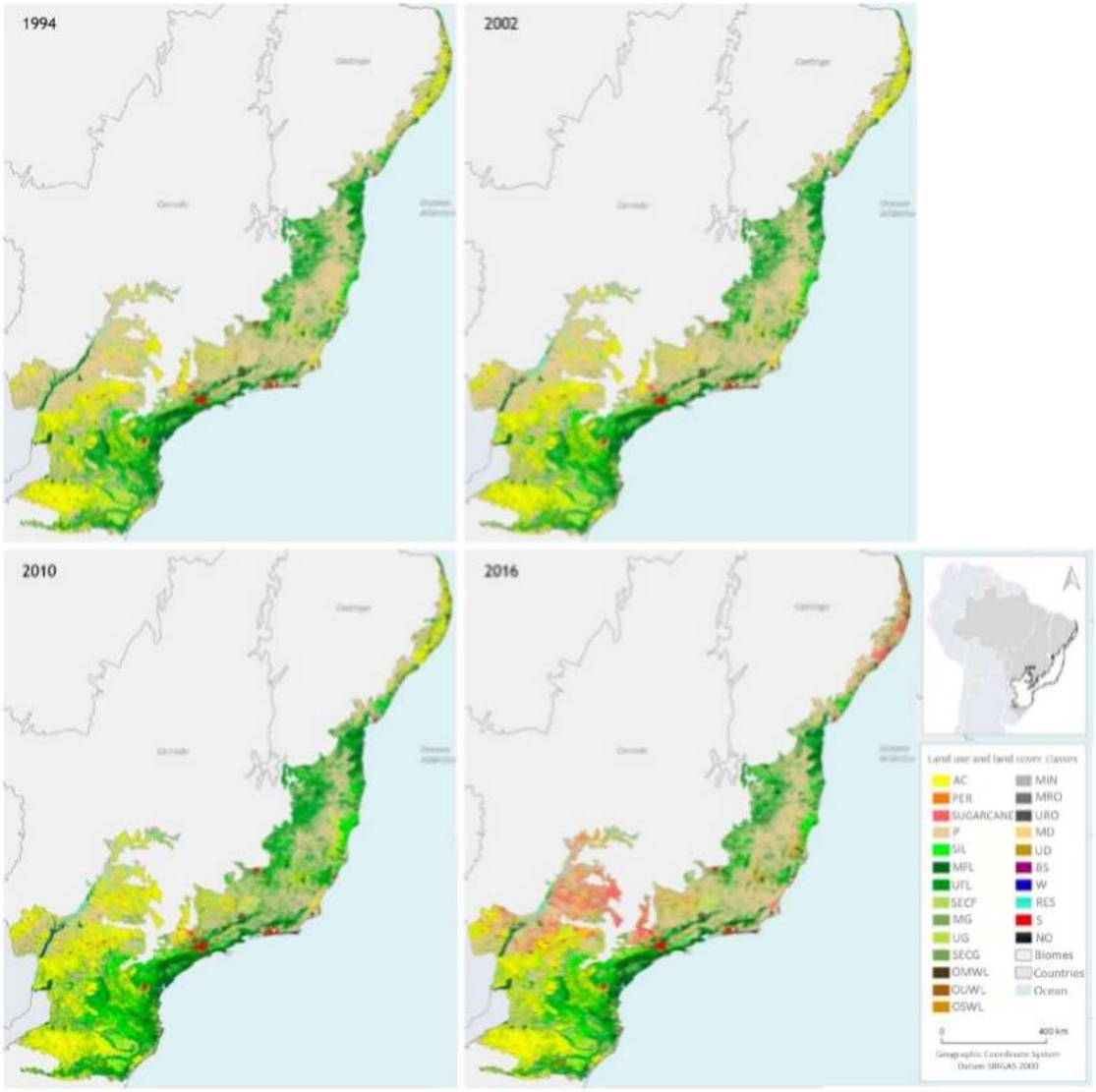


Figure A.VII.9. Land-use and land-cover maps of the Atlantic Forest biome for the years of 1994, 2002, 2010 and 2016. In 2016, the PER, SUGARCANE, MRO, URO, MD and UD classes were mapped for the first time.

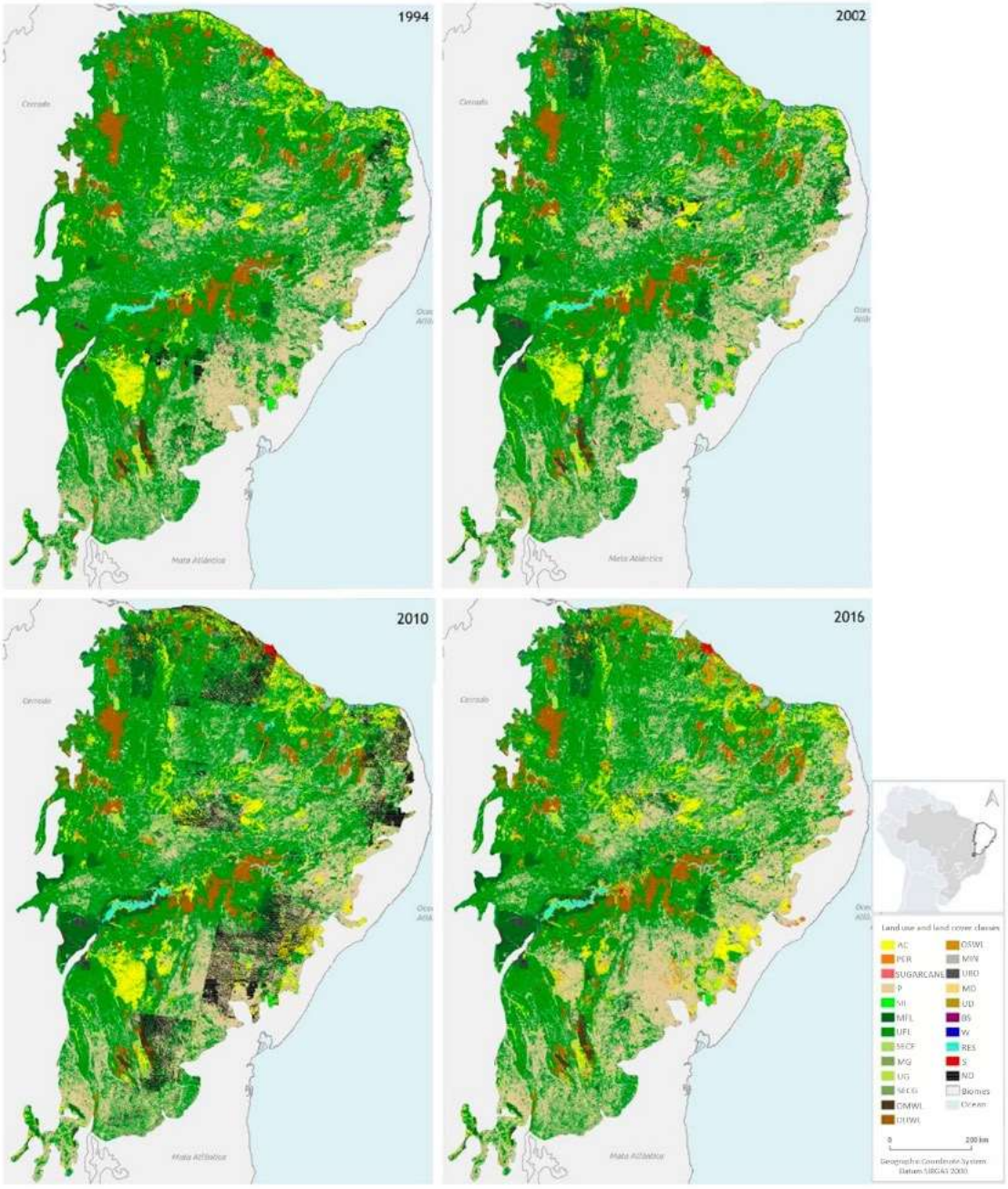


Figure A.VII.10. Land-use and land-cover maps of the Caatinga biome for the years of 1994, 2002, 2010 and 2016. In 2016, the PER, SUGARCANE, URO, MD and UD classes were mapped for the first time.

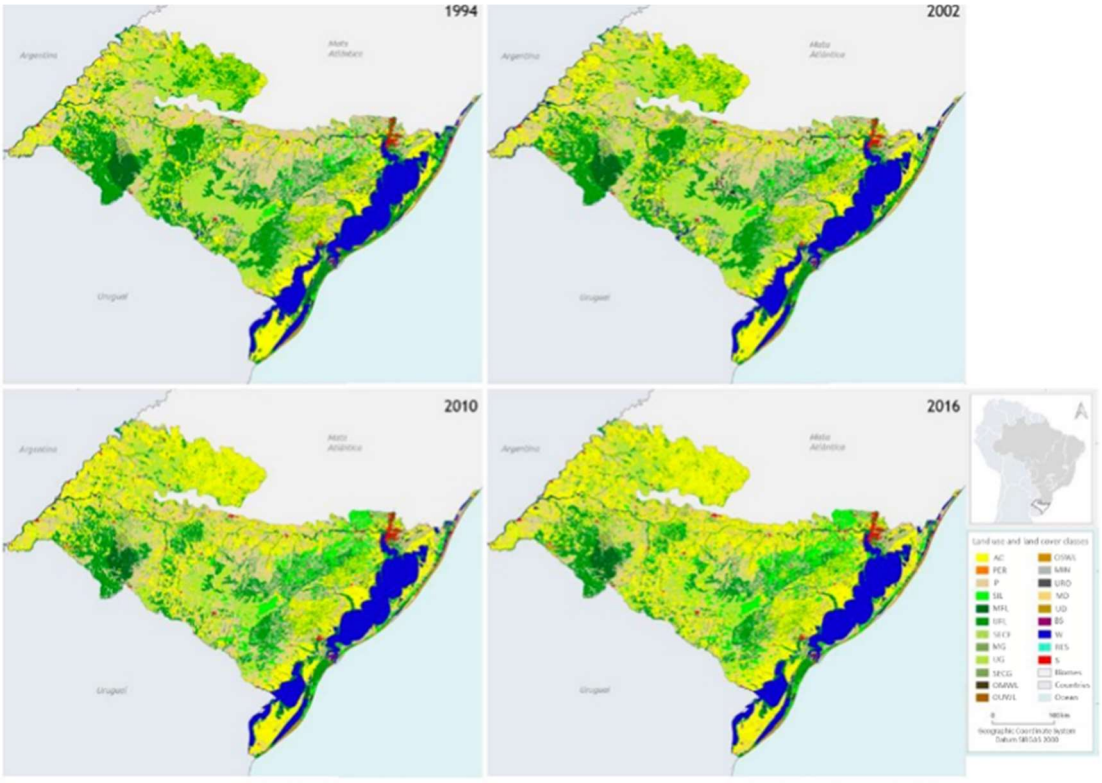


Figure A.VII.11. Land-use and land-cover maps of the Pampa biome for the years of 1994, 2002, 2010 and 2016. In 2016, the PER, URO, MD and UD classes were mapped for the first time.

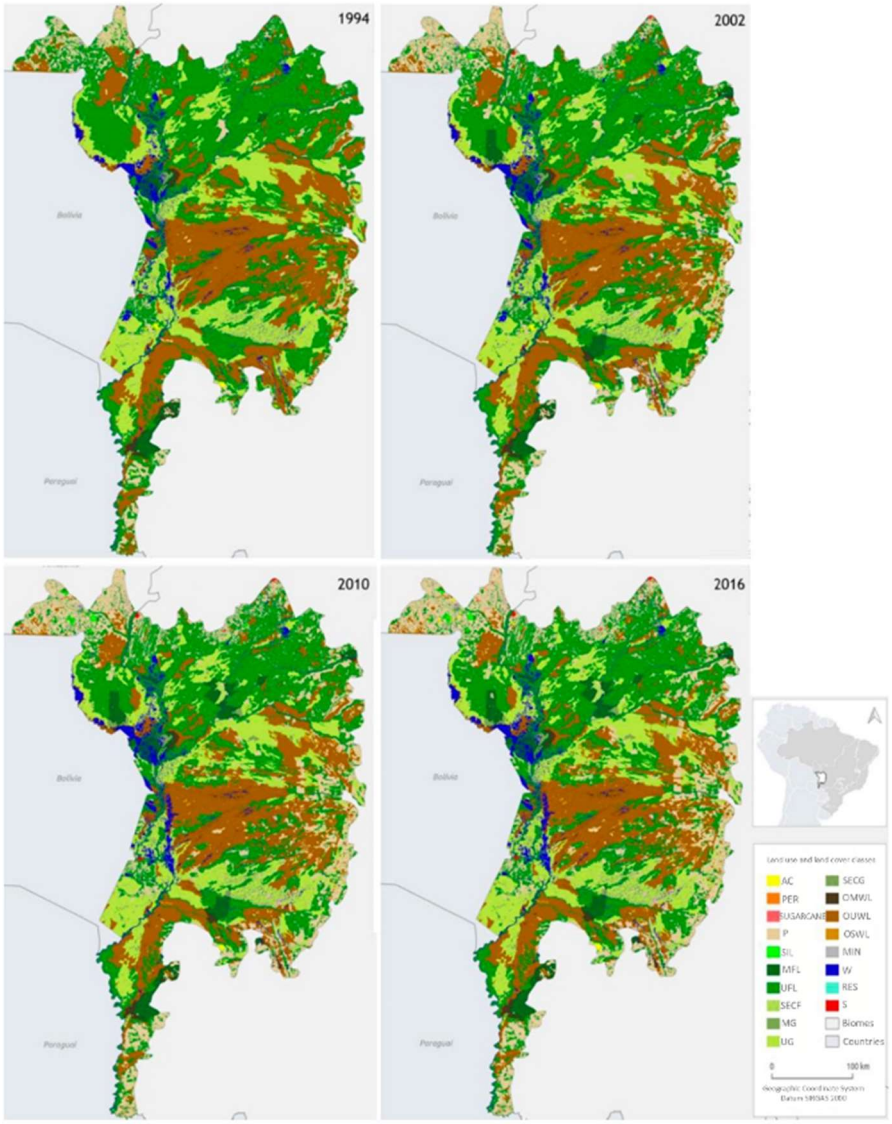


Figure A.VII.12. Land-use and land cover maps of the Pantanal biome for the years of 1994, 2002, 2010 and 2016. In 2016, the PER and SUGARCANE classes were mapped for the first time.

Data spatialization

The carbon stocks of vegetation, both natural and anthropogenic, were broken down by biome. For the natural vegetation classes, the data was spatialized in vector format and intersected with the land-cover and land-use maps, and stocks were only assigned to the natural vegetation classes. For the anthropogenic use classes, such as pastures, annual, perennial and semi-perennial cropland, the data was used in tabular format and associated with each polygon in the attribute table automatically using the PostGIS relational database. To operationalize the calculations, the carbon stock values of the anthropogenic use classes were associated directly in the command lines in the Scripts.

The association between soil organic carbon and land-use and land-cover classes was made by intersecting the soil organic carbon map and the land-use and land-cover map

produced in the Fourth National Communication inventory. It should be noted that the soil carbon stock map used in this edition is the same as that adopted in the Second and Third National Communication inventories, produced according to the methodology proposed by Bernoux *et al*. (2002).

Generation of land-use and land-cover conversion matrices

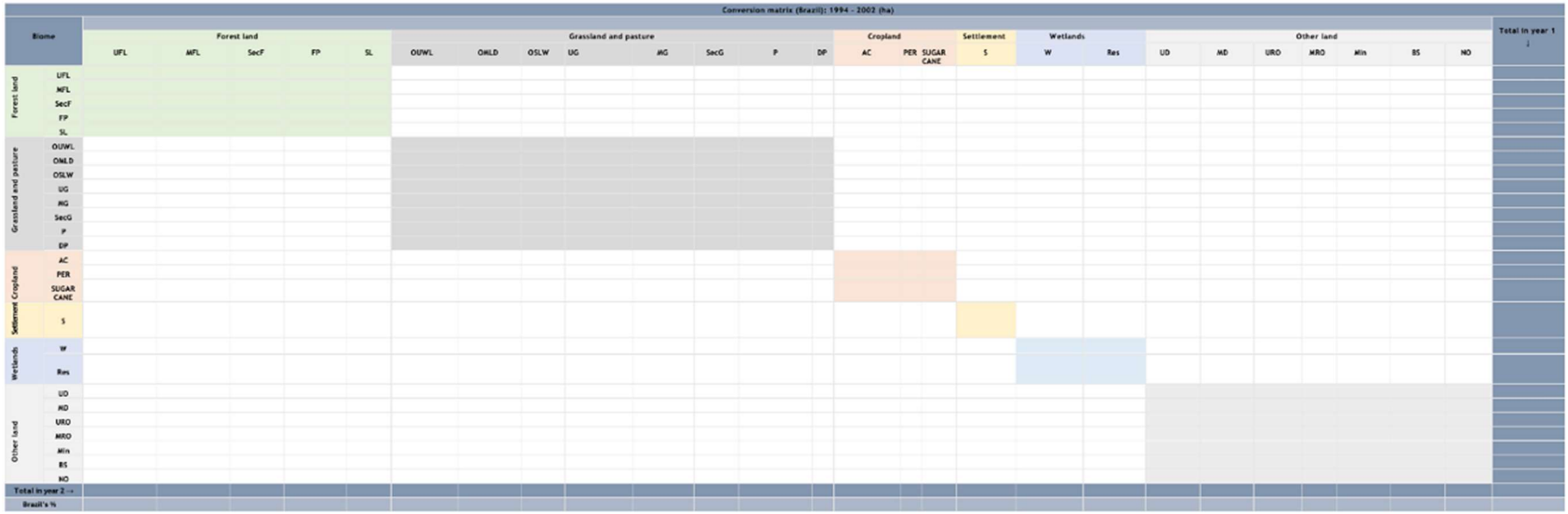
Table A.VII.1 summarizes the results obtained in the thematic class groups provided for by the IPCC. Dataframe A.VII.2 shows a conversion matrix model resulting from the intersection between the 2010 and 2016 maps. All land-use and land-cover classes are represented, with the exception of the classes that were incorporated from 2016 onwards. The columns show the classes for 2016 and the rows show the classes for 2010. The cells of the matrix are filled with the areas in hectares for each conversion. The highlighted row on the main diagonal shows the classes where there has been no change in land use and land cover, while the other cells show the conversions in land use and land cover. The "Total in Year 2" column shows the class areas from the 2010 map, while the "Total in Year 1" row shows the class areas from the 2016 map. The percentages of the area of each class in relation to the total area of the biome for each of the years are shown in the respective "% of biome" columns and rows.

Table A.VII.1. Estimated area of land-use and land-cover class groupings for 2016.

Biome	Forest Land	Grassland	Cropland	Settlements	Wetlands	Other Land/Other uses	Total
	ha/(%)	ha/(%)	ha/(%)	ha/(%)	ha/(%)	ha/(%)	ha
Amazon	354,572,526 (80.1)	65,998,159 (14.9)	6,469,001 (1.46)	474,394 (0.11)	14,997,500 (3.39)	289,539 (0.07)	442,801,119
Cerrado	84,733,267 (41.5)	88,058,795 (43.2)	28,233,241 (13.8)	1,061,630 (0.5)	1,539,711 (0.8)	317,659 (0.2)	203,944,304
Atlantic Forest	37,891,281 (34.0)	46,047,957 (41.3)	23,191,801 (20.8)	2,164,885 (1.9)	2,065,072 (1.9)	195,936 (0.2)	111,556,948
Caatinga	49,871,051 (60.2)	26,310,694 (31.8)	5,216,804 (6.3)	373,195 (0.5)	748,050 (0.9)	265,903 (0.3)	82,785,696
Pampa	4,136,384 (23.1)	5,608,092 (31.4)	6,085,918 (34.0)	159,105 (0.9)	1,735,070 (9.7)	158,010 (0.9)	17,882,579
Pantanal	5,542,756 (36.6)	8,947,879 (59.1)	19,841 (0.1)	12,533 (0.1)	601,622 (4.0)	5,635 (0)	15,130,267
Brazil	536,747,266 (61.4)	240,971,576 (27.6)	69,216,605 (7.92)	4,245,758 (0.49)	21,687,025 (2.48)	1,232,682 (0.14)	874,100,912

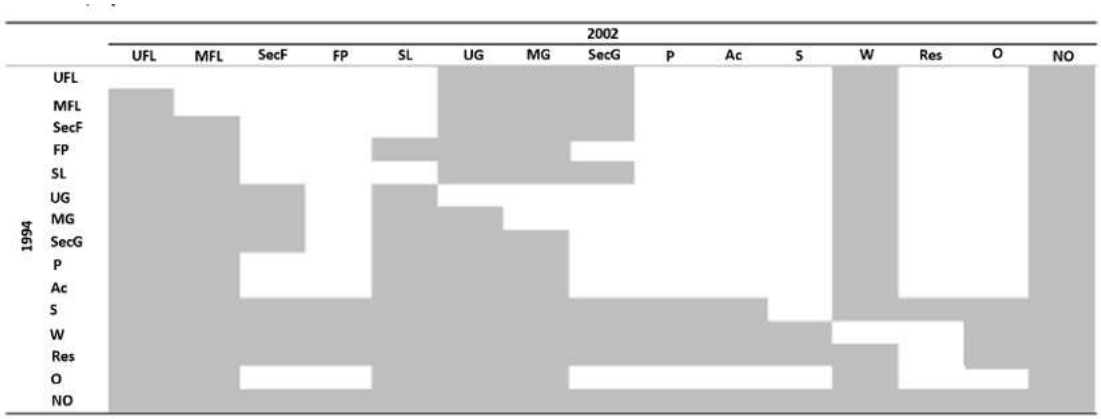
Note: The cumulative relative share (%) of each land-use and land-cover class in relation to the total area of each biome is in parentheses.

Dataframe A.VII.2. Land-use and land-cover conversion matrix model considered in the inventory.



Some conversions are impossible in terms of emissions, even if they are possible in terms of land use and land cover. Dataframe A.VII.3 shows the impossible conversions for calculating GHG emissions.

Dataframe A.VII.3. Impossible (in gray) and possible (in white) land-use and land-cover conversions in terms of GHG emissions.



Note: In this representation, the "C" category includes the "PER" and "SUGARCANE" classes; the "O" category includes the "Min", "BS", "URO", "MRO", "MD", "UD" classes; and the "G" category also refers to the "OWL" classes.

A.VII.2. Mapping of land use and land cover and generation of land-use and land-cover matrices

Map of past natural vegetation and its carbon stocks

The map of past natural vegetation includes the distribution of phytophysiognomies of all Brazilian biomes – according to the IBGE classification (2012) – disregarding human intervention and occupation. In the inventory of the Fourth National Communication, a more up-to-date and accurate base was used, the result of the vegetation map made available by IBGE (2017) on a scale of 1:250,000. Based on this map, adjustments were made by the Brazilian Forest Service (SFB) (BRASIL, 2019) to the anthropized areas. Complementary adjustments, for greater detailing of the vegetation classes, were implemented based on a comparison with the map of past natural vegetation used in the inventory of the Third National Communication (1:5.000.000 scale) (BRASIL, 2015) and secondary data on relief[134] (NASA, 2019) – for detailing of montane, submontane and lowland vegetation – and hydrology[135] (ANA – National Water Agency (Agência Nacional de Águas), 2019) – for detailing of alluvial vegetation.

Carbon stock of living biomass and dead organic matter of vegetation

Below are the data and methodology used to estimate biomass and carbon stocks in each biome (the values of which will be presented in Appendix A.VII.3).

Amazon Biome

The map of past natural vegetation developed as part of the inventory of the Fourth National Communication shows 44 different phytophysiognomies making up the Amazon biome, the most representative being the Dense Ombrophilous Forest, which covers around 51% of the biome, and the Open Ombrophilous Forest, which covers 26.93% of the biome (Table A.VII.2).

The values for above-ground living biomass (AGB) were obtained from the map of the Estimating Biomass in the Amazon (EBA, Estimativa de biomassa na Amazônia) project. In order to estimate and generate the above-ground biomass (AGB) map of the Amazon biome, field data, data generated from airborne imaging of the Light Detection and Ranging sensor (LiDAR) sensor and orbital remote sensing data were used (Ometto *et al*., 2023).

The EBA's biomass map represents the current above-ground living biomass, since the LiDAR data was obtained between 2016 and 2017. Thus, the biomass estimates for this period include areas that had already been converted previously and do not necessarily represent the carbon stock of the past natural vegetation contained in these areas. Methodological adjustments were therefore made, as described below, to estimate carbon stocks in these cases (Figure A.VII.13).

The above-ground biomass (AGB) values obtained for the natural areas (without anthropization) and associated with the different phytophysiognomies were used to estimate the past biomass value of the anthropized areas with the given phytophysiognomies. To this end, the map of phytophysiognomies was cross-referenced with the masks of natural areas and anthropized areas, generating two maps. For polygons

[134] With regard to altitude, it was decided to use altitude data from the Shuttle Radar Topographic Mission (SRTM) (NASA, 2019).

[135] This stage consisted of identifying polygons with fluvial influence, based on cross-referencing with vector files of watercourses and artificial water bodies in Brazil (ANA, 2019).

with the presence of natural vegetation, the AGB value was assigned directly from the EBA's map. For the anthropized areas, based on their natural vegetation class, the 75th percentile value of the AGB of the polygons with the presence of natural vegetation of the respective phytophysiognomy mapped in EBA was used (Figure A.VII.13).

The biomass and carbon calculations for all pools were made directly in the PostGisSQL database. To do this, we used AGB data from EBA's map, the phytophysiognomies obtained from the map of past natural vegetation of the Amazon biome and the AGB expansion factors to include the biomass of the other pools (Table A.VII.2).

For the phytophysiognomies in natural areas, which received the values directly from the pixels of the EBA's AGB map, the biomass of the other pools was calculated for each pixel and all of them were converted to carbon, thus obtaining the maximum and minimum carbon values for each pool and phytophysiognomy. Similarly, for the anthropized areas, the other pools were included based on the estimated biomass map and the carbon values were calculated for each of them. The secondary carbon removal and emission factors adopted are described in Table A.VII.8.

For the areas that remained with natural cover in 2016, estimates based on LiDAR data (in green) from the EBA's above-ground biomass map were used. In the areas where there was no longer any natural vegetation (in yellow), the distribution of phytophysiognomies from the past natural vegetation map (source) was used and the associated values were obtained based on the 75th percentile of the above-ground biomass values of the respective phytophysiognomies based on the data of the areas with natural cover. In order to calculate the carbon values for all pools, the AGB values were spatially associated with the respective phytophysiognomies on the map of past natural vegetation and with the respective carbon expansion factors for all biogeochemical pools.

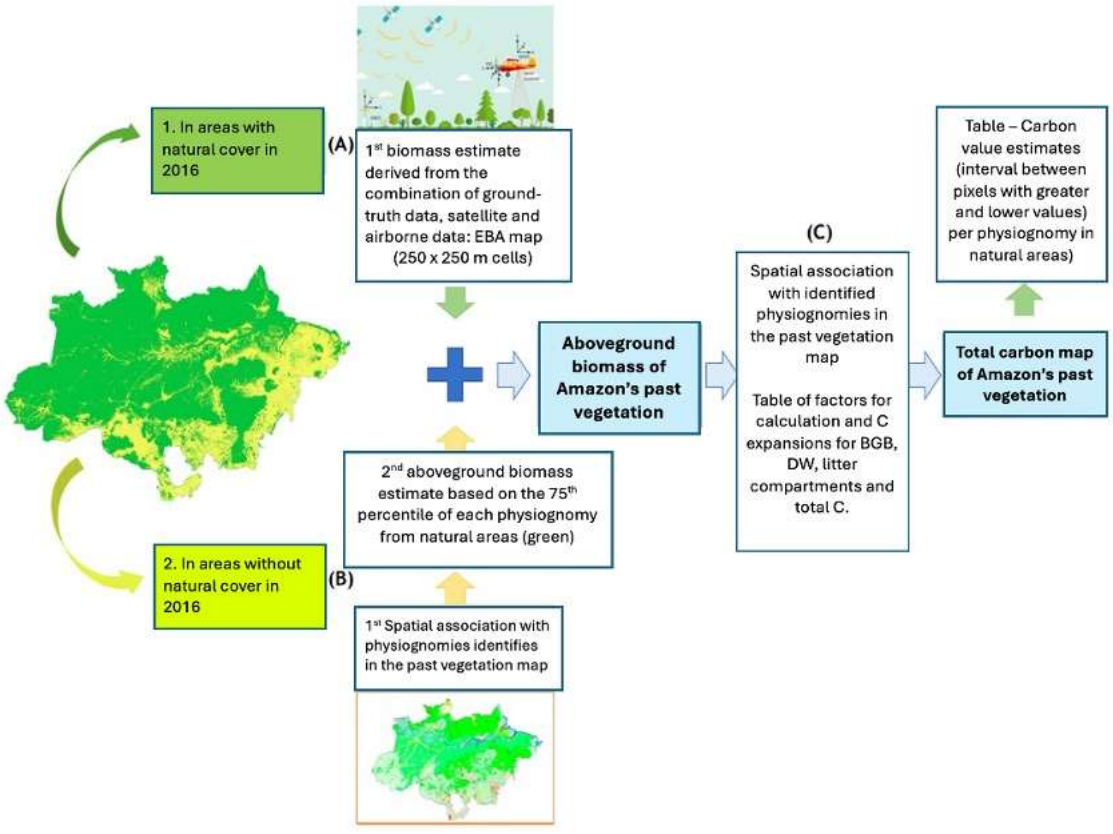


Figure A.VII.13. Methodology for estimating above-ground biomass and carbon

values for reconstructing the map of past natural vegetation in the Amazon biome.

Figure A.VII.14 shows the carbon stock maps (tC/ha) of the Amazon biome for each reservoir, while Figure A.VII.15 shows the sum of all these pools. These maps represent the carbon stock by phytophysiognomy for each reservoir, ranging from the minimum to the maximum value found in the pool.

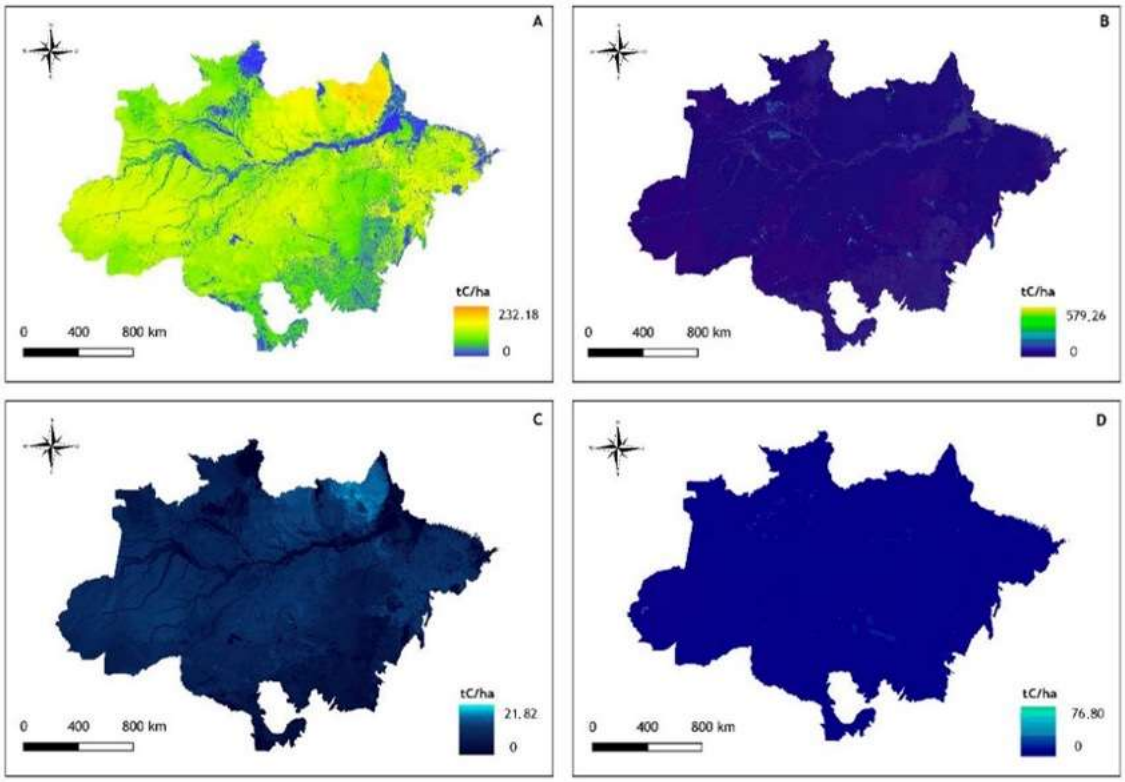


Figure A.VII.14. Carbon stock maps of the different Amazon reservoirs (A – Above ground; B – Below ground; C – Dead wood; and D – Litter).

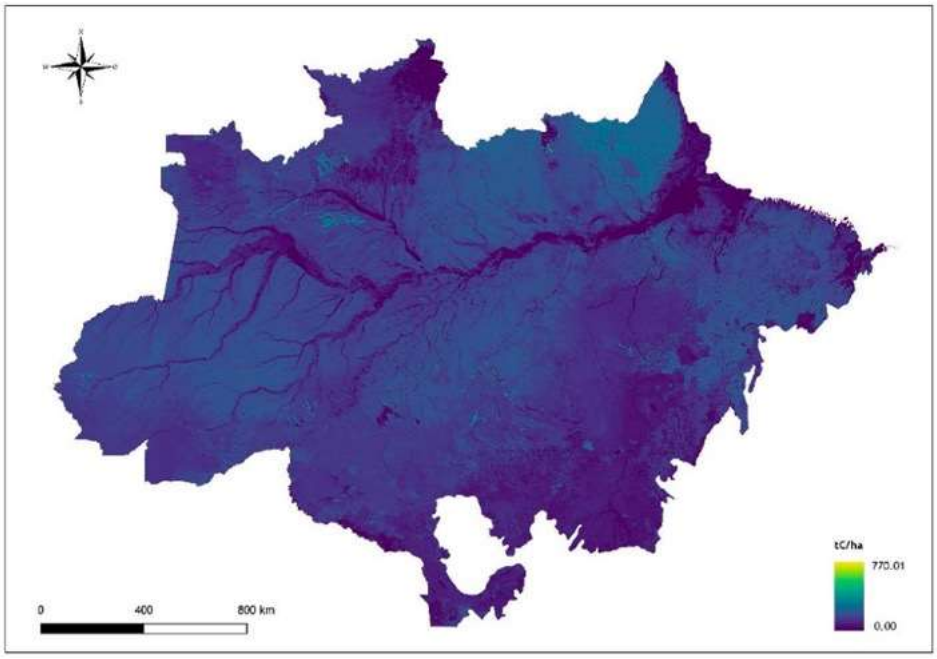


Figure A.VII.15. Map of the total carbon stock (tC/ha) in the Amazon.

Cerrado

The Cerrado biome is of great importance for the stocks and flows of carbon from vegetation to the atmosphere, due to its large territorial extension (approximately 24% of Brazil) and due to the high dynamics of change in land use and land cover in recent decades, mainly land conversion to grassland and cropland (Sano *et al*., 2010; Brasil, 2016; Lahsen *et al*., 2016).

The main improvement in biomass stock estimates in the Cerrado was in the Wooded Savannah (Sa) class, which comprises 48.7% of past natural vegetation (Table A.VII.3). Another important progress was the updating of biomass estimates for the formations for which reference values from other biomes were used (due to the lack of data and information for the biome itself), which represents 14.8% of the past natural vegetation. For the formations whose estimates were based on studies carried out in the Cerrado, with the exception of Wooded Savannah (Sa), the above-ground biomass values obtained in the Inventory drawn up in the Third National Communication were maintained.

In the map of past natural vegetation from the inventory of the Fourth National Communication, some classes are no longer represented in the Cerrado: Dense Montane Ombrophilous Forest (Dm) and Wooded Steppic Savannah (Ea). On the other hand, new classes were included in the biome:

- Formations: Grassy-Woody Steppe (Eg), Alluvial Seasonal Deciduous Forest (Ca), Lowland Dense Ombrophilous Forest (Db) and Alluvial Mixed Ombrophilous Forest (Ma).
- Formations subgroups: Pioneer Formations (P), Savannah (S) and Steppic Savannah (T).
- Transition zones: Ombrophilous Forest/Seasonal Forest Transition (ON), Savannah/Seasonal Forest Transition (SN), Savannah/Ombrophilous Forest Transition (SO), Savannah/Mixed Ombrophilous Forest Transition (SM), Savannah/Steppic Savannah Transition (ST), Savannah/Steppic

Savannah/Seasonal Forest Transition (STN) and Steppic Savannah/Seasonal Forest Transition (TN).

For 22 vegetation classes, single carbon values were considered for the entire biome (Table A.VII.3). As with the Third National Communication inventory, the values for six formations were regionalized by state or groups of states: Forested Savannah (Sd), Montane (Cm) and Submontane (Cs) Seasonal Deciduous Forests, Alluvial (Fa), Lowland (Fb) and Submontane (Fs) Seasonal Semideciduous Forests. For the other classes (Sa, S and transition zones), the values varied according to the location of the polygon. For this reason, the average estimates for these three classes are shown in Table A.VII.3.

Wooded savannah (Sa)

In the Third National Communication inventory, a single biomass and carbon stock value was assigned to wooded Savannah (Sa). In the inventory of the Fourth National Communication, the above-ground tree biomass of Sa was estimated based on the interpolation with regression of biomass data from 150 areas in the Cerrado.

In addition to above-ground tree biomass, the below-ground biomass expansion factor for Sa was updated to 2.04, obtained from the average of estimates in ten areas (DF, GO, MG, BA) (Abdala *et al*., 1998; Castro; Kauffman, 1998; Castro-Neves, 2007; Lilienfein; Wickle, 2003; Miranda, 2012).

Savannah formation subgroup (S)

The average between Forested Savannah (Sd) (which varies according to the state) and Sa was calculated. The Sa value used to compose the average for Savannah (S) was the Sa average of the ecoregion where the polygon is located, according to the Cerrado ecoregions map (Sano *et al.*, 2019).

Transition Zones

For the transition zones, the averages between the vegetation classes were taken into account. The values computed varied according to the location of the polygon. Thus, the estimates varied according to a) ecoregion (Sano et al., 2019) and state, for the transition zones with S; and b) state and altitude, for the transition zones with Mixed Forests (M), Seasonal Forests (N), Ombrophilous Forests (O). This resulted in 139 combinations distributed over the seven transition zones.

In addition to the variation associated with the location of the polygon, the estimates for the transition zones varied according to the type of average used (weighted or simple). The selection of the type of average used depended on the vegetation class of the polygon classified on the map of past natural vegetation from the Third National Communication inventory, and its compatibility with the transition zone class on the map of past natural vegetation used in the inventory of the Fourth National Communication. For example, for a SN transition zone polygon, the classes considered to be compatible were all the formations in the Savannah formation subgroup (Sa, Sd, Sg, Sp) and all the formations in the Seasonal Forest formation subclass (Ca, Cb, Cm, Cs and Fa, Fb, Fm, Fs). The weighted average was used when the sum of the areas of the compatible classes represented 60% or more of the total area of the polygon. When this sum was less than 60%, the simple average was used. The secondary carbon removal and emission factors adopted are described in Table A.VII.8.

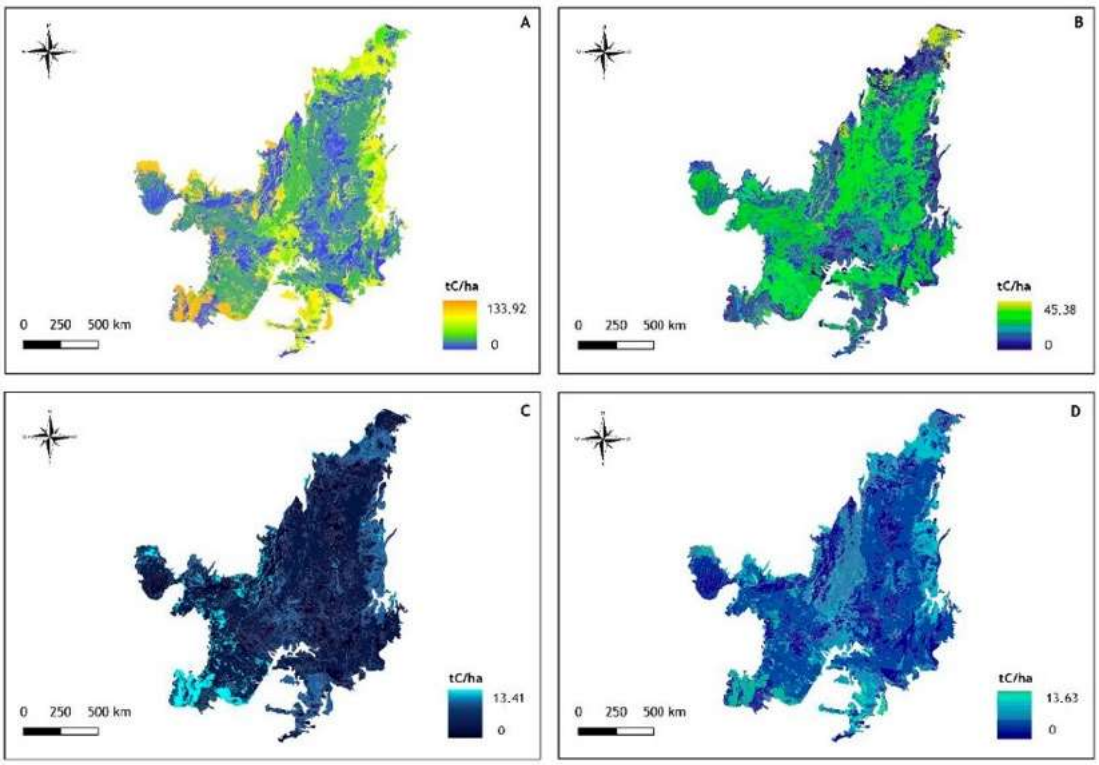


Figure A.VII.16. Carbon stock maps of the different Cerrado reservoirs (A – Above ground; B – Below ground; C – Dead wood; and D – Litter).

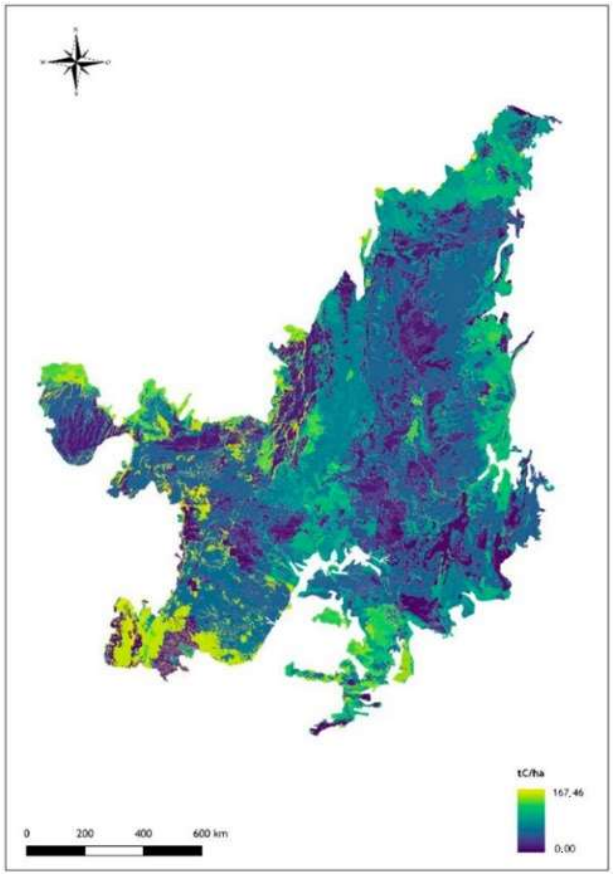


Figure A.VII.17. Map of the Cerrado's total carbon stock.

Note: Figure A.VII.16 shows the carbon stock maps (tC/ha) of the Cerrado for each reservoir, while Figure A.VII.17 shows the total carbon stock. These maps represent the carbon found by phytophysiognomy for each reservoir, ranging from the minimum to the maximum value found in the pool.

Atlantic Forest

The Atlantic Forest is made up of a diversity of native tropical forest formations (ombrophilous and seasonal forests) and associated ecosystems (i.e., mangroves, *restingas* (sand bank vegetation) and highland swamps). The Atlantic Forest is the most anthropized biome in the country, mainly as a result of historical occupation and the establishment of the country's first capitals, which led to the establishment of human activities in the area of this biome from the very beginning, with the development of agricultural production (sugar cane), fruit growing and forest plantation. The biome is made up of many phytophysiognomies, 37 in all, as well as 12 transition zones. The percentage of representativeness of each phytophysiognomy is shown in Table A.VII.4, where the 10 most representative phytophysiognomies are highlighted, which together represent around 78% of the biome.

As a result of the detailing of the past natural vegetation map, 17 new phytophysiognomies are now represented in the biome, compared to the inventory of the Third National Communication (approximately 25% of the biome), namely: Steppe/Mixed Ombrophilous Forest Transition (EM); Campinarana – wooded (La); Campinarana – Grassy-Woody (Lg); Mixed Ombrophilous Forest-Montane (Mm); Seasonal Forest/Mixed Ombrophilous Forest Transition (NM); Seasonal Forest/Pioneer Formations Transition – Specific for Marine-Influenced Pioneer Formation (Restinga) (NP); Ombrophilous Forest/Pioneer Formations Transition – Specific for Marine-Influenced Pioneer Formation (Restinga) (OP); Savannah – Wooded (Sa); Savannah/Ombrophilous Forest Transition (SO); Savannah/Mixed Ombrophilous Forest Transition (SM); Savannah/Seasonal Forest Transition (SN); Steppic Savannah/Seasonal Forest Transition (TN); Ombrophilous Forest/Seasonal Forest Transition (ON); Savannah/Pioneer Formation Transition – Specific for Marine-Influenced Pioneer Formation (Restinga) (ST); Dense Ombrophilous Forest/Mixed Ombrophilous Forest Transition (OM); Steppe/Seasonal Forest Transition (EN); Savannah/Seasonal Forest Transition (SN).

For these new phytophysiognomies, the biomass and carbon values were based on similar vegetation in studies conducted in the same or in other biomes, or on the values of the dominant classes. Table A.VII.4 consolidates the total carbon stock values and those for the different pools for the Atlantic Forest phytophysiognomies, the references and the methodology used to determine the biomass and carbon stocks by phytophysiognomy. The secondary carbon removal and emission factors adopted are described in Table A.VII.8.

There were cases in which, for the Atlantic Forest, different values of below-ground carbon stocks were assigned to the same phytophysiognomy, depending on the region where it is located, such as the Northeast Region (NE) and Other Regions (OR). This is due to the great heterogeneity of the Atlantic Forest remnants, the fragmentation process and its deleterious effects (Tabarelli *et al.*, 2006).

Figure A.VII.18 shows the carbon stock maps (tC/ha) of the Atlantic Forest for each reservoir, while Figure A.VII.19 shows the total carbon stock. These maps represent the carbon found by phytophysiognomy for each reservoir, ranging from the minimum to the maximum value found in the pool.

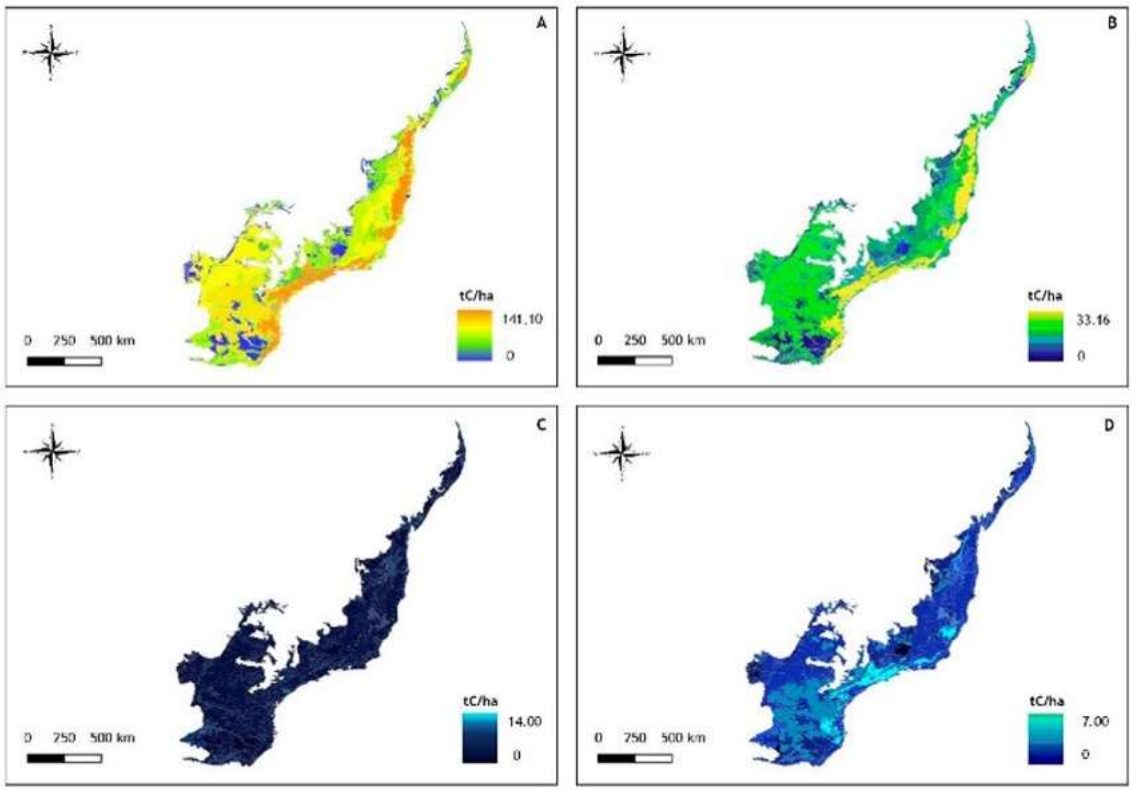


Figure A.VII.18. Carbon stock maps of the different Atlantic Forest reservoirs (A – Above ground; B – Below ground; C – Dead wood; and D – Litter).

