# FOURTH NATIONAL COMMUNICATION OF BRAZIL TO THE UNFCCC

COMUNICAÇÃO NACIONAL DO BRASIL À CONVENÇÃO-QUADRO DAS NAÇÕES UNIDAS SOBRE MUDANÇA DO CLIMA

# FOURTH NATIONAL COMMUNICATION OF BRAZIL TO THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

GLOBAL ENVIRONMENT FACILITY
INVESTING IN OUR PLANET

UNDP

MINISTRY OF SCIENCE, TECHNOLOGY AND INNOVATIONS

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# FOREWORD

The Ministry of Science, Technology and Innovations (MCTI) – whose institutional view is "to play a leading role in the country's sustainable development through Science, Technology and Innovation" – coordinates the Brazilian Government's activities towards fulfilling its commitment to report updated information on various initiatives under the national climate agenda to the United Nations Framework Convention on Climate Change (UNFCCC) on a regular basis. In this regard, the MCTI implements an international technical cooperation project with international funds sourced from the Global Environment Facility (GEF) and the support of the United Nations Development Programme (UNDP).

In fulfilling this reporting commitment, Brazil has submitted three National Communications, in 2004, 2010 and 2016. Moreover, three Biennial Updates Reports were submitted in 2014, 2017 and 2019.

In order to secure the submission of a new National Communication by December 2020, technical and scientific input have been developed from official national data, as well as through established partnerships and contracts, which represented the direct involvement of more than 400 experts from 217 renowned institutions. As part of a quality assurance procedure, the main technical documents developed were submitted to public consultation with experts not directly involved in the studies.

The five chapters of the Fourth National Communication to the Convention on Climate Change were organized towards meeting the guidelines for the elaboration of National Communications by developing countries, defined by Decision 17/CP.8. These are: *Chapter 1. National Circumstances; Chapter 2. National Inventory of Anthropogenic Emissions and Removals of Greenhouse Gases; Chapter 3. Impacts, Vulnerability and Adaptation to Climate Change; Chapter 4. Climate Change Adaptation and Mitigation Measures; and Chapter 5. Other Relevant Information for Achieving the Objectives of the Convention in Brazil.*

Therefore, another relevant step was taken in coordinating the Brazilian engagement in processes related to transparency arrangements under the UNFCCC and the enhanced transparency framework for action and support under the Paris Agreement.

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*MapBiomas*
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*Intergovernmental Panel on Climate Change(IPCC)*
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*Brazilian Association of Fisheries (Associação Brasileira de Psicultura)*
*Central Bank of Brazil (Banco Central do Brasil)*
*World Bank*
*Cemig - Energy Company of the state of Minas Gerais*
*Center of Studies in Sustainability - FGV (Centro de Estudos em Sustentabilidade da FGV)*
*The European Centre for Medium-Range Weather Forecasts - ECM/WF (Centro Europeu de Previsões Meteorológicas de Médio Prazo (ECM/WF))*
*National Center for Monitoring and Early Warnings of Natural Disasters (Centro Nacional de Monitoramento e Alertas de Desastres)*
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*Climate Prediction Center/ National Oceanic and Atmospheric Administration*
*Coalition Brazil, Climate, Forests and Agriculture (Coalizão Brasil, Clima, Florestas e Agricultura)*
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*National Municipality Confederation (Confederação Nacional de Municípios)*
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*Conservation International*
*Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH*
*Brazilian Agricultural Research Corporation (Empresa Brasileira de Pesquisa Agropecuária)*
*Energy Research Office (Empresa de Pesquisa Energética)*
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*The São Paulo State Research Foundation (Fundação de Amparo à Pesquisa do Estado de São Paulo)*
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*National Institute for Space Research (Instituto Nacional de Pesquisas Espaciais)*
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*Trata Brasil Institute (Instituto Trata Brasil)*
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## Chapter 5: OTHER RELEVANT INFORMATION FOR ACHIEVING THE OBJECTIVES OF THE CONVENTION IN BRAZIL

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*United Nations Development Programme*

## SYMBOLS, ACRONYMS AND ABBREVIATIONS

4NC – Fourth National Communication of Brazil to the United Nations Framework Convention on Climate Change

AAC − Alter do Chão Aquifer (*Aquífero Alter do Chão*)

ABAL– Brazilian Aluminum Association (*Associação Brasileira do Alumínio*)

ABCERAM – Brazilian Ceramics Association (*Associação Brasileira de Cerâmica*)

ABCM – Brazilian Mineral Coal Association (*Associação Brasileira do Carvão Mineral*)

AbE − Adaptation based on Ecosystems

ABIQUIM – Brazilian Chemical Industry Association (*Associação Brasileira da Indústria Química*)

ABLV – Brazilian Long Life Milk Association (*Associação Brasileira da Indústria de Leite Longa Vida*)

ABPC – Brazilian Lime Producers Association (*Associação Brasileira dos Produtores de Cal*)

ABRACAL – Brazilian Limestone Producers Association (*Associação Brasileira dos Produtores de Calcário*)

AFD – French Development Agency (*Agence Française de Développement*)

AFN – Fernando de Noronha Archipelago (*Arquipélago de Fernando de Noronha*)

AFOLU – Agriculture, Forestry and Other Land Use

AgriTempo – Agrometeorological Monitoring System (*Sistema de Monitoramento Agrometeorológico*)

AICHI – Biodiversity Targets

AM – state of Amazonas

ANA – National Water Agency (*Agência Nacional de Águas*)

ANAC – National Civil Aviation Agency (*Agência Nacional de Aviação Civil*)

ANDA – National Association for the Diffusion of Fertilizers (*Associação Nacional para Difusão de Adubos*)

ANE – Affluent Natural Energy (*Energia natural afluente*)

ANEEL– National Energy Agency (*Agência Nacional de Energia Elétrica*)

ANFAVEA – National Association of Automotive Vehicle Manufacturers (*Associação Nacional dos Fabricantes de Veículos Automotores*)

ANN − Artificial Neural Networks

ANP – National Agency of Petroleum, Natural Gas and Biofuels (*Agência Nacional do Petróleo, Gás Natural e Biocombustíveis*)

ANTAQ – National Agency for Waterway Transportation (*Agência Nacional de Transportes Aquaviários*)

APA – Environmental Protection Areas (*Área de Proteção Ambiental*)

APIB – Brazil's Indigenous People Articulation (*Articulação dos Povos Indígenas do Brasil*)

APP – Permanent Preservation Areas (*Área de Preservação Permanente*)

AQUIPESCA – Aquaculture and Fishing (*Aquicultura e Pesca*)

AR4 – Fourth Assessment Report

AR5 – Fifth Assessment Report

ARPA – Amazon Region Protected Areas Program (*Programa Áreas Protegidas da Amazônia*)

ASD – Area Susceptible to Desertification (*Área Suscetível à Desertificação*)

ASPSP – Saint Peter and Saint Paul Archipelago (*Arquipélago de São Pedro e São Paulo*)

ATCM – *Antarctic Treaty Consultative Meeting*

AUC – *Area Under the Curve*

AUR – Restricted Use Areas (*Áreas de Uso Restrito*)

BACEN − Central Bank of Brazil (*Banco Central do Brasil*)

BAU – *Business-As-Usual*

BCP − Continuous Cash Benefit Programme (*Benefício da Prestação Continuada*)

BEIS – *Department for Business, Energy & Industrial Strategy*

BEN – National Energy Balance (*Balanço Energético Nacional*)

BESM – The Brazilian Earth System Model (*Modelo Brasileiro do Sistema Terrestre*)

BEU – Useful Energy Balance (*Balanço de Energia Útil*)

BHSF – São Francisco River Watershed

BIMTRA – Air Traffic Movement Database (*Banco de Informações de Movimento de Tráfego Aéreo*)

BIOMAR – Marine Biotechnology (*Biotecnologia Marinha*)

BMUB – German's Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (*Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit*)

BNDES – Brazilian Development Bank (*Banco Nacional de Desenvolvimento Econômico e Social*)

BNF – Biological Nitrogen Fixation

BOD − Biochemical Oxygen Demand

BPC – Continuous Cash Benefit Programme (*Benefício da Prestação Continuada*)

BrOA − Brazilian Ocean Acidification Network (*Rede Brasileira de Pesquisa em Acidificação dos Oceanos*)

BUR – Biennial Update Report

BVJ – Varying Transfer to Youngsters (*Benefício Variável Jovem*)

C – Carbon

CAF – Development Bank of Latin America (*Banco de Desenvolvimento da América Latina*)

CAPES – Coordination for The Improvement of Higher Education Personnel (*Coordenação de Aperfeiçoamento de Pessoal de Nível Superior*)

CAR – Rural Environmental Registry (*Cadastro Ambiental Rural*)

CBD – Convention on Biological Diversity

CBH − Watershed Committees (*Comitês de Bacia Hidrográfica*)

CBPG – The Global Compact Brazilian Committee (*Comitê Brasileiro do Pacto Global*)

CC – Climate change

CCST – Earth System Science Center of the National Institute for Space Research (*Centro de Ciência do Sistema Terrestre do INPE*)

CDD – Cooling Degree Days

CDM – Clean Development Mechanism

CDO – Climate Data Operators

CE – state of Ceará

CEBDS – Business Council for Sustainable Development (*Conselho Empresarial para o Desenvolvimento Sustentável*)

CEC – Scenarios Development Committee (*Comitê de Elaboração de Cenários*)

Cedeplar – Center for Development and Regional Planning (*Centro de Desenvolvimento e Planejamento regional*)

CEEZ – Coastal Ecological-Economic Zoning

CELESC – Electricity Utility of the state of Santa Catarina (*Centrais Elétricas de Santa Catarina*)

CEMADEN – National Center for Monitoring and Early Warnings of Natural Disasters (*Centro Nacional de Monitoramento e Alerta de Desastres Naturais*)

CENAD – National Center of Risk and Disaster Management (*Centro Nacional de Gerenciamento de Riscos e Desastres*)

CEPED – University Centre for Studies and Research on Disaster (*Centro de estudos e pesquisas em desastres*)

CERs – Certified Emission Reduction

CETESB – State of São Paulo Environmental Company (*Companhia Ambiental do Estado de São Paulo*)

CF – Federal Constitution or Forest Code (*Constituição Federal ou Código Florestal*)

$CF_4$ – Tetrafluoromethane

CGCL – General Coordination of Climate Science and Sustainability (*Coordenação-Geral de Ciência do Clima e Sustentabilidade*)

CGEE – Management and Strategic Studies Center (*Centro de Gestão e Estudos Estratégicos*)

CGH – Hydroelectric Generation Utility (*Centrais de geração hidrelétricas*)

CGU − Comptroller General of Brazil (*Controladoria Geral da União*)

$CH_4$ – Methane

CHESF – São Francisco Hydroelectric Company (*Companhia Hidrelétrica de São Francisco*)

$CHF_3$ – Trifluoromethane

CI – Conservation International

CIM – Interministerial Committee on Climate Change (*Comitê Interministerial sobre Mudança do Clima*)

CMIP − Coupled Model Intercomparison Project

CMVP – Professional Certification in Measurement and Verification

CNCD – National Commission to Combat Desertification (*Comissão Nacional de Combate à Desertificação*)

CNI – National Industry Confederation (*Confederação Nacional da Indústria*)

CNM − National Municipality Confederation (*Confederação Nacional de Municípios*)

CNPCT− National Commission for the Sustainable Development of Traditional Peoples and Communities (*Comissão Nacional de Desenvolvimento Sustentável dos Povos e Comunidades Tradicionais*)

CNPE – National Energy Policy Council (*Conselho Nacional de Política Energética*)

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

$CO_2$ – Carbon Dioxide

$CO_2e$ – Carbon Dioxide Equivalent

COFA – Amazon Fund Guidance Committee (*Comitê Orientador do Fundo Amazônia*)

COIAB – Coordination of the Indigenous Organizations of the Brazilian Amazon (*Coordenação das Organizações Indígenas da Amazônia Brasileira*)

Conab − Brazil's National Supply Company (*Companhia Nacional de Abastecimento*)

CONABIO – National Biodiversity Council (*Conselho Nacional de Biodiversidade*)

CONACER – National Commission on the Sustainable Cerrado Program (*Comissão Nacional do Programa Cerrado Sustentável*)

CONAMA − National Environment Council (*Conselho Nacional de Meio Ambiente*)

CONANTAR – National Commission for Antarctic Affairs (*Comissão Nacional para Assuntos Antárticos*)

CONAPA – National Committee on Antarctic Research (*Comitê Nacional de Pesquisas Antárticas*)

CONAVEG – National Committee for the Recovery of Native Vegetation (*Comissão Nacional para Recuperação Nativa*)

CONPET − Rational Use of Oil and Natural Gas Derivatives

COP – Conference of Parties to the UNFCCC

CPRM − Geological Service of Brazil (*Serviço Geológico do Brasil*)

CPTEC – Center for Weather Forecasts and Climate Studies (*Centro de Previsão de Tempo e Estudos Climáticos do INPE*)

CRA – Environmental Reserve Units (*Cota de Reserva Ambiental*)

CT – Thematic Chambers (*Câmaras Temáticas*)

CTA − *Classification Tree Analysis*

CTAM – Climate Change Transparency Coordination (*Coordenação de Transparência de Ações em Mudança do Clima*)

CTCN – Climate Technology Centre and Network (*Centro e Rede de Tecnologia para o Clima*)

CTIBC – Technical Committee of the Low Carbon Industry (*Comitê Técnico da Indústria de Baixo Carbono*)

CZ – Coastal zone

DATASUS − Universal Health System (*Sistema Único de Saúde do Brasil*)

DEPPC – Department of Science Policies and Programs (*Departamento de Políticas e Programas de Ciências*)

DETER − Real-Time Deforestation Detection System (*Sistema de Detecção do Desmatamento na Amazônia Legal em Tempo Real*)

DMAF – Climate Change Monitoring, Support and Action Department (*Departamento de Monitoramento, Apoio e Fomento de Ações em Mudança do Clima*)

DNA – Designated National Authority

DPMC – Department of Climate Change Policies (*Departamento de Políticas em Mudança do Clima*)

EAD – Distance Learning Education (*Educação à Distância*)

EAESP – Getulio Vargas Foundation's São Paulo School of Business Administration (*Escola de Administração Pública e de empresas da FGV)*

ECMWF − *European Centre for Medium-Range Weather Forecasts*

*Economia de Baixa Emissão de Carbono na Agricultura*)

EEA – *European Environment Agency*

EEGM – Energy Efficiency Guarantee Mechanism

EEZ – Exclusive Economic Zone

EIB – European Investment Bank

ELETROBRAS – Brazil’s Electricity Utility (*Centrais Elétricas Brasileiras S.A*)

Emater − Technical Assistance and Rural Extension Company (*Empresa de Assistência Técnica Rural*)

Embrapa − Brazilian Agricultural Research Corporation (*Empresa Brasileira de Pesquisa Agropecuária*)

EMEP – European Monitoring and Evaluation Programme

ENCE – National Label for Energy Conservation (*Etiqueta Nacional de Conservação de Energia*)

ENCTI – National Strategies for Science, Technology and Innovation (*Estratégias Nacionais de Ciência, Tecnologia e Inovação*)

ENREDD+ – National Strategy for REDD+ (*Estratégia Nacional para REDD+*)

EOR – *Enhanced Oil Recovery*

EPE – Energy Research Office (*Empresa de Pesquisa Energética*)

ES – state of Espírito Santo

ESCOs – Energy Service Companies (*Empresas de Serviços de Conservação de Energia*)

ESF – Family Health Strategy (*Estratégia Saúde da Família*)

ETR/ETM − Ratio between real and maximum evapotranspiration

EVO – Efficiency Valuation Organization

FAO – Food and Agriculture Organization of the United Nations

FAOSTAT − Food and Agriculture Organization Statistics

FAPESP – São Paulo State Research Foundation (*Fundação de Amparo à Pesquisa do Estado de São Paulo*)

FBMC – Brazilian Forum on Climate Change (*Fórum Brasileiro de Mudança do Clima*)

FDA − Function Discriminant Analysis

FGVces – Center of Studies in Sustainability - Getúlio Vargas Foundation (*Centro de Estudos em Sustentabilidade da Fundação Getúlio Vargas*)

FIESP − Industry Federation of the State of São Paulo (*Federação das Indústrias do Estado de São Paulo*)

FIFA – International Federation of Association Football (*Federação Internacional de Futebol*)

Fipe − Economic Research Foundation Institute (*Fundação Instituto de Pesquisas Econômicas*)

FNDCT – National Fund for Scientific and Technological Development (*Fundo Nacional de Desenvolvimento Científico e Tecnológico*)

FNDF – National Fund for Forestry Development (*Fundo Nacional do Desenvolvimento Florestal*)

FNMC – National Fund for Climate Change (*Fundo Nacional sobre Mudança do Clima*)

FONPLATA – Plata Basin Financial Development Fund (*Fundo de Desenvolvimento Financeiro da Bacia do Prata*)

FUNAI – National Indian Foundation (*Fundação Nacional do Índio*)

FUNBIO – Brazilian Biodiversity Fund (*Fundo Brasileiro para a Biodiversidade*)

FUNDEB – Fund for the Maintenance and Development of Basic Education and Respect for Educators (*Fundo de Manutenção e Desenvolvimento da Educação Básica e de Valorização dos Profissionais da Educação*)

FURG – Rio Grande Federal University (*Universidade Federal de Rio Grande*)

GA − Council of Cities Monitoring Group (*Grupo de Acompanhamento do Conselho das Cidades*)

GAAM – PROANTAR's Environmental Assessment Group (*Grupo de Avaliação Ambiental do PROANTAR*)

GAM − Generalized Aditive Models

GBIF − Global Biodiversity Information Facility

GBM – Generalized Aditive Models

GCF – Green Climate Fund

GCM – General Circulation Model

GDP – Gross Domestic Product

GEF – Global Environment Facility

GHG – Greenhouse Gases

GIDES – National Strategy for Integrated Natural Disaster Management (*Estratégia Nacional de Gestão Integrada de Riscos em Desastres Naturais*)

*GIZ* – German Corporation for International Cooperation (*Deutsche Gesellschaft für Internationale Zusammenarbeit*)

GLM – *Generalized Linear Models*

GO – state of Goiás

GOOS Brazil – Brazilian Ocean Observing System and Climate Studies (*Sistema Brasileiro de Observação dos Oceanos e Estudos do Clima*)

GT – Working Group (*Grupo de Trabalho*)

GTP – Global Temperature change Potential

GTTm – Thematic Technical Group to Monitor the National Adaptation Plan (*Grupo Técnico Temático para o Monitoramento do PNA*)

GWP – Global Warming Potential

HCFCs – hydrochlorofluorocarbons

HDI – Human Development Index

HFCs – hydrofluorocarbons

$HNO_3$ – nitric acid

Ibama – Brazilian Institute of the Environment and Renewable Natural Resources (*Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis*)

IBGE – Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística*)

IBRAVIN – Brazilian Wine Institute (*Instituto Brasileiro do Vinho*)

IBRD – International Bank for Reconstruction and Development

ICMBio – Chico Mendes Biodiversity Conservation Institute (*Instituto Chico Mendes de Conservação da Biodiversidade*)

ICMS – State tax on goods circulation (*Imposto sobre Circulação de Mercadorias e Serviços*)

IDB – Inter-American Development Bank

IDEB – Brazilian Education Development Index (*Índice de Desenvolvimento da Educação Básica*)

IDSUS – Universal Health System Performance Index (*Índice de desempenho do sistema único de saúde*)

IE – included elsewhere

IEA – International Energy Agency

IES Brasil – Economic and Social Implications of GHG Mitigation Scenarios in Brazil (*Implicações Econômicas e Sociais de Cenários de Mitigação de GEE*)

IFC – International Finance Corporation

IIED – International Institute for Environment and Development

IKI – International Climate Initiative

iLP – Integrated Crop-Livestock systems (Integração lavoura-pecuária)

iLPF – Integrated Crop-Livestock-Forestry systems (Integração Lavoura Pecuária Floresta)

IMF – International Monetary Fund

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)

INMET– National Institute of Meteorology (Instituto Nacional de Meteorologia)

INMETRO – National Institute of Metrology, Standardization and Industrial Quality

INPA – National Institute of Environmental Research (*Instituto Nacional de Pesquisas Ambientais*)

INPE – National Institute for Space Research (*Instituto Nacional de Pesquisas Espaciais*)

INPUT − Land Use Initiative (*Iniciativa para o Uso da Terra*)

IPAM – Institute of Environmental Research of the Amazon (*Instituto de Pesquisa Ambiental da Amazônia*)

IPCC – Intergovernmental Panel on Climate Change

IPCC-NGGIP – The IPCC National Greenhouse Gas Inventories Programme

Ipea − Institute of Applied Economic Research (*Instituto de Pesquisa Econômica Aplicada*)

iPF – Integrated Livestock-Forestry systems (*Integração pecuária-floresta*)

IPPU – Industrial Processes and Product Use

ISH− Water Security Index (*Índice de Segurança Hídrica*)

ISHmc – Water Security Index in the context of climate change (*Índice de Segurança Hídrica no contexto da mudança do clima*)

IT – Technology Institutions (*Instituições Tecnológicas*)

IVA – Impacts, Vulnerability and Adaptation

IVU – Urban Vulnerability Index (*Índice de Vulnerabilidade Urbana*)

IVUexp – Urban Vulnerability Index with an exposure factor (*Índice de Vulnerabilidade Urbana com fator de exposição*)

JBIC – Japan Bank for International Cooperation

JRC – Joint European Research Center

KfW – KfW Development Bank (*KfW Entwicklungsbank*)

LBA – Large Scale Biosphere-Atmosphere in the Amazon Program

LOAS − Social Assistance Act (*Lei Orgânica de Assistência Social*)

LPVN − Native Vegetation Protection Law (*Lei de Proteção à Vegetação Nativa*)

LUC − Land Use Change

LULUCF – Land Use, Land-Use Change and Forestry

M&V – Measurement and Verification

MacroEEZ − Macro Ecological Economic Zoning (*Macrozoneamento Ecológico−Econômico*)

MAPA – Ministry of Agriculture, Livestock and Supply (*Ministério da Agricultura, Pecuária e Abastecimento*)

MARS − Multiple Aditive Regression Splines

Matopiba − an important agricultural frontier in Brazil. The region comprises the Cerrado portions of the states of Maranhão, Tocantins, Piauí and Bahia.

MCT – Ministry of Science and Technology (*Ministério da Ciência e Tecnologia*)

MCTI – Ministry of Science, Technology and Innovations (*Ministério da Ciência, Tecnologia e Inovações*)

MCTIC – Ministry of Science, Technology, Innovations and Communications (*Ministério da Ciência, Tecnologia, Inovações e Comunicações*)

MD – Ministry of Defense (*Ministério da Defesa*)

MDA − Ministry of Agrarian Development (*Ministério do Desenvolvimento Agrário*)

MDI – Investment Decision Modelling (*Modelo Computacional de Decisão de Investimentos*)

MDR − Ministry of Regional Development (*Ministério do Desenvolvimento Regional*)

ME– Ministry of Economy (*Ministério da Economia*)

MEC – Ministry of Education (*Ministério da Educação*)

MG – state of Minas Gerais

MGB−IPH − Large Basins Model and Institute of Hydraulic Research of the Federal University of Rio Grande do Sul (*Modelo Hidrológico de Grandes Bacias do Instituto de Pesquisas Hidráulicas da Universidade Federal do Rio Grande do Sul*)

MI – Ministry of National Integration (*Ministério da Integração Nacional*)

MinC – Ministry of Culture (*Ministério da Cultura*)

MMA – Ministry of the Environment (*Ministério do Meio Ambiente*)

MME – Ministry of Mines and Energy (*Ministério de Minas e Energia*)

MPDG – Ministry of Planning, Budget and Management (*Ministério do Planejamento, Desenvolvimento e Gestão*)

MRE – Ministry of Foreign Affairs (*Ministério das Relações Exteriores*)

MRV – Measurement, Reporting and Verification

MS – Ministry of Health (*Ministério da Saúde*)

MTE – Ministry of Labor and Employment (*Ministério do Trabalho e Emprego*)

MVC – monomeric vinyl chloride

N – nitrogen

$N_2O$ – nitrous oxide

NA – not applicable

NAMAs – Nationally Appropriate Mitigation Actions

NCs – National Communications

NDB – New Development Bank

NDC – Nationally Determined Contribution

NE – not estimated

$NF_3$ – Nitrogen trifluoride

NGOs − Non-governmental Organizations

$NH_3$ – Ammonia

NMVOC – Non-methane volatile organic compound

NO – not occurring

NOx – nitrogen oxides

OBT − Earth Observation General-Coordination (*Coordenação Geral de Observação da Terra*)

OCIS – surface incident shortwave radiation (*Onda Curta Incidente na Superfície*)

ONS – National Electric System Operator (*Operador Nacional do Sistema Elétrica*)

Ox – oxidation factor

PAA – Food procurement programs (*Programa de Aquisição de Alimentos*)

PACS – Community Health Workers Program (*Programa de Agentes Comunitários de Saúde*)

PAE – Emergency Plan of Action in the state of Paraná (*Plano para Ações Emergenciais do Paraná*)

PAF-ZC – Federal Action Plan for the Coastal Zone (*Plano de Ação Federal para a Zona Costeira*)

PAM – Municipal Agricultural Production (*Produção Agrícola Municipal*)

PAN – National Action Plans for the Conservation of Endangered Species (*Planos de Ação Nacional para a Conservação das Espécies Ameaçadas de Extinção*)

PAP − Agriculture and Livestock Plan (*Plano Agrícola e Pecuário*)

PAS – Sustainable Amazon Plan (*Plano Amazônia Sustentável*)

PBE – Brazilian Labeling Programme (*Programa Brasileiro de Etiquetagem*)

PBMC – Brazilian Panel on Climate Change (*Painel Brasileiro de Mudanças Climáticas*)

PCS – Sustainable Cerrado Initiative (*Programa Cerrado Sustentável*)

PCTs – Traditional peoples and communities (*Povos e Comunidades Tradicionais*)

PD&I – Research, Development and Innovation (*Pesquisa, Desenvolvimento e Inovação*)

PDE – Ten-Year Energy Plan (*Plano Decenal de Energia*)

PEE - Energy Efficiency Program

PEGC – State Coastal Management Plan (*Plano Estadual de Gerenciamento Costeiro*)

PERH – State Water Resources Plan (*Plano Estadual de Recursos Hídricos*)

PES − Payment for Environmental Services

PF – Planted Forests

PFCs – perfluorocarbons

PFPMCG – Fapesp Global Climate Change Research Program (*Programa FAPESP de Pesquisa sobre Mudanças Climáticas Globais*)

PGPM – Minimum Price Guarantee Bio-Policy for Sociobiodiversity Products (*Bio-Política de Garantia de Preços Mínimos para Produtos da Sociobiodiversidade*)

PGTAs – Territorial and Environmental Management Plans (*Planos de Gestão Territorial e Ambiental de Terras Indígenas*)

PGZC – Coastal Zone Management Plan (*Plano de Gestão da Zona Costeira*)

PISF – Project to Integrate the São Francisco River (*Projeto de Integração do Rio São Francisco*)

PLANAFE – National Plan for the Strengthening of Extraction and Riverbank Communities (*Plano Nacional de Fortalecimento das Comunidades Extrativistas e Ribeirinhas*)

PLANAPO − National Plan on Agroecology and Organic Production (*Plano Nacional de Agroecologia e Produção Orgânica*)

Planaveg – National Plan for the Recovery of Native Vegetation (Plano Nacional de Recuperação da Vegetação Nativa)

Plano ABC – Sectoral Climate Change Mitigation and Adaptation Plan for the Consolidation of a Low Carbon Emission Economy in Agriculture (*Plano Setorial de Mitigação e de Adaptação às Mudanças Climáticas para a Consolidação de uma Economia de Baixa Emissão de Carbono na Agricultura*)

PlanSab − National Basic Sanitation Plan (*Plano Nacional de Saneamento Básico*)

PLANSAN – National Plan for Food and Nutrition Security (*Plano Nacional de Segurança Alimentar e Nutricional*)

Plataforma ABC – Multi-Institutional Platform for Monitoring Greenhouse Gas Emission Reductions (*Plataforma Multi-institucional de Monitoramento das Reduções de Emissões de Gases de Efeito Estufa*)

PMABB – Environmental Monitoring of Brazilian Biomes (*Programa de Monitoramento Ambiental dos Biomas Brasileiros*)

PMDBBS − Project of Satellite Deforestation Monitoring of the Brazilian Biomes (*Projeto de Monitoramento do Desmatamento nos Biomas Brasileiros por Satélite*)

PMGC – Municipal Coastal Management Plan (*Plano Municipal de Gerenciamento Costeiro*)

PNA – National Climate Change Adaptation Plan (*Plano Nacional de Adaptação à Mudança do Clima*)

PNAD − National Household Sample Survey (*Pesquisa Nacional por Amostra de Domicílios*)

PNAD C – Continuous National Household Sample Survey (*Pesquisa Nacional por Amostra de Domicílios Contínua*)

PNE – National Energy Plan (*Plano Nacional de Energia*)

PNGATI – National Policy on Territorial and Environmental Management of Indigenous Lands (*Política Nacional de Gestão Territorial e Ambiental de Terras Indígenas*)

PNGC – National Coastal Management Plan (*Plano Nacional de Gerenciamento Costeiro*)

PNLI – National Integrated Logistics Plan (*Plano Nacional de Logística Integrada*)

PNMA − National Environment Policy (*Política Nacional do Meio Ambiente*)

PNMC – National Policy for Climate Change (*Política Nacional sobre Mudança do Clima*)

PNPB – National Biodiesel Use and Production Program (*Programa Nacional de Produção e Uso do Biodiesel*)

PNPCT − National Policy for Sustainable Development of People and Traditional Communities (*Política Nacional de Desenvolvimento Sustentável de Povos Indígenas e Comunidades Tradicionais*)