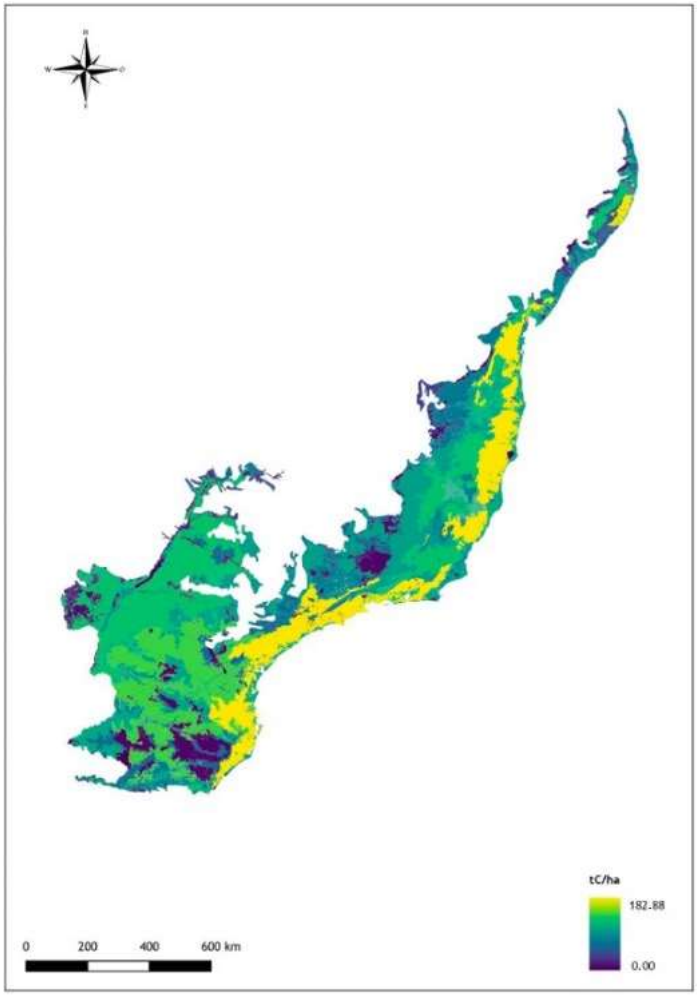


Figure A.VII.19. Map of the total carbon stock of the Atlantic Forest.

Caatinga

The Caatinga, located in the Northeast region, has the steppic savannah as its main vegetation type. The biome is located in a semi-arid climate, with irregular rainfall concentrated in a few months during the year, marked by high evapotranspiration, which determines the presence of plant structures related to adaptation to water deficiency. The soils are highly diverse and vary in depth and texture (Sampaio, 2010).

On the map of past natural vegetation, the original biome has 30 phytophysiognomies, 99.4% of forest land and 0.5% of grassland. The percentage representation of each phytophysiognomy is shown in Table A.VII.5, with emphasis on those that together represent around 89% of the biome.

As a result of the detailing of the past natural vegetation map, seven new phytophysiognomies were represented in the biome (in relation to the Third National Communication inventory), which represent approximately 13% of the biome: Open Ombrophilous Forest – Alluvial (Aa), Seasonal Deciduous Forest – Alluvial (Ca), Alluvial Ombrophilous Dense Forest (Da), Montane Ombrophilous Dense Forest (Dm), Savannah/Forest Transition (SN), Savannah/Pioneer Formation Transition – Specific for Marine-Influenced Pioneer Formation (Restinga) (ST) and Savannah/Seasonal Forest Transition (TN). The High Mountain Refuge phytophysiognomy (RL), included in the inventory

of the Third National Communication, was not observed in the map of past natural vegetation in the inventory of the Fourth National Communication.

For these new phytophysiognomies, the biomass and carbon values were based on similar vegetation in studies conducted in the same or in other biomes, or on the values of the dominant classes. Table A.VII.5 consolidates the total carbon stock values and those for the different pools for the Caatinga phytophysiognomies, as well as the references and methodologies used to determine the biomass and carbon stocks by phytophysiognomy. The secondary carbon removal and emission factors adopted are described in Table A.VII.8.

Figure A.VII.20 shows the carbon stock maps (tC/ha) of the Caatinga for each reservoir, while Figure A.VII.21 shows the total carbon stock. These maps represent the carbon found by phytophysiognomy for each reservoir, ranging from zero to the maximum value found in the pool.

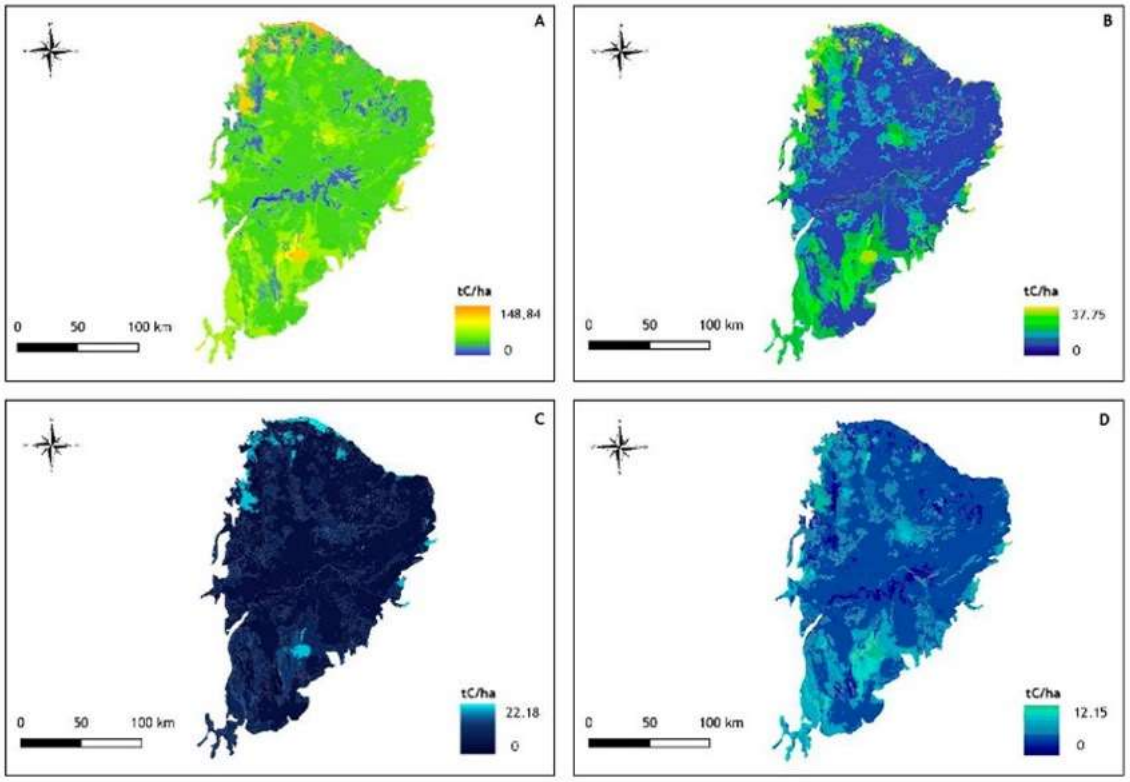


Figure A.VII.20. Carbon stock maps of the different Caatinga reservoirs (A – Above ground; B – Below ground; C – Dead wood; and D – Litter).

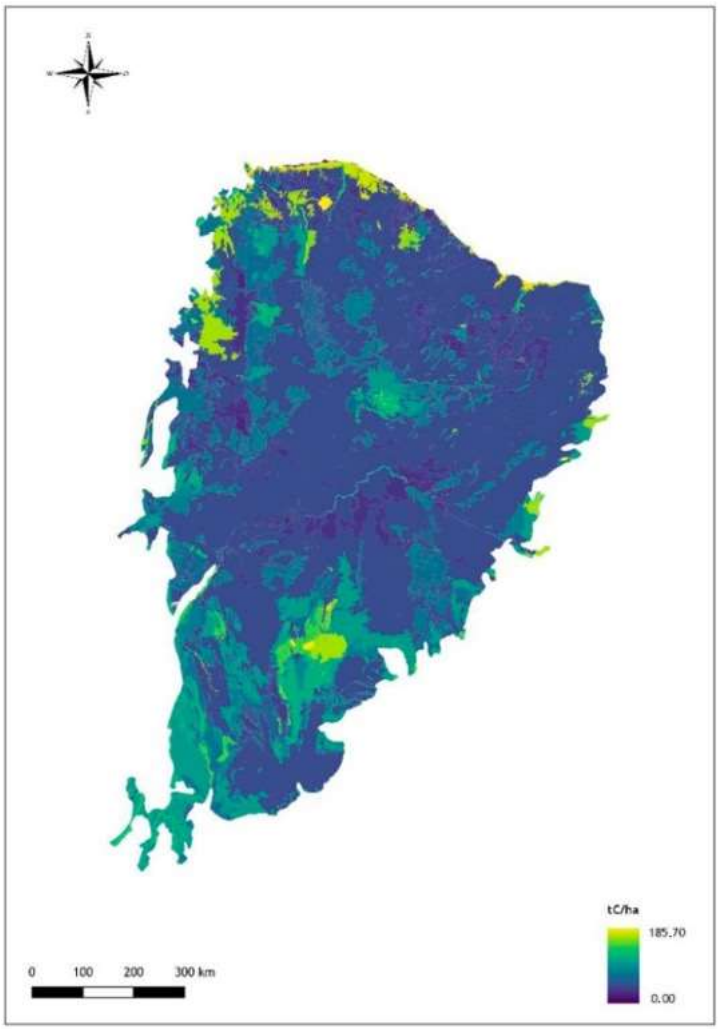


Figure A.VII.21. Map of the total carbon stock of the Caatinga.

Pampa

The Pampa is represented by a large mosaic of vegetation with predominantly forest and savannah formations. It has a total of 33 phytophysiognomies, of which forest land represents 63% and grassland represents 27.6% of the biome's past natural vegetation. In addition, the water class occupies 9.4% of the biome. The percentage representation of each phytophysiognomy is shown in Table A.VII.6.

Some phytophysiognomies still have no data in the literature regarding their carbon stocks. Therefore, in these cases, biomass values obtained for other biomes were used for the Pampa.

As a result of the detailing of the map of past natural vegetation obtained in the inventory of the Fourth National Communication, 19 phytophysiognomies were added compared to the previous edition (approximately 19% of the biome), namely: Seasonal Deciduous Forest – Lowlands (Cb), Dense Ombrophilous Forest – Alluvial (Da), Dense Ombrophilous Forest – Lowlands (Db), Dense Ombrophilous Forest – Montane (Dm), Dunes (Dn), Steppe (E), Park Steppe (Ep), Steppe/Mixed Ombrophilous Forest Transition (EM), Steppe/Seasonal Forest Transition (EN), Steppe/Formations Transition (EP), Seasonal Semideciduous Forest – Alluvial (Fa), Mixed Ombrophilous Forest – Alluvial (Ma), Seasonal Forest/Mixed Ombrophilous Forest Transition (NM), Seasonal Forest/Pioneer Formations Transition

(Specific for Marine-Influenced Pioneer Formation, Restinga) (NP), Dense Ombrophilous Forest/Mixed Ombrophilous Forest Transition (OM), Ombrophilous Forest/Pioneer Formation Transition (Specific for Marine-Influenced Pioneer Formation, Restinga) (OP), Pioneer Formation Areas (P), Steppic Savannah (T) and Steppic Savannah – Park (TP).

For these new phytophysiognomies, the biomass and carbon values were based on similar vegetation in studies conducted in other biomes, or on the values of the dominant classes. On the other hand, the phytophysiognomy named "Montane Mixed Ombrophilous Forest (Mm)" was excluded, but its values were used as the basis for the new class, named "Mixed Ombrophilous Forest – Submontane (Ms).

Table A.VII.6 consolidates the total carbon stock values and those for the different pools for the Pampa phytophysiognomies, as well as the references and methodologies used to determine the biomass and carbon stocks by phytophysiognomy. The secondary carbon removal and emission factors adopted are described in Table A.VII.8.

Figure A.VII.22 shows the carbon stock maps (tC/ha) of the Pampa for each reservoir, while Figure A.VII.23 shows the total carbon stock. These maps represent the carbon found by phytophysiognomy for each reservoir, ranging from the minimum to the maximum value found in the pool.

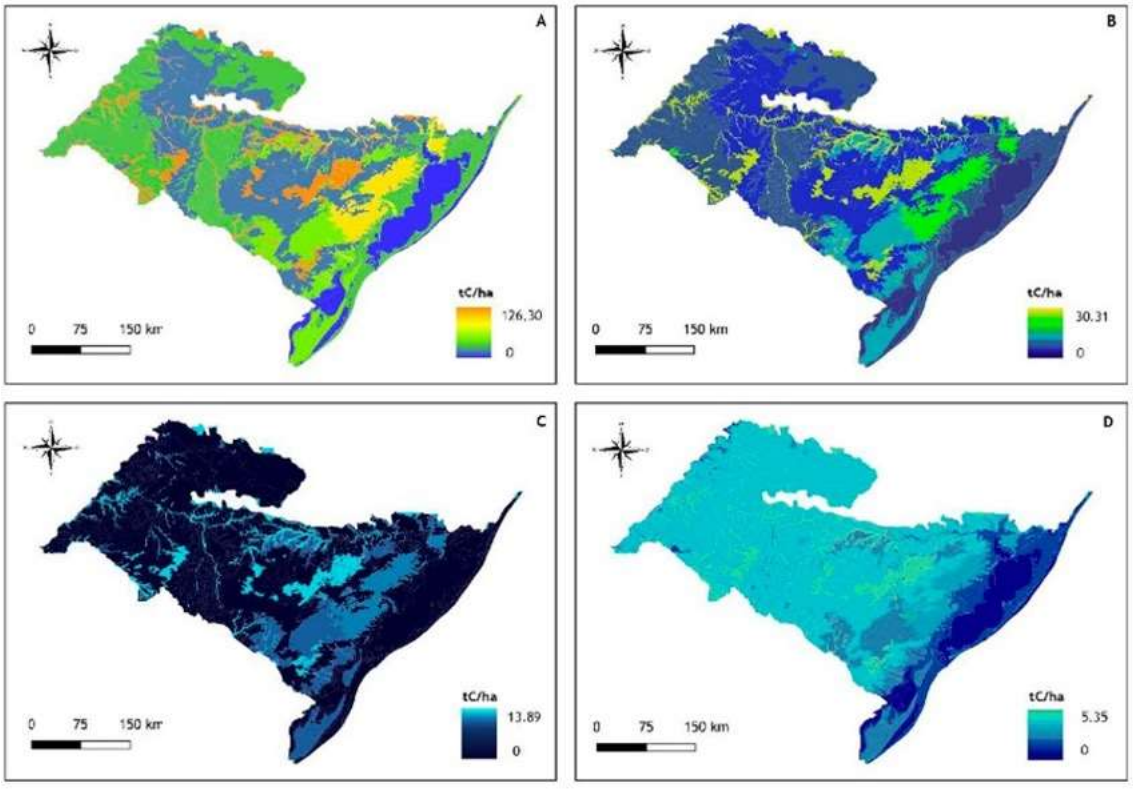


Figure A.VII.22. Carbon stock maps of the different Pampa reservoirs (A – Above ground; B – Below ground; C – Dead wood; and D – Litter).

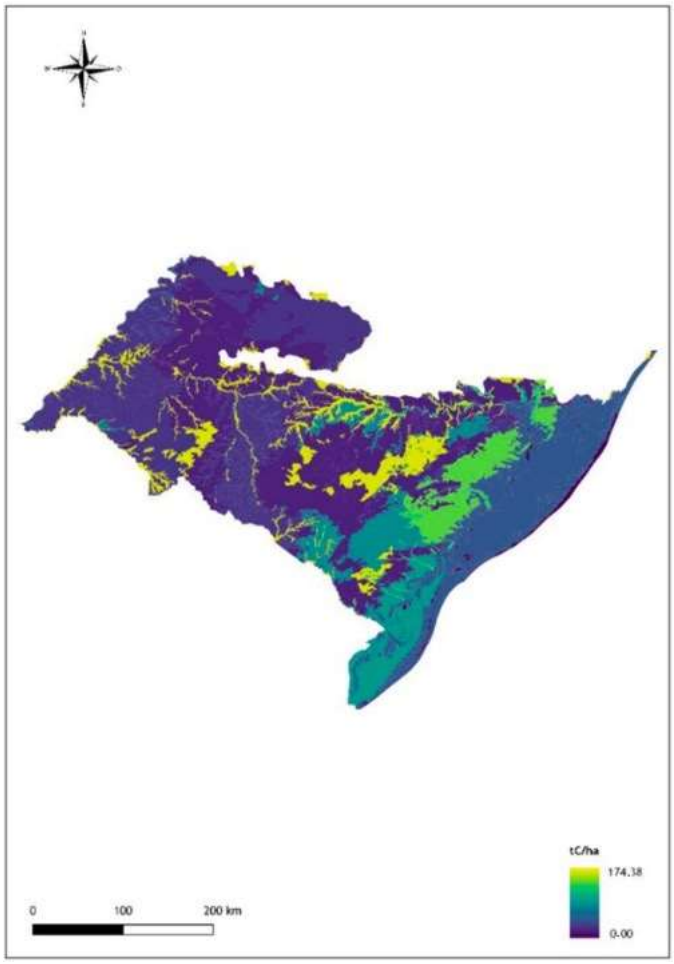


Figure A.VII.23. Map of the total carbon stock of the Pampa**.**

Pantanal

The Pantanal is represented by a large mosaic of vegetation with forest land, savannah and grassland formations, as well as vegetation with fluvial influence (floodplains). The original biome has 19 phytophysiognomies, 77% of which are forest land and 21% are grassland. In addition, the water class occupies around 2% of the biome. The percentage representation of each phytophysiognomy is shown in Table A.VII.7.

Pantanal is related to the Chaco to the south, the Amazon Rainforest to the north, and the Atlantic Rainforest and Cerrado to the south and east of the biome. Therefore, some biomass values obtained for these biomes were used for the Pantanal, when data from the literature or field data from the Pantanal itself were unavailable.

As a result of the detailing of the map of past natural vegetation obtained in the preparation of the inventory of the Fourth National Communication, five phytophysiognomies were added in relation to the inventory of the Third National Communication (approximately 1.3% of the biome): Savannah (S), Steppic Savannah (T), Savannah/Seasonal Forest Transition (SN), Savannah/Steppic Savannah Transition (ST), Steppic Savannah/Seasonal Forest Transition (TN). For these new phytophysiognomies, the biomass and carbon values were based on similar vegetation in studies conducted in other biomes, or on the values of the dominant classes.

On the other hand, the phytophysiognomy named "Fluvial and/or Lacustrine Influenced Vegetation (Pa)" was excluded, but its values were used as the basis for the new class, named Savannah/Steppic Savannah Transition (ST). Table A.VII.7 consolidates the total carbon stock values and those for the different pools (above-ground biomass, below-ground biomass, standing dead wood and litter) for the Pantanal phytophysiognomies, references and methodology used to determine the biomass and carbon stocks, by phytophysiognomy. The secondary carbon removal and emission factors adopted are described in Table A.VII.8.

Figure A.VII.24 shows the carbon stock maps (tC/ha) of the Pantanal for each reservoir, while Figure A.VII.25 shows the total carbon stock. These maps represent the carbon found by phytophysiognomy for each reservoir, ranging from zero to the maximum value found in the pool.

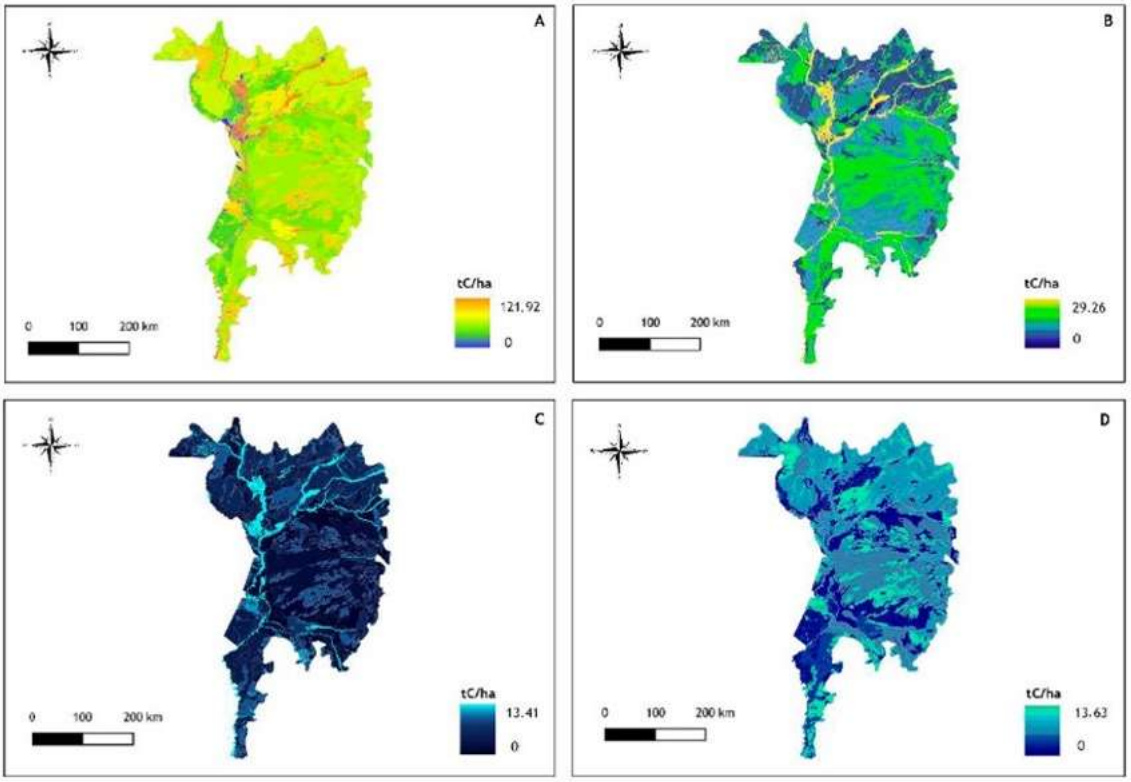


Figure A.VII.24. Carbon stock maps of the different Pantanal reservoirs (A – Above ground; B – Below ground; C – Dead wood; and D – Litter).

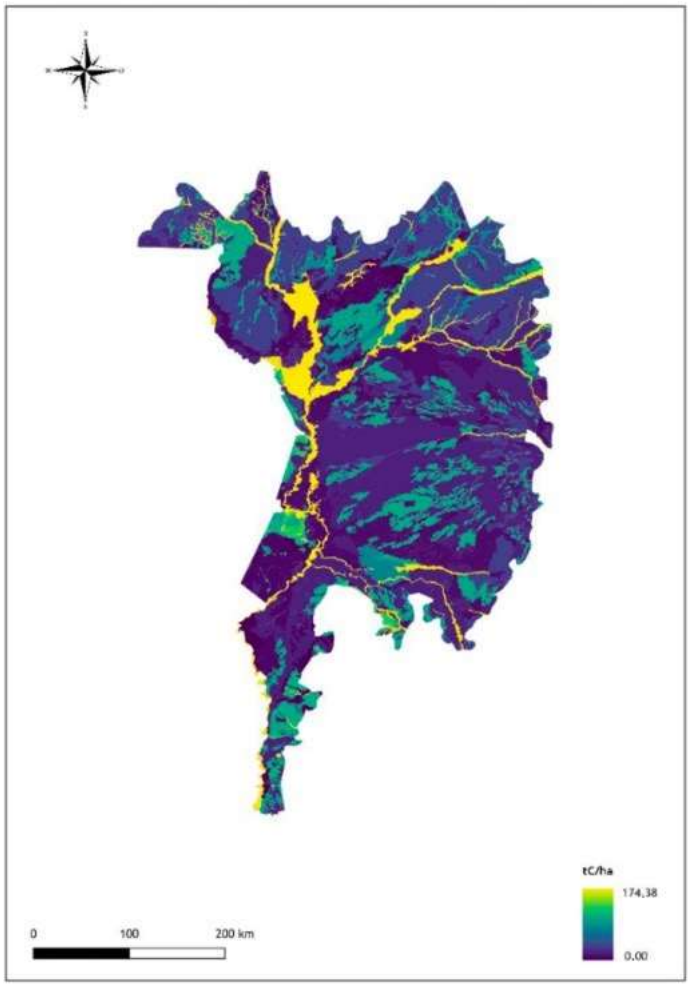


Figure A.VII.25. Map of the Pantanal's total carbon stock.

A.VII.3. Complementary tables on carbon stocks and emission and removal factors

Table A.VII.2. Carbon stocks of the phytophysiognomies of the Amazon biome.

Phytophysiognomy Acronym/Name	% in biome	Category	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Below-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock		Littler carbon stock /Methodology/reference for the calculation of biomass/stock		Total Stock
			(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
Aa/Open Ombrophilous Forest – Alluvial	2.30	FL	117.3 (0.47-172)	Values calculated based on AGB (EBA)	11.7 (0.05-17.2)	Expansion factor of 0.1 for non-dense forest (Nogueira *et al*., 2008)	9.5 (0.04-13.9)	Expansion factor of 0.081 for non-dense forest (Nogueira *et al*., 2008)	6.8 (0.03-9.93)	Expansion factor of 0.059 for non-dense forest (Nogueira *et al*., 2008)	145.3 (0.58-213)
Ab/Open Ombrophilous Forest – Lowlands	9.75	FL	133.9 (0.47-155)	Same as	13.4 (0.05-15.5)	Expansion factor of 0.1 for non-dense forest (Nogueira *et al*., 2008)	10.9 (0.04-12.6)	Expansion factor of 0.081 for non-dense forest (Nogueira *et al*., 2008)	7.7 (0.03-8.96)	Expansion factor of 0.059 for non-dense forest (Nogueira *et al*., 2008)	165.9 (0.58-192)
As/Open Ombrophilous Forest – Submontane	14.35	FL	106.5 (0-198)	Same as	10.7 (0-19.8)	Expansion factor of 0.1 for non-dense forest (Nogueira *et al*., 2008)	8.6 (0-16.0)	Expansion factor of 0.081 for non-dense forest (Nogueira *et al*., 2008)	6.2 (0-11.4)	Expansion factor of 0.059 for non-dense forest (Nogueira *et al*., 2008)	132.0 (0-245)
Cb/Seasonal Deciduous Forest – Lowlands	0.02	FL	47.7 (0.94-85)	Same as	4.8 (0.09-8.5)	Expansion factor of 0.1 for non-dense forest (Nogueira *et al*., 2008)	3.9 (0.08-6.89)	Expansion factor of 0.081 for non-dense forest (Nogueira *et al*., 2008)	2.8 (0.05-4.91)	Expansion factor of 0.059 for non-dense forest (Nogueira *et al*., 2008)	59.1 (1.16-105)
Cs/Seasonal Deciduous Forest – Submontane	0.19	FL	104.8 (0.47-141)	Same as	10.5 (0.05-14.1)	Expansion factor of 0.1 for non-dense forest (Nogueira *et al*., 2008)	8.5 (0.04-11.4)	Expansion factor of 0.081 for non-dense forest (Nogueira *et al*., 2008)	6.1 (0.03-8.11)	Expansion factor of 0.059 for non-dense forest (Nogueira *et al*., 2008)	129.8 (0.58-174)
Da/Ombrophilous Dense Forest – Alluvial	4.84	FL	90.5 (0.47-223)	Same as	28.1 (0.15-69.2)	Expansion factor of 0.31 for dense forest (Nogueira *et al*., 2008)	8.5 (0.04-21.0)	Expansion factor of 0.094 for non-dense forest (Nogueira *et al*., 2008)	3.6 (0.02-8.96)	Expansion factor of 0.041 for non-dense forest (Nogueira *et al*., 2008)	130.7 (0.68-322)
Db/Dense Ombrophilous Forest – Lowlands	22.77	FL	128.3 (0-202)	Same as	39.8 (0-62.5)	Expansion factor of 0.31 for dense forest (Nogueira *et al*., 2008)	12.1 (0-19.0)	Expansion factor of 0.094 for non-dense forest (Nogueira *et al*., 2008)	5,2 (0-9.09)	Expansion factor of 0.041 for non-dense forest (Nogueira *et al*., 2008)	185.3 (0-291)
Dm/Dense Ombrophilous Forest – Montane	0.93	FL	96.0 (0.94-181)	Same as	29.8 (0.29-56.2)	Expansion factor of 0.31 for dense forest (Nogueira *et al*., 2008)	9.0 (0.09-17.1)	Expansion factor of 0.094 for non-dense forest (Nogueira *et al*., 2008)	3.9 (0.04-7.28)	Expansion factor of 0.041 for non-dense forest (Nogueira *et al*., 2008)	138.7 (1.36-262)
Ds/Dense Ombrophilous Forest – Submontane	23.67	FL	139.3 (0-243)	Same as	43.2 (0-75.5)	Expansion factor of 0.31 for dense forest (Nogueira *et al*., 2008)	13.1 (0-22.9)	Expansion factor of 0.094 for non-dense forest (Nogueira *et al*., 2008)	5.6 (0-9.77)	Expansion factor of 0.041 for non-dense forest (Nogueira *et al*., 2008)	201.1 (0-352)
Fa/Seasonal Semideciduous Forest – Alluvial	0.18	FL	53.0 (0-125)	Same as	5.3 (0-12.4)	Expansion factor of 0.1 for non-dense forest (Nogueira *et al*., 2008)	4.3 (0-10.1)	Expansion factor of 0.081 for non-dense forest (Nogueira *et al*., 2008)	3.1 (0-7.19)	Expansion factor of 0.059 for non-dense forest (NOGUEIRA et al., 2008)	65.6 (0-154)
Fb/Seasonal Semideciduous Forest -	0.50	FL	66.0 (0.47-101)	Same as	6.6 (0.05-	Expansion factor of 0.1 for non-dense forest	5.3 (0.04-8.19)	Expansion factor of 0.081 for non-dense forest	3.8 (0.03-5.84)	Expansion factor of 0.059 for non-dense	81.7 (0.58-125)

Phytophysiognomy Acronym/Name	% in biome	Category	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Below-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock		Littler carbon stock /Methodology/reference for the calculation of biomass/stock		Total Stock
			(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
Lowlands					10.1)	(Nogueira *et al.*, 2008)		(Nogueira *et al.*, 2008)		forest (Nogueira *et al.*, 2008)	
Fm/Seasonal Semideciduous Forest – Montane	0.02	FL	101.5 (1.41-136)	Same as	10.2 (0.14-13.6)	Expansion factor of 0.1 for non-dense forest (Nogueira *et al.*, 2008)	8.2 (0.11-11.0)	Expansion factor of 0.081 for non-dense forest (Nogueira *et al.*, 2008)	5.9 (0.08-7.87)	Expansion factor of 0.059 for non-dense forest (Nogueira *et al.*, 2008)	125.8 (1.75-169)
Fs/Seasonal Semideciduous Forest – Submontane	4.53	FL	71.7 (0-140)	Same as	7.2 (0-14)	Expansion factor of 0.1 for non-dense forest (Nogueira *et al.*, 2008)	5.8 (0-11.3)	Expansion factor of 0.081 for non-dense forest (Nogueira *et al.*, 2008)	4.1 (0-8.06)	Expansion factor of 0.059 for non-dense forest (Nogueira *et al.*, 2008)	88.9 (0-172)
La/Campinarana – Wooded	0.58	FL	100.8 (1.41-166)	Same as	181.5 (2.54-299)	Expansion factor of 1.8 in campinarana (low bana) (Bongers *et al.*, 1985)	11.1 (0.16-18.3)	Expansion factor of 0.11 (IPCC, 2003, tab. 3.2.2)	9.3 (0.13-15.3)	Expansion factor of 0.094 - litter/AGB (grassy-woody) (Barbosa; Ferreira, 2004)	302.7 (4.23-498)
Lb/Campinarana – Shrub	0.30	OWL	68.8 (4.23-150)	Same as	114.2 (7.0-249)	Expansion factor of 1.66 (BGB:AGB) grassland (IPCC 2006, tab. 6.1)	0	Considered not significant	6.3 (0.39-13.8)	Expansion factor of 0.094 - litter/AGB (grassy-woody) (Barbosa; Ferreira, 2004)	189.3 (11.6-413)
Ld/Campinarana – Forested	3.07	FL	104.4 (1.41-153)	Same as	12.5 (0.17-18.4)	Expansion factor of 0.12 (Woortmann *et al.*, 2018)	8.5 (0.11-12.4)	Expansion factor of 0.081 for non-dense forest (Nogueira *et al.*, 2008)	6.2 (0.08-9.15)	Expansion factor of 0.061 (Woortmann *et al.*, 2018)	131.6 (1.78-193)
Lg/Campinarana – Grassy-Woody	0.41	G	37.8 (1.41-144)	Same as	62.7 (2.34-240)	Expansion factor of 1.66 (BGB:AGB) grassland (IPCC, 2006, tab. 6.1)	0	Considered not significant	20.5 (0.77-78.3)	Expansion factor of 0.64 - litter/AGB (Open Bana) (Bongers *et al.*, 1985)	121.0 (4.52-462)
Pa/Fluvial and/or Lacustrine-Influenced Vegetation	1.67	OWL	38.4 (0-184)	Same as	14.2 (0-68.0)	Expansion factor of 0.37 for tropical moist forest (IPCC, 2006, tab. 4.4)	4.2 (0-20.2)	Expansion factor of 0.11 (IPCC, 2003, tab. 3.2.2)	1.4 (0-6.64)	Expansion factor of 0.037 (IPCC, 2006, chap. 2, tab. 2.2)	58.2 (0-279)
Pf/Fluviomarine-influenced Pioneers (mangrove)	0.44	FL	25.8 (0.47-126)	Same as	9.6 (0.17-46.6)	Expansion factor of 0.37 for tropical moist forest (IPCC, 2006, tab. 4.4)	2.8 (0.05-13.9)	Expansion factor of 0.11 (IPCC, 2003, tab. 3.2.2)	0.04 (0.00-0.20)	Expansion factor of 0.0016 - litter/AGB (Assis *et al.* 2011, IPCC, 2006)	38.3 (0.70-187)
Pm/Marine-influenced Pioneers (restinga [sand-bank vegetation])	0.001	FL	23.5 (0.94-53)	Same as	8.7 (0.35-19.5)	Expansion factor of 0.37 (IPCC, 2006, chap. 4, tab. 4.4)	2.6 (0.10-5.79)	Expansion factor of 0.11 (IPCC, 2003, tab. 3.2.2)	0.04 (0.001-0.08)	Expansion factor of 0.0016 - litter/AGB (Assis *et al.* 2011, IPCC, 2006)	34.8 (1.39-78)
Rm/Mountain refuge	0.09	OWL	72.5 (0.94-148)	Same as	7.25 (0.09-14.8)	Expansion factor of 0.1 for non-dense forest (Nogueira *et al.*, 2008)	0	Considered not significant	10.5 (0.14-21.4)	Expansion factor of 0.15 (Barbosa; Fearnside, 1999)	90.2 (1.17-184)

Phytophysiognomy Acronym/Name	% in biome	Category	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Below-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock		Littler carbon stock /Methodology/reference for the calculation of biomass/stock		Total Stock
			(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
Sa/Savannah – Wooded	1.10	FL	55.9 (0-187)	Same as	114.0 (0-382)	Expansion factor of 2.04 (BGB:AGB) Shrublands (Miranda *et al.*, 2014)	0.2 (0-0.65)	Expansion factor of 0.0035 - standing and fallen dead wood/AGB (Barbosa; Fearnside, 2005	3.0 (0-10.1)	Expansion factor of 0.055 - leaf and litter/AGB (Barbosa; Fearnside, 2005)	173.1 (0-579)
Sd/Savannah – Forested	1.51	FL	100.4 (0-180)	Same as	22.1 (0-39.7)	Expansion factor of 0.22 (BGB:AGB) Shrublands (Miranda *et al.*, 2014)	11.1 (0-19.9)	Expansion factor of 0.11 (IPCC, 2003, tab. 3.2.2)	16.3 (0-29.3)	Expansion factor of 0.17 - litter/AGB in Cerradão (Forested Savannah) (Morais *et al.*, 2013)	150.0 (0-269)
Sg/Savannah – Grassy-Woody	0.40	G	11.2 (0.47-157)	Same as	37.4 (1.57-523)	Expansion factor of 3.34 (BGB:AGB) Shrublands (Miranda *et al.*, 2014)	0.4 (0.02-6.14)	Expansion factor of 0.037 - standing and fallen dead wood/AGB (Barbosa; Fearnside 2005	0.8 (0.03-10.9)	Expansion factor of 0.082 - leaf and litter/AGB (Barbosa; Fearnside, 2005)	49.8 (2.09-696)
Sp/Savannah – Park	1.50	OWL	25.7 (0.47-197)	Same as	85.8 (1.57-658)	Expansion factor of 3.34 (BGB:AGB) Shrublands (Miranda *et al.*, 2014)	0.8 (0.01-5.83)	Expansion factor of 0.029 - standing and fallen dead wood/AGB (Barbosa; Fearnside, 2005)	1.8 (0.03-13.8)	Expansion factor of 0.072 - leaf and litter/AGB (Barbosa; Fearnside, 2005)	114.0 (2.09-874)
* Ta/Steppic Savannah – Wooded	0.0001	FL	46.4 (1.41-88)	Same as	77.1 (2.34-147)	Expansion factor of 1.66 (BGB:AGB) Shrublands (Miranda *et al.*, 2014)	2.4 (0.07-4.56)	Expansion factor of 0.052 - standing and fallen dead wood/AGB (Barbosa; Fearnside, 2005)	3.0 (0.09-5.74)	Expansion factor of 0.066 - leaf and litter/AGB (Barbosa; Fearnside, 2005)	128.9 (3.91-245)
Td/Steppic Savannah – Forested	0.12	FL	8.7 (0.94-117)	Same as	14.5 (1.56-193)	Expansion factor of 1.66 (BGB:AGB) Shrublands (Miranda *et al.*, 2014)	1.0 (0.10-12.8)	Expansion factor of 0.11 (IPCC 2003, tab. 3.2.2)	0.9 (0.10-12.5)	Expansion factor of 0.11 - litter/AGB (Barbosa; Fearnside, 1999)	25.2 (2.71-335)
* Tg/Steppic Savannah – Grassy-Woody	0.02	G	3.9 (0.94-83)	Same as	13.1 (3.14-276)	Expansion factor of 3.34 (BGB:AGB) Shrublands (Miranda *et al.*, 2014)	0.1 (0.03-2.29)	Expansion factor of 0.026 - standing and fallen dead wood/AGB (Barbosa; Fearnside, 2005)	0.3 (0.08-6.93)	Expansion factor of 0.098 - leaf and litter/AGB (Barbosa; Fearnside, 2005)	17.5 (4.18-368)
Tp/Steppic Savannah – Park	0.07	OWL	6.0 (0.94-100)	Same as	19.9 (3.14-334)	Expansion factor of 3.34 (BGB:AGB) Shrublands (Miranda *et al.*, 2014)	0.1 (0.02-1.63)	Expansion factor of 0.016 - standing and fallen dead wood/AGB (Barbosa; Fearnside, 2005)	0.6 (0.09-9.90)	Expansion factor of 0.101 - standing and fallen dead wood/AGB (Barbosa; Fearnside, 2005)	26.5 (4.18-446)
Am/Open Ombrophilous Forest – Montane	0.0002	FL	31.6 (3.29-63)	Same as	3.2 (0.33-6.35)	Expansion factor of 0.1(BGB:AGB)	2.6 (0.27-5.14)	Expansion factor of 0.081 for non-dense forest (Nogueira *et al.*, 2008)	1.8 (0.19-3.66)	Expansion factor of 0.059 for non-dense forest (Nogueira *et al.*, 2008)	39.2 (4.08-79)

Phytophysiognomy Acronym/Name	% in biome	Category	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Below-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock		Littler carbon stock /Methodology/reference for the calculation of biomass/stock		Total Stock
			(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
Ca/Seasonal Deciduous Forest – Alluvial	0.004	FL	86.9 (14.1-93)	Same as	8.7 (1.41-9.26)	Expansion factor of 0.1 for non-dense forest (Nogueira *et al*., 2008)	7.0 (1.14-7.50)	Expansion factor of 0.081 for non-dense forest (Nogueira *et a*l., 2008)	5.0 (0.81-5.35)	Expansion factor of 0.059 for non-dense forest (Nogueira et al., 2008)	107.7 (17.5-115)
* Rl/High Mountain Refuge	0.001	OWL	62.9 (10.3-87)	Same as	210.1 (34.5-290)	Expansion factor of 3.34 for non-dense forest (Nogueira *et al*., 2008)	0	Considered not significant	9.1 (1.50-12.6)	Expansion factor of 0.15 (Barbosa; Fearnside, 1999)	282.1 (46.4-390)
* Rs/Submontane Refuge	0.0004	OWL	148.7 (4.7-198)	Same as	14.9 (0.47-19.8)	Expansion factor of 0.1 for non-dense forest (Nogueira *et al*., 2008)	0	Considered not significant	21.6 (0.68-28.7)	Expansion factor of 0.15 (Barbosa; Fearnside, 1999)	185.1 (5.85-246)
SP/Savannah/Pioneer Formations Transition – Specific for Marine-Influenced Pioneer Formation (Restinga – Sand-bank vegetation])	0.001	FL	16.0 (2.82-54)	Same as	53.5 (9.42-179)	Expansion factor of 3.34 for non-dense forest (Nogueira *et al*., 2008)	0.6 (0.11-2.10)	Ratio 3.69% - standing and fallen dead wood/AGB ratio: 0.03691874 (Barbosa; Fearnside, 2005)	1.1 (0.20-3.74)	Expansion factor of 0.082 - leaf and litter/AGB (Barbosa; Fearnside, 2005)	71.2 (12.5-238)
SN/Savannah/Seasonal Forest Transition SN	0.43	FL	46.5 (0-118)	Same as	4.7 (0-11.8)	Expansion factor of 0.1 for non-dense forest (Nogueira *et al*., 2008)	3.8 (0-9.59)	Expansion factor of 0.081 for non-dense forest (NOGUEIRA et al., 2008)	2.7 (0-6.84)	Expansion factor of 0.059 for non-dense forest (Nogueira *et al*., 2008)	57.6 (0-147)
SO/Savannah/ Transition	0.39	FL	90.9 (0.47-169)	Same as	28.2 (0.15-52.5)	Expansion factor of 0.31 for non-dense forest (Nogueira *et al*., 2008)	8.5 (0.04-15.9)	Expansion factor of 0.094 for dense forest (Nogueira *et al*., 2008)	3.7 (0.02-6.79)	Expansion factor of 0.041 for non-dense forest (Nogueira *et al*., 2008)	131.2 (0.68-244)
ST/Savannah/Steppic Savannah Transition ST	0.07	FL	11.2 (0.47-87)	Same as	37.3 (1.57-290)	Expansion factor of 3.34 for non-dense forest (Nogueira *et al*., 2008)	0.4 (0.02-3.41)	Expansion factor of 0.037 - standing and fallen dead wood/AGB (Barbosa; Fearnside, 2005)	0.8 (0.03-6.08)	Expansion factor of 0.082 - leaf and litter/AGB (Barbosa; Fearnside, 2005)	49.7 (2.09-387)
TN/Steppic Savannah/ Seasonal Forest Transition TN	0.01	FL	17.9 (0.47-80)	Same as	29.8 (0.78-133)	Expansion factor of 1.6 (BGB:AGB) Shrublands (Miranda *et al*., 2014)	2.0 (0.05-8.79)	Expansion factor of 0.11 (IPCC 2003, tab. 3.2.2)	1.9 (0.05-8.60)	Expansion factor of 0.11 - litter/AGB (Barbosa; Fearnside, 1999)	51.6 (1.35-230)
LO/Campinarana / Ombrophilous Forest Transition LO	0.42	FL	103.1 (1.41-141)	Same as	12.4 (0.17-16.9)	Expansion factor of 0.12 (Woortmann *et al*., 2018)	8.4 (0.11-11.4)	Expansion factor of 0.081 for non-dense forest (Nogueira *et al*., 2008)	6.2 (0.08-8.39)	Expansion factor of 0.061 (Woortmann *et al*., 2018)	130.0 (1.78-177)
ON/Ombrophilous Forest/ Seasonal Forest Transition ON	0.85	FL	47.1 0..88	Same as	4.7 (0-11.3)	Expansion factor of 0.1 for non-dense forest (Nogueira *et al*., 2008).	3.8 (0-9.14)	Expansion factor of 0.081 for non-dense forest (Nogueira *et al*., 2008)	2.7 (0-6.51)	Expansion factor of 0.059 for non-dense forest (Nogueira *et al*., 2008)	58.4 (0-140)

Phytophysiognomy Acronym/Name	% in biome	Category	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Below-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock		Littler carbon stock /Methodology/reference for the calculation of biomass/stock		Total Stock
			(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
T/Steppic Savannah	0.0001	FL	69.6 (21-78)	Same as	115.6 (34.3-130)	Expansion factor of 1.6 (BGB:AGB) Shrublands (Miranda *et al.*, 2014)	3.6 (1.07-4.03)	Expansion factor of 0.052 – standing and fallen dead wood/AGB (Barbosa; Fearnside, 2005)	4.5 (1.35-5.07)	Expansion factor of 0.066 – leaf and litter/AGB (Barbosa; Fearnside, 2005)	193.4 (57.4-217)
S/Savannah	0.01	FL	45.0 (0.94-95)	Same as	91.9 (1.92-195)	Expansion factor of 2.04 (BGB:AGB) Shrublands (Miranda *et al.*, 2014)	0.2 (0.003-0.33)	Expansion factor of 0.0035 - standing and fallen dead wood/AGB (Barbosa; Fearnside, 2005	2.4 (0.05-5.13)	Expansion factor of 0.055 – leaf and litter/AGB (Barbosa; Fearnside, 2005)	139.5 (2.91,296)
P/Pioneer Formation Areas	0.0003	FL	43.9 (2.35-141)	Same as	16.2 (0.87-52.3)	Expansion factor of 0.37 for tropical moist forest (IPCC, 2006, tab. 4.4)	4.8 (0.26-15.6)	Expansion factor of 0.11 (IPCC, 2003, tab. 3.2.2)	1.6 (0.08-5.11)	Expansion factor of 0.037 – litter/AGB (IPCC, 2006, chap. 2, tab. 2.2)	66.6 (3.56-214)
L/Campinarana	0.001	FL	53.2 (1.9-123)	Same as	88.3 (3.12-204)	Expansion factor of 1.66 (BGB:AGB) grasslands (Miranda *et al.*, 2014)	0	Considered not significant	28.9 (1.02-66.9)	Expansion factor of 0.64 – litter/AGB (Open Bana) (Bongers *et al.*, 1985)	170.4 (6.02-394)

Note: Carbon stocks (75th percentile obtained from EBA's AGB map for anthropized areas) per unit of total area (tC/ha) and in the different reservoirs (above-ground biomass – AGB, below-ground biomass – BGB, standing dead wood – DW and litter) of the phytophysiognomies of the Amazon biome. The values in parentheses represent the minimum and maximum carbon stocks. All the carbon stock values for the different reservoirs are from the study site of the Amazon biome. * Indicates the four phytophysiognomies that occur exclusively in natural areas. The highlighted rows (in gray) represent the most representative phytophysiognomies in the biome, which together account for over 75%. Representation of the phytophysiognomy in the biome (%), study site, references and methodology used to calculate biomass/stock. The water class occupies 2.49. FL = Forest Land; G = Grassland; OWL= Other Wooded Land. The highlighted rows (in gray) represent the most representative phytophysiognomies in the biome, which together account for 79.7%. The carbon stock values presented here were obtained using the 75th percentile value of the AGB from EBA's map for natural areas. The sum of the percentage of each phytophysiognomy (% in the biome) is less than 100% due to the water category, which was disregarded. NA – not applicable.

Table A.VII.3. Carbon stocks of the phytophysiognomies of the Cerrado biome.

Phytophysiognomy Acronym/Name	FU/State	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for biomass/stock calculation		Below-ground carbon stock / Methodology/reference for biomass/stock calculation		Dead wood carbon stock / Methodology / reference for biomass/stock calculation		Litter carbon stock / Methodology / reference for biomass/stock calculation		Total Stock
					(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
Aa/Open Ombrophilous Forest – Alluvial	single value	0.05	FL	Amazon	117.29	Same as Alluvial Open Ombrophilous Forest (Aa) of the Amazon	11.73	Same as Alluvial Open Ombrophilous Forest (Aa) of the Amazon	9.50	Same as Alluvial Open Ombrophilous Forest (Aa) of the Amazon	6.77	Same as Alluvial Open Ombrophilous Forest (Aa) of the Amazon	145.3
Ab/Open Ombrophilous Forest – Lowlands	single value	0.05	FL	Amazon	133.92	Same as Lowlands Open Ombrophilous Forest (Ab) of the Amazon	13.39	Same as Lowlands Open Ombrophilous Forest (Ab) of the Amazon	10.85	Same as Lowlands Open Ombrophilous Forest (Ab) of the Amazon	7.73	Same as Lowlands Open Ombrophilous Forest (Ab) of the Amazon	165.89
As/Open Ombrophilous Forest – Submontane	single value	0.21	FL	Cerrado (TO)	71.1	Trees: allometric equation (Brown,1997) applied to plots (98) of this phytophysiognomy (6) and of Dense Ombrophilous Forest (1) (Haidar *et al.*, (2013). Non-dense forest expansion factor for understorey (3.9%), lianas (2.1%) and palm trees (8.6%) (Nogueira *et al.* 2008)	7.11	Expansion factor of 0.10 for non-dense forest (Nogueira *et al.*, 2008)	5.76	Expansion factor of 0.081 for non-dense forest (Nogueira *et al.*, 2008)	4.11	Expansion factor of 0.059 for non-dense forest (Nogueira *et al.*, 2008)	88.08
Ca/Seasonal Deciduous Forest – Alluvial	single value	0.06	FL	Caatinga	88.36	Same as Alluvial Seasonal Deciduous Forest (Ca) of the Caatinga	21.27	Same as Alluvial Seasonal Deciduous Forest (Ca) of the Caatinga	9.75	Same as Alluvial Seasonal Deciduous Forest (Ca) of the Caatinga	2.08	Same as Alluvial Seasonal Deciduous Forest (Ca) of the Caatinga	121.46
Cb/Seasonal Deciduous Forest – Lowlands	single value	0.09	FL	Pantanal	69.38	Same as Lowlands Seasonal Deciduous Forest (Cb) of the Pantanal	16.65	Same as Lowlands Seasonal Deciduous Forest (Cb) of the Pantanal	7.63	Same as Lowlands Seasonal Deciduous Forest (Cb) of the Pantanal	11.21	Same as Lowlands Seasonal Deciduous Forest (Cb) of the Pantanal	104.87
Cm/Seasonal Deciduous Forest – Montane	BA/GO/MG/PI	1.55	FL	Caatinga	31.10	Same as Montane Seasonal Deciduous Forest (Cm) of the Caatinga	11.50	Same as Montane Seasonal Deciduous Forest (Cm) of the Caatinga	4.67	Same as Montane Seasonal Deciduous Forest (Cm) of the Caatinga	4.67	Same as Montane Seasonal Deciduous Forest (Cm) of the Caatinga	51.94

Phytophysiognomy Acronym/Name	FU/State	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for biomass/stock calculation		Below-ground carbon stock / Methodology/reference for biomass/stock calculation		Dead wood carbon stock / Methodology / reference for biomass/stock calculation		Litter carbon stock / Methodology / reference for biomass/stock calculation		Total Stock
					(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
	MS/TO		FL	Pantanal	84.38	Same as Montane Seasonal Deciduous Forest (Cm) of the Pantanal	20.25	Same as Montane Seasonal Deciduous Forest (Cm) of the Pantanal	9.28	Same as Montane Seasonal Deciduous Forest (Cm) of the Pantanal	13.63	Same as Montane Seasonal Deciduous Forest (Cm) of the Pantanal	127.54
Cs/Seasonal Deciduous Forest – Submontane	BA/GO /MA/M G/PI/ TO	4.04	FL	Caatinga	41.4	Same as Submontane Seasonal Deciduous Forest (Cs) of the Caatinga	15.3	Same as Submontane Seasonal Deciduous Forest (Cs) of the Caatinga	6.21	Same as Submontane Seasonal Deciduous Forest (Cs) of the Caatinga	6.1	Same as Submontane Seasonal Deciduous Forest (Cs) of the Caatinga	69.01
	MS/MT /SP		FL	Pantanal	84.38	Same as Submontane Seasonal Deciduous Forest (Cs) of the Pantanal	20.25	Same as Submontane Seasonal Deciduous Forest (Cs) of the Pantanal	9.28	Same as Submontane Seasonal Deciduous Forest (Cs) of the Pantanal	13.63	Same as Submontane Seasonal Deciduous Forest (Cs) of the Pantanal	127.54
Da/Dense Ombrophilous Forest – Alluvial	single value	0.04	FL	Amazon	90.51	Same as Alluvial Dense Ombrophilous Forest (Da) of the Amazon	28.06	Same as Alluvial Dense Ombrophilous Forest (Da) of the Amazon	8.51	Same as Alluvial Dense Ombrophilous Forest (Da) of the Amazon	3.63	Same as Alluvial Dense Ombrophilous Forest (Da) of the Amazon	130.71
Db/Dense Ombrophilous Forest – Lowlands	single value	0	FL	Atlantic Forest	85.73	Same as Lowlands Dense Ombrophilous Forest (Db) of the Atlantic Forest	45.38	Same as Lowlands Dense Ombrophilous Forest (Db) of the Atlantic Forest (see Table A.VII.2)	2.98	Same as Lowlands Dense Ombrophilous Forest (Db) of the Atlantic Forest (see Table A.VII.2)	4.11	Same as Lowlands Dense Ombrophilous Forest (Db) of the Atlantic Forest (see Table A.VII.2)	138.2
Ds/Dense Ombrophilous Forest – Submontane	single value	0.06	FL	Cerrado (TO)	81.99	Trees: allometric equation (Brown,1997) applied to plots (29) of Dense Ombrophilous Forest (Haidar *et al.* 2013). Dense forest expansion factor for understorey (4.3%), lianas (3.4%) and palm trees (1.9%) (Nogueira *et al.*, 2008)	25.42	Expansion factor of 0.31 for dense forest (Nogueira *et al.*, 2008)	7.71	Expansion factor 0.094 for dense forest (Nogueira *et al.*, 2008)	3.29	Expansion factor of 0.041 for dense forest (Nogueira *et al.*, 2008)	118.41
Eg/Steppe – Grassy-Woody	single value	0.01	G	Pampa	0.73	Same as Grassy-Woody Steppe (Eg) of the Pampa	0.77	Same as Grassy-Woody Steppe (Eg) of the Pampa	0	Same as Grassy-Woody Steppe (Eg) of the Pampa	3.63	Same as Grassy-Woody Steppe (Eg) of the Pampa	5.13

Phytophysiognomy Acronym/Name	FU/State	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for biomass/stock calculation (tC/ha)		Below-ground carbon stock / Methodology/reference for biomass/stock calculation (tC/ha)		Dead wood carbon stock / Methodology / reference for biomass/stock calculation (tC/ha)		Litter carbon stock / Methodology / reference for biomass/stock calculation (tC/ha)		Total Stock (tC/ha)
Fa/Seasonal Semideciduous Forest – Alluvial	MA/PA /TO	2.03	FL	Amazon	52.99	Same as Alluvial Seasonal Semideciduous Forest (Fa) of the Amazon	5.3	Same as Alluvial Seasonal Semideciduous Forest (Fa) of the Amazon	4.29	Same as Alluvial Seasonal Semideciduous Forest (Fa) of the Amazon	3.06	Same as Alluvial Seasonal Semideciduous Forest (Fa) of the Amazon	65.64
	BA/GO /MG/P I		FL	Cerrado (MG)	56.89	Trees: average of 30 areas of "Mature Riparian Semideciduous Forest" in MG (Scolforo *et al.*, 2008b)	11.38	Expansion factor of 0.20 for "Tropical Moist Deciduous Forest" with above-ground biomass < 125 ton/ha) (IPCC, 2006a)	6.26	Expansion factor of 0.11 for "Tropical forest" (IPCC, 2003)	1.34	Expansion factor of 0.024 for "mesophilic riparian forest" (Moreira-Burger; Delitti, 1999).	75.86
	PR/SP		FL	Atlantic Forest	58.05	Same as Alluvial Seasonal Semideciduous Forest (Fa) of the Atlantic Forest	13.66	Same as Alluvial Seasonal Semideciduous Forest (Fa) of the Atlantic Forest	2.98	Same as Alluvial Seasonal Semideciduous Forest (Fa) of the Atlantic Forest	5.24	Same as Alluvial Seasonal Semideciduous Forest (Fa) of the Atlantic Forest	79.93
	MS/MT		FL	Pantanal	121.92	Same as Alluvial Seasonal Semideciduous Forest (Fa) of the Pantanal	29.26	Same as Alluvial Seasonal Semideciduous Forest (Fa) of the Pantanal	13.41	Same as Alluvial Seasonal Semideciduous Forest (Fa) of the Pantanal	2.87	Same as Alluvial Seasonal Semideciduous Forest (Fa) of the Pantanal	167.46
Fb/Seasonal Semideciduous Forest – Lowlands	MA/M T	0.05	FL	Amazon	65.98	Same as Lowlands Seasonal Semideciduous Forest (Fb) of the Amazon	6.60	Same as Lowlands Seasonal Semideciduous Forest (Fb) of the Amazon	5.34	Same as Lowlands Seasonal Semideciduous Forest (Fb) of the Amazon	3.81	Same as Lowlands Seasonal Semideciduous Forest (Fb) of the Amazon	81.73
	GO		FL	Atlantic Forest	63.07	Same as Lowlands Seasonal Semideciduous Forest (Fb) of the Atlantic Forest	14.84	Same as Lowlands Seasonal Semideciduous Forest (Fb) of the Atlantic Forest	2.98	Same as Lowlands Seasonal Semideciduous Forest (Fb) of the Atlantic Forest	3.03	Same as Lowlands Seasonal Semideciduous Forest (Fb) of the Atlantic Forest	83.92
	PI		FL	Atlantic Forest			33.4	Same as Lowlands Seasonal Semideciduous Forest (Fb) of the Atlantic Forest					102.48
Fm/Seasonal Semideciduou	BA/PI	1.36	FL	Atlantic Forest	50.48	Same as Montane Seasonal Semideciduous	26.73	Same as Montane Seasonal Semideciduous Forest	2.98	Same as Montane Seasonal Semideciduous	2.42	Same as Montane Seasonal Semideciduous Forest	82.61

Phytophysiognomy Acronym/Name	FU/State	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for biomass/stock calculation (tC/ha)		Below-ground carbon stock / Methodology/reference for biomass/stock calculation (tC/ha)		Dead wood carbon stock / Methodology / reference for biomass/stock calculation (tC/ha)		Litter carbon stock / Methodology / reference for biomass/stock calculation (tC/ha)		Total Stock (tC/ha)
s Forest - Montane						Forest (Fm) of the Atlantic Forest		(Fm) of the Atlantic Forest		Forest (Fm) of the Atlantic Forest		(Fm) of the Atlantic Forest	
	GO/MG/MS/PR/SP/TO		FL	Atlantic Forest			11.88	Same as Montane Seasonal Semideciduous Forest (Fm) of the Atlantic Forest					67.76
Fs/Seasonal Semideciduous Forest – Submontane	BA/MA/PI	2.9	FL	Cerrado (PI, MA)	39.96	Trees: allometric equation (Brown, 1997) applied to plots (38) of Seasonal Semideciduous Forest (Haidar *et al.*, 2008; Françoso *et al.* 2013)	7.99	Expansion factor of 0.20 for tropical moist deciduous forest (with above-ground biomass < 125 ton/ha) (IPCC, 2006a)	4.4	Expansion factor of 0.11 for "Tropical Forest" (IPCC, 2003)	2.58	Expansion factor of 0.066 for Montane Seasonal Semideciduous Forest (Amaro *et al.*, 2013)	54.93
	GO/MG/MS/MT/SP/TO		FL	Atlantic Forest	62.23	Same as Submontane Seasonal Semideciduous Forest (Fs) of the Atlantic Forest	14.64	Same as Submontane Seasonal Semideciduous Forest (Fs) of the Atlantic Forest	2.98	Same as Submontane Seasonal Semideciduous Forest (Fs) of the Atlantic Forest	3.63	Same as Submontane Seasonal Semideciduous Forest (Fs) of the Atlantic Forest	83.48
Ma/Mixed Ombrophilous Forest - Alluvial	single value	0	FL	Atlantic Forest	64.25	Same as Alluvial Mixed Ombrophilous Forest (Ma) of the Atlantic Forest	15.12	Same as Alluvial Mixed Ombrophilous Forest (Ma) of the Atlantic Forest	2.98	Same as Alluvial Mixed Ombrophilous Forest (Ma) of the Atlantic Forest	3.08	Same as Alluvial Mixed Ombrophilous Forest (Ma) of the Atlantic Forest	85.43
Ml/Mixed Ombrophilous Forest – High Montane	single value	0.01	FL	Atlantic Forest	78.82	Same as High Montane Mixed Ombrophilous Forest (Ml) of the Atlantic Forest	18.54	Same as High Montane Mixed Ombrophilous Forest (Ml) of the Atlantic Forest	2.98	Same as High Montane Mixed Ombrophilous Forest (Ml) of the Atlantic Forest	3.78	Same as High Montane Mixed Ombrophilous Forest (Ml) of the Atlantic Forest	104.12
Mm/Mixed Ombrophilous Forest – Montane	single value	0.03	FL	Atlantic Forest	60.11	Same as Montane Mixed Ombrophilous Forest (Mm) of the Atlantic Forest	14.15	Same as Montane Mixed Ombrophilous Forest (Mm) of the Atlantic Forest	2.98	Same as Montane Mixed Ombrophilous Forest (Mm) of the Atlantic Forest	2.88	Same as Montane Mixed Ombrophilous Forest (Mm) of the Atlantic Forest	80.12

Phytophysiognomy Acronym/Name	FU/State	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for biomass/stock calculation		Below-ground carbon stock / Methodology/reference for biomass/stock calculation		Dead wood carbon stock / Methodology / reference for biomass/stock calculation		Litter carbon stock / Methodology / reference for biomass/stock calculation		Total Stock
					(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
ON/Ombrophilous Forest/Seasonal Forest Transition	average value	0.12	FL	Amazon Caatinga Cerrado Atlantic Forest and Pantanal	72.88	Average between Open Ombrophilous Forest and the Seasonal Forest subclass (average between Deciduous and Semideciduous, excluding alluvial formations)	15.48	Average between Open Ombrophilous Forest and the Seasonal Forest subclass (average between Deciduous and Semideciduous, excluding alluvial formations).	6.06	Average between Open Ombrophilous Forest and the Seasonal Forest subclass (average between Deciduous and Semideciduous, excluding alluvial formations)	7.77	Average between Open Ombrophilous Forest and the Seasonal Forest subclass (average between Deciduous and Semideciduous, excluding alluvial formations)	102.18
P/Pioneer Formation	average value	0.00	FL	Amazon	24.64	Average between fluviomarine-influenced Pioneer formations (mangrove) (Pf) and marine-influenced Pioneer formations (restinga) (Pm)	9.12	Average between fluviomarine-influenced Pioneer formations (mangrove) (Pf) and marine-influenced Pioneer formations (restinga) (Pm)	2.71	Average between fluviomarine-influenced Pioneer formations (mangrove) (Pf) and marine-influenced Pioneer formations (restinga) (Pm)	0.04	Average between fluviomarine-influenced Pioneer formations (mangrove) (Pf) and marine-influenced Pioneer formations (restinga) (Pm)	36.51
Pa/Fluvial and/or lacustrine-influenced Pioneer Formation	single value	0.35	OWL	Cerrado	25.63	Trees: allometric equation (Brown, 1997) applied to two veredas (hygrophilous communities, marked by the presence of palm tree species (Mauritia flexuosa) emerging in the wetter zones) (Bahia *et al.*, 2009). Herbaceous component: Value of components "forbs, graminoids, dead" in vereda (FIDELIS *et al.*, 2013)	7.28	Expansion factor of 0.22 of "*Forestland*" (Miranda *et al.*, 2014) applied to the tree component, added to the fixed value obtained under herbaceous vegetation (FIDELIS *et al.*, 2013).	2.29	Expansion factor of 0.11 for "Tropical forest" (IPCC, 2003) applied to the tree component	1.0	Expansion factor of 0.024 for riparian mesophytic forest (Moreira-Burger; DelittiELITTI, 1999) applied to the tree component. Expansion factor of 0.11 for campo limpo (low-grassd savannah) (Ottmar *et al.*, 2001) applied to the herbaceous stratum	36.21
Pf/fluviomarine-influenced Pioneer Formation (mangrove)	single value	0.06	FL	Amazon	25.82	Same as Fluviomarine-influenced Pioneer Formation (mangrove) (Pf) of the Amazon	9.55	Same as Fluviomarine-influenced Pioneer Formation (mangrove) (Pf) of the Amazon	2.84	Same as Fluviomarine-influenced Pioneer Formation (mangrove) (Pf) of the Amazon	0.04	Same as Fluviomarine-influenced Pioneer Formation (mangrove) (Pf) of the Amazon	38.26
Pm/Marine-	single	0.03	FL	Amazon	23.46	Same as Marine-	8.68	Same as Marine-	2.58	Same as Marine-	0.04	Same as Marine-	34.76

Phytophysiognomy Acronym/Name	FU/State	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for biomass/stock calculation		Below-ground carbon stock / Methodology/reference for biomass/stock calculation		Dead wood carbon stock / Methodology / reference for biomass/stock calculation		Litter carbon stock / Methodology / reference for biomass/stock calculation		Total Stock
					(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
influenced Pioneer Formation (restinga)	value					influenced Pioneer Formation (restinga) (Pm) of the Amazon		influenced Pioneer Formation (restinga) (Pm) of the Amazon		influenced Pioneer Formation (restinga) (Pm) of the Amazon		influenced Pioneer Formation (restinga) (Pm) of the Amazon	
Rm/Mountain Refuge	single value	0.09	OWL	Cerrado	4.17	Herbaceous stratum (grasses, dicotyledons and palm trees) of seven campo limpo areas (DF, GO) (Ottmar *et al.*, 2001)	13.94	Expansion factor of 3.34 for "*Grasslands*" (Miranda*et al.*, 2014).	0	A null value was assumed for dead wood, as it is a grassland phytophysiognomy. Fallen dead wood was incorporated into the litter component	0.44	Litter and woody material (diameter < 2.5 cm) from campo limpo (Ottmar *et al.*, 2001)	18.55
S/Savannah	averag e value	1.28	FL	Cerrado Pantanal	26.69	Average between the Wooded Savannah (Sa) (ecoregion's average) and Forested Savannah (Sd) formations	16.94	Average between the Wooded Savannah (Sa) (ecoregion's average) and Forested Savannah (Sd) formations	3.12	Average between the Wooded Savannah (Sa) (ecoregion's average) and Forested Savannah (Sd) formations	4.88	Average between the Wooded Savannah (Sa) (ecoregion's average) and Forested Savannah (Sd) formations	51.63
Sa/Savannah – Wooded	averag e value	48.69	FL	Cerrado	12.03	Trees: interpolation with regression biomass data 150 areas in the Cerrado (Roitmar *et al.*, unpublished)	24.54	Expansion factor of 2.04 obtained with the average of ten areas (Abdala *et al.*, 1998; Castro; Kauffman, 1998; Castro-Neves, 2007; Lilienfein; Wickle, 2003; Miranda, 2012)	1.68	Expansion factor of 0.14 obtained based on the average of estimates of tree biomass ("trees with foliage") and standing dead wood ("trees with foliage") in 18 areas (Ottmar *et al.*, 2001)	3.06	Expansion factor of 0.26 obtained with estimates of 18 areas for litter, grasses and dicotyledons pools (Ottmar *et al.*, 2001)	41.31
Sd/Savannah – Forested	PR/SP	8.53	FL	Cerrado (SP)	46.14	Tree biomass (dbh ≥ 5 cm) of cerradão (SP) estimated by (Pinheiro, 2008)	10.15	Expansion factor of 0.22 for "*Forestlands*" (Miranda *et al.*, 2014)	5.08	Expansion factor of 0.11 for "*Tropical forest*" (IPCC, 2003)	7.45	Expansion factor of 0.165, obtained from estimates in cerradão (MG) (Morais *et al.*, 2013)	68.82
	BA/DF /GO/ MG		FL	Cerrado (MG)	35.06	Trees: Average estimates for cerradão in three areas (Scolforo *et al.*, 2008b)	7.71	Expansion factor of 0.22 for "*Forestlands*" (Miranda *et al.*, 2014).	3.86	Expansion factor of 0.11 for "*Tropical forest*" (IPCC, 2003)	5.66	Expansion factor of 0.165, obtained from cerradão estimates (Morais *et al.*, 2013)	52.29
	MS/MT		FL	Pantanal	69.2	Same as Forested Savannah (Sd) of Pantanal	15.22	Same as Forested Savannah (Sd) of Pantanal	7.61	Same as Forested Savannah (Sd) of Pantanal	11.17	Same as Forested Savannah (Sd) of Pantanal	103.21

Phytophysiognomy Acronym/Name	FU/State	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for biomass/stock calculation		Below-ground carbon stock / Methodology/reference for biomass/stock calculation		Dead wood carbon stock / Methodology / reference for biomass/stock calculation		Litter carbon stock / Methodology / reference for biomass/stock calculation		Total Stock
					(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
	MA/PI /TO		FL	Cerrado (TO)	33.29	Trees: allometric equation (Brown, 1997) applied to plots (64) of six Cerradão areas in (Haidar *et al.*, 2013)	7.32	Expansion factor of 0.22 for "*Forestlands*" (Miranda *et al.*, 2014)	3.66	Expansion factor of 0.11 for "*Tropical forest*" (IPCC, 2003)	5.38	Expansion factor of 0.165, obtained from estimates in cerradão (MG) (Morais *et al.*, 2013)	49.64
Sg/Savannah – Grassy-Woody	single value	4.97	G	Cerrado (GO, DF)	4.17	Herbaceous stratum (grasses and dicotyledons) and palm trees for campo limpo (Ottmar *et al.*, 2001)	13.94	Expansion factor of 3.34 for "*Grasslands*" (Miranda *et al.*, 2014)	0	Null value for standing dead wood in campo limpo (Ottmar *et al.*, 2001)	0.38	Average accumulated litter, woody material in seven areas of campo limpo (Ottmar *et al.*, 2001)	18.49
SM/Savannah/Mixed Ombrophilous Forest Transition	average value	0.1	FL	Cerrado, Atlantic Forest and Pantanal	44.16	Average between Savannah (S) and Mixed Ombrophilous Forest (excluding alluvial forest)	16.07	Average between Savannah (S) and Mixed Ombrophilous Forest (excluding alluvial forest)	3.21	Average between Savannah (S) and Mixed Ombrophilous Forest (excluding alluvial forest)	4.15	Average between Savannah (S) and Mixed Ombrophilous Forest (excluding alluvial forest)	67.57
SN/Savannah/Seasonal Forest Transition	average value	5.64	FL	Amazon, Caatinga, Cerrado, Atlantic Forest and Pantanal	43.49	Average between Savannah (S) and Seasonal Forest (average between Deciduous and Semideciduous formations, excluding alluvial formations)	15.42	Average between Savannah (S) and Seasonal Forest (average between Deciduous and Semideciduous formations, excluding alluvial formations)	4.26	Average between Savannah (S) and Seasonal Forest (average between Deciduous and Semideciduous formations, excluding alluvial formations)	5.33	Average between Savannah (S) and Seasonal Forest (average between Deciduous and Semideciduous formations, excluding alluvial formations)	68.5
SO/Savannah/ Ombrophilous Forest Transition	average value	0.03	FL	Amazon Cerrado and Pantanal	39.01	Average between Savannah (S) and Open Ombrophilous Forest (excluding alluvial forest)	17.61	Average between Savannah (S) and Open Ombrophilous Forest (excluding alluvial forest)	4.12	Average between Savannah (S) and Open Ombrophilous Forest (excluding alluvial forest)	5.59	Average between Savannah (S) and Open Ombrophilous Forest (excluding alluvial forest)	66.33
Sp/Savannah – Park	single value	15.58	OWL	Cerrado (GO, DF, MG)	3.81	Herbaceous stratum (grasses and dicotyledons) and palm trees for campo sujo (ow-grass savannah with scattered shrubs in some areas) (Ottmar *et al.*, 2001)	12.72	Expansion factor of 3.34 for "*Grasslands*" (Mliranda *et al.*, 2014)	0	Average coarse woody material in seven areas of campo sujo (Ottmar *et al.*, 2001).	1.25	Average accumulated litter, fallen woody material in seven areas of campo sujo (Ottmar *et al.* 2001).	26.79

Phytophysiognomy Acronym/Name	FU/State	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for biomass/stock calculation		Below-ground carbon stock / Methodology/reference for biomass/stock calculation		Dead wood carbon stock / Methodology / reference for biomass/stock calculation		Litter carbon stock / Methodology / reference for biomass/stock calculation		Total Stock
					(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
			OWL	Cerrado (TO)	11	Trees: allometric equation (DELLITI *et al.*, 2006) applied to plots (HAIDAR *et al.* 2013). Herbaceous stratum (grasses, dicotyledons) and palm trees of cerrado ralo (open scrub) (OTTMAR *et al.*, 2001)	22.44	Expansion factor of 2.04 obtained from the average of estimates in ten areas (ABDALA *et al.*, 1998; CASTRO; KAUFFMAN, 1998; CASTRO-NEVES, 2007; LILIENFEIN; WICKLE, 2003; MIRANDA, 2012)	0.06	Average coarse woody material in nine areas of cerrado ralo (OTTMAR *et al.*, 2001)	2.31	Average accumulated litter and fallen woody material in nine areas of cerrado ralo (OTTMAR *et al.*, 2001).	
ST/Savannah/Steppic Savannah Transition	averag e value	0.24	FL	Cerrado and Caatinga	18.64	Average between Savannah (S) and Wooded Steppic Savannah (Sa)	13.26	Average between Savannah formation (S) and Wooded Steppic Savannah (Sa)	3.21	Average between Savannah (S) and Wooded Steppic Savannah (Sa)	4.34	Average between Savannah (S) and Wooded Steppic Savannah (Sa)	36.11
STN/Savannah/Steppic Savannah/Seasonal Forest Transition	averag e value	0.15	FL	Amazon, Caatinga, Cerrado, Atlantic Forest and Pantanal	25.27	Average between Savannah (S), Seasonal Forest (average between Deciduous and Semideciduous formations, excluding alluvial formations) and Wooded Steppic Savannah (Ta)	15.5	Average between Savannah (S), Seasonal Forest (average between Deciduous and Semideciduous formations, excluding alluvial formations) and Wooded Steppic Savannah (Ta)	3.2	Average between Savannah (S), Seasonal Forest (average between Deciduous and Semideciduous formations, excluding alluvial formations) and Wooded Steppic Savannah (Ta)	4.44	Average between Savannah (S), Seasonal Forest (average between Deciduous and Semideciduous formations, excluding alluvial formations) and Wooded Steppic Savannah (Ta)	47.57
T/Steppic Savannah	averag e value	0	FL	Cerrado and Caatinga	17.8	Average between Wooded Steppic Savannah (Ta) and Forested Steppic Savannah (Td)	7.7	Average between Wooded Steppic Savannah (Ta) and Forested Steppic Savannah (Td)	2.97	Average between Wooded Steppic Savannah (Ta) and Forested Steppic Savannah (Td)	2.33	Average between Wooded Steppic Savannah (Ta) and Forested Steppic Savannah (Td)	30.8
Ta/Steppic Savannah – Wooded	single value	0.49	FL	Caatinga	9.6	Same as Wooded Steppic Savannah (Ta) of the Caatinga	5.8	Same as Wooded Steppic Savannah (Ta) of the Caatinga	1.25	Same as Wooded Steppic Savannah (Ta) of the Caatinga	1.25	Same as Wooded Steppic Savannah (Ta) of the Caatinga	17.9
Td/Steppic Savannah – Forested	single value	0.14	FL	Caatinga	26	Same as Forested Steppic Savannah (Td) of the Caatinga	9.6	Same as Forested Steppic Savannah (Td) of the Caatinga	4.68	Same as Forested Steppic Savannah (Td) of the Caatinga	3.05	Same as Forested Steppic Savannah (Td) of the Caatinga	43.33
Tg/Steppic Savannah –	single value	0.02	G	Amazon	3.93	Same as Grassy-Woody Steppic	13.12	Same as Grassy-Woody Steppic	0.11	Same as Grassy-Woody	0.33	Same as Grassy-Woody Steppic	17.49

Phytophysiognomy Acronym/Name	FU/State	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for biomass/stock calculation (tC/ha)		Below-ground carbon stock / Methodology/reference for biomass/stock calculation (tC/ha)		Dead wood carbon stock / Methodology / reference for biomass/stock calculation (tC/ha)		Litter carbon stock / Methodology / reference for biomass/stock calculation (tC/ha)		Total Stock (tC/ha)
Grassy-Woody						Savannah (Tg) of the Amazon		Savannah (Tg) of the Amazon		Steppic Savannah (Tg) of the Amazon		Savannah (Tg) of the Amazon	
TN/Steppic Savannah/Seasonal Forest Transition	average value	0.79	FL	All biomes	30.03	Average between the Wooded Steppic Savannah Formation (Ta) and Seasonal Forest (excluding alluvial forests)	10.28	Average between Wooded Steppic Savannah and Seasonal Forest	4.46	Average between Wooded Steppic Savannah and Seasonal Forest	4.15	Average between Wooded Steppic Savannah and Seasonal Forest	45.83
Tp/Steppic Savannah – Park	single value	0.16	OWL	Amazon	5.95	Same as Park Steppic Savannah (Tp) of the Amazon	19.87	Same as Park Steppic Savannah (Tp) of the Amazon	0.1	Same as Park Steppic Savannah (Tp) of the Amazon	0.59	Same as Park Steppic Savannah (Tp) of the Amazon	26.51

Note: Total carbon stocks per unit area (tC/ha) and in the different carbon pools (above-ground biomass – AGB, below-ground biomass – BGB, standing dead wood – DW and litter). Representation of phytophysiognomy in the biome (%), study site, references and methodology used to calculate biomass/stock. The water, dunes and rock outcrop classes occupy 0.9 of the biome. For the Savannah formation subclass, Wooded Savannah formation and Transition zones (Ombrophilous Forest/Seasonal Forest Transition), Savannah/Seasonal Forest Transition, Savannah/Ombrophilous Forest Transition, Savannah/Mixed Ombrophilous Forest Transition, Savannah/Steppic Savannah Transition, Savannah/Steppic Savannah/Seasonal Forest Transition and Steppic Savannah/Seasonal Forest Transition) the values varied per polygon. For this reason, the averages of the estimates were presented. The highlighted rows (in gray) represent the most representative phytophysiognomies in the biome, which together account for 77.7%. FL = Forest Land; G = Grassland; OWL= Other Wooded Land. The sum of the percentage of each phytophysiognomy (% in the biome) is less than 100% due to the water category, which was disregarded. NA – not applicable.

Table A.VII.4. Carbon stocks of the phytophysiognomies of the Atlantic Forest biome.

Phytophysiognomy Acronym/Name	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Below-ground carbon stock /Methodology/reference e for the calculation of biomass/stock		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock		Littler carbon stock /Methodology/reference for the calculation of biomass/stock		Total Stock
				(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
Aa/Open Ombrophilous Forest – Alluvial	0.07	FL	Atlantic Forest	35.06	AGB (Silveira, 2009; Ferraz; Rodal, 2006; Gama *et al.*, 2007; allometric equation; Brown, 1997). Expansion factor of 1.2 for the pools: tree regeneration, herbaceous plants and other forms of life (APNE, NP)	7.19	Ratio of 0.205 for SB (Shoot Biomass) <125 Mg ha^{-1} (Mokany *et al.*, 2006)	2.98	Weighted average (Proceke de Deus, 2015; Sanqueta *et al.*, 2014; Silva, 2013; Cardoso *et al.*, 2012; Vieira *et al.*, 2011; Luccas, 2011)	1.86	Albuquerque (2015); APNE- UFPE – Federal University of Pernambuco (Universidade Federal de Pernambuco)/DEN – Nuclear Energy Department (Departamento de Energia Nuclear); (Rede C-NE – Northeast Carbon Network (Rede de Carbono do Nordeste), NP)	47.09
Ab/Open Ombrophilous Forest – Lowlands	0.22	FL	Atlantic Forest	35.06	Same as Open Ombrophilous Forest – Alluvial (Aa)	7.19	Same as Open Ombrophilous Forest – Alluvial (Aa)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	1.86	Same as Open Ombrophilous Forest – Alluvial (Aa)	47.09
Am/Open Ombrophilous Forest – Montane	0.01	FL	Atlantic Forest	35.06	Same as Open Ombrophilous Forest – Alluvial (Aa)	7.19	Same as Open Ombrophilous Forest – Alluvial (Aa)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	1.68	Litter (0.05): above-ground biomass ratio (AlbuquerqueE, 2015); APNE-UFPE/DEN; REDE C-NE, NP	46.91
As/Open Ombrophilous Forest – Submontane	0.51	FL	Atlantic Forest	35.06	Same as Open Ombrophilous Forest – Alluvial (Aa)	7.19	Same as Open Ombrophilous Forest – Alluvial (Aa)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	4.19	Same as Open Ombrophilous Forest – Alluvial (Aa)	49.42
Ca/Seasonal Deciduous Forest – Alluvial	0.14	FL	Caatinga	88.6	Average dry matter weight values (Table 8.8; Scolforo *et al.*, 2008c)	21.3	Ratio of 0.24 for tropical moist deciduous forests with biomass greater than 125 t/ha (IPCC, 2006, vol. 4, chap. 4, tab. 4.4)	9.8	Ratio of dead wood stock to live wood stock (0.11) – table 3.2.2, IPCC (2003)	2.1	Ratio of 0.024 (Moreira Burger; Delitti, 1999)	121.8
Cb/Seasonal Deciduous Forest – Lowlands	0.01	FL	Atlantic Forest	52.08	Average of plots (41) of seasonal deciduous forest (APNE, NP)	10.68	Same as Open Ombrophilous Forest – Alluvial (Aa)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	2.5	Same as Open Ombrophilous Forest – Montane (Am)	68.24

Phytophysiognomy Acronym/Name	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Below-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock		Littler carbon stock /Methodology/reference for the calculation of biomass/stock		Total Stock
				(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
Cm/Seasonal Deciduous Forest – Montane	2.86	FL	Atlantic Forest	58.14	Average of plots (24) of this phytophysiognomy with 100% vegetation cover from IFN – National Forest Inventory (Inventário Florestal Nacional) FFSC – Santa Catarina Floristic Forest Inventory (Inventário Florístico Florestal de Santa Catarina), I IFMG – Federal Institute of Education, Science and Technology of Minas Gerais (Instituto Federal de Educação, Ciência e Tecnologia de Minas Gerais) and APNE (NP)	11.92	Same as Open Ombrophilous Forest – Alluvial (Aa)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	2.79	Same as Open Ombrophilous Forest – Montane (Am)	75.83
Cs/Seasonal Deciduous Forest – Submontane	3.22	FL	Atlantic Forest	74.1	Brun, 2004	19.60	Brun, 2004	8.2	IPCC, 2003	4.6	Brun, 2004	106.5
D/Dense Ombrophilous Forest (Tropical Rain Forest)	0	FL	Atlantic Forest	63.17	Average of plots (256) of dense ombrophilous forest (APNE, NP)	14.84	Ratio of 0.235 for SB (Shoot Biomass) <125 Mg ha^{-1} (Mokany *et al.*, 2006)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	3.03	Same as Open Ombrophilous Forest – Montane (Am)	84.02
Da/Dense Ombrophilous Forest – Alluvial	0.32	FL	Atlantic Forest	127.1	Britez *et al.*, 2006	29.9	Mokany *et al.*, 2006	14	IPCC, 2003	2.9	Socher *et al.*, 2008	173.9
Db/Dense Ombrophilous Forest – Lowlands	2.32	FL	Atlantic Forest	85.73	Average of plots (49) of this phytophysiognomy with 100% vegetation cover from IFN, IFFSC, IFMG and APNE (NP)	20.15	Same as Dense Ombrophilous Forest (D)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	4.11	Same as Open Ombrophilous Forest – Montane (Am)	112.97

Phytophysiognomy Acronym/Name	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Below-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock		Littler carbon stock /Methodology/reference for the calculation of biomass/stock		Total Stock
				(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
Dl/Dense Ombrophilous Forest – High Montane	0.16	FL	Atlantic Forest	64.63	Average of plots (4) of this phytophysiognomy with 100% vegetation cover from IFN, IFFSC, IFMG and APNE (NP)	15.19	Same as Dense Ombrophilous Forest (D)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	3.1	Same as Open Ombrophilous Forest – Montane (Am)	85.9
Dm/Dense Ombrophilous Forest – Montane	5.85	FL	Atlantic Forest	140	Average above-ground biomass in vegetation with a successional stage classified as mature vegetation (Cunha *et al.*, 2009; Silva Neto, 2017; Stefani, 2017; Vieira *et al.*, 2011)	32.9	Same as Dense Ombrophilous Forest (D)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	7.0	Same as Open Ombrophilous Forest – Montane (Am)	182.88
Ds/Dense Ombrophilous Forest - Submontane	8.34	FL	Atlantic Forest	141.1	Average above-ground biomass in vegetation with a successional stage classified as mature vegetation (Ruthner, 2010; Silva Neto, 2017; Stefani, 2017; Vieira *et al.*, 2011)	33.16	Same as Dense Ombrophilous Forest (D)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	3.41	Same as Open Ombrophilous Forest – Alluvial (Aa)	180.65
E/Steppe	0.4	FL	Atlantic Forest	0.8	Average of plots (3) of this phytophysiognomy with 100% of vegetation cover from IFN, IFFSC, IFMG and APNE (NP)	0.16	Same as Open Ombrophilous Forest – Alluvial (Aa)	0.04	Factor 0.05 (APNE, NP)	0.04	Same as Open Ombrophilous Forest – Montane (Am)	1.04
Eg/Steppe - Grassy-Woody	3.99	G	Atlantic Forest	0.72	AGB (Fidelis *et al.*, 2006). Expansion factor of 1.2 for the pools: tree regeneration, herbaceous and other forms of life (APNE, NP)	4.64	Paruelo *et al.*, 2010	0.78	Paruelo *et al.*, 2010	2.85	Paruelo *et al.*, 2010	8.99
EM/Steppe/Mixed Ombrophilous Forest Transition	1.18	FL	Atlantic Forest	49.26	Average of plots (17) of this phytophysiognomy with 100% vegetation cover	10.1	Same as Open Ombrophilous Forest – Alluvial (Aa)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	2.36	Same as Open Ombrophilous Forest – Montane (Am)	64.70

Phytophysiognomy Acronym/Name	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Below-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock		Littler carbon stock /Methodology/reference for the calculation of biomass/stock		Total Stock
				(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
					from IFN, IFFSC, IFMG and APNE (NP)							
EN/Steppe/Seasonal Forest Transition	0.57	FL	Atlantic Forest	52.17	Average of plots (153) of these phytophysiognomies with 100% of vegetation cover from IFN, IFFSC, IFMG and APNE (NP)	10.69	Same as Open Ombrophilous Forest Alluvial (Aa)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	2.50	Same as Open Ombrophilous Forest – Montane (Am)	68.34
F/Seasonal phytophysiognomies	0	FL	Atlantic Forest	57.86	Average of the subclasses of the seasonal semideciduous forest phytophysiognomies	11.86	Same as Open Ombrophilous Forest – Alluvial (Aa)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	2.78	Same as Open Ombrophilous Forest – Montane (Am)	75.48
Fa/Seasonal Semideciduous Forest – Alluvial	1.59	FL	Atlantic Forest	58.05	Scolforo *et al.*, 2008a. Expansion factor of 1.2 for the pools: tree regeneration, herbaceous plants and other forms of life (APNE, NP)	11.90	Same as Open Ombrophilous Forest – Alluvial (Aa)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	5.24	Same as Open Ombrophilous Forest – Montane (Aa)	78.17
Fb/Seasonal Semideciduous Forest - Lowlands	1.07	FL	Atlantic Forest	63.07	Same as Seasonal Semideciduous Forest – Alluvia (Fa)	14.82	Same as Dense Ombrophilous Forest (D)	2.98	Same as Open Ombrophilous Forest - Alluvial (Aa)	3.03	Same as Open Ombrophilous Forest - Montane (Am)	83.90
Fm/Seasonal Semideciduous Forest – Montane	13.17	FL	Atlantic Forest	75.10	Average above-ground biomass in vegetation with a successional stage classified as mature vegetation (Amaro *et al.*, 2013; Gaspar, 2014; Ribeiro *et al.*, 2009)	17.65	Same as Dense Ombrophilous Forest (D)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	3.76	Same as Open Ombrophilous Forest – Montane (Am)	99.49
Fs/Seasonal Semideciduous Forest – Submontane	21.68	FL	Atlantic Forest	96.50	Averages of above-ground biomass in vegetation with a successional stage classified as mature vegetation (Diniz *et al.*,	22.68	Same as Dense Ombrophilous Forest (D))	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	3.63	Same as Open Ombrophilous Forest – Montane (Aa)	125.79

Phytophysiognomy Acronym/Name	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Below-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock		Littler carbon stock /Methodology/reference for the calculation of biomass/stock		Total Stock
				(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
				2015; Ferez, 2010; Metzker *et al.*, 2011; Souza *et al.*, 2012; Tiepolo *et al.*, 2002)								
L/Campinarana	0	FL	Atlantic Forest	4.89	Weighted average of plots (33) of the steppe (E) and steppic savannah (T) phytophysiognomies	2.59	Same as Open Ombrophilous Forest – Alluvial (Aa)	0.24	Factor of 0.05 (APNE, NP)	0.23	Same as Open Ombrophilous Forest – Montane (Am)	7.95
La/Campinarana - Wooded	0	FL	Atlantic Forest	8.88	Average of Ea (9.44) and Ta (7.99)	4.7	Same as Open Ombrophilous Forest – Alluvial (Aa)	0.44	Factor 0.05 (APNE, NP)	0.43	Same as Open Ombrophilous Forest – Montane (Am)	14.45
Lg/Campinarana - Grassy-Woody	0.07	G	Atlantic Forest	0.89	Average of Eg (0.80) and Tg (0.99)	0.48	Same as Open Ombrophilous Forest – Alluvial (Aa)	0.05	Factor 0.05 (APNE, NP)	0.05	Same as Open Ombrophilous Forest – Montane (Am)	1.47
M/Mixed Ombrophilous Forest	0	FL	Atlantic Forest	62.51	Weighted average of the subclasses of mixed ombrophilous forest (IFN, APNE (NP)	12.81	Same as Dense Ombrophilous Forest (D))	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	3.00	Same as Open Ombrophilous Forest – Montane (Am)	81.3
Ma/Mixed Ombrophilous Forest - Alluvial	0.11	FL	Atlantic Forest	64.25	Average of plots (216) of mixed ombrophilous forest (IFN, APNE NP)	15.10	Same as Dense Ombrophilous Forest (D)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	3.08	Same as Open Ombrophilous Forest – Montane (Am)	85.41
Ml/Mixed Ombrophilous Forest – High Montane	1,83	FL	Atlantic Forest	78.82	Average of plots (50) of this phytophysiognomy with 100% vegetation cover from IFN, IFFSC, IFMG and APNE (NP)	18.52	Same as Dense Ombrophilous Forest (D)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	3.78	Same as Open Ombrophilous Forest – Montane (Am)	104.10
Mm/Mixed Ombrophilous Forest – Montane	12.56	FL	Atlantic Forest	108.3	Average above-ground biomass in vegetation with a successional stage classified as mature vegetation (Alves et al., 2010; Britez et al., 2006; Vieira et al., 2011; Watzlawick et al., 2012).	25.45	Same as Dense Ombrophilous Forest (D)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	5.42	Same as Open Ombrophilous Forest – Montane (Am)	142.15
Ms/Mixed Ombrophilous Forest – Submontane	0.08	FL	Atlantic Forest	108.0	Watzlawick et al., 2012	19.00	Watzlawick et al., 2012	11.9	IPCC, 2003	3.8	Watzlawick et al., 2012	142.7

Phytophysiognomy Acronym/Name	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Below-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock		Littler carbon stock /Methodology/reference for the calculation of biomass/stock		Total Stock
				(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
NM/Seasonal Forest/ Mixed Ombrophilous Forest Transition	1.71	FL	Atlantic Forest	58.28	Weighted average of plots (368) of the seasonal forest and ombrophilous forest physiognomy	11.95	Same as Open Ombrophilous Forest – Alluvial (Aa)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	2.80	Same as Open Ombrophilous Forest – Montane (Am)	76.01
NP/Seasonal Forest/ Pioneer Formations Transition – Specific for Marine-Influenced Pioneer Formation (Restinga)	0	FL	Atlantic Forest	57.95	Weighted average of plots (146) of the pioneer formations and seasonal forest phytophysiognomies classes	11.88	Same as Open Ombrophilous Forest – Alluvial (Aa)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	2.78	Same as Open Ombrophilous Forest – Montane (Am)	75.59
OM/Dense Ombrophilous Forest/ Mixed Ombrophilous Forest Transition	0.75	FL	Atlantic Forest	62.89	Weighted average of plots (472) of dense ombrophilous forest and mixed ombrophilous forest	14.78	Same as Dense Ombrophilous Forest (D)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	3.02	Same as Open Ombrophilous Forest – Montane (Am)	83.67
ON/Ombrophilous Forest/Seasonal Forest Transition	0.98	FL	Atlantic Forest	59.13	Weighted average of plots (378) of dense ombrophilous forest and seasonal forest classes	13.89	Same as Dense Ombrophilous Forest (D)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	2.84	Same as Open Ombrophilous Forest – Montane (Am)	78.84
OP/Ombrophilous Forest/ Pioneer Formations Transition – Specific to Marine-Influenced (Restinga)	0.05	FL	Atlantic Forest	63.26	Weighted average of plots (276) of dense ombrophilous forest and pioneer formations phytophysiognomies	14.87	Same as Dense Ombrophilous Forest (D)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	3.04	Same as Open Ombrophilous Forest – Montane (Am)	84.15
P/ Pioneer Formation Areas	0.15	FL	Atlantic Forest	79.15	Weighted average of the subclasses of pioneer formations	18.6	Same as Dense Ombrophilous Forest (D)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	3.80	Same as Open Ombrophilous Forest – Montane (Am)	104.53
Pa/Fluvial and/or Lacustrine-Influenced Vegetation	1.37	OWL	Atlantic Forest	78.54	AGB (Britez *et al*., 2006). Expansion factor of 1.2 for the pools: tree regeneration, herbaceous plants and other forms of life (APNE, NP)	18.46	Same as Dense Ombrophilous Forest (D)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	3.77	Same as Open Ombrophilous Forest – Montane (Am)	103.75

Phytophysiognomy Acronym/Name	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Below-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock		Littler carbon stock /Methodology/reference for the calculation of biomass/stock		Total Stock
				(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
Pf/Fluviomarine-Influenced Vegetation	0.31	FL	Atlantic Forest	62.42	Average of plots (22) of this phytophysiognomy (IFN, IFFSC, APNE unpublished data). Expansion factor of 1.2 for the pools: tree regeneration, herbaceous plants and other forms of life (APNE, NP)	14.67	Same as Dense Ombrophilous Forest (D)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	2.99	Same as Open Ombrophilous Forest – Montane (Am)	83.06
Pm/Marine-influenced Vegetation (Restinga)	0.68	FL	Atlantic Forest	79.71	AGB (Alves et al. 2010). Expansion factor of 1.2 for the pools: tree regeneration, herbaceous plants and other forms of life (APNE, NP)	18.73	Same as Dense Ombrophilous Forest (D)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	3.28	Same as Open Ombrophilous Forest – Alluvial (Aa)	104.70
Rl/High Mountain Refuges	0.12	OWL	Atlantic Forest	3.34	AGB (Ottmar et al., 2001). Expansion factor of 1.2 for the pools: tree regeneration, herbaceous plants and other forms of life (APNE, NP)	5.34	Factor of 1.6 (IPCC, 2006)	0.16	Factor of 0.05 (APNE, NP)	0.16	Same as Open Ombrophilous Forest – Montane (Am)	9.00
Rm/Mountain Refuges	0.03	OWL	Atlantic Forest	4.28	Same as High mountain refuges (Rl)	6.85	Factor of 1.6 (IPCC 2006	0.21	Factor of 0.05 (APNE, NP)	0.21	Same as Open Ombrophilous Forest – Montane (Am)	11.55
S/Savannah	0.27	FL	Atlantic Forest	26.69	Weighted average of the subclasses (Cerrado)	16.94	Same as Open Ombrophilous Forest – Alluvial (Aa)	3.12	Factor of 0.05 (APNE, NP)	4.88	Same as Open Ombrophilous Forest – Montane (Am)	51.63
Sa/Savannah – Wooded	1.85	FL	Cerrado	12.03	Same as Cerrado	24.54	Same as Cerrado	1.68	Same as Cerrado	3.06	Same as Cerrado	41.31
Sd/Savannah – Savannah	1.08	FL	Atlantic Forest	69.2	Same as Cerrado	15.22	Same as Cerrado	7.61	Same as Cerrado	11.17	Same as Cerrado	103.2
Sg/Savannah – Grassy-Woody	1.39	G	Atlantic Forest	4.17	Same as Cerrado	13.94	Same as Cerrado	0.00	Same as Cerrado	0.38	Same as Cerrado	18.49
SM/Savannah/ Mixed Ombrophilous Forest Transition	0.32	FL	Atlantic Forest	44.16	Same as Cerrado	16.07	Same as Cerrado	3.21	Same as Cerrado	4.15	Same as Cerrado	67.59

Phytophysiognomy Acronym/Name	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Below-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock		Littler carbon stock /Methodology/reference for the calculation of biomass/stock		Total Stock
				(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
SN/Savannah/Seasonal Forest Transition	3.68	FL	Atlantic Forest	43.49	Same as Cerrado	15.42	Same as Cerrado	4.26	Same as Cerrado	5.33	Same as Cerrado	68.50
SO/Savannah/ Ombrophilous Forest Transition	0.14	FL	Atlantic Forest	39.01	Same as Cerrado	17.61	Same as Cerrado	4.12	Same as Cerrado	5.59	Same as Cerrado	66.33
SP/Savannah/Pioneer Formations Transition	0	FL	Atlantic Forest	36.94	Same as Cerrado	7.57	Same as Cerrado	2.98	Same as Cerrado	1.78	Same as Cerrado	49.27
Sp/Savannah – Park	1.15	OWL	Atlantic Forest	7.4	Same as Cerrado	17.58	Same as Cerrado	0.03	Same as Cerrado	1.78	Same as Cerrado	26.79
ST/Savannah/Pioneer Formations Transition – Specific to Marine-Influenced Pioneer Formation (Restinga)	0.05	FL	Atlantic Forest	18,64	Same as Cerrado	13.26	Same as Cerrado	3.21	Same as Cerrado	4.34	Same as Cerrado	36.11
T/Savannah/Steppic Savannah Transition	0	FL	Atlantic Forest	8.13	Average of the Ta phytophysiognomies	4.31	Average of the Ta phytophysiognomies	0.40	age of the Ta phytophysiognomies	0.39	Average of the Ta phytophysiognomies	13.23
Ta/Steppic Savannah – Wooded	0.87	FL	Caatinga	8.13	Same as Caatinga: Expansion factor of 1.2 for the pools: tree regeneration, herbaceous plants and other forms of life (APNE, NP)	4.31	Caatinga adjustment factor used (0.54)	0.40	Caatinga adjustment factor used (0.05)	0.40	Caatinga adjustment factor used (0.05)	13.23
Td/Steppic Savannah – Forested	0.01	FL	Caatinga	18.94	Same as Expansion factor of 1.2 for the pools: tree regeneration, herbaceous plants and other forms of life (APNE, NP)	10.03	Caatinga adjustment factor used (0.54)	0.93	Caatinga adjustment factor used (0.05)	0.9	Caatinga adjustment factor used (0.05)	30.81
Tg/Steppic Savannah – Grassy-Woody	0	G	Atlantic Forest	1.03	AGB (Paruelo et al., 2010). Expansion factor of 1.2 for the pools: tree regeneration, herbaceous plants and other forms of life (APNE, NP)	2.88	Factor of 2.8 (IPCC, 2006)	0.15	Factor of 0.15 (APNE, NP)	0.15	Litter (0.15): above-ground biomass ratio (Albuquerque, 2015); APNE-UFPE/DEN; REDE C-NE, NP)	4.21

Phytophysiognomy Acronym/Name	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Below-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock		Littler carbon stock /Methodology/reference for the calculation of biomass/stock		Total Stock
				(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
TN/Steppic Savannah/Seasonal Forest Transition	0.63	FL	Atlantic Forest	55.88	Average of the classes of Steppic Savannah/Seasonal Forest	11.70	Same as Open Ombrophilous Forest – Alluvial (Aa)	2.98	Same as Open Ombrophilous Forest – Alluvial (Aa)	2.68	Same as Open Ombrophilous Forest – Montane (Am)	73.24

Note: Total carbon stocks per unit area (tC/ha) and in the different carbon pools (above-ground biomass – AGB, below-ground biomass – BGB, standing dead wood – DW, and litter). Representation of the phytophysiognomy in the biome (%), study site, references and methodology used to calculate biomass/stock. The water class occupies 1.9% of the biome. FL = Forest Land; G = Grassland; OWL = Other Wooded Land; APNE = Association of Plants of the Northeast (Associação Plantas do Nordeste); NP = Unpublished data (Not Published); NE = Northeast Region; OR = Other regions of the Atlantic Forest. The highlighted rows (in gray) represent the most representative phytophysiognomies in the biome, which together account for 77.7%. The sum of the percentage of each phytophysiognomy (% in the biome) is less than 100% due to the water category, which was disregarded. NA – not applicable.