PNPDEC − National Policy on Protection and Civil Defense (*Política Nacional de Proteção e Defesa Civil*)

PNPSB − National Plan for the Promotion of Socio-Biodiversity Product Chains (*Plano Nacional de Promoção das Cadeias de Produtos da Sociobiodiversidade*)

PNRH − National Policy on Water Resources (*Política Nacional de Recursos Hídricos*)

PNRS – National Solid Waste Policy (*Política Nacional de Resíduos Sólidos*)

PNSB − National Basic Sanitation Plan (*Plano Nacional de Saneamento Básico*)

PNSH – National Water Security Plan (*Plano Nacional de Segurança Hídrica*)

POLANTAR – National Policy for Antarctic Affairs (*Política Nacional para Assuntos Antárticos*)

PoMuC – Climate Change Policy Program (*Programa Políticas sobre Mudança do Clima*)

PPCDAm – Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (*Plano de Ação para Prevenção e Controle do Desmatamento na Amazônia*)

PPCerrado – Action Plan for the Prevention and Control of Deforestation and Forest Fires in the Cerrado (*Plano de Ação para Prevenção e Controle do Desmatamento e das Queimadas no Cerrado*)

PPG-Mar – Human Resources Training in Marine Science (*Formação de Recursos Humanos em Ciências do Mar*)

PPPs – Public-Private Partnership (*Parcerias Público Privadas*)

PR – state of Paraná

PRA – Environmental Regulatory Programs (*Programa de Regularização Ambiental*)

PRADAs – Project for the Recovery of Degraded and Altered Areas (*Projetos de Recomposição de Área Degradada e Alterada*)

Proagro − Agricultural Activity Guarantee Program (*Programa de Garantia da Atividade Agropecuária*)

Proagro mais − Agricultural Activity Guarantee Program for Family Farming (*Programa Garantia da Atividade Agropecuária da Agricultura Familiar*)

PROANTAR – Brazilian Antarctic Program (*Programa Antártico Brasileiro*)

PROAREA – Mineral Resources Prospection and Exploitation Program within the International South Atlantic and Equatorial Area (*Prospecção e Exploração de Recursos Minerais da Área Internacional do Atlântico Sul e Equatorial*)

PROCEL – Electric Energy Conservation National Programme (*Programa Nacional de Conservação de Energia Elétrica*)

PROCOSTA – National Program for the Conservation of the Brazilian Coastline (*Programa Nacional para Conservação da Linha Costa*)

PRODES − Program to Calculate Deforestation in the Amazon (*Sistema de Monitoramento do Desmatamento na Amazônia Legal*)

PROESF – Program for the Expansion and Consolidation of Family Health (*Programa de Expansão e Consolidação da Saúde da Família*)

PROGESTÃO – Consolidation Program for the National Pact of Water Management (*Programa de Consolidação do Pacto Nacional pela Gestão das Águas*)

Proinfa – Program of Incentives for Alternative Electricity Sources (*Programa de Incentivo às Fontes Alternativas de Energia Elétrica*)

Pronaf − National Program for Strengthening Family-based Agriculture (*Programa Nacional de Fortalecimento da Agricultura Familiar*)

PRONAMP − National Support Program for Medium-Sized Rural Producers (*Programa Nacional de Apoio ao Médio Produtor Rural*)

PRONATEC – National Program for Access to Technical Education and Employment (*Programa Nacional de Acesso ao Ensino Técnico e Emprego*)

Proveg − National Policy for the Recovery of Native Vegetation (*Política Nacional para Recuperação da Vegetação Nativa*)

PSF – Family Health Program (*Programa Saúde da Família*)

PSMC– Health Sectoral Plan for the Mitigation and Adaptation to Climate Change (*Plano Setorial da Saúde para Mitigação e Adaptação à Mudança do Clima*)

PSRM – Sectoral Plans for Sea Resources (*Plano Setorial para os Recursos do Mar*)

Q90 − Expected minimum flow rate in 90% of the time (hydrological year)

QA – Quality Assurance

QC – Quality Control

RAD – Reactive Airway Disease

RC − Ramsar Convention

RCP – Representative Concentration Pathway

REDD − Reducing Emissions from Deforestation and Forest Degradation

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*)

REDEH – Human Development Network (*Rede de Desenvolvimento Humano*)

REMPLAC – Program for Mineral Potential Assessment of the Continental Shelf (*Avaliação da Potencialidade Mineral da Plataforma Continental Jurídica Brasileira*)

RESEX − Extractive Reserves (*Reservas Extrativistas*)

Reurb − Urban Land Regularization (*Regularização Fundiária Urbana*)

REVIMAR – Assessment, Monitoring and Conservation of Marine Biodiversity (*Avaliação, Monitoramento e Conservação da Biodiversidade Marinha*)

RF − Random Forest

RIDE − Integrated Development Region of the Federal District and Surrounding Areas (*Região Integrada de Desenvolvimento do Distrito Federal e Entorno*)

RL – Legal Reserves (*Reserva Legal*)

RM − Metropolitan Region (*Região Metropolitana*)

RMBE − Metropolitan Region of Belém (*Região Metropolitana de Belém*)

RMBH − Metropolitan Region of Belo Horizonte (*Região Metropolitana de Belo Horizonte*)

RMRJ − Metropolitan Region of Rio de Janeiro (*Região Metropolitana do Rio de Janeiro*)

RMSP − Metropolitan Region of São Paulo (*Região Metropolitana de São Paulo*)

RPPN − Private Natural Heritage Reserves (*Reserva Particular do Patrimônio Natural*)

S2ID – Integrated Disaster Information System (*Sistema Integrado de Informações sobre Desastres*)

SAFs – Agroforestry Systems (*Sistemas Agroflorestais*)

SAIN – Secretariat for International Affairs (*Secretaria de Assuntos Internacionais*)

SAP – Early Warning System for Drought and Desertification (*Sistema de Alerta Precoce de Secas e Desertificação*)

SAR – Second Assessment Report

SAR/ANAC – Department of Airworthiness (*Superintendência de Aeronavegabilidade*)

Scenagri − Simulation of Future Agricultural Scenarios (*Simulador de Cenários Agrícolas*)

SDGs – Sustainable Development Goals

SDM − Spatial Durbin model

SEAF − Family Farming Insurance (*Seguro da Agricultura Familiar*)

SECIRM – Secretariat of the Interministerial Commission for Sea Resources (*Secretaria da Comissão Interministerial para os Recursos do Mar*)

SEDEC − National Civil Defense Secretariat (*Secretaria Nacional de Defesa Civil*)

SEPEF – Secretariat for Research and Scientific Training (*Secretaria de Pesquisa e Formação Científica*)

$SF_6$ – sulfur hexafluoride

SFB – Brazilian Forest Service (*Serviço Florestal Brasileiro*)

SHP – Small Hydroelectric Plants

SIAGAS − Groundwater Information System (*Sistema de Informação de Águas Subterrâneas*)

SIAGEO – Interactive Geo-spatial Analysis System (*Sistema Interativo de Análise Geoespacial*)

SiCAR – National Rural Environmental Registry System (*Sistema Nacional de Cadastro Ambiental Rural*)

SICOR – Rural Credit and Proagro Operations System (*Sistema de Operações do Crédito Rural e do Proagro*)

SIDRA − IBGE Automatic Recovery System (*Sistema IBGE de Recuperação Automática*)

SIGABC – Governance System of the ABC Plan (*Sistema de Governança do Plano ABC*)

SIGERCO – Coastal Management Information System (*Sistema de Informações do Gerenciamento Costeiro*)

SILA – Interactive Environmental Licensing Support (*Sistema Interativo de Suporte ao Licenciamento Ambiental*)

SIN – Brazilian Interconnected System (*Sistema Interligado Nacional*)

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*

SINGREH – National Water Resources Management System (*Sistema Nacional de Gerenciamento de Recursos Hídricos*)

SINIMA – National Environmental Information System (*Sistema Nacional de Informação sobre Meio Ambiente*)

SIRENE – National Emissions Registry System (*Sistema de Registro Nacional de Emissões*)

SISAN – National Food and Nutrition Security System (*Sistema Nacional de Segurança Alimentar e Nutricional*)

SISVUCLIMA – Climate Vulnerability System

SMA-ZC – Coastal Zone Environmental Monitoring System (*Sistema de Monitoramento Ambiental da Zona Costeira*)

SMCF – Forest and Climate Change Secretariat (*Secretaria de Mudança do Clima e Florestas*)

SMMARE – Modular System for Monitoring Actions and Greenhouse Gas Emissions Reductions (*Sistema Modular de Monitoramento e Acompanhamento das Reduções das Emissões de Gases de Efeito Estufa*)

SNIC – National Cement Industry Union (*Sindicato Nacional da Indústria do Cimento*)

SNIRH − National Water Resources Information System (*Sistema Nacional de Informações de Recursos Hídricos*)

SNIS − National Sanitation Information System (*Sistema Nacional de Informações sobre Saneamento*)

SNUC − Brazilian System of Conservation Units (*Sistema Nacional de Unidades de Conservação*)

SOMAI – System for Observation and Monitoring of the Indigenous Amazon (*Sistema de Observação e Monitoramento da Amazônia Indígena*)

SPD – No-till farming (*Sistema de Plantio Direto*)

SPEI − Standardised Precipitation-Evapotranspiration Index

SSA − Socioenvironmental security (*Segurança Socioambiental*)

SUAS – Universal Social Assistance System (*Sistema Único de Assistência Social*)

Sudene − Superintendence for the Development of the Northeast (*Superintendência de Desenvolvimento do Nordeste*)

SUS – Universal Health System (*Sistema Único de Saúde*)

SWL – Specific Warming Level

TC – Thematic Chambers

TFT – thin film transistor

TI – Indigenous territory (*Territórios Indígenas*)

Tier – methodological approach

TNC – Third National Communication of Brazil to the United Nations Framework Convention on Climate Change

TODA – Animal Waste Treatment (*Tratamento de Dejetos Animais*)

UC – Conservation Unit (*Unidade de Conservação*)

UN – United Nations

UNCCD – United Nations Convention to Combat Desertification

UNCLOS – United Nations Convention on the Law of the Sea (*Convenção das Nações Unidas sobre os Direitos do Mar*)

UNDP – United Nations Development Programme

UNEP – United Nations Environment Programme

UNFCCC – United Nations Framework Convention on Climate Change

UNICA – Brazilian Sugarcane Industry Association (*União da Indústria de Cana-de-Açúcar*)

USA – United States of America

USDA – United States Department of Agriculture

USP – University of São Paulo (*Universidade de São Paulo*)

UST – Technical Support Units (*Unidades de Suporte Técnico*)

UVIBRA – Brazilian Viticulture Union (*União Brasileira de Vitivinicultura*)

VBP – Value of Gross Production (*Valor Bruto de Produção*)

VIARS – Vulnerability-Impacts-Adaptation-Resilience-Sustainability

VIGIAGUA – National Drinking Water Quality Surveillance Program (*Programa Nacional de Vigilância da Qualidade da Água para Consumo Humano*)

VSWI – Vegetation Supply Water Index

WB – World Bank

WBGT – Wet Bulb Globe Temperature

WEI – Water Exploitation Index

WG – Working Group

WHO – World Health Organization

WMO – World Meteorological Organization

ZARC – Agro-Climate Risk Zoning (*Zoneamento Agrícola de Risco Climático*)

ZEIS – Special Zones of Social Interest (*Zonas Especiais de Interesse Social*)

# COMPLETE SUMMARY

# CHAPTER 1

## SUMMARY

# 1. NATIONAL CIRCUMSTANCES

## 1.1. CHARACTERIZATION OF THE BRAZILIAN TERRITORY

The Federative Republic of Brazil is located in South America and occupies nearly half of the continent's territory, between the parallels 5°16'20" north latitude and 33°45'03" south latitude, and the meridians 34°47'30" and 73°59'32" west. (BRAZIL, 2016). It is the world's fifth largest country, exceeded in size only by Russia, Canada, China and the United States (IBGE, 1994). It is bounded by the Atlantic Ocean along nearly 8,500 km of its eastern coastline, and shares inland borders with all South American countries, except Chile and Ecuador (Figure 1.1). Specifically, Brazil borders Uruguay to the south; Argentina, Paraguay and Bolivia to the southeast; Peru to the west; Colombia to the northwest; and Venezuela, Guyana, Suriname and French Guyana to the north (IBGE, 1994; BRASIL, 2016). It encompasses a wide range of tropical and subtropical landscapes, including wetlands, savannas and plateaus, besides containing most of the Amazon River watershed, which has the world's largest river system and the world's most extensive rainforest (IBGE, 1994; MMA, 2019a) (Panel 1.1).

*Panel 1.1 Relevant information about Brazil.* [1]

| Standards | Characteristics |
|---|---|
| Territory | Total area of 8,510,295.914 $km^2$; divided in five political-administrative regions – North, Northeast, Central West, South and Southeast; composed of 26 states and the Federal District (seat of government and also the Executive, Legislative and Judicial branches) and 5,570 municipalities. |
| Climate | Five climatic regions: Equatorial (North), Tropical (most of the territory), Semi-arid (Northeast), Tropical of Altitude (Southeast), and Subtropical (South). |
| Biodiversity | Six biomes[2]: Amazon (49.5%), Cerrado (23.3%), Atlantic Forest (13%), Caatinga (10.1%), Pantanal (1.8%), and Pampa (2,3%). |
| Native vegetation cover | The country has 84% of the Amazon and 60% of the territory preserved. |
| Protected Areas | Protected areas account for 30.68% of the territory, including Conservation Units (18.1%) and Indigenous Lands (12.48%), in addition to Conservation Units in marine areas (26.62%). The country has over 2,000 terrestrial conservation units, which corresponds to nearly 18% of the Brazilian territory. |
| Water resources | The country has approximately 12% of the planet's surface fresh water. 12 river basins provide abundant water resources; however, they are unevenly distributed throughout the |

[1] *Data from the Brazilian Institute of Geography and Statistics. Available in Portuguese from the portal < www.ibge.gov.br>. Accessed on: 15 May 2020.*

[2] *A Biome is defined as collection of life (plant and animal life) constituted by the grouping of contiguous vegetation types identifiable on a regional scale, with similar geoclimatic conditions and a shared history of changes, which results in a unique biological diversity. (IBGE, 2004). Biome distribution data available in Portuguese at: https://biblioteca.ibge.gov.br/visualizacao/livros/liv101676.pdf*

| Standards | Characteristics |
|---|---|
| | territory (ANA, 2019). Currently, the primary use of water in the country is irrigation (in terms of utilized volumes), with more than 900 $m^3/s$. |
| Population | 212 million people, of which nearly 84% is urban population and 16% is rural population[3], with the Southeastern region being the most densely populated and the Northern region the least densely populated. |
| Energy mix | The percentage of renewable sources in the Brazilian Energy Mix in 2019 was 46.1%, a significantly higher share than the average in OECD countries (10.8%) and the world (14.2%). In the electricity mix, renewable sources accounted for 83% of energy sources for electricity generation in 2019, with the average of OECD countries in 2019 at 28.5% and the world average at 26.7%. |

Source: Updated from BRAZIL (2017) and IBGE (2020).