Table A.VII.5. Carbon stocks of the phytophysiognomies of the Caatinga biome.

Phytophysiognomy Acronym/Name	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Below-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock		Littler carbon stock /Methodology/reference for the calculation of biomass/stock		Total Stock
				(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
Aa/Open Ombrophilous Forest – Alluvial	0.004	FL	Atlantic Forest, Cerrado, Amazon	44.69	Average AGB values (Silveira, 2009; Ferraz; Rodal, 2006; Gama *et al.*, 2007) and allometric equation (Brown, 1997). Expansion factor of 1.3 for the pools: tree regeneration, herbaceous plants and other forms of life (APNE, NP)	8.08	Ratio Mokany *et al.* 2006 (compilation of various studies, cited in the IPCC as a source). Tab 2 for "Tropical / subtropical moist forest / plantation" (>125 ton/ha): 0.235	3.78	Ratio (0.11) dead wood stock/live - tropical forest – tab. 3.2.2 IPCC (2003)	0.77	Ratio (0.023) Socher *et al.* 2008 – alluvial mixed ombrophilous forest	57.33
Ab/Open Ombrophilous Forest – Lowlands	0.0002	FL	Atlantic Forest, Cerrado, Amazon	44.69	Same as Alluvial Open Ombrophilous Forest (Aa)	8.08	Same as Alluvial Open Ombrophilous Forest (Aa)	3.78	Ratio (0.11) dead wood stock/live – tropical forest – tab. 3.2.2 IPCC (2003)	0.77	Ratio (0.023) Socher *et al.*, 2008 – alluvial mixed ombrophilous forest	57.33
Am/Open Ombrophilous Forest – Montane	0.01	FL	Atlantic Forest, Cerrado, Amazon	44.69	Same as Alluvial Open Ombrophilous Forest (Aa)	8.08	Same as Alluvial Open Ombrophilous Forest (Aa)	3.78	Ratio (0.11) dead wood stock/live – tropical forest – tab. 3.2.2 IPCC (2003)	0.77	Ratio (0.023) Socher *et al.*, 2008 – alluvial mixed ombrophilous forest	57.33
RO/ Rock Outcrop	0.0008	NA	Caatinga	NA	NA	NA	NA	0.00	0.00	0.00	NA	0.00
As/Open Ombrophilous Forest – Submontane	0.33	FL	Caatinga	76.38	Same as Alluvial Open Ombrophilous Forest (Aa)	28.26	BGB: total AGB ratio (0.37) (APNE, NP)	11.46	Necromass/total above-ground biomass ratio (0.15) (APNE, NP)	11.21	Ratio of litter to total above-ground biomass (0.15) (APNE, NP)	127.3
Ca/Seasonal Deciduous Forest – Alluvial	0.008	FL	Caatinga	88.62	Average dry matter weight values (Scolforo *et al.*, 2008c)	21.27	Ratio of 0.24 for tropical moist deciduous forests with AGB greater than 125 t/ha (IPCC 2006, vol. 4, chap. 4, tab. 4.4)	9.75	Ratio of dead wood stock to live wood stock (0.11) – tab. 3.2.2, IPCC (2003).	2.08	Ratio of 0.024 (Moreira-Burger; Delitti, 1999)	121.72

Phytophysiognomy Acronym/Name	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Below-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock		Littler carbon stock /Methodology/reference for the calculation of biomass/stock		Total Stock
				(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
Cb/Seasonal Deciduous Forest – Lowlands	0.002	FL	Caatinga	55.26	Dry matter weight (Scolforo *et al.*, 2008c). Expansion factor of 1.3 for the pools: tree regeneration, herbaceous plants and other forms of life (APNE, NP)	8.50	BGB: above-ground tree biomass ratio (0.20) - Tab. 4.4 IPCC 2006 – Above-ground biomass <125 t/ha – Tropical moist deciduous forest	4.68	Ratio (0.11) dead wood stock/live – tropical forest – tab. 3.2.2 IPCC (2003)	6.86	Ratio (0.165) Morais *et al.*, 2013 for Cerradão-MG (above-ground biomass 70.49)	75.30
Cm/Seasonal Deciduous Forest – Montane	1.03	FL	Caatinga	31.10	Average from MG (Minas Gerais) Forest Inventory (Scolforo *et al.*, 2008c). Expansion factor of 1.3 for the pools: tree regeneration, herbaceous plants and other forms of life	11.51	Same as Submontane Open Ombrophilous Forest (As)	4.66	Necromass: total above-ground biomass ratio (0.15) (APNE, NP)	4.57	Ratio of litter to total above-ground biomass (0.15) APNE, unpublished data	51.84
Cs/Seasonal Deciduous Forest – Submontane	1.79	FL	Caatinga	41.43	Same as Montane Seasonal Deciduous Forest (cm)	15.33	Same as Submontane Open Ombrophilous Forest (As)	6.21	Necromass: total above-ground biomass ratio (0.15) (APNE, NP)	6.08	Ratio of litter to total above-ground biomass (0.15) (APNE, NP)	69.05
Da/Ombrophilous Dense Forest – Alluvial	0.02	FL	Atlantic Forest	148.84	AGB (Britez *et al.*, 2006). Expansion factor of 1.3 for the pools: tree regeneration, herbaceous plants and other forms of life	22.54	Fine roots collected from a depth of 0-10cm and roots (estimated by equation)	10.9	Dead trees standing or leaning up to 45° + fallen necromass (≥ 7.5 cm in diameter)	3.43	Litter	185.70
Dm/Dense Ombrophilous Forest – Montane	0.07	FL	Atlantic Forest	148.84	Same as Alluvial Dense Ombrophilous Forest (Da)	22.54	Fine roots collected from a depth of 0-10 cm and roots (estimated by equation	10.9	Dead trees standing or up to 45° inclined + fallen necromass (≥ 7.5cm in diameter)	3.43	Litter	185.70
Dn/Dunes	0.08	-	Caatinga	NA	NA	NA	NA	0.00	0.00	0.00	NA	0.00
Ds/Dense Ombrophilous Forest – Submontane	0.04	FL	Atlantic Forest	148.84	Same as Alluvial Dense Ombrophilous Forest (Da)	22.54	fine roots collected from a depth of 0-10cm and roots (estimated by equation)	10.9	Dead trees standing or up to 45° inclined + fallen necromass (≥ 7.5cm in diameter)	3.43	Litter	185.70

Phytophysiognomy Acronym/Name	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Below-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock		Littler carbon stock /Methodology/reference for the calculation of biomass/stock		Total Stock
				(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
Fa/Seasonal Semideciduous Forest – Alluvial	0.32	FL	Caatinga	73.96	AGB (Scolforo *et al.*, 2008c). Expansion factor of 1.3 for the pools: tree regeneration, herbaceous plants and other forms of life	11.38	BGB: AGB ratio (0.20) - Table 4.4 IPCC 2006 – Above-ground biomass <125 t/ha – Tropical moist deciduous forest	6.26	Ratio (0.11) dead wood stock/live - tropical forest – tab. 3.2.2 IPCC (2003)	1.34	Ratio (0.024) mesophytic riparian forest Atlantic forest/SP – Moreira-Burger; Delitti, 1999	92.94
Fb/Seasonal Semideciduous Forest – Lowlands	0.04	FL	Caatinga	80.38	Above-ground dry matter (Scolforo *et al.*, 2008c). Expansion factor of 1.3 for the pools: tree regeneration, herbaceous plants and other forms of life	14.84	BGB: AGB ratio – The IPCC 2006 default value, Table 4.4, for Tropical Moist Deciduous Forest was used >125ton/ha: 0.24	6.80	Ratio (0.11) dead wood stock/live – tropical forest – tab. 3.2.2 IPCC (2003)	3.99	Litter (0.066) – Amaro *et al.* 2013 - Seasonal Semideciduous Forest – Montane - MG	106.01
Fm/Seasonal Semideciduous Forest – Montane	0.82	FL	Caatinga	59.33	Same as Montane Seasonal Deciduous Forest (Cm)	21.95	Same as Submontane Open Ombrophilous Forest (As)	8.90	Necromass: total above-ground biomass ratio (0.15) (APNE, NP)	8.71	Litter: Total above-ground biomass ratio (0.15) APNE, unpublished data	98.89
Fs/Seasonal Semideciduous Forest - Submontane	2.24	FL	Caatinga	82.73	Same as Montane Seasonal Deciduous Forest (Cm)	30.61	Same as Submontane Open Ombrophilous Forest (As)	12.41	Necromass: total above-ground biomass ratio (0.15) (APNE, NP)	12.15	Litter: Total above-ground biomass ratio (0.15) (APNE, NP)	137.89
Pa/Fluvial and/or Lacustrine-Influenced Vegetation	0.34	OWL	Caatinga	65.17	Average of 10 values in floodplains (Pereira, 2013) – density and basal area; *Brown*, 1997 (allometric equation)	10.03	BGB: AGB ratio (0.20) - Tab. 4.4, IPCC 2006 – Above-ground biomass <125 t/ha - Tropical moist deciduous forest	5.51	Ratio (0.11) dead wood stock/live – tropical forest - tab. 3.2.2 IPCC (2003)	1.18	Ratio (0.024) mesophytic riparian forest Atlantic forest/SP Moreira-Burger; Delitti, 1999	81.89

Phytophysiognomy Acronym/Name	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Below-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock		Littler carbon stock /Methodology/reference for the calculation of biomass/stock		Total Stock
				(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
Pf/Fluviomarine-influenced Pioneers (mangrove)	0.27	FL	Amazon/ French Guiana, Northeast of Brazil and Others	123.08	Average from Fromard *et al.* (1998). Expansion factor of 1.3 for the pools: tree regeneration, herbaceous plants and other forms of life	37.75	Using the Hutchison equation *et al.* 2013	9.53	Percentage of 10% calculated based on the work of Fernandes (1997)	0.18	Ramos; Silva *et al.* 2007; Northeast of Brazil	170.54
Pm/Marine-Influenced Pioneers (restinga)	0.55	FL	Atlantic Forest	101.61	AGB (Assis *et al.*, 2011). Expansion factor of 1.3 for the pools: tree regeneration, herbaceous plants and other forms of life	21.89	LULUCF ratio 28% - tropical dry forest >20t/ha – tab. 4.4 IPCC, 2006	22.18	Veiga, 2010	1.41	Pires k coefficient 0.92	147.09
Rm/Mountain Refuge	0.64	OWL	Cerrado - campo limpo	5.42	Ottmar *et al.* 2001	11.69	BGB: AGB ratio (2.8) IPCC 2006, v.6 - Tab. 6.1 – Semi arid grasslands – tropical dry	0	There is no pool for this phytophysiognomy	0.44	Ottmar *et al.* 2001 – accumulated litter, fine and coarse woody material (diameter < 2.5 cm) - campo limpo Same as Cerrado	17.55
Sa/Savannah - Wooded	4.57	FL	Cerrado	12.03	Same as Cerrado	24.54	Same as Cerrado	1.68	Same as Cerrado	3.06		41.31
Sd/Savannah – Forested	0.06	FL	Caatinga	39.47	Same as Montane Seasonal Deciduous Forest (Cm)	14.60	Same as Submontane Open Ombrophilous Forest (As)	5.92	Necromass: total above-ground biomass ratio (0.15) (APNE, NP)	5.79	Litter: total above-ground biomass ratio (0.15) (APNE, NP)	65.79
Sg/Savannah – Grassy-Woody	0.29	G	Cerrado	5.42		13.94	BGB: AGB ratio (3.34) Miranda *et al.* 2014 – Grasslands	0	Ottmar *et al.* 2001 – coarse woody material (diameter 7.7 to 22.9 cm)	0.38	Ottmar *et al.* 2001 – accumulated litter, fine and coarse woody material (diameter < 2.5 cm) - campo limpo	19.74

Phytophysiognomy Acronym/Name	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Below-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock		Littler carbon stock /Methodology/reference for the calculation of biomass/stock		Total Stock
				(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
SN/Savannah / Forest Transition	0.99	FL	Caatinga/ Cerrado Transition	44.72	Weighted average according to the percentage cover of savannah and forest phytophysiognomies	14.73	Weighted average according to the percentage cover of savannah and forest phytophysiognomies of the BGB: total AGB ratio (0.37) (APNE, NP)	5.32	Weighted average according to the percentage cover of savannah and pioneer formations phytophysiognomies	4.89	Weighted average according to the percentage cover of savannah and pioneer formations phytophysiognomies	69.66
Sp/Savannah – Park	0.92	OWL	Cerrado	4.95	Ottmar et al. 2001	12.72	BGB: AGB ratio (3.34) Miranda *et al.* 2014 – Grasslands	0	Ottmar *et al.* 2001 – coarse woody material (diameter 7.7 to 22.9 cm)	1.25	Ottmar *et al.* 2001 – accumulated litter, fine and coarse woody material (diameter < 7.7 cm)	18.92
ST/Savannah/Pioneer Formations Transition – Specific for Marine-Influenced Pioneer Formation (Restinga)	3.97	FL	Caatinga/ Cerrado Transition	13.53	Weighted average according to the percentage cover of savannah and pioneer formations phytophysiognomies	9.24	Weighted average according to the percentage cover of savannah and pioneer formations of the BGB: total AGB ratio (0.37) (APNE, NP)	1.82	Weighted average according to the percentage cover of savannah and pioneer formations phytophysiognomies	1.88	Weighted average according to the percentage cover of savannah and pioneer formations phytophysiognomies	26.47
Ta/Steppic Savannah – Wooded (open caatinga)	59.67	FL	Caatinga	9.59	Average AGB: UNDP/FAO Project for the Northeast Region (litter, herbaceous stratum, other forms of life and tree regeneration); inventories and database of the Caatinga's PMFS – Sustainable Forest Management Plan (Plano de Manejo Florestal Sustentável) (APNE); Albuquerquer, 2015; Costa, 2017; Nascimento, 2015; Scolforo *et al.*, 2008c; Lima Junior, 2014.	5.85	BGB: total AGB ratio (0.61) (APNE, NP)	1.25	Necromass: total above-ground biomass ratio (0.13) (APNE, NP)	1.60	Ratio of litter to total above-ground biomass (0.12) (APNE, NP)	18.28

Phytophysiognomy Acronym/Name	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Below-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock		Littler carbon stock /Methodology/reference for the calculation of biomass/stock		Total Stock
				(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
					Expansion factor of 1.4 for the pools: tree regeneration, herbaceous plants and other forms of life.							
Td/Steppic Savannah – Forested (dense caatinga)	6.89	FL	Caatinga	25.99	Average AGB: UNDP/FAO Project for the Northeast Region (litter, herbaceous stratum, other forms of life and tree regeneration); inventories and databases from the Caatinga's PMFS (APNE); Albuquerque, 2015; Costa, 2017; Nascimento, 2015; Scolforo *et al.*, 2008c; Lima Junior 2014. Expansion factor of 1.2 for the pools: tree regeneration, herbaceous plants and other forms of life	9.62	Same as Submontane Open Ombrophilous Forest (As)	4.68	Necromass: total above-ground biomass ratio (0.18) (APNE, NP)	3.05	Ratio of litter to total above-ground biomass (0.18) (APNE, NP)	43.34
Tg/Steppic Savannah – Grassy-Woody	0.26	G	Amazon	1.53	Barbosa; Fearnside, 2005. Expansion factor of 1.3 for the pools: tree regeneration, herbaceous plants and other forms of life) (APNE, NP)	3.32	BGB: AGB ratio (2.8) IPCC 2006v.6 – Table 6.1 - Semi arid grasslands – tropical dry	0.03	Standing and fallen dead wood	0.10	Leaf, litter, fallen and standing wood – probably <10 cm	4.98

Phytophysiognomy Acronym/Name	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Below-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock		Littler carbon stock /Methodology/reference for the calculation of biomass/stock		Total Stock
				(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
TN/Savannah/Seasonal Forest Transition	8.17	FL	Caatinga	42.11	Average between savannah and seasonal forest phytophysiognomies	13.10	Weighted average according to the percentage cover of savannah and seasonal forest phytophysiognomies of the BGB: total AGB ratio (0.37) (APNE, NP)	5.05	Average between the Savannah and Seasonal Forest phytophysiognomies	3.90	Average between the Savannah and Seasonal Forest phytophysiognomies	64.16
Tp/Steppic Savannah – Park	5.59	OWL	Amazon	3.35	Paruelo *et al.*, 2010. Expansion factor of 1.3 for the pools: tree regeneration, herbaceous plants and other forms of life) (APNE, NP)	7.22	BGB: AGB ratio (2.8) IPCC 2006 v.6 – Table 6.1 – Semi arid grasslands - tropical dry	0.04	Standing and fallen dead wood	0.25	Leaf and litter	10..87

Note: Total carbon stocks per unit area (tC/ha) and in the different carbon pools (above-ground biomass – AGB, below-ground biomass – BGB, standing dead wood – DW, and litter). *Values kept from the Third National Communication inventory. Representation of the phytophysiognomy in the biome (%), study site, references and methodology used to calculate biomass/stock. The water class occupies 0.9% of the biome. FL= Forest Land; G= Grassland; OWL= Other Wooded Land; APNE= Plants of the Northeast Association NP= unpublished data. PMFS= Sustainable Forest Management Plans for the Caatinga. The highlighted rows (in gray) represent the most representative phytophysiognomies in the biome, which together account for 88.86%. The sum of the percentage of each phytophysiognomy (% in the biome) is less than 100% due to the water category, which was disregarded. NA – not applicable.

Table A.VII.6. Carbon stocks of the phytophysiognomies of the Pampa biome.

Phytophysiognomy Acronym/Name	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Below-ground carbon stock /Methodology/reference for the calculation of biomass/stock		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock		Littler carbon stock /Methodology/reference for the calculation of biomass/stock		Total Stock
				(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
Ca/Seasonal Deciduous Forest – Alluvial	0.84	FL	Pampa	98.7	Vogel *et al.*, 2015	23.69	Ratio of 0.24 for tropical moist deciduous forests with above-ground biomass greater than 125 t/ha (IPCC 2006, vol. 4, chap. 4, tab. 4.4)	10.86	Ratio of 0.11 (IPCC 2003, chap. 3, tab. 3.2.2)	2.93	Average between values found by Moreira- Burger; Delitti (1999) and Cardoso *et al.* (2012)	136.17
Cb/Seasonal Deciduous Forest – Lowlands	0.33	FL	Atlantic Forest	52.08	Same as Seasonal Deciduous Forest – Low lands (Cb) of the Atlantic Forest (see Table VII.A.3)	12.25	Same as Seasonal Deciduous Forest – Lowlands (Cb) of the Atlantic Forest	2.98	Same as Seasonal Deciduous Forest – Lowlands (Cb) of the Atlantic Forest	2.50	Same as Seasonal Deciduous Forest – Lowlands (Cb) of the Atlantic Forest	69.80
Cm/Seasonal Deciduous Forest – Montane	0.006	FL	Pampa	120.58	Average value between two studies in the Pampa (Brun 2004; Balbinot *et al.* 2017)	28.94	Ratio of 0.24 for tropical moist deciduous forests with above-ground biomass greater than 125 t/ha (IPCC 2006, vol. 4, chap. 4, tab. 4.4).	13.26	Average value between two studies in the Pampa (Brun 2004; Balbinot *et al.* 2017)	4.51	Brun, 2004	167.29
Cs/Seasonal Deciduous Forest – Submontane	3.93	FL	Pampa	120.58	Average value between two studies in the Pampa (Brun 2004; Balbinot *et al.* 2017)	28.94	Ratio of 0.24 for tropical moist deciduous forests with above-ground biomass greater than 125 t/ha (IPCC 2006, vol. 4, chap. 4, tab. 4.4)	13.26	Ratio of 0.11 (IPCC 2003, chap. 3, tab. 3.2.2)	4.38	Average between values found by Vogel *et al.* (2013) and Brun (2004)	167.16
Da/Dense Ombrophilous Forest – Alluvial	0.0003	FL	Atlantic Forest	64.625	Same as Dense Ombrophilous Forest – Alluvial (Da) of the	15.21	Same as Dense Ombrophilous Forest – Alluvial (Da) of the Atlantic	2.98	Same as Dense Ombrophilous Forest - Alluvial (Da) of the	3.10	Same as Dense Ombrophilous Forest – Alluvial (Da) of the Atlantic Forest	85.91

Phytophysiognomy Acronym/Name	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock (tC/ha)		Below-ground carbon stock /Methodology/reference for the calculation of biomass/stock (tC/ha)		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock (tC/ha)		Littler carbon stock /Methodology/reference for the calculation of biomass/stock (tC/ha)		Total Stock (tC/ha)
					Atlantic Forest		Forest		Atlantic Forest			
Db/Dense Ombrophilous Forest – Lowlands	0.004	FL	Atlantic Forest	85.728	Same as Dense Ombrophilous Forest – Lowlands (Db) of the Atlantic Forest	20.17	Same as Dense Ombrophilous Forest – Lowlands (Db) of the Atlantic Rainforest	2.98	Same as Dense Ombrophilous Forest – Lowlands (Db) of the Atlantic Forest	4.11	Same as Dense Ombrophilous Forest – Lowlands (Db) of the Atlantic Forest	112.98
Dm/Dense Ombrophilous Forest – Montane	0.0002	FL	Pampa	114.38	Average value between two studies in the Pampa with a difference of less than 30% (MASS, 2015; Alves *et al.*, 2011)	28.97	Ratio of 0.24 for tropical moist deciduous forests with above-ground biomass greater than 125 t/ha (IPCC 2006, vol. 4, chap. 4, tab. 4.4)	12.53	Average value between works by Vieira *et al.* (2011) and Luccas (2011)	3.53	Mass, 2015	159.41
Dn/Dunes	0.62	-	Pampa	NA	NA	NA	NA	0.00	0.00	0.00	NA	0.00
Ds/Dense Ombrophilous Forest – Submontane	0.03	FL	Pampa	126.30	Average value between two studies carried out in the Pampa with a difference of less than 30% (Scaranello 2015; Alves *et al.* 2011)	30.31	Ratio of 0.24 for tropical moist deciduous forests with above-ground biomass greater than 125 t/ha (IPCC 2006, vol. 4, chap. 4, tab. 4.4).	13.89	Average value between works by Vieira *et al.* (2011) and Scaranello (2015). The latter used a ratio of 0.11 (IPCC, 2003, ch. 3, tab. 3.2.2)	3.87	Average between values found by Cardoso *et al.* (2012) and Vieira *et al.* (2011)	174.38
E/Steppe	21.65	FL	Pampa	1.03	Tg. value: Dominant class (89.8%) – Leidinger et al.	4.74	Paruelo *et al.*, 2010	0.00	Not significant for this type of phytophysiognomy	3.63	Paruelo *et al.*, 2010	9.40

Phytophysiognomy Acronym/Name	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock (tC/ha)		Below-ground carbon stock /Methodology/reference for the calculation of biomass/stock (tC/ha)		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock (tC/ha)		Littler carbon stock /Methodology/reference for the calculation of biomass/stock (tC/ha)		Total Stock (tC/ha)
					2017; Mônaco *et al*,. 2017; Altesor *et al*. 2005							
Ea/Steppe – Forested	6.27	FL	Pampa	37.74	Gasparri et al., 2008	10.58	Ratio of 0.28 for tropical moist deciduous forests with above-ground biomass greater than 20 t/ha (IPCC, 2006, v. 4, chap. 4, tab. 4.4)	5.12	Ratio of 0.14 (IPCC, 2003, ch. 3, tab. 3.2.2)	2.07	GASPARRI *et al.* 2008 and ratio of 0.14 (IPCC, 2003, chap. 3, tab. 3.2.2)	55.51
Eg/Steppe – Grassy-Woody	26.78	G	Pampa	0.73	Average value between two studies carried out in the Pampa with a difference of less than 30% (Trentin, 2015; Fidelis *et al.*, 2006)	0.77	Fidelis *et al.*, 2006	0.00	Not significant for this type of phytophysiognomy	3.63	Paruelo *et al.*, 2010	5.13
Ep/Steppe – Park	3.96	G	Pampa	120.58	Cs value: Dominant class. Average value between two studies carried out in the Pampa (Brun, 2004; Balbinot *et al.* 2017)	28.94	Cs value: Dominant class. Ratio of 0.24 for tropical moist deciduous forests with above-ground biomass greater than 125 t/ha (IPCC, 2006, v. 4, chap. 4, tab. 4.4)	13.26	Ratio of 0.11 (IPCC 2003, Ch. 3. Table 3.2.2)	4.38	Average between values found by Vogel *et al.* (2013) and Brun (2004)	167.16
EM/Steppe/Mixed Ombrophilous Forest Transition	0.14	FL	Pampa	1.03	Tg. value: Dominant class (64%). Average value between three studies. (Leidinger *et al.* 2017; MÔNACO *et al.*	4.74	Paruelo *et al.*, 2010	0.00	Not significant for this type of phytophysiognomy	3.63	Paruelo *et al.*, 2010	9.40

Phytophysiognomy Acronym/Name	% in biome	Category	Study Site	Above-ground carbon stock (tC/ha)	/Methodology/reference for the calculation of biomass/stock	Below-ground carbon stock (tC/ha)	/Methodology/reference for the calculation of biomass/stock	Dead wood carbon stock (tC/ha)	/Methodology/reference for the calculation of biomass/stock	Littler carbon stock (tC/ha)	/Methodology/reference for the calculation of biomass/stock	Total Stock (tC/ha)
					2017; ALTESOR *et al.* 2005)							
EN/Steppe/Seasonal Forest Transition	4.98	FL	Pampa	0.73	Eg value: Dominant class (31.06 %). Average value between two studies carried out in the Pampa with a difference of less than 30% (Trentin 2015; Fidelis *et al.* 2006)	0.77	Eg value: Dominant class in the 3rd National Communication (31.06 %) (Fidelis *et al.*, 2006)	0.00	Not significant for this type of phytophysiognomy	3.63	Paruelo *et al.*, 2010	5.13
EP/Stepp/Formations Transition	3.11	FL	Pampa	37.74	Ea value: dominant class (33.97 %) (Gasparri *et al.*, 2008)	10.58	Ea value: dominant class in the 3rd National Communication (33.97 %). Ratio of 0.28 for tropical moist deciduous forests with above-ground biomass greater than 20 t/ha (IPCC, 2006, v. 4, chap. 4, tab. 4.4)	5.12	Ratio of 0.14 (IPCC, 2003, chap. 3, tab. 3.2.2)	2.07	Ratio of 0.14 (IPCC 2003, chap. 3, tab. 3.2.2)	55.51
Fa/Seasonal Semideciduous Forest – Alluvial	0.10	FL	Atlantic Forest	58.04	Same as Seasonal Semideciduous Forest – Alluvial (Fa) of the Atlantic Forest	13.66	Same as Seasonal Semideciduous Forest – Alluvial (Fa) of the Atlantic Forest	2.98	Same as Seasonal Semideciduous Forest – Alluvial (Fa) of the Atlantic Forest	5.24	Same as Seasonal Semideciduous Forest - Alluvial (Fa) of the Atlantic Forest	79.92
Fb/Seasonal Semideciduous Forest -	0.43	FL	Pampa	62.65	Moreira-Burger; Delitti, 1999	15.04	Ratio of 0.24 for tropical moist deciduous forests	6.89	Ratio of 0.11 (IPCC, 2003, chap. 3, tab.	1.47	Moreira-Burger; Delitti (1999)	86.05

Phytophysiognomy Acronym/Name	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock (tC/ha)		Below-ground carbon stock /Methodology/reference for the calculation of biomass/stock (tC/ha)		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock (tC/ha)		Littler carbon stock /Methodology/reference for the calculation of biomass/stock (tC/ha)		Total Stock (tC/ha)
Lowlands							with above-ground biomass greater than 125 t/ha (IPCC 2006, vol. 4, chap. 4, tab. 4.4)		3.2.2)			
Fm/Seasonal Semideciduous Forest – Montane	0.08	FL	Pampa	82.24	Amaro *et al.*, 2013	16.12	Ratio of 0.24 for tropical moist deciduous forests with above-ground biomass greater than 125 t/ha (IPCC 2006, vol. 4, chap. 4, tab. 4.4)	3.06	Amaro *et al.*, 2013	5.35	Vogel *et al*. (2013)	106.76
Fs/Seasonal Semideciduous Forest – Submontane	4.56	FL	Pampa	78.82	Average value between two studies carried out in the Pampa with a difference of less than 30% (Souza *et al.* 2012; Metzker *et al.* 2011)	18.92	Ratio of 0.24 for tropical moist deciduous forests with above-ground biomass greater than 125 t/ha (IPCC 2006, vol. 4, chap. 4, tab. 4.4)	8.48	Ratio of 0.11 (IPCC, 2003, chap. 3, tab. 3.2.2)	3.07	Vogel *et al*. (2013)	109.29
Ma - Mixed Ombrophilous Forest – Alluvial	0.0008	FL	Atlantic Forest	64.249	Same as Mixed Ombrophilous Forest – Alluvial (Ma) of the Atlantic Forest	15.12	Same as Mixed Ombrophilous Forest – Alluvial (Ma) of the Atlantic Forest	2.98	Same as Mixed Ombrophilous Forest – Alluvial (Ma) of the Atlantic Forest	3.08	Same as Mixed Ombrophilous Forest – Alluvial (Ma) of the Atlantic Forest	85.42
Ms/Mixed Ombrophilous Forest – Submontane	0.006	FL	Pampa	92.77	Average value between two studies (Watzlawick *et at*. 2012; Mognon *et al.*, 2013)	23.49	Ratio of 0.24 for tropical moist deciduous forests with above-ground biomass greater than 125 t/ha (IPCC, 2006, v. 4, chap. 4, tab. 4.4)	10.77	Ratio of 0.11 (IPCC 2003, Ch. 3. Table 3.2.2)	3.68	Average between values found by Watzlawick *et al.* (2012) and Mognon *et al.* (2013)	130.71

Phytophysiognomy Acronym/Name	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock (tC/ha)		Below-ground carbon stock /Methodology/reference for the calculation of biomass/stock (tC/ha)		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock (tC/ha)		Littler carbon stock /Methodology/reference for the calculation of biomass/stock (tC/ha)		Total Stock (tC/ha)
NM/Seasonal Forest/Mixed Ombrophilous Forest Transition	0.03	FL	Pampa	120.58	Cs value. Dominant class (30.03%). Average value between two studies carried out in the Pampa (Brun, 2004; Balbinot et al., 2017)	28.94	Cs value. Dominant class (30.03%). Ratio of 0.24 for tropical moist deciduous forests with above-ground biomass greater than 125 t/ha (IPCC, 2006, vol. 4, chap. 4, tab. 4.4)	13.26	Cs value. Dominant class (30.03%). Ratio of 0.11 (IPCC, 2003, chap. 3, tab. 3.2.2)	4.38	Average between values found by Vogel *et al.* (2013) and Brun (2004)	167.16
NP/Seasonal Forest/Marine-Influenced Pioneer Formations Transition (Restinga)	2.20	FL	Pampa	1.04	Pa. value Dominant class (68.85%) (CunhaA *et al.*, 2005)	10.15	Pa. value Dominant class (68.85%) (Cunha *et al.*, 2005)	0.00	Not significant for this type of phytophysiognomy	1.59	Cunha *et al.*, 2005	12.77
OM/Dense Ombrophilous Forest / Mixed Ombrophilous Forest Transition	0.002	FL	Pampa	120.58	Cs value. Dominant class (79.06%). Average value between two studies carried out in the Pampa (Brun, 2004; Balbinot *et al.* 2017)	28.94	Cs value. Dominant class (79.06%). Ratio of 0.24 for tropical moist deciduous forests with above-ground biomass greater than 125 t/ha (IPCC 2006, vol. 4, chap. 4, tab. 4.4)	13.26	Cs value. Dominant class (79.06%). Ratio of 0.11 (IPCC, 2003, chap. 3, tab. 3.2.2)	4.38	Average between values found by Vogel *et al.* (2013) and Brun (2004)	167.16
OP/Ombrophilous Forest/ Marine-Influenced Pioneer Formations Transition (Restinga)	0.12	FL	Pampa	1.04	Pf value Dominant class (89.04%) (Cunha *et al.*, 2005)	10.15	Pf value Dominant class (89.04%) (Cunha et al., 2005)	0.0	Not significant for this type of phytophysiognomy	1.59	Cunha *et al.*, 2005	12.77
P/Pioneer Formation Areas	2.87	FL	Pampa	1.03	Tg value. Dominant class (81%) (Leidinger *et al.* 2017; Mônaco *et al.* 2017; Altesor *et al.* 2005)	4.74	Paruelo *et al.*, 2010	0.00	Not significant for this type of phytophysiognomy	3.63	Paruelo *et al.*, 2010	9.40

Phytophysiognomy Acronym/Name	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for the calculation of biomass/stock (tC/ha)		Below-ground carbon stock /Methodology/reference for the calculation of biomass/stock (tC/ha)		Dead wood carbon stock /Methodology/reference for the calculation of biomass/stock (tC/ha)		Littler carbon stock /Methodology/reference for the calculation of biomass/stock (tC/ha)		Total Stock (tC/ha)
Pa/Fluvial and/or Lacustrine-Influenced Vegetation	5.75	OWL	Pampa	1.04	Cunha *et al.* (2005)	10.15	Cunha *et al.* (2005)	0.00	Not significant for this type of phytophysiognomy	1.59	Cunha *et al.* (2005)	12.77
Pf/Fuviomarine-Influenced Vegetation	0.01	FL	Pampa	1.04	Cunha *et al.* (2005)	10.15	Cunha *et al.* (2005)	0.00	Not significant for this type of phytophysiognomy	1.59	Cunha *et al.* (2005)	12.77
Pm/Marine-Influenced Vegetation (Restinga)	0.80	FL	Pampa	1.04	Cunha *et al.* (2005)	10.15	Cunha *et al.* (2005)	0.00	Not significant for this type of phytophysiognomy	1.59	Cunha *et al.* (2005)	12.77
T/Steppic Savannah	0.006	FL	Pampa	120.58	Average value between two studies in the Pampa (Brun, 2004; Balbinot *et al.*, 2017)	28.94	Ratio of 0.24 for tropical moist deciduous forests with above-ground biomass greater than 125 t/ha (IPCC 2006, vol. 4, chap. 4, tab. 4.4)	13.26	Ratio of 0.11 (IPCC 2003, chap. 3, tab. 3.2.2)	4.38	Average between values found by Vogel *et al.* (2013) and Brun (2004)	167.16
Tg/Steppic Savannah – Grassy-Woody	0.89	G	Pampa	1.03	Average value between three studies (Leidinger *et al.*, 2017; Mônaco *et al.*, 2017; Altesor *et al.*, 2005)	4.74	Paruelo *et al.*, 2010	0.00	Not significant for this type of phytophysiognomy	3.63	Paruelo *et al.*, 2010	9.40
Tp/Steppic Savannah - Park	0.11	OWL	Amazon	5.95	Same as Steppic Savannah – Park (Tp) of the Amazon	19.87	Same as Steppic Savannah – Park (Tp) of the Amazon	0.10	Same as Steppic Savannah - Park (Tp) of the Amazon	0.59	Same as Steppic Savannah – Park (Tp) of the Amazon	26.51

Note: Total carbon stocks per unit area (tC/ha) and in the different carbon pools (above-ground biomass, below-ground biomass, standing dead wood and litter). Representation of the phytophysiognomy in the biome (%), study site, references and methodology used to calculate biomass/stock. The water class occupies 9.40% of the biome. FL = Forest Land; G = Grassland; OWL= Other Wooded Land. The highlighted rows (in gray) represent the most representative phytophysiognomies in the biome, which together account for 81%. The sum of the percentage of each phytophysiognomy (% in the biome) is less than 100% due to the water category, which was disregarded. NA – not applicable.

Table A.VII.7. Carbon stocks of the phytophysiognomies of the Pantanal biome.

Phytophysiognomy Acronym/Name	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for biomass/stock calculation		Below-ground carbon stock /Methodology/reference for biomass/stock calculation		Carbon stock dead wood/Methodology/reference for biomass/stock calculation		Carbon stock litter/Methodology/reference for biomass/stock calculation		Total Stock
				(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
Ca/Seasonal Deciduous Forest – Alluvial	0.003	FL	Caatinga	88.62	Average dry matter weight values (Table 8.8 – Scolforo *et al.* 2008c)	21.27	Ratio of 0.24 for tropical moist deciduous forests with above-ground biomass greater than 125 t/ha (IPCC, 2006, v. 4, chap. 4, tab. 4.4)	9.75	Ratio of dead wood stock to live wood stock (0.11) – table 3.2.2, IPCC (2003)	2.08	Ratio of 0.024 (Moreira-Burger; Delitti, 1999)	121.72
Cb/Seasonal Deciduous Forest – Lowlands	1.80	FL	Pantanal	69.38	Brown's equation (1997, equation 3.2.1) based on the average values of basal area and density of individuals presented by Lima *et al.* (2009)	16.65	Ratio of 0.24 for tropical moist deciduous forests with above-ground biomass greater than 125 t/ha (IPCC, 2006, v. 4, chap. 4, tab. 4.4)	7.63	Ratio of dead wood stock to live wood stock (0.11) – tab. 3.2.2, IPCC (2003)	11.21	Ratio of 0.165 – Cerradão (above-ground biomass 70.49) (Morais *et al.*, 2013)	104.87
Cs/Seasonal Deciduous Forest – Submontane	0.80	FL	Pantanal	84.38	Brown's equation (1997, equation 3.2.1) based on the average basal area and density values of individuals presented by Lima *et al.* (2009)	20.25	Ratio of 0.24 for tropical moist deciduous forests with above-ground biomass greater than 125 t/ha (IPCC 2006, v. 4, chap. 4, tab. 4.4)	9.28	Ratio of dead wood stock to live wood stock (0.11) – table 3.2.2, IPCC (2003)	13.63	Ratio of 0.165 - Cerradão (above-ground biomass 70.49) (Morais *et al.*, 2013)	127.54
Fa/Seasonal Semideciduous Forest – Alluvial	6.06	FL	Pantanal	121.92	The above-ground biomass value in seasonally flooded riparian forest in the Pantanal was used (Wittmann *et al.* 2008)	29.26	Ratio of 0.24 for tropical moist deciduous forests with above-ground biomass greater than 125 t/ha (IPCC 2006, v. 4, chap. 4, tab. 4.4)	13.41	Ratio of dead wood stock to live wood stock (0.11) – tab. 3.2.2, IPCC (2003)	2.87	Ratio of 0.024 - Riparian semi-deciduous mesophytic forest (Moreira- Burger; Delitti, 1999)	167.46
Fb/Seasonal Semideciduous Forest – Lowlands	1.60	FL	Amazon	65.98	Same as Seasonal Semideciduous Forest – Lowlands (Fb) of the Amazon	6.60	Same as Seasonal Semideciduous Forest – Lowlands (Fb) of the Amazon	5.34	Same as Seasonal Semideciduous Forest – Lowlands (Fb) of the Amazon	3.81	Same as Seasonal Semideciduous Forest – Lowlands (Fb) of the Amazon	81.73

Phytophysiognomy Acronym/Name	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for biomass/stock calculation		Below-ground carbon stock /Methodology/reference for biomass/stock calculation		Carbon stock dead wood/Methodology/reference for biomass/stock calculation		Carbon stock litter/Methodology/reference for biomass/stock calculation		Total Stock
				(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
Fs/Seasonal Semideciduous Forest - Submontane	0.02	FL	Atlantic Forest	62.23	Same as Seasonal Semideciduous Forest (FS) of the Atlantic Forest	14.64	Same as Seasonal Semideciduous Forest (FS) of the Atlantic Forest	2.98	Same as Seasonal Semideciduous Forest (FS) of the Atlantic Forest	3.63	Same as Seasonal Semideciduous Forest (FS) of the Atlantic Forest	83.48
SN/Savannah/Seasonal Forest Transition	0.09	FL	Cerrado	12.03	Same as Wooded Savannah (Sa)	24.53	Same as Wooded Savannah (Sa)	1.68	Same as Wooded Savannah (Sa)	3.06	Same as Wooded Savannah (Sa)	41.31
TN/Steppic Savannah/Seasonal Forest Transition	0.06	FL	Pantanal	121.92	Same as Alluvial Seasonal Semideciduous Forest (Fa)	29.26	Same as Alluvial Seasonal Semideciduous Forest (Fa)	13.41	Same as Alluvial Seasonal Semideciduous Forest (Fa)	2.87	Same as Alluvial Seasonal Semideciduous Forest (Fa)	167.46
S/Savannah	0.08	FL	Cerrado	69.20	Same as Forested Savannah (Sd)	15.22	Same as Forested Savannah (Sd)	7.61	Same as Forested Savannah (Sd)	11.17	Same as Forested Savannah (Sd)	103.21
Sa/Savannah - Wooded	19.55	FL	Cerrado	12.03	Same as Wooded Savannah (Sa) of the Cerrado	24.53	Same as Wooded Savannah (Sa) of the Cerrado	1.68	Same as Wooded Savannah (Sa) of the Cerrado	3.06	Same as Wooded Savannah (Sa) of the Cerrado	41.31
Sd/Forested Savannah	10.62	FL	Pantanal	69.20	Above-ground biomass (Embrapa/Probio – National Project for Integrated Public-Private Actions for Biodiversity (Projeto Nacional de Ações Integradas Público-Privadas para Biodiversidade), 2002)	15.22	Below-ground biomass/above-ground biomass ratio (0.22) - Forest Land (Miranda et al., 2014)	7.61	Ratio of dead wood stock to live wood stock (0.11) – table 3.2.2, IPCC (2003)	11.17	Ratio of 0.165 - Cerradão (above-ground biomass 70.49) (Morais et al., 2013)	103.21
ST/Savannah/Steppic Savannah Transition	1.11	FL	Pantanal	59.82	Average of the four successional stages of Cambarazal (open areas of the	13.76	Below-ground biomass/above-ground biomass ratio (0.23) (STAPE et al.,	6.58	Dead wood to live wood stock ratio (0.11) – tab. 3.2.2, IPCC (2003)	1.40	Ratio of 0.024 (Moreira-Burger; Delitti, 1999)	81.56

Phytophysiognomy Acronym/Name	% in biome	Category	Study Site	Above-ground carbon stock /Methodology/reference for biomass/stock calculation		Below-ground carbon stock /Methodology/reference for biomass/stock calculation		Carbon stock dead wood/Methodology/reference for biomass/stock calculation		Carbon stock litter/Methodology/reference for biomass/stock calculation		Total Stock
				(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)		(tC/ha)
					Pantanal with dominance of the species Vochysia divergens Pohl (Vochysiaceae) (Brazilian name: cambará)) in the Pantanal (Schöngart et al., 2011)		2011)					
T/Steppic Savannah	0.003	FL	Pampa	120.58	Same as Steppic Savannah (T) of the Pampa	28.94	Same as Steppic Savannah (T) of the Pampa	13.26	Same as Steppic Savannah (T) of the Pampa	4.38	Same as Steppic Savannah (T) of the Pampa	167.16
Ta/Steppic Savannah – Wooded	2.89	FL	Amazon Savannahs	4.31	Barbosa; Fearnside, 2005	7.15	Below-ground biomass/above-ground biomass ratio (1.66) – Savannah (Miranda et al., 2014)	0.22	Barbosa; Fearnside, 2005	0.28	Barbosa; Fearnside, 2005	11.96
Td/Steppic Savannah – Forested	2.43	FL	Pantanal	66.43	Average of the three above-ground biomass values found in Padilha (2011)	14.62	Below-ground biomass/above-ground biomass ratio (0.22) – Forest Land (Miranda et al., 2014)	7.31	Ratio of dead wood stock to live wood stock (0.11) – table 3.2.2, IPCC (2003)	10.73	Ratio of 0.165 – Cerradão (above-ground biomass 70.49) (MoraisS et al., 2013)	99.09
Sg/Savannah - Grassy-Woody	14.93	G	Cerrado	4.17	Same as Grassy-Woody Savannah (Sg) of the Cerrado	13.94	Same as Grassy-Woody Savannah (Sg) of the Cerrado	0.00	Same as Grassy-Woody Savannah (Sg) of the Cerrado	0.38	Same as Grassy-Woody Savannah (Sg) of the Cerrado	18.49
Tg/Steppic Savannah – Grassy-Woody	6.03	G	Amazon	3.93	Same as Grassy-Woody Steppic Savannah (Tg) of the Amazon	13.12	Same as Grassy-Woody Steppic Savannah (Tg) of the Amazon	0.11	Same as Grassy-Woody Steppic Savannah (Tg) of the Amazon	0.33	Same as Grassy-Woody Steppic Savannah (Tg) of the Amazon	17.49
Sp/Savannah – Park	26.66	OWL	Cerrado	7.40	Same as Park Savannah (Sp) of the Cerrado	17.58	Same as Park Savannah (Sp) of the Cerrado	0.03	Same as Park Savannah (Sp) of the Cerrado	1.78	Same as Park Savannah (Sp) of the Cerrado	26.79
Tp/Steppic Savannah – Park	3.36	OWL	Amazon	5.95	Same as Steppic Savannah (Tp) of the Amazon	19.87	Same as Steppic Savannah (Tp) of the Amazon	0.10	Same as Steppic Savannah (Tp) of the Amazon	0.59	Same as Steppic Savannah (Tp) of the Amazon	26.51

Note: Carbon stock per unit of total area (tC/ha) and in the different reservoirs (above-ground biomass, below-ground biomass, standing dead wood and litter). Representation of the phytophysiognomy in the biome (%), study site, references and methodology used to calculate biomass/stock. For the Savannah phytophysiognomy (S), the same value was used as for Forested Savannah (Sd); for the Savannah/Seasonal Forest Transition (SN), the value of Sa – dominant class (50.79%), was used; for the Steppic Savannah (T), the value of this phytophysiognomy in the Pampa - dominant class (80.18%), was used; for the Savannah/Steppic Savannah Transition (ST), the fluvial and/or Lacustrine-Influenced Vegetation (Pa) of the 3rd National Communication – dominant class (65.4%), was used as a basis; and for the Steppic Savannah/Seasonal Forest Transition (TN), the Seasonal Semideciduous Forest – Alluvial (Fa), dominant class (30.5%), was used. The water class occupies 1.89% of the biome. FL = Forest Land; G = Grassland; OWL = Other Wooded Land. The highlighted rows (in gray) represent the most representative phytophysiognomies in the biome, which together account for 84%. The sum of the percentage of each phytophysiognomy (% in the biome) is less than 100% due to the water category, which was disregarded. NA – not applicable.