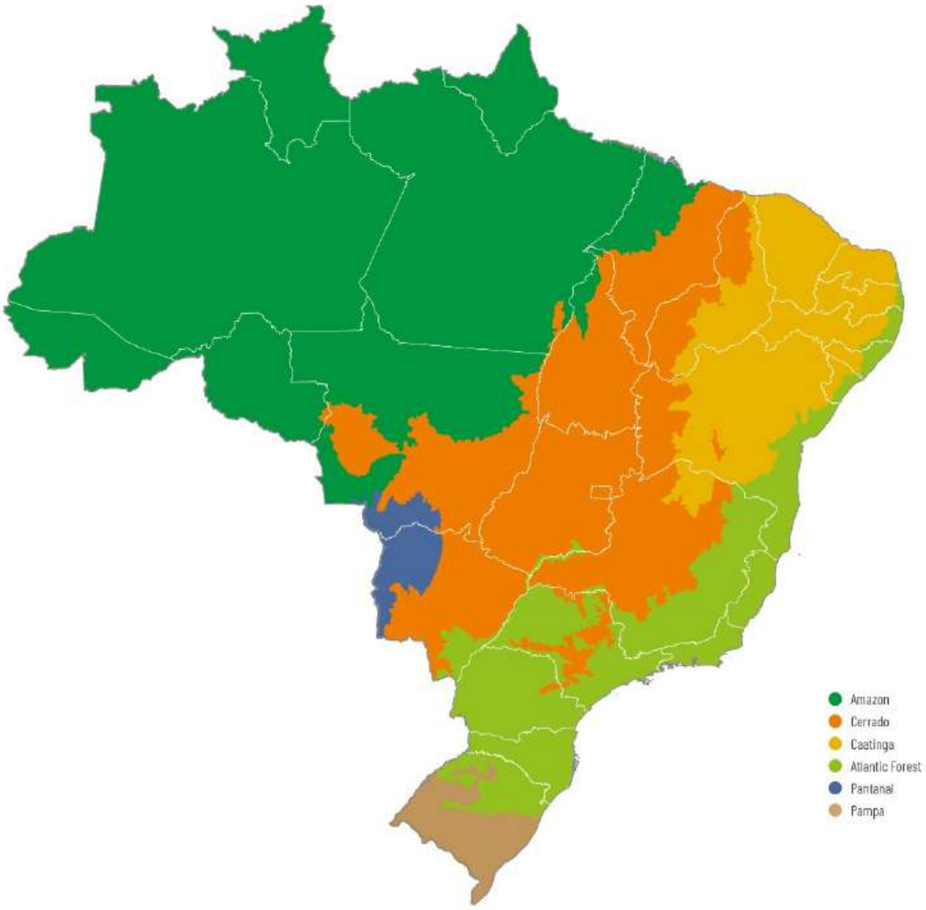
A series of Brazilian census shows that population grew almost 20 times since the first census in Brazil, in 1872 (IBGE, 2010b; BRASIL, 2016). The Southeastern region is the country's most populated region and the Central West region is the one with the smaller population (IBGE, 2017). Between 2000 and 2010, an increase in the degree of the Brazilian urbanization was observed, caused by the natural growth in urban areas, in addition to persistent migration to urban areas, mostly from the Northern and Northeastern regions towards the Southeastern region (IBGE, 2017).

Brazil has one of the world's longest coastal zones, a privileged portion of the territory in terms of natural, economic and human resources. However, it is an area where approximately 26.6% of the Brazilian population lives, resulting in a demographic density where large urban centers stand out: of Brazil's 10 largest cities, 4 are located on the coast (IBGE, 2010). This region includes 13 of 27 Brazilian capital cities (BRAZIL, 2010). Population and urban growth brought the challenge of striking a balance between economic development, environmental conservation and social inclusion. Hence, Brazil has been making efforts in the sustainability front and, thanks to investments in research and innovation, has succeeded in expanding its industrial and agricultural production while preserving the environment and fighting poverty, which are pillars of sustainable development.

### 1.1.1. Vegetation, flora resources and coastal ecosystems

Brazil has a wide variety of natural features (soil, relief, vegetation and fauna), that are part of a unique natural composition. According to the Brazilian Institute of Geography and Statistics, the country comprises six large biomes, which, together, form one of the planet's richest biodiversities (Figure 1.1).

[3] *IBGE. Percentage distribution of the population by household - Brazil - 1980 to 2010. Available in Portuguese at: https://brasilemsintese.ibge.gov.br/populacao/distribuicao-da-populacao-por-situacao-de-domicilio.html*




Source: adapted from IBGE (2004).

*Figure 1.1 Brazilian biome distribution across the national territory*

In Brazil, there are several vegetation formations, whether forest or grasslands, distributed per climate and relief characteristics. Most of the country's territory is occupied by forest formations, constituted by ombrophilous and seasonal forests, which are particularly usual in the Amazon and Atlantic Forest (IBGE, 2004). Savanna formations are predominant in the Cerrado, but they also appear in other regions of the country, including the Amazon. Steppe savanna formations appear mainly in the Northeastern Caatinga. Steppe formations appear mainly in plateau and prairies in the far south area of Brazil, in the Pampa biome, due to the subtropical climate. Campinaranas can be found mainly in the Amazon, in the Rio Negro watershed (IBGE, 2010a). Finally, the Pantanal biome stretches across most of the states of Mato Grosso and Mato Grosso do Sul.

Panel 1.2 represents the main characteristics of those biomes, as well as coastal ecosystems.

*Panel 1.2. Main characteristics of biomes and coastal ecosystems.*

| Biomes | Amazon | Atlantic Forest | Pampa | Pantanal | Cerrado | Caatinga | Coastal ecosystems |
|---|---|---|---|---|---|---|---|
| Area | 4,196,943 km², corresponding to 49.5% of the national territory (IBGE, 2004). | Most of this biome is located in the coastal strip along the state of Rio Grande do Norte to the state of Rio Grande do Sul (IBGE, 2004, MMA, 2009, MMA/IBAMA, 2012). It has 1.1 million km² (13% of the Brazilian territory), and is the second largest tropical forest in the South-American continent. | This biome has an area 178,000 km² represents 2.3% of the Brazilian territory (CSR/IBAMA, 2011a). | This biome has 151,313 km², corresponding to 1.8% of the Brazilian territory (CSR/IBAMA, 2011b). | This biome has 2,045,000 km ² (23.3% of the Brazilian territory), and occupies the central part of Brazil (IBGE. 2004). | This biome has 844,000 km² and represents 10.1% of the national territory (IBAMA, 2004). | Brazil's coastal zone extends for over 8,500km, encompassing 17 states and over 400 municipalities, distributed from the country's equatorial North to the temperate South. It is comprised of a maritime strip formed by territorial sea, that is 12 nautical miles wide from the baseline out to 200 nautical miles, and includes the continental marine shelf and the Exclusive Economic Zone - EEZ. In addition to this area, Brazil also has an extension of 900 thousand km² in points where the Continental Shelf does not exceed 350 nautical miles according to the United Nations Convention on |

| Biomes | Amazon | Atlantic Forest | Pampa | Pantanal | Cerrado | Caatinga | Coastal ecosystems |
|---|---|---|---|---|---|---|---|
| | | | | | | | the Law of the Sea – UNCLOS (BRAZIL, 2016). This area is known as Blue Amazon and includes areas around the archipelagos of Fernando de Noronha and Saint Peter and Saint Paul, and the Trindade and Martim Vaz islands (BRASIL, 2010; 2016). |
| Covered states | The entire states of Acre, Amapá, Amazonas, Pará and Roraima, and parts of the states of Rondônia (98.8%), Mato Grosso (54%), Maranhão (34%) and Tocantins (9%) (IBGE, 2004). | Its original limits encompass areas in 17 states (PI, CE, RN, PE, PB, SE, AL, BA, ES, MG, GO, RJ, MS, SP, PR, SC and RS) (IBGE, 2004, MMA, 2019b). | Rio Grande do Sul (RS). | Mato Grosso (40.3%) and Mato Grosso do Sul (59.7%) (IBGE, 2004; CSR/IBAMA, 2011b). | Its continuous area covers the states of Goiás, Tocantins, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Bahia, Maranhão, Piauí, Rondônia, Paraná, São Paulo and the Federal District, in addition to entrances in Amapá, Roraima and Amazonas. | This biome stretches across nearly the entire state of Ceará (almost 100%), Rio Grande do Norte (95%), Paraíba (92%), Pernambuco (83%), Piauí (63%) and Bahia (54%), Alagoas (48%) and Sergipe (49%), and minor parts of Minas Gerais (2%) and Maranhão (1%). | Overlaps with the Amazon and Atlantic Forest biomes, and also, but to a lesser extent, with the Caatinga, Cerrado, and Pampa, which describes it as a complex of contiguous ecosystems forming environments of high ecological complexity and of utmost importance for sustaining life at sea. |

| Biomes | Amazon | Atlantic Forest | Pampa | Pantanal | Cerrado | Caatinga | Coastal ecosystems |
|---|---|---|---|---|---|---|---|
| Formation and ecosystems | Its main formations are dense and open forests. It also presents other ecosystems such as: seasonal forests, igapó forests, floodplain grasslands, lowlands, savannas, mountain refuges, campinaranas, and pioneer formations. | The Atlantic Forest presents a major environmental diversity and its relief presents major variations, with mountain ranges, valleys, plateaus and plains (IBGE, 2004; MMA, 2019b). | It is a grassland ecosystem with grassy areas scattered with shrubs. Near watercourses and plateau slopes the vegetation becomes thicker, with the occurrence of trees. The so-called "Banhados", swamp-like areas near the coast, are also part of this biome (CSR/IBAMA, 2011a). Landscapes include from mountains to plains, from rocky hills to hilly grasslands. | The Pantanal is a low region, with a flat relief, located in the center of a watershed, where the rivers food the plain and nourish an intricate drainage system that includes extensive lakes, divergent watercourses and differing areas of runoff and seasonal food. | The Cerrado contributes with 14% of the country's superficial water supply and reaches 43% of Brazil's total water production, not considering the Amazon Watershed. The springs of three major watersheds of South America are located in the Cerrado biome (Amazon/Tocantins, São Francisco and Prata). It also encompasses some aquifers, such as the Guarani Aquifer (MMA, 2014a). Predominant soils are Latosol, which cover 46% of the area. Besides Latosol, the biome also presents Neosol (23.2%), Argisol (11.9%), Plinthosol (10.2%) and Cambisol (9.3%) (MMA, 2012; 2014; EMBRAPA Cerrados, 2018). | The Caatinga is comprised of mountains and plateaus that form large geological barriers for the action of the wind and other factors, preventing the rains in higher areas of the eastern and the northern sides of mountains and plateaus. This is where the São Francisco, the region's largest perennial river, is located. Over 80% of the Caatinga soils present low fertility and low depth, hampered drainage and excessive concentrations of interchangeable sodium. | They encompass varied climatic environments (Wet Equatorial, Tropical, Semiarid and Subtropical). Geological formation is diversified, fed by watersheds and rivers with different dimensions and geographical characteristics, such as the Amazon Watershed, the seasonal rivers in the Northeast, the São Francisco, Doce, Jequitinhonha and Paraíba do Sul Rivers, the Atlantic watersheds, limited by the Serra do Mar mountains, and the Lagoa dos Patos Watershed. |

| Biomes | Amazon | Atlantic Forest | Pampa | Pantanal | Cerrado | Caatinga | Coastal ecosystems |
|---|---|---|---|---|---|---|---|
| Predominant vegetation | Most of its territory is covered predominantly by Dense Humid Forest, a type of vegetation typical of humid climates. The second most common type of vegetation is the Open Humid Forest. Other types: Semi-Deciduous Forests, campinas, campinaranas and relict savannas. It is home to 2,500 tree species (one-third of all the world's tropical wood) and 30 thousand plant species (of South America's 100 thousand), which makes it the largest gene bank on the planet (BRASIL, 2016). | Vegetation is formed by ombrophilous (dense, open and mixed) forests and seasonal (semideciduous and deciduous) forests. There are also other special environments, such as pioneering formations (wetland areas or meadows), sandbanks, mangroves, rupestrian and altitude fields, besides mixed humid forest with araucaria. It is estimated that there are about 20,000 plant species (about 35% of the existing species in Brazil) in the Atlantic Forest (MMA, 2019b). | Native grasslands are the predominant landscape, but other formations are also found, such as riparian vegetation, slope forests, ironwood formations, shrub formations, butiazais (jelly palms), swamps, rocky outcrops, among others. Grasslands predominate, interspersed with mesophile forests, subtropical forests (mainly Araucaria forests) and seasonal forests. | Vegetation is very diversified, with hydrophilic species (adapted to humidity), Cerrado and Amazon biome typical plants and xerophyte species in dryer areas. | Three general formations: forests, savannas, and grasslands. Complex landscape, composed of a mosaic of vegetation, scattered from grasslands to forest formations, and intermediate types of vegetation, such as deciduous forests in more fertile soil and gallery/riparian forest along the rivers. | The Caatinga vegetation is heterogeneous, characterized by short sized, thorny trees, with most species with small, thin leaves, some xerophytic characteristics and abundant herbaceous strata in the rainy season. Steppe savanna is predominantly comprised of low trees and shrubs, dropping their leaves during the dry season, and many cacti species (SFB, 2018). It is estimated that the Caatinga vegetation is composed of about 930 species, including 380 endemic ones (BRASIL, 2011; 2016). | Not applicable |

| Biomes | Amazon | Atlantic Forest | Pampa | Pantanal | Cerrado | Caatinga | Coastal ecosystems |
|---|---|---|---|---|---|---|---|
| Predominant climate | Mean annual temperatures between 24°C and 26°C and rainfall levels that vary spatially. Total annual rainfall exceeds 3,000mm in some regions, such as the mouth of the Amazon River, the state of Amapá coast and northwest end of the state of Amazonas. In west/southeast corridors, which go from the state of Roraima to the eastern part of the state of Pará, total annual rainfall varies between 1,500mm and 1,700mm. On the other hand, some parts in southern and western Amazon state may face up to 5-month periods with less than 100 mm rainfall. | Climate is characterized by a distinct two-season climate: a) tropical – intense summer rains followed by intense droughts; b) subtropical – physiological drought with mean temperatures below 15°C (winter cold) without the occurrence of the typical dry period (EMBRAPA/REDE-ILPF, 2019). Climate at the Atlantic Forest presents a wide variability since the biome is spread all along the Brazilian coast. It has aspects that include some characteristics of the other biomes it borders: Pampa, Cerrado and Caatinga. | Climate is mostly humid subtropical. Mean annual rainfall varies between 1,200 to 1,600 mm/year, with mean annual temperatures ranging from 13ºC to 17ºC, but with areas where climate is humid temperate with temperatures between -3°C and 18°C in colder months, and above 22°C for summer. The rainiest season coincides with the summer, decreasing during the winter, between the months of April and September. However, the dry season is not severe, and the distribution of rainfall is uniform throughout the year, rarely below 60 mm/month. | The Pantanal experiences tropical climate with a dry season or savanna climate (mean monthly temperatures are above 18°C. Rainfall regime presents two well-defined seasons: a rainy season between October and March, and a dry season between April and September. The annual flooding cycle covers 26 ± 7% of the biome's total area (42,700 ± 11,719 km²). | Climate is characterized by two well-defined seasons, a dry one between May and September, and a rainy one between October and April Mean temperatures is between 22°C and 23°C and rainfall levels vary between 1,200 to 1,800 mm (MMA; IBAMA, 2009) | Predominant climate is Tropical semiarid, with extremely varied rainfall levels – from 240 to 1.500 mm/year. Rains are concentrated in the so-called "rainy season", which last for about 3 to 4 months and in an irregular distribution. Mean annual temperature is between 25°C and 30°C, with little variation, but reaching up to 40°C for summer, with relative humidity usually lower than 50%. | Not applicable |

Source: Based on BRAZIL (2016).

## 1.1.2 Fauna

Brazil is known for being the world's most biologically diverse country. The estimated number of Brazil's known species, published in 2015 by the Ministry of the Environment and the Ministry of Science, Technology and Innovations in their first Brazilian Fauna Taxonomic Catalog [4], is 118,541 valid species. The catalog shows that 9% of all animals around the globe are in Brazil, and 30% of the planet's bird species live in the domestic territory. The first outcomes of this research were released in 2015, with the participation of 500 Brazilian and foreign scientists, who cataloged the Brazilian biodiverse fauna into 28 categories. So far, the huge majority of species known to Brazil are arthropods (about 85% with almost 94,000 species) and chordates (about 10%). All other species are members of other invertebrate groups. In general, except for some phyla, the number of species of the large majority of phyla exceeded those disclosed in recent estimates. Special mentions are the Annelida (almost 1,600 species), Mollusca (with almost 3,100 of valid species), birds (almost 3,000), bony fish (almost 4,400) and amphibians (slightly more than 1,000 species). However, knowledge about the diversity of Brazilian fauna is still incomplete. It is estimated that less than 10% of the existing total is actually known.

Protected areas are the most used instrument in Brazil for biodiversity conservation. A second instrument used within the country by the environmental agency under the Ministry of the Environment (the Chico Mendes Biodiversity Conservation Institute - ICMBio) for the conservation of species are the National Action Plans for the Conservation of Endangered Species, prepared and implemented together with state and municipal governments, universities and the civil society. At present, 545 endangered species are part of at least one of more than 40 such Plans in effect (ICMBio, 2016).

## 1.1.3. Water resources

The major input of water to the Brazilian territory derives from rainwater and the inflow of foreign rivers to the Amazon. This water is used for different economic activities, then returns to the environment and leaves the territory, whether towards the Atlantic Ocean, or neighboring countries in the Platina Basin.

The country's hydrological network is divided into 12 regions (Figure 1.2), and watersheds serve different uses, such as: irrigation, human and animal supply, industrial supply, energy generation, mining, aquiculture, navigation, tourism and leisure. Currently, the primary use of water in the country is irrigation (in terms of utilized volumes), with more than 900 $m^3/s$ (ANA, 2019).

[4] *Available in Portuguese at http://fauna.jbrj.gov.br/fauna/listaBrasil/PrincipalUC/PrincipalUC.do?lingua=pt.*


Source: ANA (2017).

*Figure 1.2 Distribution of hydrological regions across the territory*

Brazil is one of the countries with the world's largest fresh water availability (12% of the planet's surface water resources), but these resources are unevenly distributed over the territory, both spatially and temporally. On average, about 260,000 $m^3/s$ of water flow through the Brazilian territory. In spite of the abundance, some 80% of this total is located in the Amazon region, the country's least populated region, where the demand for water is lower. It is estimated that superficial water availability in Brazil is around 78,600 $m^3/s$, or 30% of the average flow, with 65,617 $m^3/s$ corresponding to the share of the Amazon Watershed alone. Part of this flow is destined to the various uses of water, even on dryer years (ANA, 2019).

The Brazilian Northeast requires special attention with regards to water supply, particularly the northern part of the region (states of Ceará, Rio Grande do Norte, Paraíba and Pernambuco), with 87.8 % located in the semi-arid (BRASIL, 2016). Low and irregular rainfall, year-round high temperatures, low temperature ranges (between 2 °C and 3 °C), strong insolation and high rates of associated evapotranspiration combined with hydrogeological characteristics, such as the region's intermittent rivers, contribute to the reduced water availability values observed (ANA, 2010).

In most of the rivers, ponds/reservoirs are the only possible way to ensure continuous water supply, given that these rivers naturally become dry in the dryer months, both due to low rainfall and low soil thickness. In other regions, reservoirs are used to increase the supply of continuous demands, such as human supply (ANA, 2017).

It is estimated that groundwater availability in Brazil is around 14,650 $m^3$/s. Similar to superficial waters, groundwater distribution across the national territory is not uniform, aquifer productivity varies, occurring both in scarce regions and regions with relative abundance. The most recent estimate points to some 2.4 million ponds in Brazil, updated in 2017 (IBGE, 2019) - an increment of 1 million additional ponds to the previous estimate. Out of this total, 308 thousand were entered in the Groundwater Information System (SIAGAS, for its acronym in Portuguese) of the Mineral Resource Research Company (CPRM, for its acronym in Portuguese) (ANA, 2019).

## 1.2. CLIMATES OF BRAZIL

Brazil is a country with equatorial, tropical and subtropical climates. The tropical climate extends to 81.4% of the national territory. The main reason for this to be the predominant climate in most of the country is the lack of limiting factors of altitude, rainfall and temperature that would favor other climatic zones. The semiarid climate, present in 4.9% of the national territory, is remarkably the typical climate in Northeastern Brazil, occurring basically in regions were mean annual rainfall is below 800 mm/year (IBGE, 2017). The subtropical climate covers 13.7% of the Brazilian territory, which is mainly located in the Southern region's mountains and plateaus.

Brazil is a country of continental dimensions with great diversity of climatic regimes that influence its climates. El Niño and La Niña are significant sources of interannual variability. Two relevant climate categories that express this differentiation are briefly discussed below, namely rainfall climatology and temperature, and climate extremes.

### 1.2.1 Rainfall climatology and temperature

Based on its rainy seasons, Brazil can be divided into four regions: Amazon, Northeastern Brazil, Central Brazil and Southern Brazil.

From 1981 to 2010, annual rainfall varied from approximately 400 a 3.450 mm in Brazil, with average occurrence above 3,000 mm in the state of Amazonas, and below 850 mm in the semiarid northern part of the state of Bahia. In Central Brazil, mean annual rainfall varied between 1,050 and 1,800 mm (INMET, 2018).

The seasonal cycle of rain in Brazil is affected by interannual variations, which can interfere causing, for example, droughts during the rainy season, or even an abundant rainy season. As mentioned above, El Niño and La Niña are significant sources of interannual variability, which also affect temperature.

Regarding average annual temperature (°C) distribution in Brazil, the highest temperatures were registered in the North and Northeast regions, reaching on average over 28°C. In most territories of the North and Northeast regions and the state of Mato Grosso, temperatures ranged between 26-30 °C. Averages ranged between 22-26 °C in most of the Southeast region, and states of Bahia, Mato Grosso do Sul and Goiás and the Distrito Federal, with lowest values in higher regions of the states of Minas Gerais and São Paulo, reaching up to 18-20 °C. In most of southern Brazil, averages ranged between 14-20 °C, with lower values on the hills (INMET, 2018).

### 1.2.2. Climate extremes

Climate change impacts are addressed as one of the factors that contribute to increased risks of natural disasters (MMA, 2016). In Brazil, the urban expansion process, which is characteristic of the past 60 years, resulted in the concentration of the most vulnerable population in areas that are more likely to be exposed to risks. These populations are exposed to both sudden events (such as landslides, flash floods, etc.), as well as gradual events (such as droughts and floods).

Brazil presents different types of natural disasters, and most of them are water and climate-related hazards in which rain (whether excess or shortage thereof) is responsible for triggering the physical processes that put populations and their economic activities at risk.

*See **Chapter 3** for more information on perspective of future extreme climate events in the country.*

Among the hazards registered in Brazil, some examples of the most important climatic extremes observed between 2014 and 2018 are presented below, subdivided by event typology. Extreme events registered in the previous ten years (2004 and 2014) were described in the Third National Communication of Brazil to the United Nations Framework Convention on Climate Change (UNFCCC) (BRAZIL, 2016).

### *Droughts*

Brazil endures droughts because of the climatic and water-related conditions in the Northeastern region. However, in the past few years, Brazilians living in the Central-West and Southeastern regions have also experienced this problem.

According to the National Water Agency's economic report on water resources, 48 million Brazilians have been affected by long-lasting droughts or temporary dry spells between 2013 and 2016. During that period, 4,824 dry spell events were registered, with damages to the population[5].

Data presented by the IBGE in March 2018 show that from 2013 to 2015, there was a decline in the country's renewable water resources. This total was 7.4 trillion cubic meters in 2013, increased to 7.6 trillion cubic meters in 2014 and dropped to 6.2 trillion cubic meters in 2015 (IBGE et al., 2018).

The drought that tormented the Brazilian semiarid region from 2012 to 2017, especially the Northeastern countryside, was the worst ever recorded. A total of six consecutive years with rainfall below average, according to the Meteorological Database of the National Institute of Meteorology. The most stricken state, Ceará, presented mean rainfall of 516 mm, compared to the minimum historical average of 600 mm (INMET, 2019).

Besides that of the Northeastern region, two major water crisis have recently shown that no region in the country is exempt from experiencing shortages: one in the metropolitan region of São Paulo, between 2014 and 2016, and the other one in the Federal District, that lasted from the beginning of 2017 until mid-2018, when the Capital of the country experienced a watering day roster scheme with other administrative regions.

### *Floods*

In the past few years, floods in Brazil have caused many deaths and significant economic losses, material damages and damages to properties.

Urban floods are linked to environmental degradation, intense urban sprawl and heavy rains, which are becoming increasingly more intense and concentrated (IPCC, 2007).

For instance, the city of Rio de Janeiro and its metropolitan region (RJMR) have been severely stricken, mainly during the rainy season (November to March), by intense rain events that cause great inconvenience to the population. Climate in the municipality of Rio de Janeiro is becoming wetter. Based on RJRM's climate series since 1960, total annual rainfall is on the rise, and intense rainfall events have happened more frequently. This difference might be associated both to a change in circulation at a synoptic scale, as well as to local circulation due to the effects of urban heatwaves (PBMC, 2016).

***Synoptic scale***
Corresponds to a large horizontal portion of the Earth's atmosphere, in which large-scale weather and meteorological phenomena occur (such as depressions, cyclones and anticyclones).

[5] *The report is commissioned every 4 years, and that is why data comprises the period from 2013 to 2016.*

The storm that swept through the city on 25 February 2020 was the heaviest in the city's history. An accumulated 123.6 mm of rain fell within one hour. Before that, the record-breaking rainfall had been 123.2mm in one hour, in 2018. Also, in February 2020, the city of São Paulo recorded the highest accumulated amount of rain (114 mm) for February in 37 years. Those events caused landslides, floods, deaths, power outage, destruction of infrastructure, among other damages (INMET, 2019).

*Coastal flooding*

***Salvador, Bahia***

The accelerated growth of the city of Salvador led to the appearance and occupation of areas vulnerable to the occurrence of risks and natural and social disasters. In recent years, high tides and sea swells have also destroyed beach huts and beach-front construction in the state of Bahia, in cities like Prado, Porto Seguro and Valença. One such case happened in April 2015, when the tide reached 3.30 meters high and hit constructions protected by barriers (PBMC, 2016).

***Santos, São Paulo***

The coast of the state of São Paulo concentrates ecosystems and populations that are very exposed to environmental risks, such as sea level rise, storms, floods, landslides, and proliferation of diseases due to climate-sensitive vectors.

In 2016 alone, two severe sea swells were registered, which caused the Port of Santos – of the country's busiest – to close, and resulted in losses and destruction of public services. The northeastern region of Santos experiences floods during the syzygy high tides, which is particularly sensitive during the summer season when floods are aggravated by rain. On the other hand, the eastern part of Santos has a complex drainage system, built in the early 90s, which allows for the flow of water from tides and rain through the canals, protecting this region from flooding (ICF-GHK, 2012; SOUSA; GREEN, 2016).

***Syzygy high tides***
Correspond to the highest high tides, as a consequence of the gravitational influence of the new and full moons.

***Cities at the mouth of the Vale do Itajaí, Santa Catarina***

Between 28 and 31 October 2016, sea swells hit 32 cities on the coast of the state of Santa Catarina, according to a report by the Civil Defense (PBMC, 2016). The most affected cities were located in the Greater Florianópolis and the state's northern coast. The phenomenon was caused by the displacement of an extratropical cyclone towards the sea, combined with high pressure generating winds from the south quadrant and, consequently, causing positive meteorological tides associated with the syzygy high tides. In Balneário Camboriú, the sea invaded the Atlantic Avenue, hitting cross streets and beach-front constructions, leaving about 2 to 4 thousand m3 of sand on the avenue. The National Institute of Meteorology weather station recorded wind gusts of up to 53.2 km/h (14.8 m/s) in the city of Itajaí on the days of the event, with sea level exceeding 2 meters.

## 1.3.SPECIAL CIRCUMSTANCES

Particularly in the national context, special circumstances must by underlined in relation to regions with fragile ecosystems, maritime islands, sea level in coastal regions and desertification process, for which there are specific demands and concerns raised by climate change impacts.

## 1.3.1. Regions with Fragile Ecosystems

> ***Environmental fragility or fragile areas***
> Concept that encloses the vulnerability of an environment to any type of damage, with ecosystems or fragile areas considered as important portions or fragments with unique characteristics and resources (BRASIL, 2016).

In the case of Brazil, it is possible to identify eight major categories of fragile areas: hilltops, slopes and cliffs; springs of water courses; margins of water courses, floodplains and flood beds; lakes, ponds and lagoons; aquifer recharge areas; mangroves; sandbanks; and areas susceptible to desertification (GOMES; PEREIRA, 2011; BRAZIL, 2012).

Some disturbances observed in the most susceptible areas, with the respective indication of response measures, are described below (Panel 1.3).