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Table A.VII.8. Secondary factors for calculating estimates of carbon emissions and removals for all Brazilian biomes.

Factor acronym	Parameter	Amazon Factor Methodology/Reference	Caatinga Factor Methodology/Reference	Cerrado Factor Methodology/Reference	Atlantic Forest Factor Methodology/Reference	Pampa Factor Methodology/Reference	Pantanal Factor Methodology/Reference
CAp	Pasture stock (tC/ha)	10	1.19	7.57	2.60	7.57	7.57
		Above-ground stock value (Silva Neto *et al.*, 2012). Expansion factor for below-ground biomass of 1.6 (IPCC, 2006)	Above-ground and below-ground biomass stock. There was no break down between degraded and non-degraded pasture. APNE/Northeast Carbon Network (NP)	Components: above-ground biomass and below-ground biomass for "Tropical – Moist &Wet" (IPCC, 2006, tab. 6.4)	Collection of the entire herbaceous stratum in 1x1m plots. Albuquerque, 2015; APNE (NP)	IPCC (2006, v. 4, chap. 6, tab.6.4)	IPCC (2006, v. 4, chap. 6, tab.6.4)
CApD	Degraded pasture stock (tC/ha)	3.67		3.67			
		Stock value (Silva Neto *et al.*, 2012). Expansion factor for below-ground biomass of 1.6 (IPCC, 2006)		Above-ground biomass estimated in plots. Expansion factor for below-ground biomass of 1.6 and carbon conversion factor of 0.47 for all pools (Silva Neto *et al.*, 2012; IPCC, 2006, tab. 6.1)			
Annual CAc	Annual cropland carbon stock (tC/ha)	6.18 (spatialized values by FU/State)	0.56 (spatialized values by FU/State)	5.00 (spatialized values by FU/State)	3.83 (spatialized values by FU/State)	5.00 (spatialized values by FU/State)	5.00 (spatialized values by FU/State)
		Weighted average between the above-ground and below-ground biomass stocks (Gris, 2006; Brasileiro *et al.* 2015; Assis *et al.* 2014; Alvarez *et al.* 2006; Ohland *et al.* 2005; Almeida Filho *et al.* 1999) (Mazzilli *et al.* 2014) of soybeans and corn	Estimation of root stock in 0.7x0.7x1m trenches in the states of Pernambuco, Ceará and Sergipe. Northeast Carbon Network	IPCC (2006, tab. 5.9)	Weighted average for estimates of sugar cane, bananas and other crops	IPCC (2006, v. 4, chap. 5, tab. 5.9)	IPCC (2006, v. 4, chap. 5, tab. 5.9)
CAc Per	Perennial cropland stock (tC/ha)	11.37	24.80	21.00	23.52	21.00	21.00
		Average between above- and below-ground biomass stocks in coffee plantations (Meireles *et al.* 2016; Silva *et al.* 2013; Coltri *et al.* 2011; Bragança *et al.* 2010; Hutchinson *et al.* 2007). Ratio of 21.97% (Bragança *et al.* 2010) for studies that did not have a below-ground component	Estimate of above-ground stock based on MMA's (2018) estimate of below-ground [biomass] based on factor 0.61 (APNE, NP)	IPCC 2006 (Table 5.1)	Weighted average of own estimate and MMA's estimate, 2018. BGB:AGB (0.54) was used	IPCC (2006, v. 4, chap. 5, tab. 5.1)	IPCC (2006, v. 4, chap. 5, tab. 5.1)
		0.91	1.37	2.60	1.31	2.60	2.60

Factor acronym	Parameter	Amazon Factor Methodology/Reference	Caatinga Factor Methodology/Reference	Cerrado Factor Methodology/Reference	Atlantic Forest Factor Methodology/Reference	Pampa Factor Methodology/Reference	Pantanal Factor Methodology/Reference
ΔCGAc Per	Removal from perennial cropland (tC/ha year)	Average values in coffee plantations (Meireles *et al.* 2016; Silva *et al.* 2013; Coltri *et al.* 2011; Bragança *et al.* 2010; Hutchinson *et al.* 2007). The value obtained was divided by the average number of years since the first drastic pruning (12.5 years)	Estimate of the sum of above-ground and below-ground biomass	IPCC (2006, tab. 5.1)	Estimated based on MMA, 2018.	The value was generated after multiplying the factor of 2.6 by 6 years (period from 2010 to 2016) and dividing by 2, since there is no information on when the crop was harvested. (2.6 x 6 /2=7.8)	IPCC (2006, v. 4, chap. 5 - tab. 5.1)
ΔCGAc Semi-perennial	Removal from semi-perennial cropland (tC/ha year)	0	0	0	0	0	0
		It is considered to be zero, since the balance between the biomass that is incorporated into the crop and the crop rotation is frequent, leading to the non-removal of carbon	The entire stock is lost annually through harvesting (MMA, 2018)	Data obtained from a Conab – National Supply Company (Companhia Nacional de Abastecimento) guide (2016, 2017). Components (leaves, straw and roots) estimated based on secondary data published by Chohfi (2004)	There is no removal from semi-perennial cropland	There is no removal from semi-perennial cropland	Conab, 2016; Chohfi *et al.*, 2004
ΔCGMFL	Removal from primary forest (tC/ha year)	0.48	0.10	0.2	0.32	0.32	0.20
		Average values (Philips *et al.*, 2009; Baker *et al.*, 2004). 25.8% increase in below-ground increment (Nogueira *et al.*, 2008)	Data from the network of permanent plots monitored between 2004 and 2015. APNE – Forest Management Network of the Caatinga (NP)	Turbulent vortex correlation (eddy correlation) in a micrometeorological tower in Wooded Savannah (Rocha *et al.*, 2002)	The value of the inventory of the Third National Communication was maintained	Weighted average based on the work of Scaranello (2010) – the value of the Third National Communication inventory was kept.	Average between the maximum and minimum values found by Rocha *et al.* (2002)
ΔCLSecF	Percentage of remaining secondary forest stock in relation to initial carbon stock (%)	44	44	44	44	44	44
		Average values for the Amazon (Fearnside; Guimarães, 1996; Alves *et al.*, 1997), Atlantic Forest (Melo; Durigan, 2006) and Pantanal (Schöngart *et al.*, 2011)	Average values for the Amazon (Fearnside; Guimarães, 1996; Alves*et al.*, 1997), Atlantic Forest (Melo; Durigan, 2006) and Pantanal (Schöngart *et al.*, 2011)	Average percentage estimates in secondary forests in the Amazon (2 to 18 years old) (Alves *et al.*, 1997), in the Amazon and Pará (5 to 80 years old) (Fearnside; Guimarães, 1996), regenerating riparian forest (1.1 to 28 years old) in São Paulo (Melo; Durigan, 2006) and Cambrazal in Mato Grosso (Schöngart *et al.*, 2011)	Average values for the Amazon (Fearnside; Guimarães, 1996; Alves *et al.*, 1997), Atlantic Forest (Melo; Durigan, 2006) and Pantanal (Schöngart *et al.*, 2011)	Average values for the Amazon (Fearnside; Guimarães, 1996; Alves *et al.*, 1997), Atlantic Forest (Melo; Durigan, 2006) and Pantanal (Schöngart *et al.*, 2011).	Average values for the Amazon (Fearnside; Guimarães, 1996; Alves *et al.*, 1997), Atlantic Forest (Melo; Durigan, 2006) and Pantanal (Schöngart *et al.*, 2011).
		4.97	1.03	1.72	1.66	1.76	2.77

Factor acronym	Parameter	Amazon Factor Methodology/Reference	Caatinga Factor Methodology/Reference	Cerrado Factor Methodology/Reference	Atlantic Forest Factor Methodology/Reference	Pampa Factor Methodology/Reference	Pantanal Factor Methodology/Reference
ΔCGSecF1	Removal from secondary forest with a forest history (tC/ha year)	Average values found by Alves *et al.* 1997 and Wandelli; Fearnside 2015 (3.94 tC/ha). 25.8% increase relative to the below-ground increment (Nogueira *et al.*, 2008)	Leal Junior *et al.*, 1999; ARAÚJO; ARCANJO-SILVA, 2010 and PAREYN *et al.*, 2010; Riegelhaupt *et al.*, 2010; Sampaio *et al.*, 1998, ZákiaA *et al.*, 1991; Pareyn *et al.*, 2015; Lima *et al.*, 2009; Sampaio; Costa, 2011; Costa,2013; Rocha *et al.*, 2002; Goedert *et al.*, 1980; Mello, 1999; Jesus; Garcia, 1992; Mews *et al.*, 2011; Aquino *et al.*, 2007; Silva Neto *et al.*, 2017; Roitman *et al.*, 2007; Felfili *et al.*, 2000; Figueredo *et al.*, 2010; Gomes *et al.*, 2004	The above-ground biomass value for secondary forest vegetation (Cerradão in SP) of 1.41 tC/ha per year (average between 2 and 4 t/ha/year) was considered (Durigan, 2004), taking into account a carbon conversion factor of 0.47 (0.94 to 1.88 tC/ha/year). Expansion factor for below-ground biomass of 0.22 for forest land (MIRANDA *et al.*, 2014)	Above-ground and root biomass stock	1.40 tC/ha for the annual increase in above-ground biomass. Increase of 26% relative to the below-ground increment (Brun *et al.*, 2004)	2.25 tC/ha for annual above-ground biomass increment (Schöngart *et al.*, 2011). 23% increase relative to the below-ground increment (Stape *et al.*, 2011)
ΔCGSecF2		3.03	0.64	2.85	1.66	2.85	2.85
	Removal from secondary forest with a pasture history (tC/ha year)	Average values found by WANDELLI; FEARNSIDE 2015 and FELDPAUSCH *et al.* 2007 (2.40 tC/ha). 25.8% increase relative to the below-ground increment (Nogueira *et al.*, 2008)	Post-pasture regeneration Takes into account above-ground and below-ground biomass. APNE (NP)	Average between abandoned pastures between 1 to 5 years and 6 to 10 years in the Amazon (Feldpausch *et al.*, 2007). Expansion factor for below-ground biomass of 9.20 (IPCC 2006, vol, 4, chap, 4, tab, 4.4)	Above-ground and root biomass stock	2.37 tC/ha for annual above-ground biomass increment (average of two values) (Feldpausch *et al.*, 2007). Increase of 20% relative to the below-ground increment (IPCC, 2006, vol. 4, chap. 4, tab. 4.4)	2.37 tC/ha for annual above-ground biomass increment (average of two values) (Feldpausch *et al.*, 2007). Increase of 20% relative to the below-ground increment (IPCC, 2006, vol. 4, chap. 4, tab. 4.4)
ΔCGSecF3	Removal from secondary forest with a cropland history (tC/ha year)	5.22	0.66	4.73	1.66	4.73	4.73
		Average values found by Wandelli; Fearnside, 2015; Alves *et al.*, 1997; Fearnside; Guimarães, 1996 (4.15 tC/ha). 25.8% increase relative to the below-ground increment (Nogueira *et al.*, 2008)	Post-cropland regeneration. Takes into account above-ground and below-ground biomass. APNE (NP)	Tree biomass data (dbh ≥ 5cm) from 130 plots (10 x 10 m) in Roraima (Alves et al., 1997)	Above-ground and root biomass stock	3.94 tC/ha for the annual increase in above-ground biomass (average of five values) (Alves *et al.*, 1997). Increase of 20% relative to the below-ground increment (IPCC, 2006, v. 4, chap. 4, tab. 4.4)	3.94 tC/ha for the annual increase in above-ground biomass (average of five values) (Alves*et al.*, 1997). Increase of 20% relative to the below-ground increment (IPCC, 2006. v. 4, chap. 4, tab. 4.4)
ΔCGSecF4		0.62	0.59	0.59	1.66	0.59	0.59

Factor acronym	Parameter	Amazon Factor Methodology/Reference	Caatinga Factor Methodology/Reference	Cerrado Factor Methodology/Reference	Atlantic Forest Factor Methodology/Reference	Pampa Factor Methodology/Reference	Pantanal Factor Methodology/Reference
	Removal from secondary forest with other history (tC/ha year)	Calculated in a 9-year-old area that underwent restoration with forest plantation and soil addition after open-pit mining (Salomão *et al.*, 2007), using the Brown equation (1997), equation 3.2.4. 25.8% increase relative to the below-ground increment (Nogueira *et al.*, 2008)	Calculated in a 9-year-old area that underwent restoration with forest plantation and soil addition after open-pit mining (SALOMÃO *et al.*, 2007), using the Brown equation (1997), equation 3.2.4. 25.8% increase relative to the below-ground increment (Nogueira *et al.*, 2008)	Estimated based on an area that underwent 9 years of forest plantation restoration and soil addition after open-pit mining (Salomão *et al.*, 2007), using the Brown equation (1997, equation 3.2.4) to estimate above-ground biomass, divided by the number of years of forest restoration. 20% increase in the ratio for below-ground biomass (IPCC, 2006, vol. 4, chap. 4, tab. 4.4)	Above-ground and root biomass stock	Calculated in a 9-year-old area that underwent restoration with forest plantation and soil addition after open-pit mining (Salomão *et al.*, 2007), using the Brown equation (1997), equation 3.2.4. 20% increase relative to the below-ground increment (IPCC, 2006, vol. 4, chap. 4, tab. 4.4)	Calculated in a 9-year-old area that underwent restoration with forest plantation and soil addition after open-pit mining (Salomão *et al.*, 2007), using the Brown equation (1997), equation 3.2.4. 20% increase relative to the below-ground increment (IPCC, 2006, v. 4, chap. 4, tab. 4.4)
ΔCLSL and ΔCGSL	Carbon loss and gain in forest areas subjected to selective logging	Table A.VII.15	NA				
CFP	Average carbon stock in forest plantation	Table A.VII.16 Average values for all FUs/States (Table A.VII.13), obtained by multiplying the average annual carbon increment values and the average carbon stock values of each crop by the fraction of the crop's area in each FU/state.	Table A.VII.16 Average values for all FUs/states (Table A.VII.13), obtained by multiplying the average annual carbon increment values and the average carbon stock values of each crop by the fraction of the crop's area in each FU/state.	Table A.VII.16 Average values for all FUs/states (Table A.VII.13), obtained by multiplying the average annual carbon increment values and the average carbon stock values of each crop by the fraction of the crop's area in each FU/state.	Table A.VII.16 Average values for all FUs, obtained by multiplying the average annual carbon increment values and the average carbon stock values of each crop by the fraction of the crop's area in each FU/state.	Table A.VII.16 Average values for all FUs/States (Table A.VII.13), obtained by multiplying the average annual carbon increment values and the average carbon stock values of each crop by the fraction of the crop's area in each FU/state.	Table A.VII.16 Average values for all FUs/States (Table A.VII.13), obtained by multiplying the average annual carbon increment values and the average carbon stock values of each crop by the fraction of the crop's area in each FU/state.
ΔCGFP	Annual carbon removal from forest plantation (tC/ha year-1)	Table A.VII.16 Average values for all FUs/States (Table A.VII.13), obtained by multiplying the average annual carbon increment values and the average carbon stock values of each crop by the fraction of the crop's area in each FU/state.	Table A.VII.16 Average values for all FUs/States (Table A.VII.13), obtained by multiplying the average annual carbon increment values and the average carbon stock values of each crop by the fraction of the crop's area in each FU/state.	Table A.VII.16 Average values for all FUs/States (Table A.VII.13), obtained by multiplying the average annual carbon increment values and the average carbon stock values of each crop by the fraction of the crop's area in each FU/state.	Table A.VII.16 Average values for all FUs/States (Table A.VII.13), obtained by multiplying the average annual carbon increment values and the average carbon stock values of each crop by the fraction of the crop's area in each FU/state.	Table A.VII.16 Average values for all FUs/States (Table A.VII.13), obtained by multiplying the average annual carbon increment values and the average carbon stock values of each crop by the fraction of the crop's area in each FU/state.	Table A.VII.16 Average values for all FUs/States (Table A.VII.13), obtained by multiplying the average annual carbon increment values and the average carbon stock values of each crop by the fraction of the crop's area in each FU/state.
		0.44	0.10	0.44	0.44	0.44	0.44

Factor acronym	Parameter	Amazon Factor Methodology/Reference	Caatinga Factor Methodology/Reference	Cerrado Factor Methodology/Reference	Atlantic Forest Factor Methodology/Reference	Pampa Factor Methodology/Reference	Pantanal Factor Methodology/Reference
ΔCGMG	Removal from primary grassland (tC/ha year)	Estimate made in a protected area in the Rheas National Park (Parque Nacional das Emas) for the components of live biomass of grasses and trees, and dry biomass (Cianciaruso *et al.*, 2010)	Data from permanent plots from the Caatinga Management Network (APNE, NP)	Estimate made in a protected area in the Rheas National Park (Parque Nacional das Emas) for the components of live biomass of grasses and trees, and dry biomass (Cianciaruso *et al.*, 2010)	The value of the inventory presented in the inventory of the Third National Communication was maintained.	Estimation carried out in a protected area in the Rheas National Park for the live biomass components of grasses, trees, and dry biomass (Cianciaruso *et al.*, 2010)	Estimation carried out in a protected area in the Rheas National Park for the live biomass components of grasses, trees, and dry biomass (Cianciaruso *et al.*, 2010)
ΔCGSecG	Removal from secondary grassland (tC/ha year)	1.70 Estimate made in a protected area in the Rheas National Park (Parque Nacional das Emas) for the components of live biomass of grasses and trees, and dry biomass (Cianciaruso *et al.*, 2010)	0.60 We used data from the Sustainable Forest Management Plans, APNE (NP); Zákia *et al.*, 1999	1.70 Estimate made in a protected area in the Rheas National Park (Parque Nacional das Emas) for the components of live biomass of grasses and trees, and dry biomass (Cianciaruso *et al.*, 2010)	0.60 20 plots measuring 40 x 40m, dbh> 2 cm. Above-ground and root biomass stock (Zákia *et al.*, 1991)	1.70 Estimation carried out in a protected area in the Rheas National Park for the components of live biomass of grasses and trees, and dry biomass (Cianciaruso *et al.*, 2010)	1.70 Estimation carried out in a protected area in the Rheas National Park for the components of live biomass of grasses and trees, and dry biomass (Cianciaruso *et al.*, 2010)
ΔCLSecG	Percentage of remaining secondary grassland stock in relation to initial carbon stock (%)	44 Average values for the Amazon (Fearnside; Guimarães, 1996; Alves *et al.*, 1997), Atlantic Forest (Melo; Durigan, 2006) and Pantanal (Schöngart *et al.*, 2011)	44 Average values for the Amazon (Fearnside; Guimarães, 1996; Alves *et al.*, 1997), Atlantic Forest (MELO; Durigan, 2006) and Pantanal (Schöngart *et al.*, 2011).	44 Average values for the Amazon (ALVEZ *et al.*, 1997; FEARSIDE; GUIMARÃES, 1996), Atlantic Forest (Melo; Durigan, 2006) and Cambrazal in Mato Grosso (Schöngart *et al.*, 2011).	44 Average values for the Amazon (Fearnside; Guimarães, 1996; Alves *et al.*, 1997), Atlantic Forest (Melo; Durigan, 2006) and Pantanal (Schöngart *et al.*, 2011)	44 Average values for the Amazon (Fearnside; Guimarães, 1996; Alves *et al.*, 1997), Atlantic Forest (Melo; Durigan, 2006) and Pantanal (Schöngart *et al.*, 2011).	44 Average values for the Amazon (Fearnside; Guimarães, 1996; Alves *et al.*, 1997), Atlantic Forest (Melo; Durigan, 2006) and Pantanal (Schöngart *et al.*, 2011).
COL	C stock from other uses (tC/ha)	0	0	0	0	0	0
CRes	C stock from reservoirs (tC/ha)	0	0	0	0	0	0

Note: NA – not applicable.

Table A.VII.9. Land-use and land-cover conversion matrix for Brazil from 1994 to 2002.

Conversion matrix (Brazil): 1994 - 2002 (ha)																												
Biome		Land Use (2002)																									Total in 1994 ↓	Brazil's %
		Forest land					Grassland and pasture								Cropland			Settlement	Wetlands		Other land							
		UFL	MFL	SecF	FP	SL	OUWL	OMLD	OSLW	UG	MG	SecG	P	DP	AC	PER	SUGAR CANE	S	W	Res	UD	MD	URO	MRO	Min	BS	NO		
Forest land	UFL	389,397,616.3	55,997,294.0	872,477.6	205,357.0	238,862.7	-	-	-	-	-	-	27,230,764.2	-	2,761,972.4	-	-	127,267.4	26,435.9	366,453.1	-	-	-	-	19,485.4	594.0	212,969.2	477,457,549.1	54.6
	MFL	-	103,727,090.0	26,998.0	3,438.2	23,623.5	-	-	-	-	-	-	453,964.9	-	51,069.1	-	-	7,259.1	657.0	465.7	-	-	-	-	4,558.3	420.8	4,047.5	104,303,592.0	11.9
	SecF	-	-	796,078.0	634.8	-	-	-	-	-	-	-	636,868.2	-	4,382.2	-	-	1,169.0	19.2	0.6	-	-	-	-	827.9	-	-	1,439,979.9	0.2
	FP	-	-	52,579.7	4,757,573.4	-	-	-	3,232.8	-	-	4,191.5	282,555.2	-	76,269.3	-	-	1,633.7	-	162.9	-	-	-	-	272.3	6.9	568.0	5,179,045.8	0.6
	SL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0
Grassland and pasture	OUWL	-	-	-	12,095.1	-	29,291,377.6	5,156,222.6	15,755.9	-	-	-	1,973,621.3	-	593,219.8	-	-	18,614.8	2,042.1	14,455.1	-	-	-	-	391.2	1,016.8	5,249.4	37,084,061.7	4.2
	OMLD	-	-	-	45.5	-	-	4,479,015.6	56.1	-	-	-	34,806.7	-	4,398.4	-	-	340.6	182.6	-	-	-	-	-	1.1	-	1,153.5	4,520,000.0	0.5
	OSLW	-	-	-	104.4	-	-	-	9,394.7	-	-	-	6,842.3	-	83.2	-	-	11.0	-	-	-	-	-	-	1.7	-	-	16,437.3	0.0
	UG	-	-	-	28,041.4	-	-	-	-	14,857,474.1	1,445,406.0	5,580.0	547,145.5	-	468,950.2	-	-	2,580.9	6,126.5	1,790.3	-	-	-	-	439.7	533.6	3,747.6	17,367,815.9	2.0
	MG	-	-	-	714.7	-	-	-	-	-	1,239,674.0	27.1	4,888.4	-	2,638.9	-	-	358.2	197.5	4.0	-	-	-	-	721.3	-	-	1,249,224.0	0.1
	SecG	-	-	-	-	-	-	-	-	-	-	2,808.0	1,602.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4,410.9	0.0
	P	-	-	4,023,588.0	650,680.8	-	-	-	174,690.0	-	-	169,820.2	146,126,051.8	-	3,965,115.2	-	-	287,313.4	6,111.2	59,343.3	-	-	-	-	11,191.8	506.5	232,968.7	155,707,380.8	17.8
	DP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0
Cropland	AC	-	-	267,670.2	31,788.2	-	-	-	27,861.5	-	-	10,278.1	1,944,685.6	-	41,327,595.2	-	-	66,876.0	54,418.8	6,591.0	-	-	-	-	1,256.0	145.5	97,334.5	43,836,500.6	5.0
	PER	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0
	SUGAR CANE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0
Settlement	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,745,742.0	-	-	-	-	-	-	-	-	34.7	2,745,776.7	0.3
Wetlands	W	18,000.2	2,011.8	-	-	-	919.3	74.9	-	2,862.2	-	-	1,420.3	-	5,427.7	-	-	16.2	17,621,133.8	85,499.1	94.2	153.7	-	-	3.5	25.9	51.9	17,737,694.7	2.0
	Res	-	-	3,404.3	341.7	-	-	-	147.6	-	-	29.3	342.6	-	474.4	-	-	-	-	2,753,924.6	-	-	-	-	72.3	14.9	162.1	2,758,913.9	0.3
Other land	UD	-	-	-	1,598.6	-	-	-	-	-	-	-	795.4	-	153.7	-	-	496.1	-	36.9	308,009.5	17,806.4	-	-	-	-	-	328,896.7	0.0
	MD	-	-	-	-	-	-	-	-	-	-	-	0.2	-	-	-	-	249.6	-	-	-	126,896.6	-	-	-	-	-	127,146.3	0.0
	URO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14,015.2	76.2	-	-	-	14,091.3	0.0
	MRO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	697.3	-	-	-	697.3	0.0
	Min	-	-	1,111.5	149.7	-	-	-	43.2	-	-	90.7	1,156.8	-	10.2	-	-	329.4	7.7	126.8	-	-	-	-	174,274.9	12.5	-	177,313.4	0.0
	BS	-	-	6.3	11.8	-	-	-	-	-	-	-	633.6	-	156.5	-	-	139.0	0.1	206.6	-	-	-	-	-	194,795.7	-	195,949.7	0.0
	NO	332,395.7	46,185.6	25,639.3	2,514.2	321.1	7,808.3	9,290.2	-	1,360,3	-	25.5	1,118,931.4	-	222,207.2	-	-	4,951.9	164.4	1,185.0	-	-	-	-	1,740.1	114.8	73,598.9	1,848,433.9	0.2
Total in 2002 →		389,748,012.2	159,772,581.4	6,069,552.8	5,695,089.5	262,807.3	29,300,105.2	9,644,603.2	231,182.0	14,861,696.6	2,685,080.0	192,850.5	180,367,077.4	-	49,484,123.7	-	-	3,265,348.2	17,717,496.8	3,290,244.9	308,103.7	144,856.7	14,015.2	773.5	215,237.5	198,187.9	631,885.9	874,100,912.1	
Brazil's %		44.6	18.3	0.7	0.7	0.0	3.4	1.1	0.0	1.7	0.3	0.0	20.6	0.0	5.7	0.0	0.0	0.4	2.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.1		

Table A.VII.10. Land-use and land-cover conversion matrix for Brazil from 2002 to 2010.

Conversion matrix (Brazil): 2002 - 2010 (ha)

Biome		Land use (2010)																										Total en 2002	Brazil's %
		Forest land					Grassland and pasture								Cropland			Settlement	Wetlands		Other land								
		UFL	MFL	SecF	FP	SL	OUWL	UFL	MFL	SecF	FP	SL	OUWL	UFL	MFL	SecF	FP	SL	OUWL	UFL	MFL	SecF	FP	SL	OUWL	UFL	MFL		
Forest land	UFL	278,356,745.7	59,766,987.6	2,069,130.7	775,383.9	1,134,344.9	-	-	-	-	-	-	26,595,873.1	-	3,718,751.1	-	-	75,108.3	453,722.5	320,892.9	-	-	-	-	50,021.1	2,100.1	16,428,950.2	389,748,012.2	44.6
	MFL	-	148,780,625.8	115,328.8	19,456.7	53,595.2	-	-	-	-	-	-	1,112,867.2	-	80,751.3	-	-	5,733.8	313,165.7	36,783.8	-	-	-	-	8,219.1	42.3	9,246,011.8	159,772,581.4	18.3
	SecF	-	-	4,399,583.1	43,162.4	3,634.4	-	-	-	-	-	-	1,388,111.6	-	118,257.4	-	-	4,202.1	5,564.6	4,426.8	-	-	-	-	998.7	2.1	101,609.7	6,069,552.8	0.7
	FP	-	-	206,245.9	4,689,505.6	-	-	-	31,768.3	-	-	26,931.3	395,591.9	-	198,769.7	-	-	1,496.2	7.7	720.1	-	-	-	-	1,222.9	141.8	140,688.2	5,695,089.5	0.7
	SL	-	-	155,851.6	-	15,335.0	-	-	-	-	-	-	64,115.7	-	26,386.9	-	-	0.6	-	-	-	-	-	-	-	-	1,117.6	262,807.3	0.0
Grassland and pasture	OUWL	-	-	-	49,981.3	-	25,112,516.0	1,114,593.2	42,928.9	-	-	-	1,906,956.9	-	361,507.3	-	-	9,056.0	71,422.5	49,658.3	-	-	-	-	1,763.3	35.4	579,686.2	29,300,105.2	3.4
	OMLD	-	-	-	3,059.0	-	-	9,160,920.1	2,285.2	-	-	-	166,272.6	-	32,733.3	-	-	2,851.4	8,334.4	1,945.7	-	-	-	-	702.4	-	265,499.1	9,644,603.2	1.1
	OSLW	-	-	-	2,409.1	-	-	-	173,810.3	-	-	-	42,562.1	-	10,896.7	-	-	109.4	20.8	256.7	-	-	-	-	25.9	-	1,090.9	231,182.0	0.0
	UG	-	-	-	224,836.4	-	-	-	-	12,153,585.4	537,545.6	14,332.6	1,063,912.5	-	516,493.0	-	-	2,725.2	82,363.7	10,458.9	-	-	-	-	2,061.5	51.6	253,330.2	14,861,696.6	1.7
	MG	-	-	-	11,144.5	-	-	-	-	-	2,476,797.7	1,060.3	45,353.9	-	6,838.5	-	-	372.4	39,331.3	263.3	-	-	-	-	1,716.7	5.8	102,195.7	2,685,080.0	0.3
	SecG	-	-	-	3,949.9	-	-	-	-	-	-	125,509.3	48,463.7	-	14,207.4	-	-	92.2	60.1	163.5	-	-	-	-	40.7	-	363.7	192,850.5	0.0
	P	-	-	13,184,600.1	2,765,648.1	1,818.0	-	-	968,080.3	-	-	450,160.4	148,264,899.5	-	8,978,434.3	-	-	365,695.4	63,196.9	194,050.9	-	-	-	-	40,344.3	2,383.2	5,087,766.2	180,367,077.4	20.6
	DP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0
Cropland	AC	-	-	1,054,823.6	380,962.2	7.7	-	-	107,695.6	-	-	28,541.9	3,530,854.3	-	43,899,632.7	-	-	103,655.4	6,953.4	31,662.7	-	-	-	-	7,204.5	906.0	331,223.8	49,484,123.7	5.7
	PER	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0
	SUGAR CANE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0
Settlement	S	-	-	177.0	-	-	-	-	-	-	-	-	92.5	-	-	-	-	3,261,882.3	-	1.3	-	-	-	-	87.6	-	3,107.5	3,265,348.2	0.4
Wetlands	W	451,146.9	143,008.4	23,569.8	767.4	1.6	14,411.1	5,773.6	893.1	22,698.9	3,287.5	932.0	116,923.5	-	84,418.6	-	-	3,270.7	15,720,667.1	124,311.0	2,640.7	1,721.2	-	-	5,168.8	271.9	991,613.1	17,717,496.8	2.0
	Res	-	-	25,921.2	98.1	-	-	-	1,167.2	-	-	1,555.7	11,173.6	-	7,257.0	-	-	48.4	5.7	3,225,436.2	-	-	-	-	1,105.9	927.2	15,548.8	3,290,244.9	0.4
Other land	UD	-	-	-	8,063.7	-	-	-	-	-	-	-	1,353.1	-	515.4	-	-	1,485.5	879.3	1,417.6	260,558.3	15,880.6	-	-	-	-	17,950.1	308,103.7	0.0
	MD	-	-	-	92.6	-	-	-	-	-	-	-	2.5	-	3.7	-	-	19.1	33.9	0.0	-	137,316.3	-	-	-	-	7,388.7	144,856.7	0.0
	URO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12,782.9	1,232.2	-	-	-	14,015.2	0.0
	MRO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	773.5	-	-	-	773.5	0.0
	Min	-	-	20,908.0	612.1	-	-	-	128.5	-	-	87.9	3,821.8	-	-	-	-	444.6	7.8	641.4	-	-	-	-	184,773.6	1,793.2	2,018.7	215,237.5	0.0
	BS	-	-	1,510.6	55.0	-	-	-	632.2	-	-	-	2,049.3	-	981.8	-	-	122.4	-	226.7	-	-	-	-	15.4	192,554.9	39.4	198,187.9	0.0
	NO	55,197.2	3,446.6	60,915.2	4,655.8	-	1,817.7	246.6	2,938.6	2,763.6	-	2,471.4	270,079.6	-	56,835.4	-	-	2,680.0	237.9	1,570.2	-	-	-	-	19.2	-	166,010.9	631,885.9	0.1
Total in 2010		278,863,089.7	208,694,068.4	21,318,565.6	8,983,843.9	1,208,736.8	25,128,744.8	10,281,533.5	1,332,328.2	12,179,048.0	3,017,630.8	651,582.8	185,031,330.9	-	58,113,671.4	-	-	3,843,051.3	16,765,975.3	4,004,887.9	263,199.0	154,918.1	12,782.9	2,005.7	305,491.4	201,215.5	33,743,210.5	874,100,912.0	
Brazil's %		31.9	23.9	2.4	1.0	0.1	2.9	1.2	0.2	1.4	0.3	0.1	21.2	0.0	6.6	0.0	0.0	0.4	1.9	0.5	0.0	0.0	0.0	0.0	0.0	0.0	3.9		

Table A.VII.11. Land-use and land-cover conversion matrix for Brazil from 2010 to 2016.

Conversion matrix (Brazil): 2010 – 2016 (ha)																															
Land use in 2016																															
Biomes		Forest land					Grassland and pasture								Cropland			Settlement	Wetlands		Other land								Total in 2010 +	Brazil's %
		UFL	MFL	SecF	FP	SL	OUWL	UFL	MFL	SecF	FP	SL	OUWL	UFL	MFL	SecF	FP	SL	OUWL	UFL	MFL	SecF	FP	SL	OUWL	UFL	MFL		
Forest land	UFL	257,171,319.7	10,160,649.5	405,566.1	285,060.6	625,003.0	-	-	-	-	-	-	8,172,928.5	-	1,646,550.5	61,846.1	132,187.6	30,033.3	2,768.7	83,418.1	-	-	-	-	26,538.0	11,756.1	47,475.0		278,863,089.8	31,9
	MFL	-	207,739,044.6	54,762.2	4,215.7	45,681.3	-	-	-	-	-	-	668,818.4	-	106,725.1	1,271.4	4,613.8	4,270.1	1,437.4	3,789.3	-	-	-	-	28,367.5	331.0	30,840.6		208,694,068.4	23,9
	SecF	-	-	18,724,013.4	68,042.0	33,848.6	-	-	-	-	-	-	2,059,974.0	-	323,392.6	50,522.7	22,124.6	8,714.8	209.0	8,834.3	-	-	-	-	12,375.7	1,018.2	5,495.6		21,318,565.6	2,4
	FP	-	-	60,935.3	8,477,083.5	-	-	-	3,003.1	-	-	3,047.2	317,028.0	-	85,332.6	10,700.6	22,387.5	2,219.3	-	1,103.3	-	-	-	-	904.3	89.1	10.2		8,983,843.9	1,0
	SL	-	-	1,070,157.0	0.3	102,680.6	-	-	-	-	-	-	30,547.2	-	4,884.9	76.8	-	-	-	-	-	-	-	-	1.8	-	388.2		1,208,736.8	0,1
Grassland and pasture	OUWL	-	-	-	49,845.6	-	23,595,941.9	192,582.9	25,521.3	-	-	-	913,946.8	-	316,290.8	5,586.2	10,956.5	4,236.5	126.2	10,177.4	-	-	-	-	1,423.6	756.5	1,352.2		25,128,744.8	2,9
	OMLD	-	-	-	3,690.4	-	-	10,164,428.3	5,714.6	-	-	-	73,931.0	-	30,924.3	260.2	-	387.0	512.4	201.6	-	-	-	-	1,277.6	-	206.2		10,281,533.5	1,2
	OSLW	-	-	-	2,758.5	-	-	-	1,167,573.9	-	-	-	124,488.8	-	33,633.4	1,260.7	1,114.8	711.4	0.9	519.8	-	-	-	-	230.0	16.5	18.5		1,332,328.2	0,2
	UG	-	-	-	73,023.0	-	-	-	-	11,523,628.0	54,630.3	6,053.7	234,576.6	-	272,444.6	2,193.2	3,986.6	1,048.0	10.5	5,350.0	-	-	-	-	2,044.9	58.8	-		12,179,048.0	1,4
	MG	-	-	-	3,034.0	-	-	-	-	-	2,991,663.7	44.3	16,496.4	-	5,908.9	6.0	79.6	284.3	12.1	56.4	-	-	-	-	45.3	-	-		3,017,630.8	0,3
	SecG	-	-	-	12,269.6	-	-	-	-	-	-	563,911.1	44,604.2	-	25,658.6	3,746.7	886.9	71.3	-	386.8	-	-	-	-	47.7	-	-		651,582.8	0,1
	P	-	-	3,190,386.9	1,772,277.2	-	-	-	204,265.4	-	-	77,660.4	168,774,184.0	785,471.0	7,662,151.2	288,574.2	1,884,239.2	261,625.3	-	72,919.2	-	-	-	-	30,777.9	2,859.1	23,939.9		185,031,330.9	21,2
	DP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	0,0
Cropland	AC	-	-	251,125.5	217,196.7	-	-	-	10,080.9	-	-	7,578.1	2,056,435.0	-	41,168,857.9	3,454,510.9	10,877,269.1	51,696.7	-	12,026.8	-	-	-	-	1,983.7	1,064.5	3,845.6		58,113,671.4	6,6
	PER	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	0,0
	SUGAR CANE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	0,0
Settlement	S	-	-	48.9	-	-	-	-	-	-	-	-	-	-	-	-	-	3,842,810.6	-	22.5	-	-	-	-	-	-	169.4		3,843,051.3	0,4
Wetlands	W	2,419.3	469.5	5,359.0	-	-	6.9	-	30.1	18.9	0.0	-	3,592.1	-	2,480.9	219.5	0.6	192.9	16,689,870.9	60,386.1	-	-	-	-	44.0	50.6	834.1		16,765,975.3	1,9
	Res	-	-	168,001.5	4.2	-	-	-	26,858.3	-	-	428.8	58,248.6	-	6,128.6	81.2	-	-	-	3,742,755.2	-	-	-	-	322.4	1,796.4	272.7		4,004,887.9	0,5
Other land	UD	-	-	-	634.3	-	-	-	-	-	-	-	52.5	-	5.1	295.9	-	979.4	-	316.0	260,033.7	882.2	-	-	-	-	-		263,199.0	0,0
	MD	-	-	-	24.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	154,893.9	-	-	0.0	-	-		154,918.1	0,0
	URO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12,78..9	-	-	-	-		12,762.9	0,0
	MRO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2,005.7	-	-	-		2,005.7	0,0
	Min	-	-	4,030.5	15,.0	-	-	-	63.1	-	-	29.2	85.2	-	-	-	-	177.1	-	802.3	-	-	-	-	299,863.4	289.8	-		305,491.4	0,0
	BS	-	-	325.5	74.3	-	-	-	-	-	-	16.7	1,033.7	-	41,.8	-	-	350.2	-	1,040.3	-	-	-	-	-	198,333.1	-		201,215.5	0,0
	NO	11,000,445.8	13,274,110.1	1,512,947.6	102,347.2	42,212.1	503,272.3	295,080.3	55,763.5	200,002.7	132,004.3	8,214.8	4,816,014.5	-	439,402.8	226,506.3	17,955.4	35,950.1	951,315.0	36,656.5	15,901.8	8,350.9	-	-	9,803.4	608.1	27,914.8		33,743,210.5	3,9
Total in 2016 +		268,204,184.8	231,174,273.7	25,447,699.4	11,071,722.2	849,425.7	24,099,221.2	10,652,091.5	1,498,874.3	11,723,649.6	3,179,296.3	666,984.1	188,366,986.5	785,471.0	52,130,814.4	4,108,088.5	12,977,702.1	4,246,758.1	17,646,263.1	4,040,761.9	275,935.5	164,127.0	12,782.9	2,005.7	416,050.9	219,016.6	142,763.1		874,100,912.1	
Brazil's %		30.7	26.4	2.9	1.3	0.1	2.8	1.2	0.2	1.3	0.4	0.1	21.5	0.1	6.0	0.5	1.5	0.5	2.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0			

Table A.VII.12. Calculation logic applied to Selective Logging in the Amazon.

Possible FL-SL conversions								
1994	**2002**	**2005**	**2010**	**2016**	**Time (years)**	**ΔC_L SL AGB (%)**	**ΔC_G SL CWD (%)**	**Notes**
FL	SL	-	-	-	4	-29%	112%	Carbon loss 3 years after SL (Huang; Asner, 2010)
FL	FL	SL	-	-	2	-29%	128%	Carbon loss 2 years after SL (Huang; Asner, 2010))
FL	FL	FL	SL	-	3	-29%	128%	Carbon loss 2 years after (Huang; Asner, 2010))
FL	FL	FL	FL	SL	3	-29%	112%	Carbon loss 3 years after SL (Huang; Asner, 2010)
Possible SL-SL conversions								
1994	**2002**	**2005**	**2010**	**2016**	**Time (years)**	**ΔC_L SL AGB (%)**	**ΔC_G SL CWD (%)**	**Notes**
NA	SL	SL	-	-	7	-27%	67%	6 years after SL (Huang; Asner, 2010)
NA	FL	SL	SL	-	7	-27%	67%	6 years after SL (Huang; Asner, 2010)
NA	FL	FL	SL	SL	8	-27%	67%	6 years after SL (Huang; Asner, 2010)
Possible SL-SL-SL conversions								
1994	**2002**	**2005**	**2010**	**2016**	**Time (years)**	**ΔC_L SL AGB (%)**	**ΔC_G SL CWD (%)**	**Notes**
NA	SL	SL	SL	-	12	-26%	32%	11 years after SL (Huang; Asner, 2010)
NA	-	SL	SL	SL	13	-26%	32%	11 years after SL (Huang; Asner, 2010)
Possible SL-SL-SL-SL conversions								
1994	**2002**	**2005**	**2010**	**2016**	**Time (years)**	**ΔC_L SL AGB (%)**	**ΔC_L SL CWD (%)**	**Notes**
NA	SL	SL	SL	SL	18	-22%	-1%	21 years after SL (Huang; Asner, 2010)
Post-SL (Post-SL C) -> 44% gain is considered on the lost C alone								

Table A.VII.13. Values of annual carbon removal (ΔCGFP) and average carbon stock (CFP) in forest plantation by FU/state, for the years of 1994, 2002, 2005, 2010 and 2016.

FU/State	1994		2002		2005		2010		2016		
	ΔCGFP	CFP	ΔCGFP	CFP	ΔCGFP	CFP	ΔCGFP	CFP	ΔCGFP	CFP	Total carbon
	(t C/ha year^{-1})	(t C/ha)	(t C/ha year^{-1})	(t C/ha)	(t C/ha year^{-1})	(t C/ha)	(t C/ha year^{-1})	(t C/ha)	(t C/ha year^{-1})	(t C/ha^{1})	(Mt)
AP (Amapá)	-	-	10.87	50.85	11.09	50.67	11.16	39.08	11.55	40.43	2.63
BA (Bahia)	-	-	11.85	42.16	11.64	44.27	11.12	40.59	11.54	40.59	24.98
ES (Espírito Santo)	-	-	11.90	41.69	11.82	42.24	11.14	39.71	11.53	40.74	9.62
GO (Goiás)	-	-	-	-	11.33	47.86	11.00	45.55	11.41	42.28	5.74
MA (Maranhão)	-	-	11.90	41.68	11.88	41.57	11.16	39.07	11.55	40.43	8.97
MT (Mato Grosso)	-	-	-	-	11.88	41.60	11.16	39.07	11.55	40.63	7.49
MS (Mato Grosso do Sul)	-	-	11.90	41.68	11.24	48.91	11.13	40.40	11.54	40.56	35.90
MG (Minas Gerais)	-	-	11.85	42.17	11.58	44.96	11.08	42.41	11.49	41.19	58.77
PA (Pará)	-	-	11.74	43.15	11.88	41.61	11.16	39.07	11.55	40.43	5.41
PR (Paraná)	-	-	9.53	62.86	9.73	66.14	10.41	69.55	9.99	60.90	58.87
PI (Piauí)	-	-	-	-	-	-	11.16	39.07	11.55	40.43	1.05
RS (Rio Grande do Sul)	-	-	7.77	29.04	9.33	47.20	10.02	48.08	10.01	46.86	27.28
SC (Santa Catarina)	-	-	9.21	65.70	10.98	65.51	11.13	69.22	9.71	64.68	42.82
SP (São Paulo)	-	-	11.60	44.34	11.49	46.06	11.04	44.12	11.29	43.85	46.92
SP (São Paulo)	-	-	-	-	-	-	-		11.55	40.43	0.13
TO (Tocantins)	-	-	-	-	11.88	41.57	11.14	39.73	11.55	40.48	4.73
Other States	-	-	-	-	11.56	45.24	11.16	39.07	11.55	40.43	0.77
Average value for all FUs/States	**7.39**	**28.24**	**10.92**	**45.9**	**11.3**	**47.7**	**11.0**	**44.6**	**11.2**	**43.8**	**342.01**

Note: Black wattle is only accounted for in the state of Rio Grande do Sul.

Table A.VII.14. Equations and variables used to estimate CO_2 due to changes in land use and land cover.