*Panel 1.3. Major disturbances in fragile areas and some response measures adopted in Brazil*

<table>
<tr><th>Fragile Areas</th><th>Disturbance</th><th>Examples of response measure adopted</th></tr>
<tr><td>Springs of water courses; margins of water courses, floodplains and flood beds</td><td>• Intense erosive processes and environmental liabilities of great magnitude and regional influence (GOMES; PEREIRA, 2011).<br>• Extinction of many animals, animal population imbalance, etc. (AGOSTINHO et al., 1997).<br>• Loss of biodiversity and ecosystem services (RIBEIRO; FREITAS, 2010).</td><td rowspan="4">• Water resources planning activities.<br>• Hydrological monitoring.<br>• Monitoring and mediation of critical hydrological events.<br>• Regulation in the analysis and granting of water use licenses.<br>• Social Communication and capacity-building for officials of the National Water Resources Management System (SINGREH, for its acronym in Portuguese)[6].<br>• Implementation of all actions provided for in the National Plan on Water Resources, National Adaptation Plan</td></tr>
<tr><td>Lakes, ponds and lagoons</td><td>• Compromised structural components and functional processes, at the risk of complete depletion (PBMC, 2014a; GOMES; PEREIRA, 2011).</td></tr>
<tr><td>Aquifer recharge areas</td><td>• Groundwater quality and availability problems (ROCHA, 1996).<br>• 70% groundwater recharge reduction in the Northeast by 2050 (DOLL; FLORKE, 2005).<br>• Variations in groundwater levels below those monitored between 2004 and 2011 in the Guarani Aquifer System (MELO, 2013).</td></tr>
<tr><td>Mangroves and sandbanks</td><td>• Change in erosion and sedimentation processes of water courses, thus changing species competition for substrate (RICHIERI, 2006).<br>• Sea level rise and, consequently, increased estuary salinity, which favors the replacement of typical mangrove species</td></tr>
</table>

[6] *Available in Portuguese at:*
http://arquivos.ana.gov.br/imprensa/noticias/20151109111952_Mudancas_Climaticas_e_Recursos_Hidricos_Subsidios_ao_PNAMC_2015.pdf

| Fragile Areas | Disturbance | Examples of response measure adopted |
|---|---|---|
| | for others that easily adapt to saltier environments (PBMC, 2014b).<br>• Changes in the life cycles of plants in sandbanks (ZANI, 2017). | |
| Hilltops, slopes and cliffs | • Landslides | |

### 1.3.2. Maritime islands and sea level in coastal regions

The South Atlantic and Tropical Ocean and the Brazilian Coastal Zone are strategic locations for national development because of their living and non-living marine resources.

Regarding maritime islands, there are two groups: i) coastal islands; and ii) ocean islands. Coastal islands sit on the continental shelf, extending seawards. Oceanic islands sit on the bottom of the ocean. Some coastal islands are home to capital cities, like São Luís (state of Maranhão), Vitória (state of Espírito Santo) and the Santa Catarina island (where the capital city, Florianópolis, is located); others have major touristic relevance, like Itamaracá (state of Pernambuco), Itaparica (state of Bahia) and Ilha Grande (state of Rio de Janeiro), or are intended for ecological preservation, like Abrolhos (state of Bahia). Nearly all Brazilian oceanic islands are protected areas or research sites, like Atol das Rocas, the archipelagos of Fernando de Noronha (AFN) and Saint Peter and Saint Paul (ASPSP), and the Trindade and Martim islands.

The strategic importance of oceanic islands was established by the United Nations Convention on the Law of the Sea – UNCLOS, which grants Brazil the right to establish territorial sea and EEZ around them. Therefore, Brazil has the exclusive right and duty to explore and exploit, conserve and manage the respective natural resources with relevant socioeconomic, scientific and environmental value.

The ASPSP is formed by small rocky islands, at about 1,000 km from the coast of the state of Rio Grande do Norte, and is a Protected Area (PA), as per Decree No. 92,755, of 5 June 1986. Fortnightly scientific expeditions contribute to confirm that the archipelago is permanently occupied, which is an indispensable requirement to legitimate Brazil's right to the surrounding EEZ (PSRM, 2016).

The Trindade Island and the Martim Vaz Archipelago are part of the country's eastern border area. The Vitória-Trindade Ridge is a unique formation on the planet, composed of underwater mountain ranges that connect Brazil's central coast to the Trindade Island and the Martim Vaz Archipelago. It has about 30 seamounts, and at least 10 are between 30 and 150 meters deep, functioning as true marine biodiversity havens. The Vitória-Trindade Ridge is known worldwide as a hot spot. It has been appointed by the Convention on Biological Diversity (CBD) as a biologically significant marine area and presented by the Brazilian Government during the UN Ocean Conference/SDG 14 (June 2017) as a priority area for ocean protection and creation of marine conservation units.

Fernando de Noronha is privileged by its geographical position and isolation, and at the same time by the ease of access by land and sea, and telecommunications, and is an important location for the establishment of an advanced meteorological observation center and for environmental studies.

The Atol das Rocas is the only atoll in the South Atlantic Ocean, and it is an important nesting area for tropical seabirds and for the breeding of sea turtles (MMA, 2010). The geographical, strategic and geopolitical location of Brazil's tropical oceanic islands (AFN, ASPSP, Trindade and Martim Vaz, and the Atol das Rocas) qualify them as natural observatories of the South Atlantic and Tropical Ocean (Decree No. 8,907, of 22 November 2016[7]).

The panel below lists some of the main disturbances on maritime oceanic islands and some public initiatives and policies for their preservation (Panel 1.4).

*Panel 1.4. Disturbances on maritime oceanic islands and some public initiatives and policies considered as response measures*

| Oceanic islands | Disturbances | Response measures |
|---|---|---|
| • Atol das Rocas;<br>• Fernando de Noronha Archipelago (AFN);<br>• Saint Peter and Saint Paul Archipelago (ASPSP);<br>• Trindade and Martim Vaz | • Increased sea surface temperature;<br>• Decreased phytoplankton, which is the basis of marine food webs;<br>• Changes in ocean currents;<br>• Sea level has risen nearly 8 cm due to temperature rise and defrosting in the Antarctic continent;<br>• Increased water availability in the soil | • Sectoral Plans for Sea Resources (PSRM, for its acronym in Portuguese[8]);<br>• Creation of a Science Station at AFN;<br>• Scientific Research Programs in ASPSP (PROARQUIPÉLAGO[9]) and Trindade Island (PROTRINDADE[10]);<br>• Creation of the Protected Area (PA) around ASPSP (Decree No. 92,755, of 5 June 1986);<br>• Creation of marine federal conservation units in every Brazilian oceanic island (Decree No. 9,312[11] and 9,313[12], both dated 19 March 2018);<br>• Climate and meteorological monitoring: Meteorological Station on the Trindade Island (EMIT, for its acronym in Portuguese). |

In turn, the Brazilian Coastal Zone (CZ) lies in the intertropical and subtropical zones, and comprises a strip of approximately 8,500 km on the Atlantic Ocean. It has variable width currently comprising 395 municipalities distributed in 17 coastal states (macro), covering 16 metropolitan regions by the sea (IBAMA, 2013).

The CZ may be significantly impacted by climate change, because of its consolidated occupation and urbanization, combined with the region's natural dynamics (Panel 1.5). The main drivers of marine and coastal ecosystem change in Brazil are natural hazards and global warming (MMA, 2016).

[7] *Available in Portuguese at: http://www.planalto.gov.br/ccivil_03/_ato2015-2018/2016/decreto/d8907.htm*

[8] *The PSRM is a multi-year plan, and is an update of the National Policy for Sea Resources (PNRM), aimed at knowing and assessing the sea potential, as well as monitoring living and non-living resources, oceanographic and climate phenomena of marine areas under jurisdiction and of national interest, aiming at sustainable management and fair and equitable distribution of the benefits derived from such use. More information at: https://www.marinha.mil.br/secirm/psrm*

[9] *Available in Portuguese at: https://www.marinha.mil.br/secirm/proarquipelago#producao*

[10] *Available in Portuguese at: https://www.marinha.mil.br/secirm/protrindade#acompanhamento*

[11] *BRAZIL. Decree No. 9,312 of 19 March 2018. Official Gazette, Brasília, DF, 20 March 2018.*

[12] *BRAZIL. Decree No. 9,313 of 19 March 2018. Official Gazette, Brasília, DF, 20 March 2018.*

*Panel 1.5. Main disturbances on coastal zones and some public initiatives and policies considered as response measures*

| Disturbances | Response measures |
|---|---|
| • Relative sea level rise, causing physical, chemical and biological alterations on natural and anthropogenic coastal environments;<br>• Increased coastal erosion (oceanic and estuarine coastline);<br>• Beach profile vertical migration;<br>• Increased frequency, intensity and magnitude of coastal flooding;<br>• Changes in sedimentary processes and consequently in the coastal sedimentary balance;<br>• Loss of natural and urban terrains;<br>• Fragmentation and even complete loss of adjacent ecosystems by the oceanic coast and estuarine/lagoon line;<br>• Species and entire ecosystems vertical migration;<br>• Increased people and assets vulnerability;<br>• Reduced habitable spaces;<br>• Salinization of the coastal aquifer and surface waters;<br>• Compromised provision of basic sanitation systems (sewage and drinking water);<br>• Positive and negative impacts on port and port backup activities;<br>• Loss of fertile soils;<br>• Problems in agricultural, industrial, touristic and service-commerce activities;<br>• Compromised fishing, scenic beauty and tourism resources;<br>• High maintenance/recovery/mitigation costs;<br>• Problems in enforcing the environmental legislation;<br>• Socioeconomic losses and lowered quality of life; | • Sectoral Plan for Sea Resources (PSRM, for its acronym in Portuguese), provided by Decree No. 5,377 of 23 February 2005, and its several actions, such as[13]: Assessment, Monitoring and Conservation of Marine Biodiversity (REVIMAR); Aquaculture and Fisheries (AQUIPESCA); Program for Mineral Potential Assessment of the Continental Shelf (REMPLAC); Global Ocean Observing System (GOOS-BRAZIL); Scientific Research on Oceanic islands (ILHAS OCEÂNICAS); Marine Biotechnology (BIOMAR); Human Resources Training in Marine Science (PPG-Mar); Mineral Resources Prospection and Exploitation Program within the International South Atlantic and Equatorial Area (PROAREA);<br>• National Adaptation Plan, in which the CZ is one of the 11 sectors covered by the elaboration of guidelines, actions and goals for adaptation to climate change;<br>• Other legal instruments: National Coastal Administration and Management Plan, instituted by Law 7,661, of 16/05/88; State Coastal Management Plan; Municipal Coastal Management Plan; Coastal Management Information System; Coastal Zone Environmental Monitoring System; Coastal Zone Environmental Quality Report; Coastal Ecological-Economic Zoning; Coastal Zone Management Plan; and the Federal Action Plan for the Coastal Zone. |

Source: Based on PBMC (2016); Souza (2010).

## 1.3.3 Desertification

In Brazil, desertification areas are located mainly in the Northeast region and in the north of the states of Minas Gerais and Espírito Santo. The predominant vegetation in these areas is typical of ecosystems in the Caatinga biome, corresponding to a large part of the semiarid Northeastern Brazil (BRASIL, 2016).

[13] *More information at:* https://www.marinha.mil.br/secirm/psrm

The semiarid is the region that is more prone to degradation, desertification and droughts; located in most of the extension known as Area Susceptible to Desertification (ASD). This area encompasses a total of 1,494 municipalities, with 1,323,975.4 km² and 34.8 million inhabitants in 11 states. In addition, 70.5 thousand km² have reached a level in which is no longer possible to maintain agricultural production, as natural resources productivity is very low, reflecting on the region's capacity to supply for human and animal life (CGEE, 2016).

In this context, the economic issues and public policies in force assume a strategic position, as they promote the region's environmental, economic and social development (ANGELOTTI et al., 2015). Moreover, some measures endorsed by legal instruments may be considered, in order to prevent desertification in areas at risk and recover affected areas (Panel 1.6).

*Panel 1.6. Main desertification effects in susceptible areas and conservation initiatives implemented as response measures.*

| Desertification effects | Adaptation and conservation initiatives |
|---|---|
| ● Extensive erosion or pediplanation areas[14] .<br><br>● Low carving power, caused by the dense river system and the seasonal intermittent character of many rivers. | **Conservation measures[15]**<br><br>● Recovery of degraded pastures, integrated Crop-Livestock-Forestry systems, integrated Livestock-Forestry systems, integrated Crop-Livestock systems, inoculation with Rhizobium strains for biological nitrogen fixation, among others (MARTINS et al., 2018; BALBINO et al., 2011).<br><br>● Use of agrosilvopastoral systems by integrating tree species (native or exotic) with crops that are well adapted to the semi-arid region, such as cassava, sorghum and *caupi* beans. Additionally, this system reduces soil, water and nutrient loss, thus decreasing the erosion process (ARAÚJO FILHO, 2006; AGUIAR et al., 2006). |
| ● Occasional occurrence of water and wind-gaps.<br><br>● Most soils are degraded, with evident limitations to | **Adaptation measures[16]**<br><br>● Research with water catchment technologies, efficient use of water for irrigation purposes, conservation of soil moisture using litter cover, genetic improvement through selection of drought and high-temperature resistant material, polyculture crop production systems, use of local genetic diversity, among others, as well as management techniques to increase water-use efficiency, such as the use of underground dams, lifeline irrigation systems, drip irrigation, also associated with organic fertilization as a measure of adaptation (FURTADO et al., 2014 a;b; BRITO et al., 2012).<br><br>● Crop diversification and landscape heterogeneity in order to increase agricultural production resilience (NICHOLLS et al., 2015). In case of monocultures, temporary measures such as changing planting date, introduction of new cultivars and use of irrigation (MATTHEWS et al., 2013). |
| | **Legal instruments[17]** |

[14] *Pediplanation is the process that leads to the development of plain areas or planation surfaces in arid or semiarid regions.*

[15] *Current conservation measures implemented primarily by rural producers (private sector).*

[16] *Current adaptation measures implemented primarily by the academic sector and rural producers (private sector), respectively.*

[17] *Current legal instruments implemented in the country primarily by Federal and State Governments.*

| Desertification effects | Adaptation and conservation initiatives |
|---|---|
| agricultural use. Even soils with larger agricultural capacity are severely eroded. | ● Law No. 13,153, of 30 July 2015, established the National Policy to Combat Desertification and Mitigation of Drought Effects and provides for the establishment of a National Committee to Combat Desertification<br><br>● National Program to Combat Desertification and Mitigation of Drought Effects (PAN-Brasil, for its acronym in Portuguese), based on four thematic areas: reducing poverty and inequality; sustainable expansion of the region's productive capacity; conservation, preservation and sustainable management of natural resources; democratic management and institutional strengthening;<br><br>● State Action Programs to Combat Desertification;<br><br>● Early Warning System for Drought and Desertification[18]. |
| | **Market instruments[19]**<br><br>● Payment for Environmental Services<br><br>● Funds sourced from the Climate Fund, the Brazilian Fund for Biodiversity (Funbio, for its acronym in Portuguese), the Socioenvironmental Fund of the Federal Savings Bank (Caixa Econômica Federal in Portuguese) and the United Nations Development Programme (UNDP). |

Source: Based on PBMC (2016); Aguiar et al. (2006); Araújo e Filho (2006); Balbino et al. (2011); Brito et al. (2012); Matthews et al. (2013); Nicholls et al. (2015); Martins et al. (2018).

## 1.4. PRIORITIES FOR NATIONAL AND REGIONAL DEVELOPMENT

The country has made progress in national development priorities. There is an incremental improvement in indicators related to access to health, basic sanitation, fighting hunger, poverty and income inequality. This improvement is also due to better living conditions and household income as a result of effective social programs. In order to make this a sustained improvement, however, the government is working towards bolstering the production sector and, as a result, creating more jobs and boosting living standards, such as an emphasis on improving urban environmental conditions, with an increase in basic sanitation and proper treatment of solid waste.