Subsector	Category	Subcategory	Subdivision (Division)	Equation
4.A. Forest Land	4.A.1. Forest Land Remaining Forest Land	4.A.1. Forest Land Remaining Forest Land	a. Unmanaged Forest Land Converted to Managed Forest Land (UFL-MFL)[1]	ΔC = W x ΔCGMFL x t
			b. Unmanaged Forest Land Converted to Secondary Forest (UFL-SecF)	ΔC = W x [(ΔCGSecF1 x t/2) – CFL]
			c. Unmanaged Forest Land Converted to Forest Plantation (UFL-FP)	ΔC = A x [(ΔCGFP x t/2) – CFL]
			d. Managed Forest Land Remaining Managed Forest Land (MFL-MFL)[2]	ΔC = W x ΔCGMFL x t
			e. Managed Forest Land Converted to Secondary Forest (MFL-SecF)[3]	ΔC = W x [(ΔCGSecF1 x t/2) – CFL]
			f. Managed Forest Land Converted to Forest Plantation (MFL-FP)	ΔC = W x [(ΔCGFP x t/2) – CFL]
			g. Unmanaged Forest Land Converted to Selective Logging (UFL-SL)[4]	ΔC = W x (ΔCLSLAGB + ΔCGSLCWD)
			h. Managed Forest Land Converted to Selective Logging (MFL-SL)	ΔC = W x (ΔCLSLAGB + ΔCGSLCWD)
			i. Secondary Forest Converted to Forest Plantation (SecF-FP)	ΔC = W x [(ΔCGFP x t/2) – (ΔCLSecF x CFL)]
			j. Secondary Forest Converted to Selective Logging (SecF-SL)	ΔC = W x [(ΔCLSLAGB + ΔCGSLCWD) x (ΔCLSecF x CFL)]
			k. Forest Plantation Converted to Secondary Forest (FP-SecF)	ΔC = W x [(ΔCGSecF1 x t/2) – CFP]
			l. Selective Logging Converted to Secondary Forest (SL-SecF)	ΔC = W x [(ΔCLSLAGB + ΔCGSLCWD) x ΔCLSecF]
			m. Selective Logging Converted to Forest Plantation (SL-FP)	ΔC = W x [(ΔCGFP x t/2) – CpostSL]
			n. Selective Logging Remaining Selective Logging (SL-SL)	ΔC = W x (ΔCLSLAGB + ΔCGSLCWD)
	4.A.2 Land Converted to Forest Land	4.A.2.a. Cropland Converted to Forest Land	i. Cropland Converted to Secondary Forest (C-SecF)	ΔC = W x [(ΔCGSecF3 x t/2) – CAc]
			ii. Cropland Converted to Forest Plantation (C-FP)	ΔC = W x [(ΔCGFP x t/2) – CAc]
		4.A.2.b. Grassland Converted to Forest Land	i. Pasture Converted to Secondary Forest (P-SecF)	ΔC = W x [(ΔCGSecF2 x t/2) – Cp]
			ii. Pasture Converted to Forest Plantation (P-FP)	ΔC = W x [(ΔCGFP x t/2) – Cp]
			iii. Other Managed Wooded Land Converted to Forest Plantation (OMWL-FP)	ΔC = W x [(ΔCOWLFP x t/2) – COWL]
			iv. Other Secondary Wooded Land Converted to Forest Plantation (OSWL-FP)	ΔC = W x [(ΔCOWLFP x t/2) – COWL]
			v. Unmanaged Grassland Converted to Forest Plantation (UG-FP)	ΔC = W x [(ΔCGFP x t/2) – CG]
			vi. Managed Grassland Converted to Forest Plantation (MG-FP)	ΔC = W x [(ΔCGFP x t/2) – CG]
			vii. Secondary Grassland Converted to Forest Plantation (SecG-FP)	ΔC = W x [(ΔCGSecG x t/2) – CFP]
			viii. Other Unmanaged Wooded Land Converted to Forest Plantation (OUWL-FP)	ΔC = W x [(ΔCGOWLSec x t/2) – CFP]
		4.A.2.e. Other Land Converted to Forest Land	i. Unmanaged Dune Converted to Forest Plantation (UD-FP)	ΔC = W x [(ΔCGSecF1 x t/2) – COL]
			ii. Managed Dune Converted to Forest Plantation (MD-FP)	ΔC = W x [(ΔCGSecF1 x t/2) – COL]
			iii. Mining Converted to Secondary Forest (Min-SecF)	ΔC = W x [(ΔCGSecF1 x t/2) – COL]
			iv. Mining Converted to Forest Plantation (Min-FP)	ΔC = W x [(ΔCGSecF1 x t/2) – COL]
			v. Bare Soil Converted to Secondary Forest (BS-SecF)	ΔC = W x [(ΔCGSecF1 x t/2) – COL]
			vi. Bare Soil Converted to Forest Plantation (BS-FP)	ΔC = W x [(ΔCGSecF1 x t/2) – COL]

Subsector	Category	Subcategory	Subdivision (Division)	Equation
4.B. Cropland	4.B.2. Land Converted to Cropland	4.B.2.a. Forest Land Converted to Cropland	i. Unmanaged Forest Land Converted to Annual Cropland (UFL-AC)	ΔC = W x [(ΔCGAc x t/2) – CFL]
			ii. Unmanaged Forest Land Converted to Perennial Cropland (UFL-PER)	ΔC = W x [(ΔCGAc x t/2) – CFL]
			iii. Unmanaged Forest Land Converted to Semi-perennial Cropland (UFL-SUGAR CANE)	ΔC = W x [(ΔCGAc x t/2) – CFL]
			iv. Managed Forest Land Converted to Annual Cropland (MFL-AC)	ΔC = W x [(ΔCGAc x t/2) – CFL]
			v. Managed Forest Land Converted to Perennial Cropland (MFL-PER)	ΔC = W x [(ΔCGAc x t/2) – CFL]
			vi. Managed Forest Land Converted to Semi-perennial Cropland (MFL-SUGAR CANE)	ΔC = W x [(ΔCGAc x t/2) – CFL]
			vii. Secondary Forest Converted to Annual Cropland (SecF-AC)	ΔC = W x [(ΔCGAc x t/2) – (ΔCLSecF x CFL)]
			viii. Secondary Forest Converted to Perennial Cropland (SecF-PER)	ΔC = W x [(ΔCGAc x t/2) – (ΔCLSecF x CFL)]
			ix. Secondary Forest Converted to Semi-perennial Cropland (SecF-SUGAR CANE)	ΔC = W x [(ΔCGAc x t/2) – (ΔCLSecF x CFL)]
			x. Forest Plantation Converted to Annual Cropland (FP-AC)	ΔC = W x [(ΔCGAc x t/2) – CFP]
			xi. Forest Plantation Converted to Perennial Cropland (FP-PER)	ΔC = W x [(ΔCGAc x t/2) – CFP]
			xii. Forest Plantation Converted to Semi-perennial Cropland (FP-SUGAR CANE)	ΔC = W x [(ΔCGAc x t/2) – CFP]
			xiii. Selective Logging Converted to Annual Cropland (SL-AC)	ΔC = W x [(ΔCGAc x t/2) – CpostSL]
			xiv. Selective Logging Converted to Perennial Cropland (SL-PER)	ΔC = W x [(ΔCGAc x t/2) – CpostSL]
		4.B.2.b. Grassland Converted to Cropland	i. Secondary Grassland Converted to Perennial Cropland (SecG-PER)	ΔC = W x [(ΔCGAc x t/2) – (ΔCLSecG x CG)]
			ii. Secondary Grassland Converted to Semi-perennial Cropland (SecG-SUGAR CANE)	ΔC = W x [(ΔCGAc x t/2) – (ΔCLSecG x CG)]
			iii. Other Unmanaged Wooded Land Converted to Annual Cropland (OUWL-AC)	ΔC = W x [(ΔCGAc x t/2) – COWL]
			iv. Other Unmanaged Wooded Land Converted to Perennial Cropland (OUWL-PER)	ΔC = W x [(ΔCGAc x t/2) – COWL]
			v. Other Unmanaged Wooded Land Converted to Semi-perennial Cropland (OUWL-SUGAR CANE)	ΔC = W x [(ΔCGAc x t/2) – COWL]
			vi. Pasture Converted to Annual Cropland (P-AC)	ΔC = W x [(ΔCGAc x t/2) – Cp]
			vii. Pasture Converted to Perennial Cropland (P-PER)	ΔC = W x [(ΔCGAc x t/2) – Cp]
			viii. Pasture Converted to Semi-perennial Cropland (P-SUGAR CANE)	ΔC = W x [(ΔCGAc x t/2) – Cp]
			ix. Other Managed Wooded Land Converted to Annual Cropland (OMWL-AC)	ΔC = W x [(ΔCGAc x t/2) – COWL]
			x. Other Managed Wooded Land Converted to Perennial Cropland (OMWL-PER)	ΔC = W x [(ΔCGAc x t/2) – COWL]
			xi. Other Secondary Wooded Land Converted to Annual Cropland (OSWL-AC)	ΔC = W x [(ΔCGAc x t/2) – (ΔCLOSWL x COWL)]
			xii. Other Secondary Wooded Land Converted to Perennial Cropland (OSWL-PER)	ΔC = W x [(ΔCGAc x t/2) – (ΔCLOSWL x COWL)]

Subsector	Category	Subcategory	Subdivision (Division)	Equation
			xiii. Other Secondary Wooded Land Converted to Semi-perennial Cropland (OSWL-SUGAR CANE)	ΔC = W x [(ΔCGAc x t/2) – (ΔCLOSWL x COWL)]
			xiv. Unmanaged Grassland Converted to Annual Cropland (UG-AC)	ΔC = W x [(ΔCGAc x t/2) – CG]
			xv. Unmanaged Grassland Converted to Perennial Cropland (UG-PER)	ΔC = W x [(ΔCGAc x t/2) – CG]
			xvi. Unmanaged Grassland Converted to semi-perennial Cropland (UG-SUGAR CANE)	ΔC = W x [(ΔCGAc x t/2) – CG]
			xvii. Managed Grassland Converted to Annual Cropland (MG-Ac)	ΔC = W x [(ΔCGAc x t/2) – CG]
			xviii. Managed Grassland Converted to Perennial Cropland (MG-PER)	ΔC = W x [(ΔCGAc x t/2) – CG]
			xix. Managed Grassland Converted to Semi-perennial Cropland (MG-SUGAR CANE)	ΔC = W x [(ΔCGAc x t/2) – CG]
			xx. Secondary Grassland Converted to annual Cropland (SecG-AC)	ΔC = W x [(ΔCGAc x t/2) – (ΔCLSecG x CG)]
		4.B.2. e Other Land Converted to Cropland	i. Unmanaged Dune Converted to Annual Cropland (UD-AC)	ΔC = W x [(ΔCGAc x t/2) – COL]
			ii. Managed Dune Converted to Perennial Cropland (MD-PER)	ΔC = W x [(ΔCGAc x t/2) – COL]
			iii. Managed Dune Converted to Annual Cropland (MD-AC)	ΔC = W x [(ΔCGAc x t/2) – COL]
			iv. Unmanaged Dune Converted to Perennial Cropland (UD-PER)	ΔC = W x [(ΔCGAc x t/2) – COL]
			v. Mining Converted to Annual Cropland (Min-AC)	ΔC = W x [(ΔCGAc x t/2) – COL]
			vi. Bare Soil Converted to Annual Cropland (BS-AC)	ΔC = W x [(ΔCGAc x t/2) – COL]
4.C. Grassland	4.C.1 Grassland Remaining Grassland	4.C.1 Grassland Remaining Grassland	a. Secondary Grassland Converted to Pasture (SecG-P)	ΔC = W x [Cp – (ΔCLSecG x CG)]
			b. Other Unmanaged Wooded Land Converted to Pasture (OUWL-P)	ΔC = W x [Cp – COWL]
			c. Other Unmanaged Wooded Land Converted to Other Managed Wooded Land (OUWL-OMWL)	ΔC = W x ΔCGOMWLx t
			d. Other Unmanaged Wooded Land Converted to Other Secondary Wooded Land (OUWL-OSWL)	ΔC = W x [(ΔCGOSWL1 x t/2) – COWL]
			e. Pasture Converted to Secondary Grassland (P-SecG)	ΔC = W x [(ΔCGSecG x t/2) – Cp]
			f. Pasture Converted to Degraded Pasture (P-DP)	ΔC = W x [CDP – Cp]
			g. Pasture Converted to Other Secondary Wooded Land (P-OSWL)	ΔC = W x [(ΔCGOSWL x t/2) – Cp]
			h. Other Managed Wooded Land Converted to Pasture (OMWL-P)	ΔC = W x [Cp – COWL]
			i. Other Managed Wooded Land Remaining Other Managed Wooded Land (OMWL-OMWL)	ΔC = W x ΔCGOMWL x t
			j. Other Managed Wooded Land Converted to Other Secondary Wooded Land (OMWL-OSWL)	ΔC = W x [(ΔCGOSWL x t/2) – COWL]
			k. Other Secondary Wooded Land Converted to Pasture (OSWL-P)	ΔC = W x [Cp – (ΔCLOSWL x COWL)]
			l. Unmanaged Grassland Converted to Secondary Grassland (UG-SecG)	ΔC = W x [(ΔCGSecG x t/2) – CG]
			m. Unmanaged Grassland Converted to Pasture (UG-P)	ΔC = W x [Cp – CG]
			n. Unmanaged Grassland Converted to Managed Grassland (UG-MG)	ΔC = W x ΔCGMG x t
			o. Managed Grassland Converted to Secondary Grassland (MG-SecG)	ΔC = W x [(ΔCGSeGc x t/2) – CG]
			p. Managed Grassland Converted to Pasture (MG-P)	ΔC = W x [Cp – CG]

Subsector	Category	Subcategory	Subdivision (Division)	Equation
	4.C.2 Land Converted to Grassland		q. Managed Grassland Remaining Managed Grassland (MG-MG)	ΔC = W x ΔCGMG x t
		4.C.2.a Forest Land Converted to Grassland	i. Unmanaged Forest Land Converted to Pasture (UFL-P)	ΔC = W x [Cp – CFL]
			ii. Managed Forest Land Converted to Pasture (MFL-P)	ΔC = W x [Cp – CFL]
			iii. Managed Forest Land Converted to Degraded Pasture (MFL-DP)	ΔC = W x [CDP – CFL]
			iv. Secondary Forest Converted to Pasture (SecF-P)	ΔC = W x [Cp – (ΔCLSecF x CFL)]
			v. Forest Plantation Converted to Secondary Grassland (FP-SecG)	ΔC = W x [(ΔCGSecG x t/2) – CFP]
			vi. Forest Plantation Converted to Pasture (FP-P)	ΔC = W x [Cp – CFP]
			vii. Forest Plantation Converted to Other Secondary Wooded Land (FP- OSWL)	ΔC = W x [(ΔCGOSWL x t/2) – CFP]
			viii. Selective Logging Converted to Pasture (SL-P)	ΔC = W x [Cp – CpostSL]
		4.C.2.b Cropland Converted to Grassland	i. Cropland Converted to Secondary Grassland (C-SecG)	ΔC = W x [(ΔCGSecG x t/2) – CAc]
			ii. Cropland Converted to Pasture (C-P)	ΔC = W x [Cp – CAc]
			iii. Cropland Converted to Other Secondary Wooded Land (C-OSWL)	ΔC = W x [(ΔCGOSWL x t/2) – CAc]
		4.C.2.e Other Land Converted to Grassland	i. Unmanaged Dune Converted to Pasture (UD-P)	ΔC = W x [Cp – COL]
			ii. Managed Dune Converted to Pasture (MD-P)	ΔC = W x [Cp – COL]
			iii. Mining Converted to Secondary Grassland (Min-SecG)	ΔC = W x [(ΔCGSecG x t/2) – COL]
			iv. Mining Converted to Pasture (Min-P)	ΔC = W x [Cp – COL]
			v. Mining Converted to Other Secondary Wooded Land (Min-OSWL)	ΔC = W x [(ΔCGOSWL x t/2) – COL]
			vi. Bare Soil Converted to Secondary Grassland (BS-SecG)	ΔC = W x [(ΔCGSecG x t/2) – COL]
			vii. Bare Soil Converted to Pasture (Bs-P)	ΔC = W x [Cp – COL]
			viii. Bare Soil Converted to Other Secondary Wooded Land (BS- OSWL)	ΔC = W x [(ΔCGOSWL x t/2) – COL]
4.D. Wetlands	4.D.2 Land Converted to Wetland	4.D.2.a Forest Land Converted to Wetland	i. Unmanaged Forest Land Converted to Reservoir (UFL-Res)	ΔC = W x [CRes – CFL]
			ii. Managed Forest Land Converted to Reservoir (MFL-Res)	ΔC = W x [CRes – CFL]
			iii. Secondary Forest Converted to Reservoir (SecF-Res)	ΔC = W x [CRes – (ΔCLSecF x CFL)]
			iv. Forest Plantation Converted to Reservoir (FP-Res)	ΔC = W x (CRes – CFP)
			v. Selective Logging Converted to Reservoir (SL-Res)	ΔC = W x [COL – CpostSL]
		4.D.2.b Cropland Converted to Wetland	i. Cropland Converted to Reservoir (C-Res)	ΔC = W x (CRes – CAc)
		4.D.2.c Grassland Converted to Wetland	i. Secondary Grassland Converted to Reservoir (SecG-Res)	ΔC = W x [CRes – (ΔCLFGsec x CF)]
			ii. Other Unmanaged Wooded Land Converted to Reservoir (OUWL-Res)	ΔC = A x (CRes – COFL)
			iii. Pasture Converted to Reservoir (P-Res)	ΔC = A x (CRes – CAp)
			iv. Other Managed Wooded Land Converted to Reservoir (OMWL-Res)	ΔC = A x (CRes – COFL)
			v. Other Secondary Wooded Land Converted to Reservoir (OSWL- Res)	ΔC = W x [CRes – (ΔCLFOSWL x COWL)]

Subsector	Category	Subcategory	Subdivision (Division)	Equation
			vi. Unmanaged Grassland Converted to Reservoir (UG-Res)	ΔC = W x (CRes – CG)
			vii. Managed Grassland Converted to Reservoir (MG-Res)	ΔC = W x (CRes – CG)
4.E. Settlements	4.E.2 Land Converted to Settlements	4.E.2.a Forest Land Converted to Settlements	i. Unmanaged Forest Land Converted to Settlements (UFL-S)	ΔC = W x (CSet – CFL)
			ii. Managed Forest Land Converted to Settlements (MFL-S)	ΔC = W x (CSet – CFL)
			iii. Secondary Forest Converted to Settlements (SecF-S)	ΔC = W x [CSet – (ΔCLSecF x CFL)]
			iv. Forest Plantation Converted to Settlements (FP-S)	ΔC = W x (CSet – CFP)
		4.E.2.b Cropland Converted to Settlements	i. Cropland Converted to Settlements (C-S)	ΔC = W x (CSet – CAc)
		4.E.2.c Grassland Converted to Settlements	i. Secondary Grassland Converted to Settlements (SecG-S)	ΔC = W x [(CSet – (ΔCLSecF x CFL)]
			ii. Other Unmanaged Wooded Land Converted to Settlements (OUWL-S)	ΔC = W x (CSet – COWL)
			iii. Pasture Converted to Settlements (P-S)	ΔC = W x (CSet – Cp)
			iv. Other Managed Wooded Land Converted to Settlements (OMWL-S)	ΔC = W x (CSet – COWL)
			v. Other Secondary Wooded Land Converted to Settlements (OSWL- S)	ΔC = W x [(CSet – (ΔCLOSWL x COWL)]
			vii. Unmanaged Grassland Converted to Settlements (UG-S)	ΔC = W x (CSet – CG)
			viii. Managed Grassland Converted to Settlements (MG-S)	ΔC = W x (CSet – CG)
		4.E.2.e Other Land Converted to Settlements	i. Unmanaged Dunes Converted to Settlements (UD-S)	ΔC = W x (CSet – COL)
			ii. Managed Dunes Converted to Settlements (MD-S)	ΔC = W x (CSet – COL)
4.F. Other Land	4.F.2 Land Converted to Other Land	4.F.2.a Forest Land Converted to Other Land	i. Unmanaged Forest Land Converted to Mining (UFL-Min)	ΔC = W x (COL – CFL)
			ii. Unmanaged Forest Land Converted to Bare Soil (UFL-BS)	ΔC = w x (COL – CFL)
			iii. Managed Forest Land Converted to Mining (MFL-Min)	ΔC = W x (COL – CFL)
			iv. Managed Forest Land Converted to Bare Soil (MFL-BS)	ΔC = W x (COL – CFL)
			v. Secondary Forest Converted to Mining (SecF-Min)	ΔC = W x [(COL – (ΔCLSecF x CFL)]
			vi. Secondary Forest Converted to Bare Soil (SecF-BS)	ΔC = W x [(COL – (ΔCLSecF x CFL)]
			vii. Forest Plantation Converted to Mining (FP-Min)	ΔC = W x (COL – CFP)
			viii. Forest Plantation Converted to Bare Soil (FP-BS)	ΔC = W x (COL – CFP)
			ix. Selective Logging Converted to Mining (SL-Min)	ΔC = W x [COL – CpostSL]
		4.F.2.b Cropland Converted to Other Land	i. Cropland Converted to Mining (C-Min)	ΔC = W x (COL – CAc)
			ii. Cropland Converted to Bare Soil (C-BS)	ΔC = W x (COL – CAc)
			i. Secondary Grassland Converted to Mining (SecG-Min)	ΔC = W x [(COL – (ΔCLSecG x CFL)]

Subsector	Category	Subcategory	Subdivision (Division)	Equation
		4.F.2.c Grassland Converted to Other Land	ii. Other Unmanaged Wooded Land Converted to Mining (OUWL-Min)	$\Delta C = W \times (COL - COWL)$
			iii. Other Managed Wooded Land Converted to Mining (OMWL-Min)	$\Delta C = W \times (COL - COWL)$
			iv. Other Unmanaged Wooded Land Converted to Bare Soil (OUWL-BS)	$\Delta C = W \times (COL - COWL)$
			v. Pasture Converted to Mining (P-Min)	$\Delta C = W \times (COL - Cp)$
			vi. Pasture Converted to Bare Soil (P-BS)	$\Delta C = W \times (COL - Cp)$
			vii. Other Secondary Wooded Land Converted to Mining (OSWL- Min)	$\Delta C = W \times [(COL - (\Delta CLOSWL \times COWL)]$
			viii. Other Secondary Wooded Land Converted to Bare Soil (OSWL-BS)	$\Delta C = w \times [(COL - (\Delta CLOSWL \times COWL)]$
			ix. Unmanaged Grassland Converted to Mining (UG-Min)	$\Delta C = W \times (COL - CG)$
			x. Unmanaged Grassland Converted to Bare Soil (UG-BS)	$\Delta C = W \times (COL - CG)$
			xi. Managed Grassland Converted to Mining (MG-Min)	$\Delta C = W \times (COL - CG)$
			xii. Managed Grassland Converted to Bare Soil (MG-BS)	$\Delta C = W \times (COL - CG)$

Note: [1] In cases where there is only carbon gain, it means that there is no carbon loss, i.e., ΔCL is equal to zero; [2] For (t) the date of creation of the CU or IL is considered; [3] As there is a time gap between the land-use maps, the conversion is considered to have taken place in the middle of the period and, therefore, the removal time is divided by 2. Note: It should be noted that when the carbon change is negative, i.e., it indicates a carbon loss, there are CO_2emissions. When the carbon change is positive, there is a carbon gain and, consequently, there is CO_2 removal. For the conversions that have not been presented, it is assumed that there is no carbon gain or loss, i.e., ΔCG and ΔCL are equal to zero.

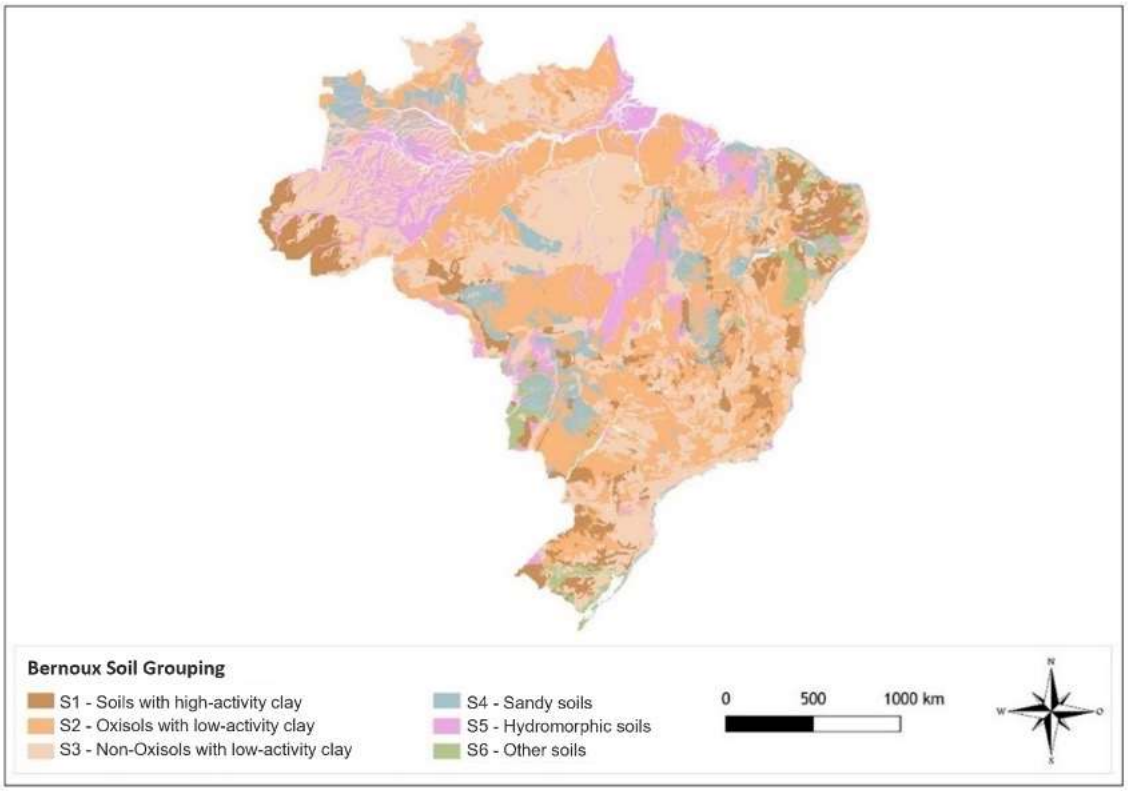


Figure A.VII.26. Distribution of soil classes grouped in the national territory, adapted from Bernoux *et al*. (2002).

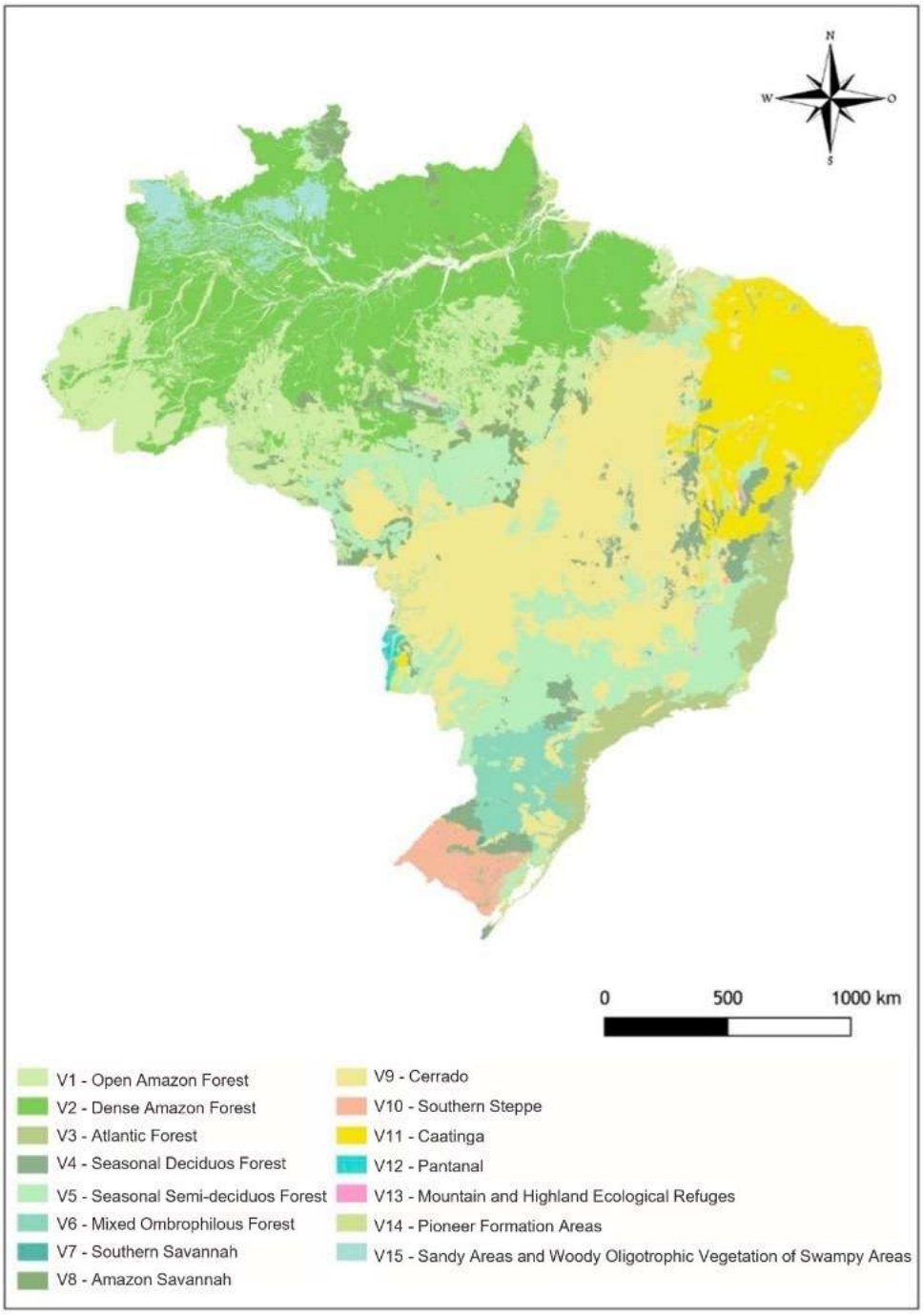


Figure A.VII.27. Distribution of aggregate vegetation classes in the national territory, adapted from Bernoux *et al*. (2002).

Table A.VII.15. Soil carbon stock by soil-vegetation association.

Vegetation Categories	Soil Categories					
	S1	S2	S3	S4	S5	S6
	(t C/ha)					
V1	50.9	47.5	48.9	41.1	43.6	78.7
V2	32.2	51.9	46.9	50.6	52.7	48.1
V3	58.3	52.3	42.9	63.3	35.8	417.8
V4	46.7	30.8	40	25.9	32.7	31.8
V5	40.9	44.3	37.4	27	53.6	31.6
V6	98.8	102.5	56.8	-	85.4	-
V7	64.2	90.9	51.6	-	74.2	32.8
V8	48	19.8	38.1	43.7	34.6	29
V9	24.4	43.1	36	19.2	66.5	32.9
V10	66	46.6	61.2	-	33.8	49.9
V11	24.2	25.8	26.2	15.1	25.1	20.9
V12	33.8	-	35.2	35.4	105.2	21.7
V13	34.1	50.4[1]	39.9	-	-	-
V14	73	41.3[2]	33.1	50.2	59.2	37.2
V15	50.9[2]	46.8	48.1	61.7	90.5	120.9

Note: [1] Single value reported.[2] See specificities described in Bernoux *et al*. (2002). Note: The carbon stocks correspond to the median values presented by Bernoux *et al*. (2002).

Table A.VII.16. Factors affecting soil organic carbon as a result of land-use change.

Land use	f_{IU}	f_{MG}	f_I	f_c
UFL	1	1	1	1
MFL	1	1	1	1
SecF	1	1	1	1
FP	0.94	1	1	0.94
SL	1	1	1	1
UG	1	1	1	1
MG	1	1	1	1
SecG	1	1	1	1
S	0	0	0	0
W	0	0	0	0
Res	0	0	0	0
O	0	0	0	0
P	Table A.VII.17			
DP	0.70	1	1	0.70
Annual Ac	Table A.VII.18			
Semiperennial Ac	0.74	1.24	1	0.92
Perennial Ac - other biomes	0.98	1	1	0.98
Perennial Ac - Caatinga	0.71	1	1	0.71

Note: [1] Only for the Cerrado and Amazon biomes. Note: The acronyms for the land-use and land-cover categories are described in Dataframe 7.4. f_{IU}: stock change factor due to the type of land

use or land- use change; f_{MG}: stock change factor due to the management system; f_I: stock change factor due to the addition of organic matter; f_c: soil carbon change factor (see Equation 7.2).

Table A.VII.17. Soil organic carbon change factors for different pasture conditions by biome.

Pasture/biome classification	Amazon	Cerrado	Caatinga	Atlantic Forest	Pantanal	Pampa
Natural	1.00					
Planted in good condition	1.11	1.11	1.00	1.11	1.11	1.11
Planted in poor condition	0.94	0.94	0.77	0.94	0.94	0.94
Severely degraded[1]	0.70	0.70	-	-	-	-

Note: [1] IPCC default value (2006).

Table A.VII.18. Pasture soil organic carbon change factors weighted by condition and FU/States.

FUs/States	Factor weighted by pasture condition	
	Caatinga Biome	Other biomes
Acre	-	0.98
Alagoas	1.03	0.99
Amazonas	-	0.99
Amapá	-	0.93
Bahia	1.04	0.96
Ceará	1.00	-
Distrito Federal (Federal District)	-	0.99
Espírito Santo	-	0.98
Goiás	-	0.99
Maranhão	1.07	0.98
Minas Gerais	1.06	0.98
Mato Grosso do Sul	-	0.99
Mato Grosso	-	0.98
Pará	-	0.98
Paraíba	1.01	0.97
Pernambuco	1.01	0.96
Piauí	1.02	0.96
Paraná	-	1.00
Rio de Janeiro	-	0.99
Rio Grande do Norte	1.00	0.98
Rondônia	-	1.00
Roraima	-	0.99
Rio Grande do Sul	-	1.00

FUs/States	Factor weighted by pasture condition	
	Caatinga Biome	Other biomes
Santa Catarina	-	0.99
Sergipe	1.05	0.98
São Paulo	-	1.00
Tocantins	-	0.98

Table A.VII.19. Soil organic carbon change factors for different tillage systems by biome.

Tillage/ biome	Amazon	Cerrado	Caatinga	Atlantic Forest	Pantanal	Pampa
Conventional[1]	0.86	0.90	0.83	0.86	0.86	0.86
No-Till[2]	0.96	0.92	0.96	0.96	0.96	0.96

Note: [1] Values based on 109 records (Caatinga = 66, Cerrado = 32, Atlantic Forest = 8, Amazon = 2, Pampa = 1 (Table A.VII.21). [2] Values based on 180 records (Cerrado = 112, Amazon = 31, Atlantic Forest = 27, Pampa = 10 – Table A.VII.22). The value of 0.96 was also applied to the Caatinga and Pantanal biomes, due to the lack of data.

Table A.VII.20. Soil organic carbon change factors applied to annual cropland, weighted according to soil tillage, by FU/State and biome.

FU/ biome	Amazon	Cerrado	Caatinga	Atlantic Forest	Pantanal	Pampa
Acre	0.87	-	-	-	-	-
Alagoas	-	-	0.83	0.86	-	-
Amapá	0.87	-	-	-	-	-
Amazonas	0.87	-	-	-	-	-
Bahia	-	0.91	0.88	0.90	-	-
Ceará	-	-	0.83	-	-	-
Distrito Federal (Federal District)	-	0.91	-	-	-	-
Espírito Santo	-	-	-	0.86	-	-
Goiás	-	0.91	-	0.91	-	-
Maranhão	0.92	0.91	0.91	-	-	-
Mato Grosso	0.91	0.91	-	-	0.91	-
Mato Grosso do Sul	-	0.91	-	0.90	0.90	-
Minas Gerais	-	0.91	0.88	0.90	-	-
Pará	0.88	0.90	-	-	-	-
Paraíba	-	-	0.83	0.86	-	-
Paraná	-	0.91	-	0.91	-	-
Pernambuco	-	-	0.83	0.86	-	-
Piauí	-	0.91	0.88	-	-	-
Rio de Janeiro	-	-	-	0.87	-	-
Rio Grande do Norte	-	-	0.83	0.86	-	-
Rio Grande do Sul	-	-	-	0.93	-	0.93
Rondônia	0.89	0.91	-	-	-	-
Roraima	0.91	-	-	-	-	-
Santa Catarina	-	-	-	0.92	-	-
São Paulo	-	0.90	-	0.87	-	-

FU/ biome	Amazon	Cerrado	Caatinga	Atlantic Forest	Pantanal	Pampa
Sergipe	-	-	0.83	0.86	-	-
Tocantins	0.90	0.91	-	-	-	-

Table A.VII.21. Studies used to evaluate the conversion of native vegetation (NV) to conventional tillage (CT) in the different Brazilian biomes.

Study	Location	Biome	Vegetation cover	Soil type	Layer (cm)	Conversion time	Carbon stock (Mg ha^{-1})	
							NV	CC
Leite *et al.*, 2010	Baixa Grande do Ribeiro – PI	Cerrado	Rice/Soybeans	Latosol	40	12	62.40	70.72
Campos *et al.*, 2013	Bom Jesus – PI	Cerrado	Rice/Soybeans	Latosol	40	3	68.84	66.68
Campos *et al.*, 2013	Bom Jesus – PI	Cerrado	Rice/Soybeans	Latosol	40	3	42.18	38.42
Araújo *et al.*, 2017	Uruçuí – PI	Cerrado	Soybean/Millet	Latosol	20	2	5.95	5.73
Pavinato, 2009	Tasso Fragoso – MA	Cerrado	Cotton/Corn/Soybeans	Latosol	20	15	40.30	37.10
Corazza *et al.*, 1999	Planaltina – DF	Cerrado	Soybeans	Latosol	20	15	39.77	30.55
Jantalia *et al.*, 2007	Planaltina - DF	Cerrado	Rice/Corn/Soybeans	Latosol	30	20	96.60	71.60
Jantalia *et al.*, 2007	Planaltina – DF	Cerrado	Rice/Corn/Soybeans	Latosol	30	20	96.60	77.50
Jantalia *et al.*, 2007	Planaltina – DF	Cerrado	Rice/Corn/Soybeans	Latosol	30	20	96.60	64.80
Jantalia *et al.*, 2007	Planaltina – DF	Cerrado	Rice/Corn/Soybeans	Latosol	30	20	96.60	69.50
Ferreira *et al.*, 2016	Planaltina – DF	Cerrado	Rice/Corn/Soybeans	Latosol	100	30	164.30	140.20
Ferreira *et al.*, 2016	Planaltina – DF	Cerrado	Rice/Corn/Soybeans	Latosol	100	30	164.30	125.80
Marchão *et al.*, 2009	Planaltina – DF	Cerrado	Corn/Soybeans	Latosol	30	13	60.87	53.30
Figueiredo *et al.*, 2018	Planaltina – DF	Cerrado	Soybeans	Latosol	20	18	57.20	42.21
Freitas *et al.*, 2000	Goiânia – GO	Cerrado	Corn/Beans	Latosol	40	5	81.90	80.29
Bayer *et al.*, 2006	Luziânia – GO	Cerrado	Corn/Soybeans	Latosol	20	8	35.40	38.60
Bayer*et al.*, 2006	Luziânia – GO	Cerrado	Corn/Soybeans	Latosol	20	8	35.40	37.72
Pavinato, 2009	Luziânia – GO	Cerrado	Corn/Soybeans	Latosol	20	28	54.30	53.70
D'Andréa *et al.* 2004	Morrinhos – GO	Cerrado	Corn/Soybeans	Latosol	40	17	61.10	61.78
Costa Jr *et al.*,2013	Rio Verde – GO	Cerrado	Corn/Soybeans	Latosol	20	26	47.10	34.90
Costa Jr *et al.*, 2013	Rio Verde – GO	Cerrado	Corn/Soybeans	Latosol	20	30	47.30	34.40
Pavinato, 2009	Sapezal – MT	Cerrado	Cotton/Corn/Soybeans	Latosol	20	8	64.60	55.10
Maia *et al.*, 2010	Sapezal – MT	Cerrado	Corn/Soybeans	Neosol	30	5	27.93	29.43
Sá *et al.*, 2013	Lucas do Rio Verde – MT	Cerrado	Rice/Soybeans	Latosol	100	19	130.30	104.10
Maia *et al.*, 2010	Itiquira – MT	Cerrado	Cotton/Soybeans	Latosol	30	15	67.10	62.60
Maia *et al.*, 2010	Novo S. Joaquim – MT	Cerrado	Cotton/Soybeans	Latosol	30	19	52.95	45.48
Bayer *et al.*, 2006	Costa Rica – MS	Cerrado	Cotton/Corn/Soybeans	Latosol	20	6	54.00	49.35

Study	Location	Biome	Vegetation cover	Soil type	Layer (cm)	Conversion time	Carbon stock (Mg ha^{-1})	
							NV	CC
Bayer *et al.*, 2006	Costa Rica – MS	Cerrado	Cotton/Corn/Soybeans	Latosol	20	6	54.00	48.96
Pavinato, 2009	Costa Rica – MS	Cerrado	Cotton/ Soybeans	Latosol	20	31	64.60	48.90
Seben Jr *et al.*, 2014	Jaboticabal – SP	Cerrado	Corn/Soybeans	Latosol	10	44	28.16	10.98
Dieckow *et al.*, 2009	Dourados – MS	Cerrado	Corn/Soybeans	Latosol	20	34	44.55	41.43
Roscoe; Buurman 2003	Sete Lagoas – MG	Cerrado	Corn/Beans	Latosol	45	30	100.00	102.00
Hickmann *et al.*, 2012	Coimbra – MG	Atlantic Forest	Corn/Beans/Soybeans/Wheat	Argisol	40	78	46.42	24.39
Hickmann *et al.*, 2012	Coimbra – MG	Atlantic Forest	Corn/Beans/Soybeans/Wheat	Argisol	40	78	46.42	26.71
Hickmann *et al.*, 2012	Coimbra – MG	Atlantic Forest	Corn/Beans/Soybeans/Wheat	Argisol	40	78	46.42	26.15
Reis *et al.*, 2014	Guarapuava – PR	Atlantic Forest	Oats/Wheat/Soybeans/Corn	Latosol	100	59	137.90	132.90
Loss *et al.*, 2016	Marmeleiro – PR	Atlantic Forest	Tobacco/Corn/Oats	Nitosol	40	56	79.55	80.10
Gubiani, 2015	Pato Branco – PR	Atlantic Forest	Oats/Soybeans/Corn	Latosol	100	36	173.30	160.51
Tiecher *et al.*, 2012	Pato Branco – PR	Atlantic Forest	Wheat/Oats/Vetch	Latosol	40	33	76.93	67.11
Bayer *et al.*, 2002	West of Santa Catarina – SC	Atlantic Forest	Wheat/Soybeans	Latosol	25	50	128.30	82.10
Reis *et al.*, 2014	Santo Ângelo – RS	Atlantic Forest	Wheat/Soybeans	Latosol	100	40	124.90	90.90
Dieckow *et al.*, 2009	Santo Ângelo – RS	Atlantic Forest	Wheat/Soybeans	Latosol	20	40	64.41	50.57
Dieckow *et al.*, 2009	Eldorado do Sul – RS	Pampa	Corn/Soybeans/Oats	Argisol	20	34	39.32	27.76
Carvalho *et al.*, 2009	Vilhena – RO	Amazon	Rice	Latosol	30	1	49.00	47.60
Carvalho *et al.*, 2009	Vilhena – RO	Amazon	Rice	Latosol	30	2	49.00	55.40
Medeiros, 2019	Santana do Ipanema – AL	Caatinga	Corn/Beans/Cotton	Planosol	50	47	103.39	53.51
Medeiros, 2019	Santana do Ipanema – AL	Caatinga	Corn/Beans	Litholic neosol	50	2	97.44	110.78
Medeiros, 2019	Santana do Ipanema – AL	Caatinga	Corn/Beans	Litholic neosol	50	38	97.44	57.83
Medeiros, 2019	Batalha – AL	Caatinga	Corn/Beans/Palm	Luvisol	70	11	90.87	97.10
Medeiros, 2019	América Dourada – BA	Caatinga	Corn/Beans/Castor beans	Cambisol	100	5	160.61	177.99
Medeiros, 2019	América Dourada – BA	Caatinga	Corn/Beans/Castor beans	Cambisol	100	15	160.61	193.05
Medeiros, 2019	América Dourada – BA	Caatinga	Corn/Beans/Castor beans	Cambisol	100	20	160.61	171.59
Medeiros, 2019	América Dourada – BA	Caatinga	Corn/Beans/Castor beans	Cambisol	100	30	160.61	153.76
Medeiros, 2019	América Dourada – BA	Caatinga	Corn/Beans/Castor beans	Cambisol	100	35	160.61	144.69
Medeiros, 2019	América Dourada – BA	Caatinga	Corn/Beans/Castor beans	Cambisol	100	40	160.61	130.66

Study	Location	Biome	Vegetation cover	Soil type	Layer (cm)	Conversion time	Carbon stock (Mg ha^{-1})	
							NV	CC
Medeiros, 2019	América Dourada – BA	Caatinga	Corn/Beans/Castor beans	Cambisol	30	33	82.93	80.20
Medeiros, 2019	América Dourada – BA	Caatinga	Corn/Beans/Castor beans	Cambisol	30	46	82.93	89.13
Medeiros, 2019	Senhor do Bonfim – BA	Caatinga	Corn/Beans	Planosol	50	10	76.45	48.33
Medeiros, 2019	Senhor do Bonfim – BA	Caatinga	Corn/Beans	Planosol	50	15	76.45	54.93
Medeiros, 2019	Senhor do Bonfim – BA	Caatinga	Corn/Beans	Planosol	70	8	105.19	112.93
Medeiros, 2019	Senhor do Bonfim – BA	Caatinga	Corn/Beans	Argisol	50	18	84.48	89.02
Medeiros, 2019	Catolé do Rocha – PB	Caatinga	Corn/Beans	Argisol	90	12	104.99	103.32
Medeiros, 2019	Catolé do Rocha – PB	Caatinga	Corn/Beans	Argisol	90	15	104.99	93.21
Medeiros, 2019	Catolé do Rocha – PB	Caatinga	Corn/Beans	Argisol	70	50	99.59	98.53
Medeiros, 2019	Catolé do Rocha – PB	Caatinga	Corn/Beans	Argisol	90	40	131.16	129.85
Medeiros, 2019	Santa Luzia – PB	Caatinga	Corn/Beans/Cotton	Luvisol	50	19	100.66	48.95
Medeiros, 2019	Santa Luzia – PB	Caatinga	Corn/Beans/Cotton	Luvisol	50	38	100.66	74.02
Medeiros, 2019	Santa Luzia – PB	Caatinga	Corn/Beans/Cotton	Luvisol	50	90	100.66	51.97
Medeiros, 2019	Santa Luzia – PB	Caatinga	Corn/Beans/Cotton	Luvisol	70	20	80.73	50.76
Medeiros, 2019	Santa Luzia – PB	Caatinga	Corn/Beans/Cotton	Luvisol	70	30	80.73	68.52
Gonzaga, 2017	Delmiro Gouveia – AL	Caatinga	Corn/Beans	Quartzarenic neosol	30	4	33.19	31.05
Gonzaga, 2017	Delmiro Gouveia – AL	Caatinga	Corn/Beans	Quartzarenic neosol	30	15	33.19	23.61
Gonzaga, 2017	Inhapí – AL	Caatinga	Corn/Beans	Argisol	30	30	42.61	44.92
Gonzaga, 2017	Pariconha – AL	Caatinga	Corn/Beans	Regolithic neosol	30	4	40.41	35.59
Moreira, 2013	Irecê – BA	Caatinga	Corn/Beans	Cambisol	40	27	54.06	50.21
Maia *et al.*, 2007	Sobral – CE	Caatinga	Corn/Beans	Luvisol	40	5	73.62	62.35
Maia *et al.*, 2007	Sobral – CE	Caatinga	Corn/Beans	Luvisol	40	5	73.62	87.32
Maia *et al.*, 2007	Sobral – CE	Caatinga	Corn/Beans	Luvisol	40	5	73.62	73.36
Maia *et al.*, 2007	Sobral – CE	Caatinga	Corn/Beans	Luvisol	40	5	73.62	92.90
Maia *et al.*, 2007	Sobral – CE	Caatinga	Corn/Beans	Luvisol	40	5	47.15	58.04
Nogueira, 2009	Sobral – CE	Caatinga	Corn/Beans	Luvisol	5	10	17.82	14.03
Nogueira, 2009	Sobral – CE	Caatinga	Corn/Beans	Luvisol	5	10	27.40	24.74
Nogueira, 2009	Sobral – CE	Caatinga	Corn/Beans	Luvisol	5	10	27.40	16.79

Study	Location	Biome	Vegetation cover	Soil type	Layer (cm)	Conversion time	Carbon stock (Mg ha^{-1})	
							NV	CC
Nogueira, 2009	Sobral – CE	Caatinga	Corn/Beans	Luvisol	5	10	27.40	19.90
Nogueira, 2009	Sobral – CE	Caatinga	Corn/Beans	Luvisol	5	10	27.40	22.97
Nunes *et al.*, 2006	Sobral – CE	Caatinga	Corn	Luvisol	20	1	57.34	71.98
Nunes *et al.*, 2006	Sobral – CE	Caatinga	Corn	Luvisol	20	2	57.34	64.66
Nunes *et al.*, 2006	Sobral – CE	Caatinga	Corn	Luvisol	20	1	57.34	57.34
Nunes *et al.*, 2006	Sobral – CE	Caatinga	Corn	Luvisol	20	2	57.34	39.77
Nunes *et al.*, 2006	Sobral – CE	Caatinga	Corn	Luvisol	20	3	57.34	51.24
Nunes *et al.*, 2006	Sobral – CE	Caatinga	Corn	Luvisol	20	4	57.34	47.09
Nunes *et al.*, 2006	Sobral – CE	Caatinga	Corn	Luvisol	20	5	57.34	50.02
Silva, 2008	Sobral – CE	Caatinga	Corn/Beans	Luvisol	5	8	26.75	20.82
Silva, 2008	Sobral – CE	Caatinga	Corn/Beans	Luvisol	5	8	26.75	19.91
Silva, 2008	Sobral – CE	Caatinga	Corn/Beans	Luvisol	5	8	26.75	17.33
Oliveira *et al.*, 2015	Limoeiro do Norte – CE	Caatinga	Corn/Beans	Cambisol	50	25	58.24	63.47
Bernardi *et al.*, 2007	Paraipaba – CE	Caatinga	Corn/Beans	Quartzarenic neosol	40	2	27.57	24.23
Fraga; Salcedo, 2004	Juarez Távora – PB	Caatinga	Corn/Beans	Quartzarenic neosol	7.5	14	118.00	96.60
Fraga; Salcedo, 2004	Juarez Távora – PB	Caatinga	Corn/Beans	Quartzarenic neosol	7.5	16	118.00	63.00
Lima *et al.*, 2011	Esperantina – PI	Caatinga	Corn/Beans	Argisol	10	3	34.16	25.65
Lima *et al.*, 2011	Esperantina – PI	Caatinga	Corn/Beans	Argisol	10	6	34.16	42.60
Lima *et al.*, 2011	Esperantina – PI	Caatinga	Corn/Beans	Argisol	10	10	34.16	45.31
Lima *et al.*, 2011	Esperantina – PI	Caatinga	Corn/Beans	Argisol	10	2	34.16	19.66
Lima *et al.*, 2011	Esperantina – PI	Caatinga	Corn/Beans	Argisol	10	3	35.59	18.08
Lima *et al.*, 2011	Esperantina – PI	Caatinga	Corn/Beans	Argisol	10	6	35.59	40.00
Lima *et al.*, 2011	Esperantina – PI	Caatinga	Corn/Beans	Argisol	10	10	35.59	35.14
Lima *et al.*, 2011	Esperantina – PI	Caatinga	Corn/Beans	Argisol	10	2	35.59	13.79
Santana *et al.*, 2019	Araripina – PE	Caatinga	Corn/Beans	Litholic neosol	60	28	54.50	22.30
Santana *et al.*, 2019	Bodocó – PE	Caatinga	Corn/Beans	Argisol	100	15	98.40	89.50
Santana *et al.*, 2019	Exu – PE	Caatinga	Corn/Beans	Latosol	100	20	72.10	57.20
Santana *et al.*, 2019	Salgueiro – PE	Caatinga	Corn/Beans	Planosol	60	15	37.70	15.20

Table A.VII.22. Studies used to evaluate the conversion of native vegetation (NV) to no-tillage system (NTS).