### 1.4.1 Social Development

#### *National Social Policies System*

Social concepts became part of the Brazilian public agenda in the late 80s, and began to guide the development of social policies in the country, as described in Panel 1.7.

[18] *This system is the result of a partnership between the Earth System Science Center of the National Institute for Space Research and the Ministry of the Environment, with the collaboration of the National Center for Monitoring and Early Warnings of Natural Disasters (Cemaden).*

[19] *Current market measures implemented primarily by the private sector, government and public and private financial agents.*

*Panel 1.7. Guiding concepts for policy-making in Brazil.*

| Guiding Concepts | Information |
|---|---|
| Reinforcement of selectivity and focus | Priority is given to programs for the poor sectors, focusing expenses and actions on basic needs at the most vulnerable groups. |
| Combination of universal and selective programs | Mutual support between focused and universal programs, i.e., they are complementary. |
| Minimum income programs | Guaranteed minimum income for citizens or families as part of programs to fight poverty, linked to school achievement and health for younger children. |
| Public-private partnership | Extending initiatives by the various organized segments of society to provide social services. |
| Expansion of production programs | Reinforcing the capacity and productivity of poor segments in generating income, via training programs, support for micro and small enterprise and job creation. |
| Expansion of access to food programs | Increasing supply of highly nutritional staples and improving the living conditions of food-insecure households. |
| Job and income generation programs | Sustainable job and income generation for poor, vulnerable families that are beneficiaries of social programs. |

Source: Based on BRAZIL (2016).

At present, a unique database known as *Cadastro Único* (Single Registry) functions as a point of intersection for social policies, collecting information from families with per capita monthly incomes of up to half a minimum wage or total family income of up to three wages.

The Single Registry, regulated by Decree No. 6,135/2007, is the instrument to identify and qualify the socioeconomic situation of low-income Brazilian families, which can be used for several social policies and programs targeted at this group. Its database allows for identifying the poorest, most vulnerable part of the population and their main characteristics, needs and potentials. It is mandatory that it is used to select beneficiaries of federal government social programs, such as the Family Allowance Program (*Bolsa Família,* in Portuguese). Management of the Single Registry is decentralized and shared by the Federal Government, States, Federal District and municipalities (BRAZIL, 2017). Based on data from the Single Registry, the government can make and implement policies that aim at contributing to reduce social vulnerabilities to which families are exposed and develop their potential.

Some of these programs are described in Panels 1.8 a 1.11, namely: The Family Allowance Program, the Happy Child Program, the Caring Brazil Program and the Productive Inclusion Program.

*Panel 1.8. Elements of the Family Allowance Program*

| Family Allowance Program | Information |
|---|---|
| Characteristics | Conditional cash transfer scheme for extremely poor or poor families, with per capita monthly income of up to BRL 85 (US$ 22)[20] or between BRL 85.01 and BRL 170 (US$ 45), respectively. |
| Transfers | ● Basic Transfer: to all extreme poor households.<br>● Varying Transfer: to poor and extremely poor households with pregnant women, breastfeeding mothers, children and teenagers aged from 0 to 16 years. The amount transferred is BRL 41 (US$ 11) and each household can receive up to 5 monthly payments.<br>● Varying Transfer to Youngsters: to poor and extremely poor households with teenagers aged between 16 and 17 years. The amount transferred is BRL 48 (US$ 13), and each household can receive up to 2 monthly payments. |
| Dimensions | (i) Immediate poverty alleviation, by direct income transfer to the household;<br>(ii) Reinforcing the exercise of basic social rights in the areas of health and education, by complying with conditionalities, helping families to break the cycle of intergenerational poverty and allowing public authorities to identify social risk situations to which families may be exposed; and;<br>(iii) Integration with other governmental actions, the so-called complementary programs, which aim at developing family capacities in a way that the beneficiaries of the Family Allowance Program may alleviate vulnerabilities and poverty. |
| Management | Decentralized and shared by the Federal Government, States, Federal District and municipalities. The three levels of Government work together to improve, broaden and enforce the program's implementation. The Federal Government transfers resources to support the actions of the municipalities, States and Federal District in managing and implementing the Family Allowance Program and the Single Registry. This is a monthly transfer based on the other levels of government's ability to register and monitor the households conditionalities. |
| Rules | Households that are eligible are those registered in the Single Registry with per capita monthly income of up to BRL 85, even without children or teenagers in the family; and those with per capita monthly income between BRL 85.01 and R$ 170 with children or teenagers aged from 0 to 17 years. Cash transfers are temporary and do not give rise to vested rights. Families eligibility must be assessed every two years. The number of Family Allowance Program eligible households between 2004 and 2017 is shown in Figure 1.5. |
| Conditionalities | Regarding health, families must comply with the Ministry of Health's vaccination schedule for children under 7 years of age; take children under 7 years of age to be weighed and measured so their growth and development are monitored; make sure pregnant women get prenatal care. |

[20] *Exchange rate at BRL 3.8/USD.*

| Family Allowance Program | Information |
|---|---|
| | Regarding education, families must enroll children and teenagers aged from 6 to 17 years in school; assure minimum monthly attendance of 85% for children aged 6-15 years; assure minimum monthly attendance of 75% for teenagers aged 16 and 17 years that received the Varying Transfer to Youngsters; inform the school whenever any reason prevents the student from going to classes; update information on the children and teenagers' schools in the Single Registry. |
| Legal framework | • Law No. 10,836 of 9 January 2004;<br>• Decrees No. 7,788, of 15 August 2012; 6,135, of 26 June 2007; 5,209, of 17 September 2004;<br>• Ordinances No. 94, of 4 September 2013; 251, of 12 December 2012; 10, of 30 January 2011; 177, of 16 June 2011; 754, of 20 October 2010; 706, of 17 September 2010; 617, of 11 August 2010; 256, of 19 March 2010; 341, of 7 October 2008; 76, of 6 March 2008; 350, of 3 October 2007;<br>• Interministerial Ordinance No. 2 of 16 September 2009;<br>• GM/MDS Ordinances No. 666, of 28 December 2005; 555, of 11 November 2005; 360, of 12 July 2005; 246, of 20 May 2005; 737, of 15 December 2004; 246, of 20 May 2005;<br>• Senarc/MDS Ordinance No. 01, of 3 September 2004;<br>• Interministerial Ordinance No. 3,789, of 17 November 2004, by the Ministry of Education and the former Ministry of Social Development;<br>• Interministerial Ordinance No. 2,509, of 18 November 2004, by the Ministry of Health and the former Ministry of Social Development;<br>• Normative Instruction No. 2/2001 and No. 4/2011; |

Source: Based on BRAZIL (2017).

*Panel 1.9. Elements of the Happy Child Program*

| Happy Child Program | Information |
|---|---|
| Characteristics | This a Federal Government initiative to expand the early childhood care network, a tool for families with children aged from 0 to 6 years to provide them with mechanisms to promote their cognitive, emotional and psychosocial development. |
| Objectives | To promote human development through support and follow-up of early childhood development and to mediate the access of pregnant women, young children, and their families to the policies and public services they might need. |
| Transfers | Eligible families will be followed-up by a team of qualified professionals, called "monitors". They will provide guidance on essential care during the first years of life. This creates a bond |

| Happy Child Program | Information |
|---|---|
| | between the families and the social assistance, health, education, culture and human rights services, provided by the Federal Government, States and municipalities. Monitors also assess the family environment as a whole, identifying factors that might compromise the child's full development. |
| Rules | Pregnant women and children aged up to 3 years and their family's beneficiaries of the Family Allowance Program; children up to six years benefiting from Continued Benefit (BPC) and their families; children up to six years away from family life because of protective measures, as provided for in Art. 101 of Law No. 8,609 of 13 July 1990, and their families, are eligible. |
| Legal framework | Decree No. 8,869 of 2016; Law No. 13,257 of 2016 (Legal Framework on Early Childhood); Law No. 8,069 of 1990 (Statute of the Child and Adolescent); National Plan for Early Childhood, of 2010; Decree No. 99,710 of 1990 (Convention on the Rights of the Child). |

Source: Based on BRAZIL (2017).

*Panel 1.10. Elements of the Caring Brazil Program*

| Caring Brazil Program | Information |
|---|---|
| Characteristics | Program that involves child development aspects associated to income, education and health. |
| Objectives | To provide additional financial support for the maintenance and development of early childhood education for daycares. |
| Transfers | Funds are allocated to children from zero to 48 months of age, enrolled in public daycares or daycares accredited by the government, whose families are beneficiaries of the Family Allowance Program. Financial support is provided to the Federal District and municipalities that responded the previous year school census informing how many children aged from zero to 48 months that meet the eligibility criteria above were enrolled. The amount is calculated based on 50% of the minimum wage per enrollment in public daycares or daycares accredited by the government, both part-time and full-time, defined by the Fund for the Maintenance and Development of Basic Education and Respect for Educators (Fundeb). |
| Rules | The Federal District and municipalities with children enrolled in day cares are eligible, they just have to respond the Basic Education School Census on a regular basis. Identifying children benefiting from the Family Allowance, BPC, disabled children, is a responsibility of the Federal Government. |
| Legal framework | Law No. 12,722/2012; Resolution CD/FNDE/MEC No. 19/2015; Resolution CD/FNDE No. 1/2016; Interministerial Commission Resolution No. 1/2014; Resolution CD/FNDE/MEC No. 19/2014. |

Source: Based on BRAZIL (2017).

*Panel 1.11. Elements of the Productive Inclusion Program.*

| Productive Inclusion Program | Information |
|---|---|
| Characteristics | Set of initiatives to encourage and facilitate the engagement of poor, rural and urban workers and entrepreneurs with opportunities that broaden and strengthen their integration and permanence in the work force. |
| Objectives | To reduce poverty and social inequalities by including poor families, with priority to be beneficiaries in the Family Allowance Program, into productive inclusion paths and opportunities within the territory, contributing to improve the quality of life of the population and to the strengthen their capacities and skills. |
| Benefits | ● Professional training.<br>● Workforce intermediation.<br>● Microcredit.<br>● Individual microentrepreneur.<br>● Technical and managerial assistance.<br>● Social economy.<br>● Fostering Urban and Rural Productive Activities.<br>● Technical assistance and Rural extension.<br>● Inputs and water supply.<br>● Food procurement programs |

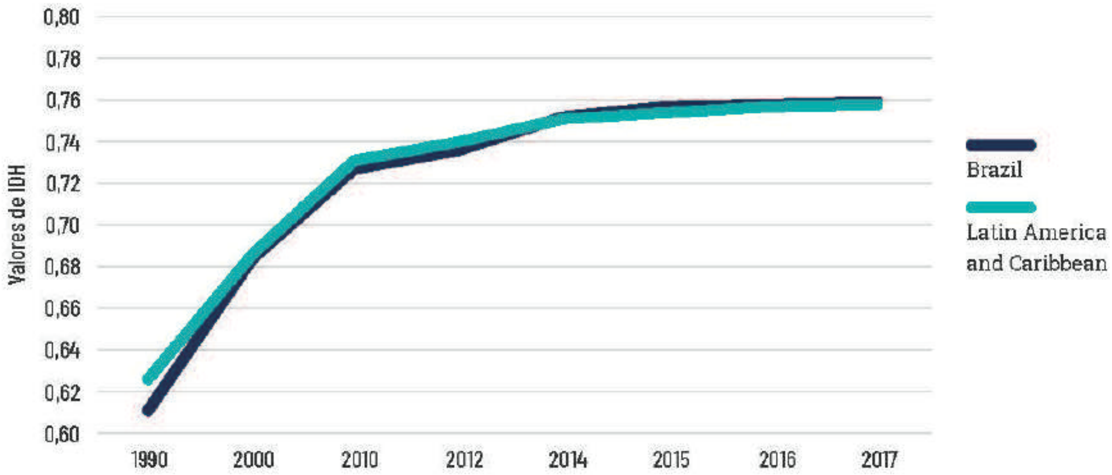
Source: Based on BRAZIL (2017).

Social assistance initiatives are part of the non-contributive Social Security Policy, which ensures a minimum. They are carried out through an integrated set of actions by the public enterprise and society, to ensure that basic needs are met. This program is organized by the Universal Social Assistance System (SUAS, for its acronym in Portuguese) across Brazil. Its objective is to ensure social protection to all citizens, i.e., to provide support to individuals, families and communities in overcoming their difficulties, by the provision of services, benefits, programs and projects (BRAZIL, 2017).

Furthermore, the Federal Constitution guarantees the right to adequate food, which means that foodstuffs must be healthy, accessible, of quality, in sufficient quantity and provided on a permanent basis. In order to promote food and nutritional security, the National Food and Nutrition Security System combines several sectors of the federal, state and municipal governments, with the participation of the civil society, which carry out programs and actions, such as the Food Procurement Program, the Cistern Program and the Program to Promote Rural Productive Activities, so that the population can have access to healthy food (BRASIL, 2017).

### *Evolution of the Human Development Index (HDI), poverty and income in Brazil*

The Human Development Index (HDI) is usually used to assess the efficiency of social policies. Brazil's HDI grew by 0.005 points in 2017 when compared to 2015, reaching 0.760, at a scale that varies from 0 to 1 – the closest to 1, the higher the human development (Figure 1.3).




Latin America and the Caribbean Brazil

Source: Based on UNDP (2018)

*Figure 1.3. Evolution of HDI in Brazil and Latin America and the Caribbean between 1990 and 2017.*

According to the United Nations Development Programme (UNDP), the increase in Brazilians' average per capita income ensured that the country continued to advance the index in the period. According to the Index, Brazil ranked 79th in 2019. The ranking included 189 countries. The HDI mean annual growth between 1990-2017 in Brazil was 0.81% (UNDP, 2018), as a response to the policies described below, which maintained economic and social gains.

Improving the living standards and increased access to quality health increased Brazilians' life expectancy at birth to 76 years of age (UNDP, 2016). Average school years went up to 7.8 years in Brazil, which shows the need to broaden the scope of the country's educational policies, since in other Latin American and Caribbean countries the average is 8.5 years. Progress of the country's economic Indicators is described in Table 1.1.