Study	Location	Biome	Soil type	Layer (cm)	Conversion time	Carbon stock (Mg ha^{-1})	
						NV	NTS
Araújo *et al.*, 2017	Uruçuí – PI	Cerrado	Latosol	20	4	14.26	17.91
Ferreira *et al.*, 2016	Planaltina – DF	Cerrado	Latosol	100	29	164.30	145.80
				100	29		135.80
Corazza *et al.*, 1999	Planaltina – DF	Cerrado	Latosol	20	15	39.77	38.74
Jantalia *et al.*, 2007	Planaltina – DF	Cerrado	Latosol	30	20	96.60	85.90
				30	20		81.30
Figueiredo *et al.*, 2018	Planaltina – DF	Cerrado	Latosol	20	18	57.20	46.71
				20	18		47.70
Carvalho *et al.*, 2010	Montividiu – GO	Cerrado	Latosol	30	21	75.40	60.90
Carvalho *et al.*, 2014	Montividiu – GO	Cerrado	Latosol	30	23	75.40	61.50
D'Andréa *et al.*, 2004	Morrinhos – GO	Cerrado	Latosol	40	5	61.10	63.54
				40	5		72.61
Freitas *et al.*, 2000	Goiânia – GO	Cerrado	Latosol	40	5	81.90	80.27
Souza *et al.*, 2016	Jataí – GO	Cerrado	Plinthosol	20	11	45.90	43.20
				20	7		38.80
Bayer *et al.*, 2002	Luziânia – GO	Cerrado	Latosol	20	8	35.40	38.63
Bayer *et al.*, 2006	Costa Rica – MS	Cerrado	Latosol	20	6	54.00	54.12
Maia *et al.*, 2010	Água Boa – MT	Cerrado	Latosol	30	18	35.21	39.73
Maia *et al.*, 2010	Itiquira – MT	Cerrado	Latosol	30	17	67.14	73.81
Maia *et al.*, 2010	Novo S. Joaquim – MT	Cerrado	Latosol	30	19	52.96	46.12
Maia *et al.*, 2010	Pontes e Lacerda – MT	Cerrado	Latosol	30	3	47.61	47.09
Maia *et al.*, 2010	Sapezal – MT	Cerrado	Neosol	30	7	25.97	30.16
			Latosol	30	7	49.00	54.40
Maia *et al.*, 2010	Itaúba – MT	Amazon	Latosol	30	7	54.38	47.63
Maia *et al.*, 2010	R. Cascalheira – MT	Amazon	Latosol	30	5	38.49	31.16
Maia *et al.*, 2010	Sorriso – MT	Amazon	Latosol	30	6	61.42	63.26
				30	15		58.16

Study	Location	Biome	Soil type	Layer (cm)	Conversion time	Carbon stock (Mg ha^{-1})	
						NV	NTS
				30	20		61.04
				30	6	46.60	53.77
Carvalho *et al.*, 2010	Santa Carmem – MT	Amazon	Latosol	30	13	74.10	56.40
Maia *et al.*, 2010	P. do Oeste – RO	Amazon	Latosol	30	12	32.35	38.24
Carvalho *et al.*, 2009	Vilhena – RO	Amazon	Latosol	30	1	49.00	66.50
				30	2		54.50
				30	3		67.50
Loss *et al.*, 2016	Marmeleiro – PR	Atlantic Forest	Nitosol	40	15	79.55	94.12

A.VII.4. Supplementary information for the Harvested Wood Products subsector (4.G)

Table A.VII.23. Data on production, imports and exports to Brazil of round wood, sawnwood and wood-based panels.

Year	Roundwood			Sawnwood			Wood-Based Panels		
	Production	Import	Export	Production	Import	Export	Production	Import	Export
	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3
1961	104,811,504	11,900	55,100	6,450,000	-	1,114,600	251,400	400	5,200
1962	106,768,603	12,600	40,300	6,769,000	-	853,500	252,400	-	3,400
1963	105,847,128	10,900	43,800	5,693,000	-	836,500	255,800	-	5,800
1964	106,684,150	500	50,800	5,531,000	-	1,101,300	276,500	-	17,800
1965	108,068,759	2,000	53,100	5,661,000	-	1,192,600	299,600	-	26,400
1966	110,372,043	100	58,100	6,073,002	200	1,274,100	406,585	-	29,100
1967	112,712,081	-	79,100	6,618,302	500	1,111,500	460,038	-	34,800
1968	114,872,955	-	117,300	6,965,000	1,000	1,394,600	523,197	-	41,700
1969	117,022,762	200	114,300	7,467,202	-	1,114,200	589,445	-	40,500
1970	119,840,582	6,000	84,400	8,035,000	-	1,074,500	722,986	-	72,600
1971	121,278,743	26,600	119,400	8,100,000	500	1,154,500	916,004	100	110,800
1972	121,116,926	69,400	130,200	7,550,000	4,600	1,040,000	1,238,013	200	119,700
1973	121,587,967	81,800	426,000	7,109,000	33,700	1,055,000	1,322,607	100	134,200
1974	123,323,265	93,700	140,000	7,642,402	82,900	711,500	1,408,780	200	136,300
1975	130,343,926	97,000	12,400	10,128,602	77,113	500,400	1,571,000	100	143,400
1976	134,534,060	50,600	22,600	11,243,102	179,900	438,900	1,786,800	100	158,800
1977	139,291,830	46,100	4,300	12,643,000	256,800	596,900	1,949,000	2,400	187,700
1978	147,877,953	84,400	10,300	13,337,000	360,200	568,400	2,028,000	3,300	253,500
1979	158,470,406	58,100	12,700	14,070,102	311,200	827,500	2,036,000	1,000	276,000
1980	167,438,475	44,700	7,000	14,881,000	461,700	809,000	2,266,000	1,000	283,900
1981	168,795,562	31,100	6,100	15,852,000	334,700	736,700	2,342,000	300	331,000
1982	171,839,359	31,000	8,000	16,470,000	341,600	523,700	2,164,000	500	273,400

Year	Roundwood			Sawnwood			Wood-Based Panels		
	Production	Import	Export	Production	Import	Export	Production	Import	Export
	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3
1983	175,388,028	26,500	4,200	17,199,000	270,700	573,000	2,289,000	400	341,700
1984	178,325,516	45,400	30,300	17,781,000	339,100	525,900	2,278,000	500	401,200
1985	181,200,611	55,800	26,200	17,781,000	353,900	492,900	2,256,000	300	404,000
1986	183,731,965	64,000	9,400	18,063,000	424,300	455,200	2,289,000	400	427,400
1987	186,515,620	55,400	9,500	18,063,000	308,100	552,200	2.524.000	900	417,600
1988	189,729,645	25,900	46,000	18,179,000	111,900	651,700	2,613,000	900	606,400
1989	197,529,534	40,000	17,100	18,179,000	258,400	561,600	2,658,000	1,900	591,700
1990	194,577,560	4,287	80,085	13,730,000	265,000	508,600	2,658,000	7,800	563,200
1991	198,423,030	5,679	78,692	15,700,000	255,400	507,200	2,508,000	4,900	542,500
1992	202,514,910	8,871	364,276	15,890,000	228,444	718,521	2,658,000	2,765	718,675
1993	205,686,483	8,245	260,635	16,340,000	219,373	1,017,187	2,933,000	4,480	1,012,096
1994	208,912,937	9,900	654,500	16,610,000	381,034	1,404,900	3,243,686	8,557	1,104,204
1995	211,129,834	11,200	1,240,400	18,100,000	456,000	1,928,000	3,095,796	69,700	1,014,700
1996	212,306,210	5,300	513,300	18,830,000	573,000	1,449,000	3,328,096	211,800	927,300
1997	213,479,519	11,000	793,100	19,310,000	380,500	1,587,000	3,504,378	254,800	954,300
1998	213,703,275	31,000	935,300	19,520,000	245,000	1,589,000	3,647,437	126,500	840,000
1999	231,562,657	16,400	442,000	20,530,000	145,300	2,174,000	4,654,000	61,400	1,388,000
2000	235,401,621	25,640	753,600	21,300,000	158,700	2,464,000	5,183,000	28,300	1,615,683
2001	223,256,218	90,034	563,079	21,950,000	165,500	2,520,000	5,537,524	72,500	1,840,906
2002	230,912,063	16,480	950,611	22,488,000	142,300	2,915,000	6,053,986	92,900	2,330,602
2003	255,902,476	19,157	123,305	23,090,000	92,000	3,374,176	7,006,005	132,300	2,947,400
2004	243,254,745	14,005	100,021	23,480,000	94,614	3,657,000	7,893,159	182,700	3,838,664
2005	231,569,000	12,464	25,004	23,557,000	146,393	3,648,365	8,681,789	304,910	4,403,549
2006	229,984,000	16,490	7,225	23,797,000	134,000	3,167,000	9,061,255	371,686	3,403,240
2007	235,158,000	8,000	18,553	24,180,000	145,000	3,167,000	8,688,951	279,300	3,022,062

Year	Roundwood			Sawnwood			Wood-Based Panels		
	Production	Import	Export	Production	Import	Export	Production	Import	Export
	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3	m^3
2008	229,064,000	18,832	27,473	21,847,000	113,000	2,121,000	8,436,456	286,733	2,435,481
2009	226,707,000	39,761	5,610	16,844,000	99,975	1,394,137	7,762,539	168,038	1,724,083
2010	235,432,000	28,788	34,254	17,450,000	81,192	1,268,000	8,910,407	186,730	1,375,909
2011	253,144,000	31,302	91,766	16,200,000	56,588	1,227,679	8,915,000	197,994	1,235,926
2012	266,769,000	39,750	86,776	15,170,000	44,535	1,127,743	10,078,000	112,430	1,423,992
2013	260,756,000	38,402	115,017	13,330,000	35,901	1,110,349	10,585,000	128,073	1,593,440
2014	259,233,000	31,177	196,279	11,340,000	32,633	1,369,093	10,410,000	97,590	1,826,000
2015	247,884,000	16,430	110,555	9,980,000	45,728	1,658,930	9,874,000	24,664	2,276,431
2016	267,102,000	46,461	174,206	9,950,000	37,274	2,097,118	10,337,000	13,437	3,101,097
2017	271,967,000	11,136	248,974	10,220,000	96,944	2,763,044	11,052,000	12,723	3,716,012
2019	282,103,000	39,139	402,144	10,240,000	61,549	3,742,043	11,462,000	14,211	4,008,130
2019	264,561,000	34,377	903,200	10,100,000	67,177	3,400,920	11,793,000	21,594	3,683,404
2020	276,865,000	11,982	1,686,384	10,000,000	106,528	2,794,096	12,879,000	23,710	4,130,902
2021	292,595,000	37,530	2,765,157	10,000,000	59,408	4,411,319	14,935,000	53,149	4,299,079
2022	303,898,000	31,202	2,395,637	10,000,000	36,558	3,559,043	12,506,000	11,550	4,100,451

Source: Based on FAO (2024).

Table A.VII.24. Production, import and export data for Brazil for paper, paperboard, wood pulp, recycled paper and industrial roundwood.

Year	Paper + paperboard			Wood Pulp (1875)+ Recycled Paper(1669) (aggregated item)			Industrial Roundwood (1865)		
	Production	Import	Export	Production	Import	Export	Production	Import	Export
	mt	mt	mt	mt	mt		m^3	m^3	m^3
1961	533,100	131,800	-	-	400	-	16,960,000	11,900	55,100
1962	601,700	106,600	100	-	4,100	-	18,057,000	12,600	40,300
1963	656,300	101,000	-	-	400	-	16,267,000	10,900	43,800
1964	718,300	58,700	100	14,500	3,500	-	16,227,000	500	50,800
1965	750,700	39,100	200	11,400	8,500	-	16,726,000	2,000	53,100
1966	813,200	42,400	500	25,100	6,200	-	18,135,000	100	58,100
1967	822,600	105,700	300	21,900	2,400	-	19,572,000	-	79,100
1968	886,900	173,600	200	70,000	11,900	-	20,821,000	-	117,300
1969	952,200	159,600	300	50,700	26,700	-	22,050,000	200	114,300
1970	1,098,600	180,900	1,400	48,400	39,300	-	23,938,000	6,000	84,400
1971	1,237,300	222,200	2,900	95,900	33,300	-	24,718,000	26,600	119,400
1972	1,345,700	264,300	9,700	150,100	140,700	-	23,948,000	69,400	130,200
1973	1,587,900	295,900	41,000	147,600	193,800	-	23,904,000	81,800	426,000
1974	1,853,700	480,200	30,200	215,300	133,700	-	24,768,000	93,400	140,000
1975	1,687,800	217,000	7,200	109,300	153,200	-	30,636,000	96,300	12,400
1976	2,044,900	260,300	29,600	71,700	140,640	-	33,875,000	50,500	22,600
1977	2,235,500	267,500	42,100	68,100	94,600	-	37,328,000	46,100	4,300
1978	2,534,100	276,200	105,800	70,000	267,900	-	44,492,000	84,400	10,300
1979	2,979,000	298,700	143,900	74,900	582,400	-	53,856,008	58,100	12,700
1980	3,361,000	261,400	197,600	60,200	890,450	-	61,722,000	44,700	7,000
1981	3,102,000	235,600	337,000	32,600	952,700	-	61,210,008	31,100	6,100
1982	3,329,000	259,300	264,300	15,100	824,600	-	62,700,000	31,000	8,000
1983	3,426,000	206,600	440,700	11,800	987,900	-	64,439,000	26,500	4,200
1984	3,768,000	215,800	702,700	27,700	978,300	-	66,122,000	45,400	30,300
1985	4,022,000	136,900	543,400	33,300	931,100	-	67,897,000	55,800	26,200

Year	Paper + paperboard			Wood Pulp (1875)+ Recycled Paper(1669) (aggregated item)			Industrial Roundwood (1865)		
	Production	Import	Export	Production	Import	Export	Production	Import	Export
	mt	mt	mt	mt	mt		m^3	m^3	m^3
1986	4,525,000	281,716	692,200	57,200	882,900	-	69,366,008	64,000	9,400
1987	4,712,000	323,300	609,400	70,000	815,600	-	70,802,016	55,400	9,500
1988	4,685,000	215,500	1,003,100	80,300	1,062,900	-	72,473,008	25,900	46,000
1989	4,806,000	258,000	830,200	112,200	1,000,800	-	78,973,016	40,000	17,100
1990	4,844,000	233,700	839,700	86,200	1,037,700	-	74,277,024	4,287	80,085
1991	4,888,000	365,000	1,039,000	107,500	1,379,300	-	76,676,016	5,679	78,692
1992	4,913,000	265,322	1,129,952	100,573	1,684,903	-	79,264,016	8,506	364,276
1993	5,352,000	364,800	1,274,820	152,900	2,050,852	-	81,350,000	7,407	259,100
1994	5,730,000	540,200	1,435,000	146,364	2,081,073	-	83,435,000	8,800	649,100
1995	5,856,000	931,900	1,223,200	252,000	1,990,505	-	84,518,000	10,100	1,235,000
1996	5,885,000	866,200	1,046,700	284,200	2,250,800	-	84,601,000	5,300	512,000
1997	6,475,000	1,171,400	1,043,300	298,500	2,505,300	-	84,684,000	11,000	791,800
1998	6,524,000	854,400	1,242,606	341,800	2,805,732	-	83,764,000	14,000	935,300
1999	6,889,000	722,700	959,716	373,600	3,111,150	-	100,395,000	16,000	442,000
2000	7,116,000	800,800	839,505	371,500	3,014,211	-	102,994,000	25,240	753,600
2001	7,354,000	598,500	939,174	328,400	3,353,980	-	89,828,000	90,034	563,079
2002	7,661,000	508,800	1,082,450	364,128	3,420,063	-	96,439,000	16,480	950,611
2003	7,811,000	514,635	1,631,693	364,172	4,570,323	-	120,360,000	19,157	123,305
2004	8,221,000	654,019	1,702,285	413,550	4,988,594	-	106,618,000	14,005	100,021
2005	8,597,000	805,525	1,909,631	367,950	5,546,938	-	117,987,000	12,464	25,004
2006	8,725,000	930,459	1,810,412	353,421	6,240,137	-	118,754,000	16,490	7,225
2007	9,009,000	1,046,296	1,838,574	340,300	6,575,259	-	121,521,000	8,000	18,553
2008	9,409,000	1,201,200	1,855,402	362,300	7,206,020	-	115,390,000	18,832	27,473
2009	9,428,000	1,005,832	1,910,000	388,734	8,587,601	-	122,160,000	39,761	5,610
2010	9,978,000	1,388,909	1,970,020	444,540	8,798,019	-	128,400,000	28,674	34,254
2011	10,159,000	1,314,502	1,942,038	420,991	8,906,718	-	139,969,000	30,982	91,746
2012	10,260,000	1,281,470	1,764,273	431,150	8,940,172	-	146,804,000	39,553	86,756

Year	Paper + paperboard			Wood Pulp (1875)+ Recycled Paper(1669) (aggregated item)			Industrial Roundwood (1865)		
	Production	Import	Export	Production	Import	Export	Production	Import	Export
	mt	mt	mt	mt	mt		m^3	m^3	m^3
2013	10,444,000	1,219,750	1,749,055	453,907	9,879,589	-	142,633,000	38,199	114,997
2014	10,398,000	1,222,713	1,718,421	454,023	11,055,858	-	137,684,000	30,974	196,259
2015	10,477,000	775,314	1,920,561	429,286	12,048,411	-	136,177,000	16,073	110,535
2016	10,335,000	617,451	1,938,847	386,928	13,553,773	-	145,102,000	46,104	174,097
2017	10,471,000	672,601	1,960,735	241,494	13,894,896	-	150,955,000	11,136	248,974
2019	10,433,000	633,762	1,853,546	220,397	15,235,287	-	158,056,000	39,139	402,144
2019	10,534,000	598,111	2,021,343	286,814	15,519,109	-	143,006,000	34,377	903,200
2020	10,184,000	476,283	1,954,749	224,540	16,469,121	-	154,720,000	11,982	1,686,384
2021	10,666,000	501,492	1,884,662	368,167	16,369,325	-	163,556,000	37,530	2,765,157
2022	11,040,000	469,757	2,263,834	207,229	19,837,477	-	170,681,000	31,179	2,395,633

Source: Based on FAO (2024).

Table A.VII.25. Production, import and export data for Brazil for other industrial roundwood, chips, particles, wood charcoal and wood residues.

Year	Other Industrial Roundwood (1871)			Chips and particles		Wood charcoal		Wood residues	
	Production	Import	Export	Import	Export	Import	Export	Import	Export
	m^3	m^3	m^3	m^3	m^3	mt	mt	m^3	m^3
1961	2,840,000	-	1,000	-	-	-	-	-	-
1962	2,927,000	-	200	-	-	-	-	-	-
1963	3,017,000	-	-	-	-	-	-	-	-
1964	3,107,000	-	-	-	-	-	-	-	-
1965	3,196,000	-	-	-	-	-	-	-	-
1966	3,285,000	-	-	-	-	-	-	-	-
1967	3,372,000	-	-	-	-	-	-	-	-
1968	3,461,000	-	-	-	-	-	-	-	-
1969	3,550,000	-	-	-	-	-	-	-	-
1970	3,638,000	-	-	-	-	-	-	-	-
1971	3,728,000	2,800	-	-	-	-	-	-	-
1972	3,818,000	15,200	-	-	-	-	-	-	-
1973	3,909,000	15,200	-	-	-	-	-	-	-
1974	4,003,000	20,200	-	-	-	-	-	-	-
1975	4,099,000	20,100	-	-	-	-	-	-	-
1976	4,198,000	15,200	-	-	-	-	-	-	-
1977	4,299,000	5,700	-	-	-	-	14,300	-	-
1978	4,402,000	7,700	-	-	-	-	23,900	-	-
1979	4,506,000	7,700	-	-	-	-	31,400	-	-
1980	4,610,000	9,300	-	-	-	-	25,800	-	-
1981	4,715,000	7,500	-	-	-	-	9,400	-	-
1982	4,818,000	5,500	-	-	-	-	2,900	-	-
1983	4,921,000	3,000	-	-	-	-	6,700	-	-
1984	5,024,000	10,000	-	-	-	-	-	-	-

Year	Other Industrial Roundwood (1871)			Chips and particles		Wood charcoal		Wood residues	
	Production	Import	Export	Import	Export	Import	Export	Import	Export
	m^3	m^3	m^3	m^3	m^3	mt	mt	m^3	m^3
1985	5,125,000	7,300	-	-	-	-	-	-	-
1986	5,226,000	6,200	-	-	-	-	-	-	-
1987	5,325,000	3,100	-	-	-	-	-	-	-
1988	5,422,000	1,400	-	-	-	-	-	-	-
1989	5,516,000	2,000	-	-	-	-	17,600	-	-
1990	5,608,000	-	-	-	-	-	7,100	-	-
1991	5,696,000	-	-	-	-	-	10,500	-	-
1992	5,784,000	-	-	79	36	459	12,814	2,238	2,047
1993	5,870,000	-	-	61	212,052	347	21,416	1,700	113
1994	5,955,000	-	-	61	533,875	6,600	11,277	200	61
1995	6,038,000	-	-	100	607,300	7,400	10,300	300	300
1996	6,121,000	-	-	100	612,800	7,600	10,300	-	-
1997	6,204,000	-	-	100	579,000	7,600	10,300	-	-
1998	6,284,000	-	-	0	830,000	9,500	9,600	-	-
1999	7,361,000	-	-	0	1,096,000	9,500	9,000	-	-
2000	7,843,000	-	-	300	1,300,000	20,000	8,000	93	18
2001	6,703,000	-	-	0	1,260,000	18,200	9,300	130	57
2002	7,287,000	-	-	1,100	1,251,500	18,000	10,100	200	159
2003	9,723,000	-	-	1,100	1,754,000	18,000	10,100	51	151,000
2004	8,282,000	-	-	1,100	2,216,000	6,100	20,598	4,430	121,997
2005	8,688,000	-	-	700	2,405,000	6,100	15,998	145,000	512,000
2006	8,736,000	-	-	2,000	2,134,000	17,200	16,000	267,000	905,000
2007	8,313,000	-	-	3,000	2,269,000	31,800	15,500	382,000	41,000
2008	7,853,000	-	-	2,000	2,262,000	100,000	8,000	296,000	4,000
2009	7,799,000	-	-	8,000	1,640,000	84,762	6,488	39,000	3,720

Year	Other Industrial Roundwood (1871)			Chips and particles		Wood charcoal		Wood residues	
	Production	Import	Export	Import	Export	Import	Export	Import	Export
	m^3	m^3	m^3	m^3	m^3	mt	mt	m^3	m^3
2010	8,047,000	-	-	5,000	1,898,000	124,188	3,000	42,000	1,000
2011	8,798,000	-	-	946	1,699,000	110,460	927	56,000	855
2012	10,017,000	-	-	368	1,749,000	77,354	882	33,000	1,794
2013	9,704,000	-	-	377	1,986,000	38,833	1,211	29,000	6,409
2014	9,017,000	-	-	537	2,162,000	41,256	1,287	31,450	654
2015	8,147,000	-	-	613	2,250,000	12,613	4,151	16,531	2,581
2016	8,229,000	-	-	790	2,574,000	3,990	5,410	13,529	3,880
2017	8,753,000	-	-	398	2,594,000	6,189	3,844	8,637	0
2019	8,969,000	-	-	532	2,597,691	14,767	4,194	11,230	78
2019	8,710,000	-	-	765	1,562,335	22,769	14,687	11,357	47
2020	9,194,000	-	-	787	1,721,454	12,404	15,784	12,951	418
2021	10,219,000	-	-	1,125	1,863,947	25,816	13,236	23,186	418
2022	9,745,000	-	-	1,290	1,977,143	31,104	4,286	18,997	2

Source: Based on FAO (2024).

Table A.VII.26. Cumulative carbon stock and carbon stock change in solid waste disposal sites in Brazil.

YEAR	Wood products in solid waste disposal sites in the country	Variable 1B
	Carbon stock (at the beginning of the year) (kt C)	Change in C stock (during a given year) (kt C)
1991	764	344
1992	1,134	370
1993	1,492	358
1994	1,917	425
1995	2,328	411
1996	2,769	441
1997	3,384	614
1998	4,118	735
1999	4,912	794
2000	5,819	906
2001	6,682	863
2002	7,527	845
2003	8,353	826
2004	9,155	803
2005	10,083	927
2006	11,089	1,006
2007	12,155	1,067
2008	13,354	1,199
2009	14,589	1,235
2010	15,799	1,209
2011	17,307	1,508
2012	18,642	1,335
2013	19,856	1,214
2014	21,087	1,231
2015	22,122	1,035
2016	23,270	1,149
2017	24,419	1,149
2018	25,567	1,149
2019	26,716	1,149
2020	27,864	1,149
2021	29,013	1,149
2022	30,161	1,149

Table A.VII.27. Annual contribution of Harvested Wood Products (HWP) to the LULUCF sector's total CO_2 removals and emissions and basic information.

Inventory year	Variable number								
	1A	1B	2A	2B	3	4	5	6	7
	Annual change in the stock of HWP in use from consumption	Annual change in the stock of HWP in SWDS from consumption	Annual change in the stock of HWP in use produced from harvesting in the country	Annual change in the stock of HWP in SWDS produced from harvesting in the country	Annual imports of wood and paper products + fuelwood, pulp, recycled paper, roundwood/chips	Annual exports of wood and paper products + fuelwood, pulp, recycled paper, roundwood/chips	Annual harvest in the country	Annual carbon emissions into the atmosphere from HWP consumption (of fuelwood & products in use and products in SWDS)	Annual carbon emissions into the atmosphere from the consumption of HWP (including fuelwood)
	$\Delta C_{HWP\ IU\ DC}$	$\Delta C_{HWP\ SWDS\ DC}$	$\Delta C_{HWP\ IU\ DH}$	$\Delta C_{HWP\ SWDS\ DH}$	P_{IM}	P_{EX}	H	$\uparrow C_{HWP\ DC}$	$\uparrow C_{HWP\ DH}$
	kt C /year								
1990	3,726	420	3,753	417	281	1,313	108,963	103,786	104,794
1991	4,532	344	4,569	342	345	1,550	111,117	105,035	106,206
1992	4,314	370	4,612	367	286	2,048	113,408	106,963	108,429
1993	4,434	358	4,962	356	350	2,564	115,184	108,177	109,867
1994	4,531	425	5,248	420	513	3,248	116,991	109,301	111,323
1995	5,153	411	5,883	404	793	3,712	118,233	109,751	111,945
1996	5,755	441	6,006	433	875	3,079	118,891	110,490	112,452
1997	5,995	614	6,370	603	939	3,409	119,549	110,469	112,576
1998	5,590	735	6,355	724	723	3,806	119,674	110,266	112,595
1999	5,866	794	6,994	786	600	4,127	129,675	119,490	121,895
2000	6,114	906	7,442	897	645	4,517	131,825	120,932	123,486
2001	6,183	863	7,699	853	586	4,683	125,023	113,881	116,471
2002	6,068	845	8,033	837	515	5,332	129,311	117,581	120,441
2003	5,874	826	8,295	820	505	6,371	143,305	130,740	134,190
2004	5,987	803	8,748	795	597	7,202	136,223	122,828	126,680
2005	6,090	927	8,880	917	775	7,954	129,679	115,483	119,882

Inventory year	Variable number								
	1A	1B	2A	2B	3	4	5	6	7
	Annual change in the stock of HWP in use from consumption	Annual change in the stock of HWP in SWDS from consumption	Annual change in the stock of HWP in use produced from harvesting in the country	Annual change in the stock of HWP in SWDS produced from harvesting in the country	Annual imports of wood and paper products + fuelwood, pulp, recycled paper, roundwood/chips	Annual exports of wood and paper products + fuelwood, pulp, recycled paper, roundwood/chips	Annual harvest in the country	Annual carbon emissions into the atmosphere from HWP consumption (of fuelwood & products in use and products in SWDS)	Annual carbon emissions into the atmosphere from the consumption of HWP (including fuelwood)
	$\Delta C_{HWP\ IU\ DC}$	$\Delta C_{HWP\ SWDS\ DC}$	$\Delta C_{HWP\ IU\ DH}$	$\Delta C_{HWP\ SWDS\ DH}$	P_{IM}	P_{EX}	H	$\uparrow C_{HWP\ DC}$	$\uparrow C_{HWP\ DH}$
	kt C /year								
2006	6,786	1,006	8,840	993	911	7,738	128,791	114,172	118,958
2007	6,858	1,067	8,602	1,052	1,000	7,431	131,688	117,333	122,035
2008	6,255	1,199	7,245	1,181	1,080	7,006	128,276	114,896	119,850
2009	3,757	1,235	4,202	1,221	838	6,756	126,956	116,046	121,532
2010	4,731	1,209	4,913	1,193	1,055	6,854	131,842	120,103	125,736
2011	3,974	1,508	4,100	1,491	998	6,761	141,761	130,515	136,169
2012	3,660	1,335	3,776	1,321	924	6,724	149,391	138,596	144,294
2013	2,724	1,214	2,944	1,201	875	7,318	146,023	135,642	141,879
2014	1,330	1,231	1,764	1,218	865	8,162	145,170	135,312	142,188
2015	-94	1,035	866	1,027	600	8,975	138,815	129,500	136,923
2016	-541	1,149	885	1,141	511	10,321	149,577	139,160	147,551
2017	-558	1,149	1,248	1,142	479	11,047	152,302	141,142	149,911
2018	-976	1,149	1,309	1,143	458	12,265	157,978	145,998	155,526
2019	-691	1,149	1,307	1,142	481	11,970	148,154	136,208	145,705
2020	-358	1,149	1,458	1,143	399	12,715	155,044	141,938	152,443
2021	-344	1,149	2,325	1,143	490	14,171	163,853	149,367	160,385
2022	-622	1,149	1,612	1,144	378	15,263	170,183	154,772	167,427

Note: SWDS – Solid waste disposal site

Table A.VII.28. Harvested Wood Products (HWP) contribution to emissions and removals to the LULUCF sector by approach.

Inventory year	HWP Contribution to LULUCF to emissions/removals by Approach					
	Approach			Simple decay approach		
	Stock Change	Atmospheric Flow	Production	Annual harvest	Annual release	Total contribution
	Net emissions (kt CO_2 eq)			Gross removals (kt CO_2 eq)	Gross emissions (kt CO_2 eq)	Net emissions (kt CO_2 eq)
1990	-15,202	-18,984	-15,289	-399,533	380,548	-18,984
1991	-17,880	-22,299	-18,005	-407,429	385,129	-22,299
1992	-17,173	-23,633	-18,259	-415,831	392,197	-23,633
1993	-17,572	-25,692	-19,496	-422,343	396,651	-25,692
1994	-18,170	-28,199	-20,782	-428,968	400,769	-28,199
1995	-20,400	-31,100	-23,053	-433,520	402,420	-31,100
1996	-22,722	-30,804	-23,610	-435,935	405,132	-30,804
1997	-24,233	-33,291	-25,566	-438,345	405,053	-33,291
1998	-23,189	-34,496	-25,955	-438,804	404,308	-34,496
1999	-24,418	-37,347	-28,527	-475,475	438,128	-37,347
2000	-25,743	-39,939	-30,577	-483,358	443,419	-39,939
2001	-25,834	-40,856	-31,359	-458,419	417,563	-40,856
2002	-25,347	-43,008	-32,523	-474,139	431,132	-43,008
2003	-24,566	-46,072	-33,421	-525,453	479,382	-46,072
2004	-24,895	-49,115	-34,991	-499,483	450,368	-49,115
2005	-25,729	-52,050	-35,921	-475,488	423,438	-52,050
2006	-28,572	-53,603	-36,055	-472,234	418,631	-53,603
2007	-29,058	-52,637	-35,395	-482,858	430,220	-52,637
2008	-27,333	-49,060	-30,894	-470,345	421,284	-49,060
2009	-18,303	-40,003	-19,887	-465,505	425,502	-40,003
2010	-21,781	-43,044	-22,388	-483,420	440,377	-43,044
2011	-20,103	-41,234	-20,502	-519,789	478,555	-41,234
2012	-18,316	-39,582	-18,687	-547,766	508,184	-39,582

Inventory year	HWP Contribution to LULUCF to emissions/removals by Approach					
	Approach			Simple decay approach		
	Stock Change	Atmospheric Flow	Production	Annual harvest	Annual release	Total contribution
	Net emissions (kt CO_2 eq)			Gross removals (kt CO_2 eq)	Gross emissions (kt CO_2 eq)	Net emissions (kt CO_2 eq)
2013	-14,439	-38,063	-15,198	-535,419	497,356	-38,063
2014	-9,391	-36,147	-10,934	-532,292	496,145	-36,147
2015	-3,447	-34,157	-6,938	-508,988	474,832	-34,157
2016	-2,227	-38,198	-7,431	-548,449	510,252	-38,198
2017	-2,167	-40,917	-8,765	-558,439	517,522	-40,917
2018	-632	-43,924	-8,988	-579,251	535,328	-43,924
2019	-1,676	-43,804	-8,981	-543,232	499,428	-43,804
2020	-2,897	-48,056	-9,538	-568,496	520,440	-48,056
2021	-2,951	-53,114	-12,716	-600,795	547,681	-53,114
2022	-1,929	-56,507	-10,105	-624,004	567,497	-56,507

Note: According to the accounting methodology used in the national inventory, a carbon balance is taken of a given area at two time points. For example, when a Forest Land is converted into Cropland, it is initially considered that all its carbon is emitted (gross emissions) and, at the final time point, that there is also carbon in the vegetation of the new use (removals). The difference between these initial and final carbon stocks corresponds to the net emissions from the vegetation in this area, plus the net emissions from the soil. Soil emissions are calculated using a formula that assigns organic carbon change factors for this pool to each type of land use.

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APPENDIX VIII. ADDITIONAL DESCRIPTIONS FOR THE WASTE SECTOR

This appendix details the methodological procedures, statistical adjustments, data and parameters adopted in the estimation of greenhouse gas (GHG) emissions from the Waste sector, submitted in the NIR 2024. The methodology adopted follows the guidelines outlined in IPCC (2006), specifically in chapters 3 to 6 of volume 5.

Solid Waste Disposal

Table A.VIII.1. Fraction of the population living in the Federative Units (FU – States) according to climate classification, for the years of 1970, 1980, 2000, 2016 and 2022.

FU	1970			1980			1990			2000			2016			2022		
	Temperate	Tropical		Temperate	Tropical		Temperate	Tropical		Temperate	Tropical		Temperate	Tropical		Temperate	Tropical	
	Humid	Dry	Humid	Humid	Dry	Humid	Humid	Dry	Humid	Humid	Dry	Humid	Humid	Dry	Humid	Humid	Dry	Humid
AC (Acre)	-	-	1.00	-	-	1.00	-	-	1.00	-	-	1.00	-	-	1.00	0	0	1.00
AL (Alagoas)	-	0.37	0.63	-	0.36	0.64	-	0.36	0.64	-	0.33	0.67	-	0.31	0.69	0	0.31	0.69
AM (Amazonas)	-	-	1.00	-	-	1.00	-	-	1.00	-	-	1.00	-	-	1.00	0	0	1.00
AP (Amapá)	-	-	1.00	-	-	1.00	-	-	1.00	-	-	1.00	-	-	1.00	0	0	1.00
BA (Bahia)	-	0.57	0.43	-	0.55	0.45	-	0.55	0.45	-	0.53	0.47	-	0.51	0.49	0	0.51	0.49
CE (Ceará)	-	0.65	0.35	-	0.61	0.39	-	0.61	0.39	-	0.55	0.45	-	0.54	0.46	0	0.54	0.46
DF (Federal District)	-	-	1.00	-	-	1.00	-	-	1.00	-	-	1.00	-	-	1.00	0	0	1.00
ES (Espírito Santo)	-	-	1.00	-	-	1.00	-	-	1.00	-	-	1.00	-	-	1.00	0	0	1.00
GO (Goiás)	-	-	1.00	-	-	1.00	-	-	1.00	-	-	1.00	-	-	1.00	0	0	1.00
MA (Maranhão)	-	-	1.00	-	-	1.00	-	-	1.00	-	-	1.00	-	-	1.00	0	0	1.00
MG (Minas Gerais)	0.06	0.07	0.87	0.06	0.06	0.88	0.06	0.06	0.88	0.06	0.06	0.89	0.05	0.05	0.89	0.05	0.05	0.89
MS (Mato Grosso do Sul)	-	-	1.00	-	-	1.00	-	-	1.00	-	-	1.00	-	-	1.00	0	0	1.00
MT (Mato Grosso)	-	-	1.00	-	-	1.00	-	-	1.00	-	-	1.00	-	-	1.00	0	0	1.00
PA (Pará)	-	-	1.00	-	-	1.00	-	-	1.00	-	-	1.00	-	-	1.00	0	0	1.00
PB (Paraíba)	-	0.71	0.29	-	0.68	0.32	-	0.68	0.32	-	0.61	0.39	-	0.59	0.41	0	0.59	0.41
PE (Pernambuco)	-	0.42	0.58	-	0.41	0.59	-	0.41	0.59	-	0.39	0.61	-	0.40	0.60	0	0.40	0.60
PI (Piauí)	-	0.35	0.65	-	0.34	0.66	-	0.34	0.66	-	0.30	0.70	-	0.28	0.72	0	0.28	0.72
PR (Paraná)	0.35	-	0.65	0.44	-	0.56	0.44	-	0.56	0.51	-	0.49	0.52	-	0.48	0.52	0	0.48
RJ (Rio de Janeiro)	0.01	-	0.99	0.01	-	0.99	0.01	-	0.99	0.01	-	0.99	0.01	0.01	0.98	0.01	0.01	0.98
RN (Rio Grande do Norte)	-	0.74	0.26	-	0.70	0.30	-	0.70	0.30	-	0.62	0.38	-	0.60	0.40	0	0.60	0.40
RO (Rondônia)	-	-	1.00	-	-	1.00	-	-	1.00	-	-	1.00	-	-	1.00	0	0	1.00
RR (Roraima)	-	-	1.00	-	-	1.00	-	-	1.00	-	-	1.00	-	-	1.00	0	0	1.00
RS (Rio Grande do Sul)	0.84	-	0.16	0.85	-	0.15	0.85	-	0.15	0.89	-	0.11	0.91	-	0.09	0.91	0	0.09
SC (Santa Catarina)	0.84	-	0.16	0.83	-	0.17	0.83	-	0.17	0.87	-	0.13	0.88	-	0.12	0.88	0	0.12
SE (Sergipe)	-	0.36	0.64	-	0.33	0.67	-	0.33	0.67	-	0.28	0.72	-	0.26	0.74	0	0.26	0.74
SP (São Paulo)	0.05	-	0.95	0.05	-	0.95	0.05	-	0.95	0.05	-	0.95	0.05	-	0.95	0.05	0	0.95
TO (Tocantins)	-	-	1.00	-	-	1.00	-	-	1.00	-	-	1.00	-	-	1.00	0	0	1.00
Brasil	0.13	0.15	0.72	0.13	0.14	0.73	0.12	0.14	0.74	0.13	0.12	0.75	0.12	0.12	0.76	0.13	0.12	0.75

Source: Average municipal data (1970 to 2010) for mean annual temperature – MAT, mean annual precipitation – MAP, and potential evapotranspiration – PET (INMET, 2015); total resident population data (IBGE, 1991; 2022).

Table A.VIII.2. Fraction of the population with access to managed solid waste disposal sites (landfills) in relation to the population served with MSW collection.

FU	1970			1980			1990			2000			2016			2022		
	Temperate	Tropical		Temperate	Tropical		Temperate	Tropical		Temperate	Tropical		Temperate	Tropical		Temperate	Tropical	
	Humid	Dry	Humid	Humid	Dry	Humid	Humid	Dry	Humid	Humid	Dry	Humid	Humid	Dry	Humid	Humid	Dry	Humid
AC (Acre)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.57	-	-	0.55
AL (Alagoas)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.36	-	0.34	0.80
AM (Amazonas)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.65
AP (Amapá)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.63	-	-	0.84
BA (Bahia)	-	-	-	-	-	-	-	-	-	-	0.03	0.39	-	0.14	0.34	-	0.15	0.45
CE (Ceará)	-	-	-	-	-	-	-	-	-	-	0.09	0.05	-	0.09	0.04	-	0.12	0.38
DF (Federal District)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.04
ES (Espírito Santo)	-	-	-	-	-	-	-	-	0.02	-	-	0.60	-	-	0.49	-	-	0.92
GO (Goiás)	-	-	-	-	-	-	-	-	-	-	-	0.07	-	-	0.19	-	-	0.29
MA (Maranhão)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.37
MG (Minas Gerais)	-	-	-	-	-	0.43	-	-	0.25	-	-	0.29	0.02	-	0.37	0.06	-	0.77
MS (Mato Grosso do Sul)	-	-	-	-	-	-	-	-	-	-	-	0.01	-	-	0.49	-	-	0.82
MT (Mato Grosso)	-	-	-	-	-	-	-	-	-	-	-	0.35	-	-	0.35	-	-	0.53
PA (Pará)	-	-	-	-	-	-	-	-	0.77	-	-	0.41	-	-	0.33	-	-	0.44
PB (Paraíba)	-	-	-	-	-	-	-	-	-	-	0.01	-	-	0.03	0.29	-	0.53	0.55
PE (Pernambuco)	-	-	-	-	0.06	-	-	0.04	0.09	-	0.04	0.08	-	0.15	0.17	-	0.36	0.64
PI (Piauí)	-	-	-	-	-	-	-	-	0.66	-	-	0.60	-	0.01	0.42	-	0.01	0.00
PR (Paraná)	0.17	-	-	0.06	-	0.10	0.29	-	0.07	0.26	-	0.15	0.31	-	0.32	0.55	-	0.49
RJ (Rio de Janeiro)	-	-	-	-	-	0.07	-	-	0.62	-	-	0.55	-	0.01	0.75	0.01	0.01	0.90
RN (Rio Grande do Norte)	-	-	-	-	-	-	-	-	-	-	-	-	-	0.15	0.28	-	0.27	0.44
RO (Rondônia)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.20	-	-	0.79
RR (Roraima)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.00
RS (Rio Grande do Sul)	-	-	-	0.01	-	-	0.05	-	-	0.39	-	-	0.43	-	0.01	1.01	-	0.10
SC (Santa Catarina)	-	-	-	-	-	-	0.15	-	-	0.21	-	0.04	0.43	-	0.05	1.05	-	0.13
SE (Sergipe)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.01	-	0.04	0.79
SP (São Paulo)	-	-	-	-	-	0.39	0.02	-	0.40	0.02	-	0.50	0.03	-	0.69	0.05	-	0.94
TO (Tocantins)	-	-	-	-	-	-	-	-	-	-	-	0.18	-	-	0.45	-	-	0.55
Brasil	0.07	-	-	0.05	0.03	0.27	0.24	0.02	0.33	0.39	0.07	0.39	0.50	0.22	0.52	0.14	0.05	0.65

Source: Adapted from the National Solid Waste Management Information System – Sinir (MMA, 2015); National Sanitation Information System – SNIS (2003 to 2024) (MCID, 2022); IBGE (1994; 2000; 2008; 2019d; 2019e); Inmet (2015). The symbol "-" means that there was no population with access to a landfill in that state, year and climate).

Incineration and Open Burning of Waste

Table A.VIII. 3. Fraction of the total population that carries out open burning of waste in the Federative Units (FU – States) between 1990 and 2022.

UF	1990	1995	2000	2005	2010	2016	2020[a]	2022
AC	0.18	0.21	0.25	0.20	0.20	0.18	0.19	0.19
AL	0.02	0.06	0.11	0.13	0.16	0.15	0.12	0.11
AM	0.09	0.21	0.26	0.22	0.21	0.15	0.15	0.15
AP	0.18	0.17	0.16	0.11	0.10	0.06	0.09	0.08
BA	0.07	0.10	0.16	0.17	0.19	0.15	0.15	0.15
CE	0.07	0.10	0.12	0.15	0.18	0.20	0.16	0.13
DF	0.03	0.03	0.03	0.02	0.01	0.01	0.01	0.01
ES	0.26	0.19	0.17	0.13	0.11	0.03	0.07	0.07
GO	0.32	0.21	0.13	0.09	0.07	0.00	0.05	0.05
MA	0.25	0.26	0.31	0.32	0.34	0.34	0.25	0.26
MG	0.20	0.17	0.15	0.13	0.11	0.04	0.07	0.07
MS	0.25	0.24	0.19	0.15	0.01	0.09	0.05	0.08
MT	0.26	0.19	0.17	0.14	0.12	0.10	0.09	0.09
PA	0.15	0.25	0.29	0.27	0.27	0.27	0.21	0.20
PB	0.04	0.07	0.12	0.15	0.17	0.16	0.16	0.14
PE	0.04	0.06	0.10	0.11	0.13	0.12	0.12	0.11
PI	0.17	0.18	0.24	0.26	0.30	0.29	0.27	0.24
PR	0.28	0.20	0.13	0.11	0.08	0.00	0.05	0.05
RJ	0.14	0.10	0.06	0.03	0.02	0.00	0.00	0.01
RN	0.06	0.09	0.13	0.12	0.13	0.08	0.09	0.08
RO	0.45	0.34	0.36	0.28	0.25	0.17	0.19	0.18
RR	0.22	0.20	0.20	0.18	0.18	0.12	0.10	0.17
RS	0.18	0.14	0.11	0.08	0.06	0.01	0.03	0.03
SC	0.30	0.20	0.13	0.09	0.06	0.01	0.03	0.03
SE	0.06	0.09	0.14	0.13	0.14	0.08	0.10	0.08
SP	0.05	0.04	0.03	0.02	0.01	0.00	0.01	0.01
TO	0.32	0.29	0.27	0.22	0.20	0.13	0.13	0.13
Brasil	0.17	0.16	0.17	0.15	0.14	0.11	0.11	0.11

Note: [a] Brasil (2004); [b] Brasil (2010); [c] Brasil (2015).

Source: Updated MCF values maintaining the rates of wastewater treated by treatment technology, except for sugar and alcohol (see previous table).

Wastewater Treatment and Discharge

Table A.VIII.4. Annual methane correction factor (MCF), by industrial sector inventoried.

Year	Sugar	Alcohol	Raw milk	Pasteurized milk	Pulp	Beer	Poultry S*	Cattle S*	Swine S*
1990[a]	-	-	0.18	0.18	0.18	0.18	0.18	0.18	0.18
1991	-	-	0.19	0.19	0.18	0.21	0.18	0.19	0.19
1992	-	-	0.19	0.20	0.17	0.24	0.19	0.19	0.19
1993	-	-	0.20	0.21	0.17	0.28	0.19	0.20	0.20
1994	-	-	0.20	0.21	0.17	0.31	0.20	0.20	0.21
1995	-	-	0.21	0.22	0.17	0.34	0.20	0.21	0.21
1996	-	-	0.21	0.23	0.16	0.37	0.21	0.21	0.22
1997	-	-	0.22	0.24	0.16	0.40	0.21	0.22	0.23
1998	-	-	0.22	0.25	0.16	0.44	0.22	0.23	0.24
1999	-	-	0.23	0.26	0.16	0.47	0.22	0.23	0.24
2000	-	-	0.23	0.27	0.15	0.50	0.23	0.24	0.25
2001	-	-	0.24	0.27	0.15	0.53	0.23	0.24	0.26
2002	-	-	0.24	0.28	0.15	0.56	0.23	0.25	0.26
2003	-	-	0.25	0.29	0.15	0.60	0.24	0.25	0.27
2004	-	-	0.25	0.30	0.14	0.63	0.24	0.26	0.28
2005[b]	-	-	0.26	0.31	0.14	0.66	0.25	0.27	0.28
2006	-	-	0.26	0.32	0.14	0.62	0.25	0.27	0.29
2007	-	-	0.27	0.33	0.14	0.59	0.26	0.28	0.30
2008	-	-	0.27	0.33	0.13	0.55	0.26	0.28	0.31
2009	-	-	0.28	0.34	0.13	0.51	0.27	0.29	0.31
2010[c]	-	-	0.28	0.35	0.13	0.47	0.27	0.30	0.32
2011	-	-	0.28	0.35	0.13	0.47	0.27	0.30	0.32
2012	-	-	0.28	0.35	0.13	0.47	0.27	0.30	0.32
2013	-	-	0.28	0.35	0.13	0.47	0.27	0.30	0.32
2014	-	-	0.28	0.35	0.13	0.47	0.27	0.30	0.32
2015	-	-	0.28	0.35	0.13	0.47	0.27	0.30	0.32
2016	-	-	0.28	0.35	0.13	0.47	0.27	0.30	0.32
2017	-	-	0.28	0.35	0.13	0.47	0.27	0.30	0.32
2018	-	-	0.28	0.35	0.13	0.47	0.27	0.30	0.32
2019	-	-	0.28	0.35	0.13	0.47	0.27	0.30	0.32
2020	-	-	0.28	0.35	0.13	0.47	0.27	0.30	0.32
2021	-	-	0.28	0.35	0.13	0.47	0.27	0.30	0.32
2022	-	-	0.28	0.35	0.13	0.47	0.27	0.30	0.32

Note: [a] Brasil (2004); [b] Brasil (2010); [c] Brasil (2015); * Slaughtering.

Source: Updated MCF values maintaining the rates of wastewater treated by treatment technology, except for sugar and alcohol (see previous table).

APPENDIX IX. TIME SERIES OF GREENHOUSE GAS EMISSIONS AND REMOVALS

The time series of greenhouse gas emissions and removals by gas and by sector, for the period from 1990 to 2022, was submitted to the UNFCCC in the CRT format. Below is a summary of net emissions (in kt CO_2 eq) for the series from 1990 to 2022.

SECTOR	NET EMISSIONS (kt CO2 eq)										
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
TOTAL	**1,588,395**	**1,428,422**	**1,552,595**	**1,603,544**	**1,602,577**	**2,748,731**	**2,014,089**	**1,713,281**	**1,997,993**	**1,968,105**	**2,048,689**
1. ENERGY	196,119	199,709	204,745	208,971	217,727	233,681	250,761	266,948	274,713	284,685	291,613
2. IPPU	56,870	61,809	60,109	62,931	62,926	67,651	67,127	70,241	74,440	73,874	77,809
3. AGRICULTURE	394,743	406,182	412,339	418,084	426,689	430,657	404,854	413,141	419,662	425,255	440,797
4. LULUCF	908,066	726,204	839,122	874,712	854,112	1,973,225	1,245,647	915,577	1,179,953	1,132,596	1,184,464
5. WASTE	32,596	34,517	36,281	38,847	41,121	43,516	45,700	47,374	49,225	51,696	54,006
SECTOR	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
TOTAL	**2,019,047**	**2,246,261**	**3,360,112**	**3,596,053**	**2,561,246**	**2,196,460**	**1,850,441**	**1,990,232**	**1,356,216**	**1,352,807**	**1,423,603**
1. ENERGY	300,269	298,946	292,016	307,869	318,363	322,870	336,288	355,898	344,452	377,678	390,598
2. IPPU	74,447	78,932	79,839	83,540	83,335	83,914	88,978	87,279	77,407	87,353	94,143
3. AGRICULTURE	457,789	469,719	499,763	520,394	520,260	519,892	504,549	514,042	520,528	538,559	541,626
4. LULUCF	1,129,709	1,339,596	2,427,048	2,621,326	1,573,714	1,201,775	852,790	963,934	342,440	277,144	324,150
5. WASTE	56,832	59,067	61,445	62,923	65,574	68,008	67,836	69,079	71,389	72,073	73,086
SECTOR	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
TOTAL	**1,305,805**	**1,586,905**	**1,465,525**	**1,562,802**	**1,603,968**	**1,493,407**	**1,523,108**	**1,727,820**	**1,824,760**	**2,116,314**	**2,039,236**
1. ENERGY	423,887	455,039	481,449	457,340	424,610	432,090	409,953	409,287	390,210	436,516	418,451
2. IPPU	95,464	97,042	94,725	95,670	93,931	97,958	99,422	95,394	96,992	105,846	102,317
3. AGRICULTURE	539,920	544,717	550,226	555,694	567,146	565,120	564,395	568,286	583,740	600,474	622,014
4. LULUCF	172,897	411,276	259,775	373,264	436,546	313,282	362,156	567,067	665,084	882,478	805,694
5. WASTE	73,636	78,832	79,350	80,833	81,735	84,956	87,184	87,785	88,735	90,999	90,761

APPENDIX X. SYMBOLS, ACRONYMS AND ABBREVIATIONS

↑ C HWP DC – Atmospheric carbon emissions from Harvested Wood Products in use + atmospheric carbon emissions from Harvested Wood products at solid waste disposal Sites
A – Burnt Area
Aa – Open Ombrophilous Forest - Alluvial
Ab – Open Ombrophilous Forest - Lowlands
ABAL – Brazilian Aluminum Association (Associação Brasileira do Alumínio)
ABC – Brazilian Cooperation Agency (ABC – Agência Brasileira de Cooperação)
ABC Plan – Sectoral Climate Change Mitigation and Adaptation Plan for the Consolidation of a Low Carbon Emission Economy in Agriculture
ABCM – Brazilian Mineral Coal Association (ABCM – Associação Brasileira do Carvão Mineral)
Abiquim – Brazilian Chemical Industry Association (Abiquim – Associação Brasileira da Indústria Química)
ABLV – Brazilian Long Life Dairy Industry Association (ABLV – Associação Brasileira da Indústria de Lácteos de Longa Vida)
ABPA – Brazilian Animal Protein Association (ABPA – Associação Brasileira de Proteína Animal)
ABRACAL – Brazilian Limestone Producers Association (Associação Brasileira dos Produtores de Calcário)
ABRACICLO – Brazilian Association of Manufacturers of Motorcycles, Mopeds, Scooters, Bicycles and Similar Products (Associação Brasileira dos Fabricantes de Motocicletas, Ciclomotores, Motonetas, Bicicletas e Similares)
ABRAVA – Brazilian Refrigeration, Air Conditioning, Ventilation and Heating Association (Associação Brasileira de Refrigeração Ar Condicionado Ventilação e Aquecimento)
AC – Acre
AD – Activity Data
AD – Annual deforestation values by biome
ADMD – Apparent Dry Matter digestibility
AFA – Atmospheric flow method
AFOLU – Agriculture, Forestry and Other Land Use
AGB – Above-Ground Biomass
AGdm – Above-ground residues dry matter
AI – Annualization indices used to estimate gross annual CO_2 emissions
Ai – Area of the polygon
AIyear i period j – Annualization index of the year in the period for the biome
AL – Alagoas
AM – Amazonas
Am – Open Ombrophilous Forest - Montane
ANA – National Water Agency (Agência Nacional de Águas)
ANAC – National Civil Aviation Agency (Agência Nacional de Aviação Civil)
ANDA – National Association for the Dissemination of Fertilizers (Associação Nacional para Difusão de Adubos)
ANFAVEA – National Association of Motor Vehicle Manufacturers (Associação Nacional dos Fabricantes de Veículos Automotores)
Annual CAc – Annual cropland carbon stock
ANP – National Agency for Petroleum, Natural Gas and Biofuels (Agência Nacional do Petróleo, Gás Natural e Biocombustíveis)

ANTAQ – National Waterway Transportation Agency (Agência Nacional de Transportes Aquaviários)
ANUALPEC – Statistical Yearbook of Animal Production (Anuário Estatístico da Produção Animal)
AP – Amapá
APA – Environmental Protection Area (Área de Proteção Ambiental)
APNE – Northeast Plants Association (Associação Plantas do Nordeste)
APP – Permanent Preservation Area (Área de Preservação Permanente)
APU – Auxiliary Power Unit
AR4 – IPCC Fourth Assessment Report
AR5 – IPCC Fifth Assessment Report
ARPA – Amazon Protected Areas Program (Programa Áreas Protegidas da Amazônia)
As – Open Ombrophilous Forest - Submontane
ASD – Area Susceptible to Desertification
ASH – Ash content in manure
Asha – Ash content in baked anodes
BA – Bahia
BA – Baked Anode Production
BEF – Biomass expansion factor to convert average annual net increment to above-ground tree biomass increment
BEN – National Energy Balance (Balanço Energético Nacional)
BEU – Useful Energy Balance (Balanço de Energia Útil)
BGB – Below-Ground Biomass
BGdm – Below-ground residues dry matter
Bo – Maximum methane producing capacity
BOD – Biochemical Oxygen Demand
BS – Bare Soil
BS-AC – Bare Soil Converted to Annual Cropland
BS-FP – Bare Soil Converted to Forest Plantation
BS-OSWL – Bare Soil Converted to Other Secondary Wooded Land
BS-P – Bare Soil Converted to Pasture
BS-SecF – Bare Soil Converted to Secondary Forest
BS-SecG – Bare Soil Converted to Secondary Grassland
BTR – Biennial Transparency Reports
BTR1 – First Biennial Transparency Report
BW – Average live body weight
BW – Body Weight
C – Carbon
C – Net energy coefficient required by the animal for growth
C – Cropland
C-BS – Cropland Converted to Bare Soil
C-Res – Cropland Converted to Reservoir
C-S – Cropland Converted to Settlement
C_2F_6 – Hexafluoroethane
C_6F_{14} – Perfluoro-hexane
Ca – Calcium
Ca – Net energy coefficient required by the animal for animal activity
Ca – Seasonal Deciduous Forest - Alluvial
CAc – Cropland carbon stock
CAc Per – Perennial cropland carbon stock
$CaCO_3$ – Calcium carbonate

CaO – Calcium Oxide
Cb – Seasonal Deciduous Forest - Lowlands
CBIT – Capacity Building Initiative for Transparency
CCST – INPE's (National Institute for Space Research [Instituto Nacional de Pesquisas Espaciais]) Earth System Science Center (Centro de Ciência do Sistema Terrestre do INPE)
CDM – Clean Development Mechanism
CDP – Degraded pasture carbon stock
CE – Ceará
Cepagro – Center for the Study and Promotion of Group Farming (Centro de Estudos e Promoção da Agricultura de Grupo)
CEPEA – Center for Advanced Studies in Applied Economics (Centro de Estudos Avançados em Economia Aplicada)
CETESB – Environmental Company of the State of São Paulo (Companhia Ambiental do Estado de São Paulo)
Cf – Combustion factor
Cf – Net energy coefficient required by the animal for maintenance
CF – Total carbon of Municipal Solid Waste
CF_4 – Tetrafluoromethane
CFCs – Chlorofluorocarbons
CFOAi – Conversion factor for organic amendment i (in terms of its relative effect with respect to straw applied shortly before cultivation)
CFP – Average carbon stock
CFP – Average carbon stock in forest plantation
CFP – Average carbon stock in forest plantation (t C ha-1)
CGCL – General Coordination of Climate Science of the MCTI (Ministry of Science Technology and Innovation) (Coordenação-Geral de Ciência do Clima do MCTI)
CH_4 – Methane
CH_4 emitted burningT – amount of CH_4 emitted from burning in the year
CH_4 emittedT – amount of CH_4 emitted from domestic effluents in the year
CH_4 emittedT – amount of CH_4 emitted in the year
CH_4 generatedx,T – amount of CH_4 generated at the final disposal site in the year
chap. – chapter
CHF_3 – Trifluoromethane
CHP – Combined heat and power - Combined heat and power generation
CIM – Interministerial Committee on Climate Change (Comitê Interministerial sobre Mudança do Clima)
CKD – Cement Kiln Dust
cm – Centimeters
Cm – Seasonal Deciduous Forest - Montane
CMA1 – Conference of the Parties serving as the meeting of the Parties to the Paris Agreement
CNA – Brazilian Confederation of Agriculture and Livestock (Confederação da Agricultura e Pecuária do Brasil)
CNG – Compressed Natural Gas for Vehicles
CNPq – National Council for Scientific and Technological Development (Conselho Nacional de Desenvolvimento Científico e Tecnológico)
CNRH – National Water Resources Council (Conselho Nacional de Recursos Hídricos)
CO – Carbon Monoxide
CO – Carbon stock from other uses
CO119 – Total amount of domestic solid waste and public solid waste collected by all agents

CO164 – Total population served in the municipality by regular waste collection at least once a week.
CO_2 – Carbon Dioxide
CO_2 emitted burningT – amount of CO_2 emitted from burning in the year
CO_2 emitted incinerationT – amount of CO_2 emitted from incineration in the year
CO_2 eq – Carbon Dioxide Equivalent
COD – Chemical Oxygen Demand
CODi – Concentration of Carbonaceous Material in Wastewater
COi – Organic load
COMEX STAT – Foreign trade statistics
Conab – National Supply Company (Companhia Nacional de Abastecimento)
Cons – Fuel consumption
COP – Conference of the Parties to the UNFCCC
Cp – Pasture carbon stock
Cpregnancy – Pregnancy rate
CPRM – Brazilian Geological Service (Serviço Geológico do Brasil)
CRA – Environmental Reserve Quota (Cota de Reserva Ambiental)
CRes – C stock from reservoirs
CRT – Common Reporting Tables
CS – Country-specific - Country-specific emission factor
Cs – Seasonal Deciduous Forest - Submontane
CSI – Cement Sustainability Initiative
CSoil – Soil organic carbon under the polygon's soil-vegetation association (reference carbon)
CT – Conventional tillage
CU – Conservation Unit
CW – Clinical Waste
CWcollection – Annual mass of CW collected in each state
CWPB – Cell Wall Prebake
CWper capita – Per capita mass of clinical waste
D – basic wood density
D – Dense Ombrophilous Forest (Tropical Rain Forest)
D – Dunes
D – IPCC default emission factor
D year i – area deforested in the year in the biome
D year i-1 – Area deforested in the year immediately preceding the year in the biome
Da – Dense Ombrophilous Forest - Alluvial
DATASUS – Brazil's National Health System
Db – Dense Ombrophilous Forest - Lowlands
DCI – Department of Communication and Information
DDOCm – Mass of decomposable degradable organic carbon
DDOCm decompT – Degradable organic matter decomposed in year T
DDOCmaT – DDOCm accumulated in SWDS at the end of year T
DDOCmaT-1 – DDOCm accumulated in SWDS at the end of year T-1
DDOCmdT – DDOCm deposited in SWDS in year T
DE – Digestible Energy, Digestibility Rate
DF – Distrito Federal (Federal District)
DGI – Image Generation Division (Divisão de Geração de Imagens)
DI – Mixed Ombrophilous Forest - High Montane
Dm – Dense Ombrophilous Forest - Montane
dm – Total dry mass of Municipal Solid Waste

dmi – Incinerated dry matter of waste (wet weight)
dmj – Dry mass of component j of open-burned Municipal Solid Waste
DOC – Degradable organic carbon fraction
DOCf – Decomposable degradable organic carbon fraction
DOCi – Degradable organic carbon in the year of deposition in each waste category
DOM – Dead Organic Matter
DP – Degraded pasture
Dperiodj – Arithmetic average of the area deforested in the period for the biome
DPVAT – Insurance for Personal Injury Caused by Land Motor Vehicles (Seguro de Danos Pessoais Causados por Veículos Automotores de Via Terrestre)
DRY – Dry matter fraction in grains
Ds – Dense Ombrophilous Forest - Submontane
DW – Standing deadwood
DWW – Domestic wastewater treatment system
E – Carbon emissions to the atmosphere from Harvested Wood Products in use
E – Steppe
Ea – Steppic Savannah - Wooded
EBA – Estimated Biomass in the Amazon
ECO_2 – CO_2 (Carbon Dioxide) emissions
EEA – European Environment Agency
EEDb – Engine Emissions Data Bank
EF – Emission factor
EF – Emission Factor – Emission Factor for continuous flooding, without organic material input
EF – Emission factors for composting treatment
EFEfluent – N_2O emission factor of discharged wastewater
EFi – N_2O emission factor for waste type
EFj – Effluent emission factor
EFk – emission factor of industry for each treatment/system used in the inventoried year
Eg – Steppe – Grassy-Woody
EM – Steppe/Mixed Ombrophilous Forest Transition
Emater – Rural Technical Assistance Company (Empresa de Assistência Técnica Rural)
Embrapa – Brazilian Agricultural Research Corporation (Empresa Brasileira de Pesquisa Agropecuária)
EMEP – European Monitoring and Evaluation Programme
EN – Steppe/Seasonal Forest Transition
ENCE – National Energy Conservation Label (Etiqueta Nacional de Conservação de Energia)
ENREDD+ – National Strategy for REDD+ (Estratégia Nacional para REDD+)
EOR – Enhanced Oil Recovery
Ep – Steppe - Park
EP – Steppe/Formations Transition
Epagri – Agricultural Research and Rural Extension Company of the state of Santa Catarina (Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina)
EPE – Energy Research Office (Empresa de Pesquisa Energética)
Eperiod j – Arithmetic average of gross CO_2 emissions in the period for the biome
ES – Espírito Santo
ESA – European Space Agency
ESi – Net emission associated with the polygon in the period due to variation in soil carbon
ETF – Enhanced Transparency Framework
EVI – Enhanced Vegetation Index

EW – Atmospheric carbon emissions from Harvested Wood Products at solid waste disposal sites
F – Fraction of methane gas in landfill gas
F – Seasonal Semideciduous Forest
Fa – Seasonal Semideciduous Forest - Alluvial
FAM – (Fraction of Manure) Amount of Nitrogen in the form of organic fertilizer corresponding to that present in managed manure.
FAO – Food and Agriculture Organization of the United Nations
FAOSTAT – Food and Agriculture Organization Statistics
Fat – Fat content - Milk fat content
Fb – Seasonal Semideciduous Forest - Lowlands
FBMC – Brazilian Forum on Climate Change (Fórum Brasileiro de Mudança do Clima)
fC – Soil carbon change factor
fc (t) – Soil carbon change factor at the time
FCF – Fossil carbon fraction
FCR – Crop residue N, including N-fixing crops and forage/ pasture renewal, returned to soils - Amount of Nitrogen corresponding to that present in crop residues and pasture renewal
fI – Stock change factor due to the addition of organic matter
FIND-CON – Factor for commercial and industrial protein co-discharged in the collection system
fIU – Stock change factor due to land-use type or land-use change
FL – Forest Land
Fm – Seasonal Semideciduous Forest - Montane
fMG – Stock change factor due to the management regime
FNON-CON – Factor for non-consumed protein added to wastewater
FNP – FNP Institute
FNPR – Fraction of nitrogen in protein
FON – Annual amount of organic nitrogen additions applied to soils - Annual amount of organic nitrogen additions applied to soils (manure, crop residues, etc.).
FOOA – Amount of nitrogen in the form of organic fertilizer present in vinasse and filter cake
FOS – Annual area of managed/drained organic soils
FP – Forest Plantation
FP-AC – Forest Plantation Converted to Annual Cropland
FP-BS – Forest Plantation Converted to Bare Soil
FP-Min – Forest Plantation Converted to Mining
FP-OSWL – Forest Plantation Converted to Other Secondary Wooded Land
FP-P- Forest Plantation Converted to Pasture
FP-PER – Forest Plantation Converted to Perennial Cropland
FP-Res – Forest Plantation Converted to Reservoir
FP-S – Forest Plantation Converted to Settlements
FP-SecF – Forest Plantation Converted to Secondary Forest
FP-SecG – Forest Plantation Converted to Secondary Grassland
FP-SUGAR CANE – Forest Plantation Converted to Semi-perennial Cropland
FPRP – Amount of nitrogen in organic fertilizer present in unmanaged manure
FRA – Global Forest Resources Assessment
FracGASF – Fraction of synthetic fertilizer nitrogen that is lost through volatilization as NH_3 and NOx gases
FracGASM – Fraction of manure nitrogen and organic fertilizer nitrogen lost through volatilization as NH_3 and NOx gases

FracGasMS – Percent of managed manure nitrogen for livestock that volatilizes as ammonia and nitrogen oxides in the manure management system
FracLEACH – Fraction of nitrogen lost by leaching and runoff from managed soils
FracLossMS – (fraction of nitrogen lost for each manure management system that is not accounted for as organic fertilizer
FracNew – Renewal factor
FracRenew – Fraction of the total area cultivated with crop T that is renewed annually
Fs – Seasonal Semideciduous Forest - Submontane
FSN – Amount of nitrogen in the form of synthetic fertilizers
FSOM – Amount of nitrogen mineralized due to carbon loss from soil
FU – Federative Unit (State)
FUNAI – National Indian Foundation (Fundação Nacional do Índio)
G – Grass
G ef – Emission factor
GA – Original Anode Weight
GDP – Gross Domestic Product
GE – Gross Energy Intake
GEEng – Google Earth Engine
Gef – Emission factor
GEF – Global Environment Facility
Gg – Giga grams
GHG – Greenhouse gases
GO – Goiás
GPG – Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories - 2000 IPCC Good Practice Guidelines
GTP – Global Temperature Change Potential - Global Temperature Increase Potential
Gw – Average annual increase in above-ground biomass
GWL – Global Warming Level
GWP – Global Warming Potential
H – Harvested wood for use in Harvested Wood Products
ha – hectare
HAC – High Activity Clay - Soils with a high clay content
HCFC-22 – Hydrochlorofluorocarbon-22
HCFCs – Hydrofluorochlorocarbons
HFCs – Hydrofluorocarbons
HNO_3 – nitric acid
HSS – Horizontal Stud Soderberg
Hw – Anode Hydrogen Content
HWP – Harvested Wood Products
I – correction factor for additional discharge of industrial BOD into the sewage system
i.e. (Id est) - That is
IABr – Brazil Steel Institute (Instituto Aço Brasil)
IAC – Agronomic Institute (Instituto Agronômico)
IBÁ – Brazilian Tree Industry (Indústria Brasileira de Árvores)
IBGE – Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística)
IBRAVIN – Brazilian Wine Institute (Instituto Brasileiro do Vinho)
IBTS – Brazilian Institute of Sustainable Transport (Instituto Brasileiro de Transporte Sustentável)
ICAO – International Civil Aviation Organization
iCLF – Integrated Crop-Livestock-Forestry

ICMBio – Chico Mendes Biodiversity Conservation Institute (Instituto Chico Mendes de Conservação da Biodiversidade)
IE – Included Elsewhere
iLF – Integrated Livestock-Forestry
ILs – Indigenous Lands
Incra – National Institute for Rural Settlement and Agrarian Reform (Instituto Nacional de Colonização e Reforma Agrária)
INCT – National Science and Technology Institute (Instituto Nacional de Ciência e Tecnologia)
inh – inhabitants
INMET – National Institute of Meteorology (Instituto Nacional de Meteorologia)
INPE – National Institute for Space Research (Instituto Nacional de Pesquisas Espaciais)
IPCC – Intergovernmental Panel on Climate Change
IPPU – Industrial Processes and Product Use
IRGA – Rio Grandense Rice Institute (Instituto Rio Grandense do Arroz)
Iv – Average annual net increase in volume, suitable for industrial processing
IVDMD – In vitro dry matter digestibility
IWi – Mass of solid waste of type i incinerated or burnt
k – Methane generation rate constant
kg – kilogram
km^2 – Square kilometer
kt – Kiloton (thousand tons)
L – Campinarana
L (cm) – Lower depth of increment
L fire – Greenhouse gas emissions from fire
La – Campinarana - Wooded
LAC – Low Activity Clay - Soils with a low clay content
Lb – Campinarana - Shrub
Ld – Campinarana - Forested
Lg – Campinarana - Grassy-Woody
LiDAR – Light Detection and Ranging
LO – Campinarana / Ombrophilous Forest Transition
LRV – Light Rail Vehicle
LSMM – Linear Spectral Mixture Model
LSPA – Systematic Survey of Agricultural Production (Levantamento Sistemático da Produção Agrícola)
LULUCF – Land Use, Land-Use Change and Forestry
LW – Live Weight
M – Mass of organic waste treated by the biological treatment of composting
M – Mixed Ombrophilous Forest
m^3 - Cub ic meters
MA – Maranhão
Ma – Mixed Ombrophilous Forest - Alluvial
MAP – Mean annual precipitation
MAPA – Ministry of Agriculture, Livestock and Supply (Ministério da Agricultura, Pecuária e Abastecimento)
MAT – Mean annual temperature
MB – Biomass available for combustion
MCF – Methane Conversion Factor
MCT – Ministry of Science and Technology (Ministério da Ciência e Tecnologia)

MCTI – Ministry of Science, Technology and Innovation (Ministério da Ciência, Tecnologia e Inovação)
MD – Managed Dunes
MD-AC – Managed Dune Converted to Annual Cropland
MD-FP – Managed Dune Converted to Forest Plantation
MD-P – Managed Dune Converted to Pasture
MD-PER – Managed Dune Converted to Perennial Cropland
MD-S – Managed Dunes Converted to Settlements
MDA – Ministry of Agrarian Development (Ministério do Desenvolvimento Agrário)
MDIC – Ministry of Industry, Foreign Trade and Services (Ministério da Indústria Comércio Exterior e Serviços)
MEC – Ministry of Education (Ministério da Educação)
MF – Ministry of Finance (Ministério da Fazenda)
MFL – Managed Forest Land
MFL-AC – Managed Forest Land Converted to Annual Cropland
MFL-BS – Managed Forest Land Converted to Bare Soil
MFL-DP – Managed Forest Land Converted to Degraded Pasture
MFL-FP – Managed Forest Land Converted to Forest Plantation
MFL-MFL – Managed Forest Land Remaining Managed Forest Land
MFL-Min – Managed Forest Land Converted to Mining
MFL-P – Managed Forest Land Converted to Pasture
MFL-PER – Managed Forest Land Converted to Perennial Cropland
MFL-Res – Managed Forest Land Converted to Reservoir
MFL-S – Managed Forest Land Converted to Settlement
MFL-SecF – Managed Forest Land Converted to Secondary Forest
MFL-SL – Managed Forest Land Converted to Selective Logging
MFL-SUGAR CANE – Managed Forest Land Converted to Semi-perennial Cropland
Mg – Ma nesium
MG – Managed Grassland
MG – Minas Gerais
MG-AC – Managed Grassland Converted to Annual Cropland
MG-BS – Managed Grassland Converted to Bare Soil
MG-FP – Managed Grassland Converted to Forest Plantation
MG-MG – Managed Grassland Remaining Managed Grassland
MG-Min – Managed Grassland Converted to Mining
MG-P – Managed Grassland Converted to Pasture
MG-PER – Managed Grassland Converted to Perennial Cropland
MG-Res – Managed Grassland Converted to Reservoir
MG-S – Managed Grassland Converted to Settlements
MG-SecG – Managed Grassland Converted to Secondary Grassland
MG-SUGAR CANE – Managed Grassland Converted to Semi-perennial Cropland
$MgCO_3$ – Magnesium carbonate
MgO – Magnesium Oxide
MI – Ministry of National Integration (Ministério da Integração Nacional)
Milk – Milk production
Min – Mining
Min-AC – Mining Converted to Annual Cropland
Min-FP – Mining Converted to Forest Plantation
Min-OSWL – Mining Converted to Other Secondary Wooded Land
Min-P – Mining Converted to Pasture
Min-SecF – Mining Converted to Secondary Forest

Min-SecG – Mining Converted to Secondary Grassland
MJ – Megajoule
Ml – Mixed Ombrophilous Forest - High Montane
mm – millimeter
Mm – Mixed Ombrophilous Forest - Montane
MMA – Ministry of the Environment (Ministério do Meio Ambiente)
MME – Ministry of Mines and Energy (Ministério de Minas e Energia)
MPDG – Ministry of Planning, Development and Management (Ministério do Planejamento, Desenvolvimento e Gestão)
MPGs – Modalities, Procedures and Guidelines
MRE – Ministry of Foreign Affairs (Ministério das Relações Exteriores)
MRO – Managed Rock Outcrop
MRV – Measurement, Reporting and Verification
Ms – Mixed Ombrophilous Forest - Submontane
MS – Fraction of manure management system utilization
MS – Mato Grosso do Sul
MSW – Municipal Solid Waste
MSWB – total mass of open-burned MSW
MSWcollected – Mass of MSW collected annually
MSWP – Waste generation per inhabitant
MT – Mato Grosso
MTE – Ministry of Labor and Employment (Ministério do Trabalho e Emprego)
MVC – Dichloroethane and Vinyl Chloride
N – Nitrogen
N – Seasonal
N HWP AFOLU AFA – Contribution of net emissions from Harvested Wood Products from Agriculture, Forestry and Other Land Use
N_2O – Nitrous Oxide
N_2O emitted from incineration or burningT – Amount of N_2O emitted from incineration or burning in the year
N_2O emittedT – Amount of N_2O emitted from the treatment of domestic effluent in the year
N_2O emittedT – Amount of N_2O emitted in the year
NA – activity in a given source/sink category that occurs in the country, but has not resulted in emissions or removals of a specific gas
NAC – Net Prebaked Anode Consumption
Nag – Fraction of nitrogen in above-ground residues
NATV – Native Vegetation
Nbg – Fraction of nitrogen in below-ground residues
NC – National Communications
NE – activity data and/or emissions by sources and removals by sinks of GHGs that have not been estimated, but for which a corresponding activity may occur in the country
NE – Categories not estimated
NE – Northeast
NE – Not estimated
NEE – Net Ecosystem Exchange
NEfluent – Nitrogen from the effluent discharged into the aquatic environment
Nex – Annual nitrogen excretion rate
NF_3 – Nitrogen Trifluoride
NGL – Natural Gas Liquids
NH_3 – Ammonia
NIR – National Inventory Report

NM – Seasonal Forest/Mixed Ombrophilous Forest Transition
NMVOC – Other Non-methane Volatile Organic Compounds
NO – Area Not Observed
NO – Not occurring
NO_x – Nitrogen oxides
NP – Seasonal Forest/Pioneer Formations Transition - Specific to Marine-Influenced Pioneer Formation (Restinga)
NP – Unpublished data
NRC – National Research Council
NSludge – Nitrogen removed via sludge
NTFS – No-Till Farming System
NV – Native vegetation
O – Ombrophilous
O – Other Land
O – Other possible cross-border carbon transfers from rest of AFOLU
ODS – Ozone Depleting Substances
of the Oceans and Climate Studies
OFi – Oxidation factor
OM – Dense Ombrophilous Forest / Mixed Ombrophilous Forest Transition
OMWL – Other Managed Wooded Land
OMWL-AC – Other Managed Wooded Land Converted to Annual Cropland
OMWL-FP – Other Managed Wooded Land Converted to Forest Plantation
OMWL-Min – Other Managed Wooded Land Converted to Mining
OMWL-OMWL – Other Managed Wooded Land Remaining Other Managed Wooded Land
OMWL-OSWL – Other Managed Wooded Land Converted to Other Secondary Wooded Land
OMWL-P – Other Managed Wooded Land Converted to Pasture
OMWL-PER – Other Managed Wooded Land Converted to Perennial Cropland
OMWL-Res – Other Managed Wooded Land Converted to Reservoir
OMWL-S – Other Managed Wooded Land Converted to Settlements
ON – Ombrophilous Forest/Seasonal Forest Transition
OP – Ombrophilous Forest/Pioneer Formations Transition - Specific to Marine-Influenced Pioneer Formation (Restinga)
OP – orbit/point
OR – Other Regions
OR – Other regions of the Atlantic Forest
OSWL – Other Secondary Wooded Land
OSWL- Min – Other Secondary Wooded Land Converted to Mining
OSWL- Res – Other Secondary Wooded Land Converted to Reservoir
OSWL- S – Other Secondary Wooded Land Converted to Settlements
OSWL-AC – Other Secondary Wooded Land Converted to Annual Cropland
OSWL-BS – Other Secondary Wooded Land Converted to Bare Soil
OSWL-FP – Other Secondary Wooded Land Converted to Forest Plantation
OSWL-P – Other Secondary Wooded Land Converted to Pasture
OSWL-PER – Other Secondary Wooded Land Converted to Perennial Cropland
OSWL-SUGAR CANE – Other Secondary Wooded Land Converted to Semi-perennial Cropland
OTH – Other
OUWL – Other Unmanaged Wooded Land
OUWL-AC – Other Unmanaged Wooded Land Converted to Annual Cropland
OUWL-BS – Other Unmanaged Wooded Land Converted to Bare Soil
OUWL-FP – Other Unmanaged Wooded Land Converted to Forest Plantation

OUWL-Min – Other Unmanaged Wooded Land Converted to Mining
OUWL-OMWL – Other Unmanaged Wooded Land Converted to Other Managed Wooded Land
OUWL-OSWL – Other Unmanaged Wooded Land Converted to Other Secondary Wooded Land
OUWL-P – Other Unmanaged Wooded Land Converted to Pasture
OUWL-PER – Other Unmanaged Wooded Land Converted to Perennial Cropland
OUWL-Res – Other Unmanaged Wooded Land Converted to Reservoir
OUWL-S – Other Unmanaged Wooded Land Converted to Settlements
OUWL-SUGAR CANE – Other Unmanaged Wooded Land Converted to Semi-perennial Cropland
OWL – Other Wooded Land
Ox – Oxidation Factor
OXT – Oxidation Factor in the year
P – Pioneer Formation
P – population
P – Pasture
P-AC – Pasture Converted to Annual Cropland
P-BS – Pasture Converted to Bare Soil
P-DP – Pasture Converted to Degraded Pasture
P-FP – Pasture Converted to Forest Plantation
P-Min – Pasture Converted to Mining
P-OSWL – Pasture Converted to Other Secondary Wooded Land
P-Res – Pasture Converted to Reservoir
P-S – Pasture Converted to Settlement
P-SecF – Pasture Converted to Secondary Forest
P-SecG – Pasture Converted to Secondary Grassland
P-SUGAR CANE – Pasture Converted to Semi-perennial Cropland
Pa – Fluvial- and/or lacustrine-influenced Pioneer Formation
PA – Pará
PAM – Municipal Agricultural Production (Produção Agrícola Municipal)
PB – Paraíba
PBE – Brazilian Labeling Programme (Programa Brasileiro de Etiquetagem)
PBMC – Brazilian Panel on Climate Change (Painel Brasileiro de Mudanças Climáticas)
PCS – Sustainable Cerrado Program (Programa Cerrado Sustentável) - National Program for the Conservation and Sustainable Use of the Cerrado Biome
PDE – Ten-Year Energy Plan (Plano Decenal de Energia)
PE – Pernambuco
PEE – Energy Efficiency Program (Programa de Eficiência Energética)
PER – Perennial
PER – Perennial cropland
PES – Payment for Environmental Services
PET – Potential evapotranspiration
PEX – Carbon transfer in the form of biomass from exported wood products
Pf – fluviomarine-influenced Pioneer Formation (mangrove)
PFCs – Perfluorocarbons
Pfrac – fraction of the population that carries out burning
PGIRS – Integrated Solid Waste Management Plan (Plano de Gestão Integrada de Resíduos Sólidos)
Pi – Industrial production
PI – Piauí

PIA – Annual Industrial Survey (Pesquisa Industrial Anual)
PIM – Carbon transfer in the form of biomass from imported wood products
Pk – total industrial production for industry of sector i
PlanSab – National Basic Sanitation Plan (Plano Nacional de Saneamento Básico)
Pm – Marine-influenced Pioneer Formation (restinga)
PMDBBS – Project of Satellite Deforestation Monitoring of the Brazilian Biomes (Projeto de Monitoramento do Desmatamento nos Biomas Brasileiros por Satélite)
PMFS – Sustainable Forest Management Plans for the Caatinga (Planos de Manejo Florestal Sustentável da Caatinga)
PNAD – National Household Sample Survey (Pesquisa Nacional por Amostra de Domicílios)
PNADC – Continuous National Household Sample Survey (Pesquisa Nacional por Amostra de Domicílios Contínua)
PNMC – National Policy on Climate Change (Política Nacional sobre Mudança do Clima)
PNRS – National Solid Waste Policy (Política Nacional de Resíduos Sólidos)
PNSH – National Water Security Plan (Plano Nacional de Segurança Hídrica)
PPCDAM – Action Plan for the Prevention and Control of Deforestation in the Amazon (Plano de Ação para Prevenção e Controle do Desmatamento na Amazônia)
PPM – Municipal Livestock Survey (Pesquisa da Pecuária Municipal)
PR – Paraná
Proálcool – National Alcohol Program (Programa Nacional do Álcool)
PROCEL – Electric Energy Conservation National Programme (Programa Nacional de Conservação de Energia Elétrica)
PROCONVE – Program for the Control of Air Pollution from Motor Vehicles (Programa de Controle da Poluição do Ar por Veículos Automotores)
Prodes – Program to Monitor Deforestation in the Legal Amazon (Sistema de Monitoramento do Desmatamento na Amazônia Legal)
Proveg – National Policy for the Recovery of Native Vegetation (Política Nacional para Recuperação da Vegetação Nativa)
PROZON – Brazilian Program for the Replacement of Ozone Depleting Substances (Programa Brasileiro de Substituição de Substâncias Destruidoras da Camada de Ozônio)
PSF – Family Health Program (Programa Saúde da Família)
PTN – Protein consumption per capita
QA – Quality Assurance
QA/QC – Quality assurance/Quality control
QC – Quality Control
R – Recovered methane
R – Root biomass/above-ground biomass ratio for each crop specifically
R – Root ratio
Rag – Ratio of dry residue to dry harvested product
Rbg-bio – Ratio of below-ground dry residue to above-ground biomass dry matter
REDD+ – Reducing Emissions from Deforestation and Forest Degradation, Conservation of Forest Carbon Stocks, Sustainable Forest Management and Enhancement of Forest Carbon Stocks
Rede CLIMA – Brazilian Research Network on Global Climate Change (Rede Brasileira de Pesquisas sobre Mudanças Climáticas Globais)
RES – Reservoirs
RIDESA – Inter-university Network for the Development of the Sugar Energy Sector (Rede Interuniversitária para o Desenvolvimento do Setor Sucroenergético)
RIMA – Environmental Impact Report (Relatório de Impacto Ambiental)
RJ – Rio de Janeiro
RL – High Mountain Refuge

RL – Legal Reserve (Reserva Legal)
Rm – Mountain refuge
RM – Metropolitan Region (Região Metropolitana)
RN – Rio Grande do Norte
RO – Rock Outcrop
RO – Rondônia
ROAi – Dose of organic material applied, based on dry matter for rice straw and fresh matter for other residues
RR – Roraima
Rs – Submontane Refuge
RS – Rio Grande do Sul
S – Organic component removed as sludge
S – Savannah
S – Settlements
S-DWW – Domestic Sewage Sludge
S1 – Soils with high-activity clay
S2 – Latosols with low-activity clay
S3 – Non-Latosols with low-activity clay
S4 – Sandy soils
S5 – Hydromorphic soils
S6 – Other Soils
Sa – Savannah - Wooded
Sa – Sulphur Content in Baked Anodes
SAE – Society of Automotive Engineers
SAF – Sustainable Aviation Fuel
SAR – Second Assessment Report - IPCC Second Assessment Report
SAR/ANAC – Department of Airworthiness of the National Civil Aviation Agency (Superintendência de Aeronavegabilidade da Agência Nacional de Aviação Civil)
SC – Santa Catarina
Sd – Asvannah - Forested
SE – Sergipe
SecF - Secondary Forest
SecF-AC – Secondary Forest Converted to Annual Cropland
SecF-BS – Secondary Forest Converted to Bare Soil
SecF-FP – Secondary Forest Converted to Forest Plantation
SecF-Min – Secondary Forest Converted to Mining
SecF-P – Secondary Forest Converted to Pasture
SecF-PER – Secondary Forest Converted to Perennial Cropland
SecF-Res – Secondary Forest Converted to Reservoir
SecF-S – Secondary Forest Converted to Settlements
SecF-SL – Secondary Forest Converted to Selective Logging
SecF-SUGAR CANE – Secondary Forest Converted to Semi-perennial Cropland
SecG - Secondary Grassland
SecG-AC – Secondary Grassland Converted to Annual Cropland
SecG-FP – Secondary Grassland Converted to Forest Plantation
SecG-Min – Secondary Grassland Converted to Mining
SecG-P – Secondary Grassland Converted to Pasture
SecG-PER – Secondary Grassland Converted to Perennial Cropland
SecG-Res – Secondary Grassland Converted to Reservoir
SecG-S – Secondary Grassland Converted to Settlements
SecG-SUGAR CANE – Secondary Grassland Converted to Semi-perennial Cropland

SEPPE – MCTI Secretariat for Strategic Policies and Programs (Secretaria de Políticas e Programas Estratégicos do MCTI)
SESI – Industry Social Service (Serviço Social da Indústria)
SF_6 – Sulfur hexafluoride
SFB – Brazilian Forest Service (Serviço Florestal Brasileiro)
SFo – Scaling factor explaining variations in the type and amount of organic material added to soil
SFp – Scaling factor explaining differences in water regime prior to rice cultivation
SFw – Scaling factor explaining differences in water regime during rice cultivation
Sg – Savannah - Grassy-Woody
SiCAR – National Rural Environmental Registry System (Sistema Nacional de Cadastro Ambiental Rural)
SIDRA – IBGE Automatic Recovery System (Sistema IBGE de Recuperação Automática)
SIECESC – Santa Catarina State Coal Extraction Industry Union (Sindicato da Indústria de Extração de Carvão do Estado de Santa Catarina)
SIN-ABC – Integrated Information System of the Sectoral Plan for the Consolidation of a Low Carbon Emission Economy in Agriculture (Sistema Integrado de Informações do Plano Setorial para Consolidação de uma Economia de Baixa Emissão de Carbono na Agricultura)
SINIR – National Solid Waste Management Information System (Sistema Nacional de Informações sobre a Gestão dos Resíduos Sólidos)
SIRENE – National Emissions Registry System (Sistema de Registro Nacional de Emissões)
SL – Selective Logging
SL-AC – Selective Logging Converted to Annual Cropland
SL-FP – Selective Logging Converted to Forest Plantation
SL-Min – Selective Logging Converted to Mining
SL-P – Selective Logging Converted to Pasture
SL-PER – Selective Logging Converted to Perennial Cropland
SL-Res – Selective Logging Converted to Reservoir
SL-SecF – Selective Logging Converted to Secondary Forest
SL-SL – Selective Logging Remaining Selective Logging
SM – Savannah/Mixed Ombrophilous Forest Transition
SN – Savannah/Seasonal Forest Transition
SNIC – National Cement Industry Union (Sindicato Nacional da Indústria do Cimento)
SNIC – National Cement Industry Union (Sindicato Nacional da Indústria do Cimento)
SNIS – National Sanitation Information System (Sistema Nacional de Informações sobre Saneamento)
SNUC – Brazilian System of Conservation Units (Sistema Nacional de Unidades de Conservação)
SO – Savannah/Ombrophilous Forest Transition
SOC – Soil Organic Carbon
SOC – Soil Organic Carbon Content
SP – Public Service Electric Power Plants (Centrais Elétricas de Serviço Público)
Sp – Savannah - Park
SP – Savannah/Pioneer Formations Transition - Specific to Marine-Influenced Pioneer Formation (Restinga)
SP – São Paulo
ST – Savannah/Pioneer Formations Transition - Specific to Marine-Influenced Pioneer Formation (Restinga)
ST – Savannah/Steppic Savannah Transition
STN – Savannah/Steppic Savannah/Seasonal Forest Transition
SUGAR CANE – Semi-perennial Cropland

SWDS – Final disposal of solid waste
SWi – Mass of type i solid waste (as wet weight) incinerated
SWS – Soil water storage capacity
t – growth time
T – Number of years of the period evaluated in the inventory
T – planting cycle time (year)
T – Steppic Savannah
T – year inventoried
T/2 – Half of the period
T1 – Tier 1
t1/2 – half-life time
T2 – Tier 2
T2a – Tier 2a
T3 – Tier 3
T3a – Tier 3a
Ta – Steppic Savannah - Wooded
TAM – Typical animal mass
TC – Thematic Chambers
Td – Steppic Savannah - Forested
TFT – thin film transistor
Tg – Steppic Savannah - Grassy-Woody
Tij – Degree of use of treatment system/discharge system or pathway for each fraction of income group in the year inventoried
TN – Steppic Savannah/Seasonal Forest Transition
TO – Tocantins
TODA – Animal Waste Treatment (Tratamento de Dejetos Animais)
TOW – Degradable organic material in industrial wastewater
Tp – Steppic Savannah - Park
U (cm) – Upper depth of increment
UD – Unmanaged Dunes
UD-AC – Unmanaged Dune Converted to Annual Cropland
UD-FP – Unmanaged Dune Converted to Forest Plantation
UD-P – Unmanaged Dune Converted to Pasture
UD-PER – Unmanaged Dune Converted to Perennial Cropland
UD-S – Unmanaged Dunes Converted to Settlements
UE – Urinary Energy
UFL – Unmanaged Forest Land
UFL-AC – Unmanaged Forest Land Converted to Annual Cropland
UFL-BS – Unmanaged Forest Land Converted to Bare Soil
UFL-MFL – Unmanaged Forest Land Converted to Managed Forest Land
UFL-Min – Unmanaged Forest Land Converted to Mining
UFL-P – Unmanaged Forest Land Converted to Pasture
UFL-PER – Unmanaged Forest Land Converted to Forest Plantation
UFL-PER – Unmanaged Forest Land Converted to Perennial Cropland
UFL-Res – Unmanaged Forest Land Converted to Reservoir
UFL-S – Unmanaged Forest Land Converted to Settlements
UFL-SecF – Unmanaged Forest Land Converted to Secondary Forest
UFL-SL – Unmanaged Forest Land Converted to Selective Logging
UFL-SUGAR CANE – Unmanaged Forest Land Converted to Semi-perennial Cropland
UG - Unmanaged Grassland
UG-AC – Unmanaged Grassland Converted to Annual Cropland

UG-BS – Unmanaged Grassland Converted to Bare Soil
UG-FP – Unmanaged Grassland Converted to Forest Plantation
UG-MG – Unmanaged Grassland Converted to Managed Grassland
UG-Min – Unmanaged Grassland Converted to Mining
UG-P – Unmanaged Grassland Converted to Pasture
UG-PER – Unmanaged Grassland Converted to Perennial Cropland
UG-Res – Unmanaged Grassland Converted to Reservoir
UG-S – Unmanaged Grassland Converted to Settlements
UG-SecG – Unmanaged Grassland Converted to Secondary Grassland
UG-SUGAR CANE – Unmanaged Grassland Converted to Semi-perennial Cropland
Ui – Population in income group i in the year inventoried
UN – United Nations Organization
UNDP – United Nations Development Programme
UNFCCC – United Nations Framework Convention on Climate Change.
UNICA – Brazilian Sugarcane Industry Association (União da Indústria de Cana-de-Açúcar)
UP003 – Type of unit, according to the reporting municipality
UP025 – Municipality of origin of waste
URO – Unmanaged Rock Outcrop
USDA – United States Department of Agriculture
v. – volume
VSS – Vertical Stud Soderberg
W – Carbon transfer from wood residues at solid waste disposal sites
W – mass of waste deposited
W – Rivers and Lakes
WBCSD – World Business Council for Sustainable Development
WFj – Gravimetric fraction of MSW waste/component type
WG – Working Group
WG – Daily weight gain
Wi – Gravimetric proportion by waste category i (fraction)
Wi – Volume of wastewater generated per unit of product
Wk – Effluent generated
WMO – World Meteorological Organization
WT – Tar Waste Collected
x – Type of waste/material
Ym – Methane conversion rate
Δ ($AFOLU$ without HWP) – annual change in the carbon stock of Agriculture, Forestry and Other Land Use without Harvested Wood Products
Δ C FP – Annual increment previously calculated for each of the two species
ΔC HWP IU DC – Annual change in the carbon stock of Harvested Wood Products in use
ΔC HWP SWDS DC – Annual change in the carbon stock of Harvested Wood Products at solid waste disposal sites where the wood comes from domestic harvesting
ΔC HWP SWDS DH – Annual change in carbon stored in Harvested Wood Products at solid waste disposal sites from the country's domestically harvested wood
ΔCGAc – Change in the carbon stock of cropland
ΔCGAc Per – Removal from perennial cropland
ΔCGAc Semiperennial – Removal from semiperennial cropland
ΔCGFP – Annual carbon removal
ΔCGFP – Annual carbon removal from forest plantation
ΔCGMFL – Removal from primary forest
ΔCGMG – Removal from primary grassland
ΔCGSecF1 – Removal from secondary forest with a forest history

ΔCGSecF2 – Removal from secondary forest with a pasture history
ΔCGSecF3 – Removal from secondary forest with a cropland history
ΔCGSecF4 – Removal from secondary forest with other history
ΔCGSecG – Removal from secondary grassland
ΔCGSL – Carbon gain in a forest area subjected to selective logging
ΔCHWP DC – Annual release of carbon into the atmosphere from Harvested Wood Products in the reporting country. It includes carbon release from all wood harvested and retained in the country and from wood imports into the country, but excluding exports
ΔCHWP DH – Annual release of carbon into the atmosphere from Harvested Wood Products from wood harvested in the reporting country. This includes the carbon release of all wood harvested in the country, including wood that is exported, but excluding imports
ΔCHWP IU DH – Annual change in carbon stored in Harvested Wood Products in use that comes from the country's domestic harvesting
ΔCLSecF – Percentage of remaining secondary forest stock in relation to initial carbon stock
ΔCLSecG – Percentage of remaining secondary grassland stock in relation to initial carbon stock
ΔCLSL – Carbon loss in a forest area subjected to selective logging

BRAZIL'S NATIONAL INVENTORY REPORT OF ANTHROPOGENIC EMISSIONS BY SOURCES AND REMOVALS BY SINKS OF GREENHOUSE GASES

FIRST BIENNIAL TRANSPARENCY REPORT OF BRAZIL TO THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE



CIÊNCIA&CLIMA





MINISTRY OF SCIENCE, TECHNOLOGY AND INNOVATION

BRAZILIAN GOVERNMENT

BRASIL

UNITING AND REBUILDING