*Table 1.1. Economic indicators in Brazil between 2000 and 2018.*

| **Socio-economic Indicators[21]** | **2000** | **2010** | **2013** | **2015** | **2016** | **2017** | **2018** |
|---|---|---|---|---|---|---|---|
| GDP (in billions of BRL, current values) | 1,199 | 3,886 | 5,332 | 5,996 | 6,267 | 6,554 | 6,828 |
| GDP (in billions of USD, constant values from 2011) | 1,993 | 2,861 | 3,123 | 3,028 | 2,928 | 2,959 | 2,992 |

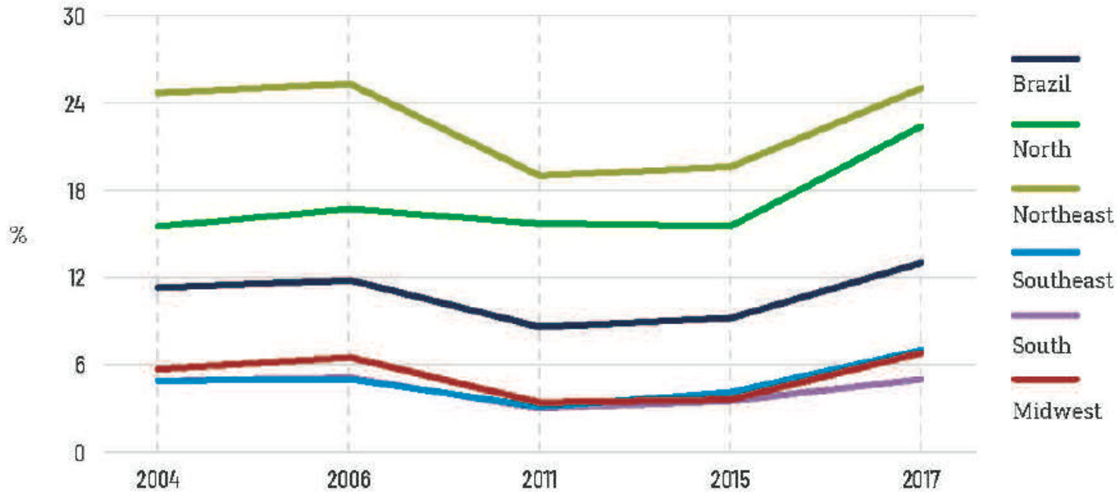
[21] *World Bank, 2020. World Bank Open Data. Available at <https://data.worldbank.org/>. Accessed on: 15 May 2020*

| Socio-economic Indicators[21] | 2000 | 2010 | 2013 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|
| GDP per capita (in thousands of BRL, current values) | 6,860 | 19,855 | 26,521 | 29,323 | 30,399 | 31,534 | 32,595 |
| GDP per capita (USD, constant values from 2011) | 11,403 | 14,620 | 15,536 | 14,807 | 14,200 | 14,236 | 14,283 |
| Human Development Index (HDI) | 0.684 | 0.726 | 0.752 | 0.755 | 0.757 | 0.760 | 0.761 |
| Gini Index (World Bank estimate) | 59(1) | 53.7(1) | 52.8 | 51.9 | 53.3 | 53.3 | 53.9 |
| Life expectancy at birth (years) [SDG 3] | 70.1 | 73.6 | 74.5 | 75.0 | 75.2 | 75.5 | 75.7 |
| Infant mortality rate (per 1,000 births) [SDG 3.2] | 30.4 | 16.7 | 14.9 | 14 | 14.6 | 13.2 | 12.8 |
| Percentage of the population living on less than US$1.9 per day (PPP[22] 2011) | 13.4(1) | 5.4(1) | 3.1 | 3.2 | 3.9 | 4.4 | 4.4 |

(1) Data unavailable for the year; previous year data repeated.

In Brazil, poverty is seen from a monetary point of view, i.e., from a value that serves as a threshold to define poor and not poor. Pursuant to the social policy objectives described above, the definition of the minimum wage as a threshold is adopted for the definition of poverty. This indicator appears when surveying IBGE social indicators since the early 2000s (IBGE, 2018a).

[22] *PPP – Purchasing Power Parity. Value outlined according to an assessment of the ideal limit to capture the country's poverty in relation to the rest of the world, but also controlling its level of development.*




Source: Based on IBGE (2018d).

*Figure 1.4. Brazilian extreme poverty threshold between 2004 e 2018.*


Source: Based on MC/VIS – DATA (2019).

*Figure 1.5. Family Allowance Program eligible households between 2004 and 2017.*

### *Health profile and access to basic sanitation in Brazil*

Since 1999, the Brazilian Institute of Geography and Statistics publishes, on an annual basis, the Abridged Life Tables corresponding to the Brazilian population. The 2017 child mortality table raised the probability that, for every thousand newborns, approximately 13.2 would not complete the first year of life, with a child mortality rate of 12.8 per thousand births (IBGE, 2018b).

Child mortality declined between 2010 and 2017. However, the rate is still high and focused on the first year of life. In 1940, chance of death between the ages of 1 and 4 years was 30.9% due to sanitary conditions, a two-fold higher chance of death than the one observed in 2017. Mortality of children under 1 year-old is an important indication of a region’s socioeconomic condition.

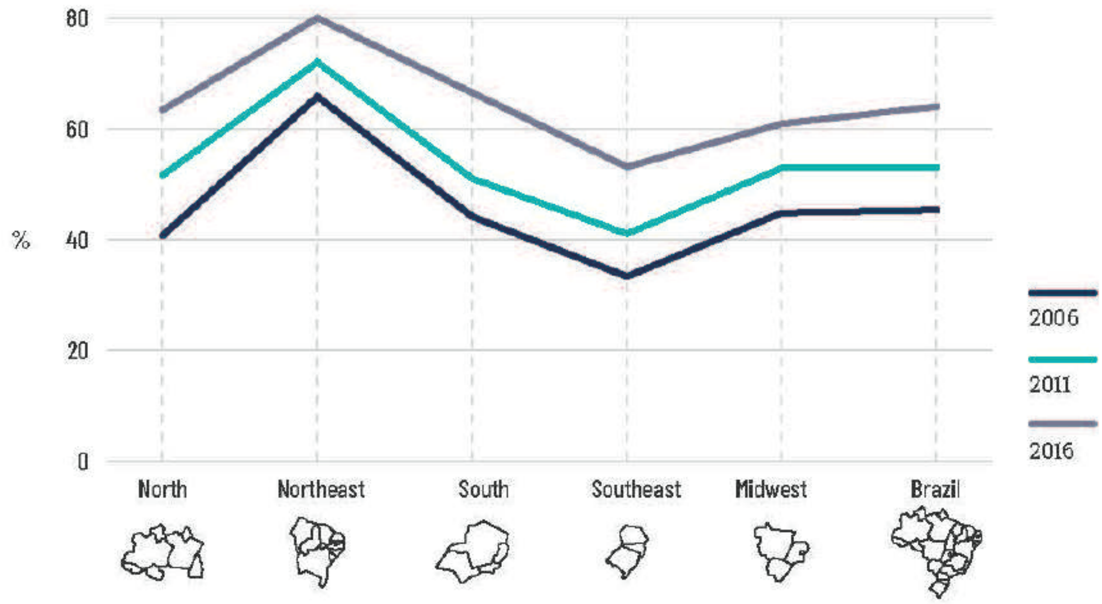
Caution and prudence during prenatal care are important factors to reduce child and maternal mortality rates. Child mortality declined by 56% in Brazil between 1990 and 2015. This decline has been noted by the World Health Organization (WHO) when it states there have been significant advances in public health policies since the 90s. According to data provided by the Mortality Information System, in 2015 Brazil registered 1,738 cases of maternal death, including deaths caused by complications during and following pregnancy and childbirth (42 days after childbirth). 1,463 cases were registered in 2016, a 16% drop in relation to the previous year (MS, 2018).

In the past few years, several actions have been implemented to reduce infant and child mortality in Brazil: campaigns for mass vaccination, prenatal care, breastfeeding, community health workers, child nutrition programs. Other factors described above have also contributed to this decline, i.e., the increase in the GDP per capita and the decrease in poverty levels. Most importantly, reference must be made to the implementation of relevant public health policies, such as the Universal Health System (SUS, for its acronym in Portuguese) and the Family Health Program (PSF, for its acronym in Portuguese).

The Family Health Program, developed from the Community Health Worker Program (PACS, for its acronym in Portuguese), was created in 1994 to modify health care and redirect the model of assistance, focusing on health promotion and disease prevention, in order to reorganize services according to the Universal Health System principles of universality, integrity and equity. The Project for the Expansion and Consolidation of Family Health (PROESF, for its acronym in Portuguese) was established in 2003.The Family Health Program became the Family Health Strategy (ESF, for its acronym in Portuguese) in 2006.

The Family Health Strategy is community-based. It reorganizes and directs the expansion, qualification and consolidation of primary care following the principles of the Universal Health System, besides increasing problem-solving and improving the health conditions of individuals and groups, through actions aimed at promoting health, and preventing diseases and other potential harm.

From 2006 to 2016, the Family Health Strategy scope jumped from 45.3% to 64.0% of the Brazilian population. The country's five regions showed an upward trend in broadening the program's scope (Figure 1.6), as well as most states, except for Roraima, Amapá, Piauí, Rio Grande do Norte and Paraíba, which remained stable.

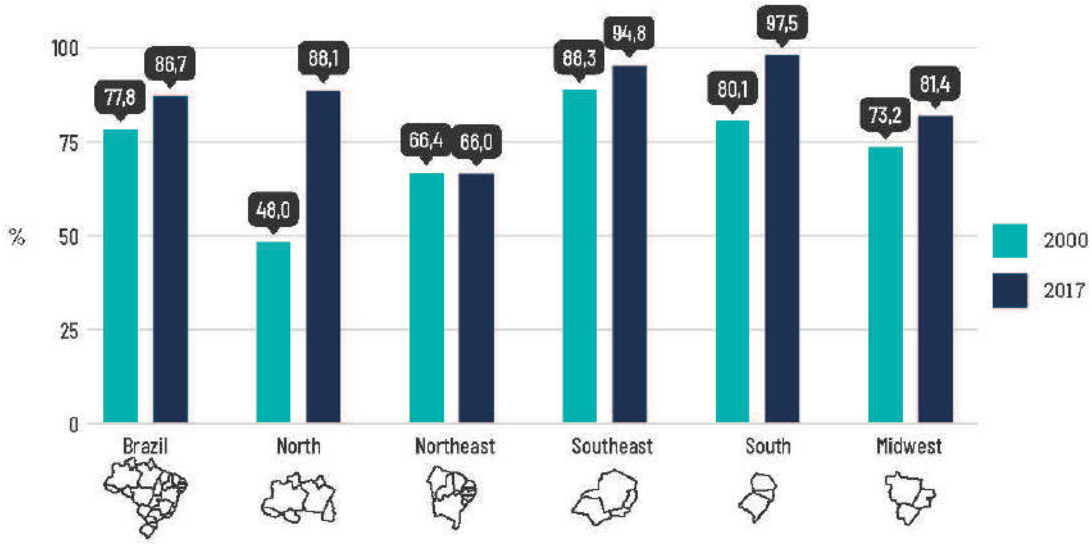



Source: Based on Neves et al. (2018).

*Figure 1.6. Scope (%) of the Family Health Strategy Program in major regions and Brazil, 2006-2016.*

Improvements in health indicators, such as the decline in child mortality, increased vaccination reach, reduced malnutrition, and increased prenatal visits, are directly associated with increased access to basic sanitation.

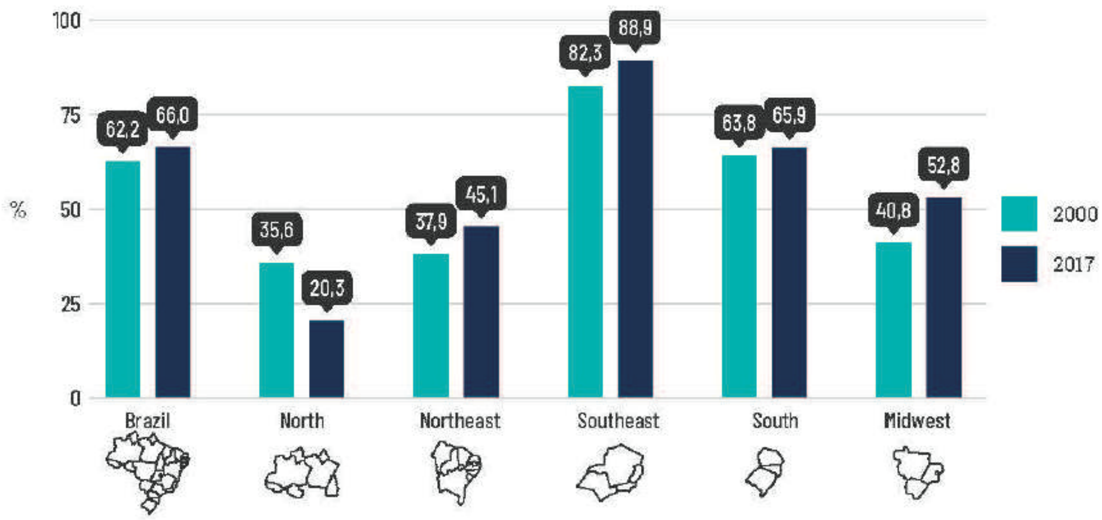
In this regard, it is worth mentioning a significant increase in the percentage of households supplied by the general water supply network between 2000 and 2017. Most Brazilian regions presented the same progress in terms of percentage of households supplied by the general network, except for the Northeastern region, which remained stable throughout the period assessed (Figure 1.7).




Source: Based on BRASIL (2016); IBGE (2018d).

*Figure 1.7. Proportion (%) of households supplied by the general water supply, by regions.*

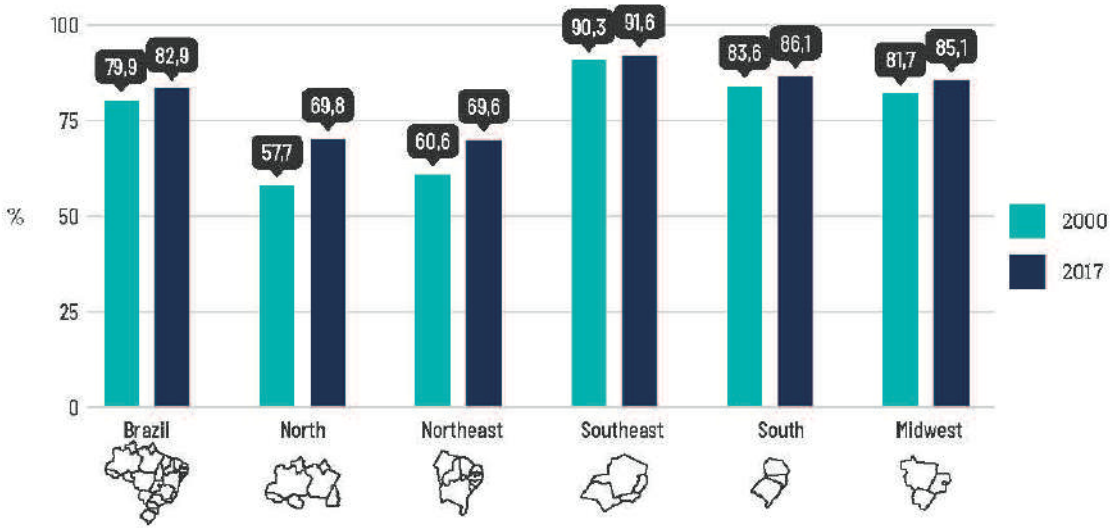
The proportion of households where sewage collection was made either by the public sewer system or septic systems was different among regions. In relation to 2000, these percentages increased in Brazil, mainly in the Northeastern and Central-West regions (Figure 1.8).




Source: Based on BRASIL (2016); IBGE (2018d).

*Figure 1.8. Proportion (%) of households served by a public sewer system and septic system, by regions.*

In 2017, the percentage of households whose waste was collected directly by a garbage collection system presented a relative increase when compared to the early 2000s. The Northeastern and Northern regions presented lower percentages in comparison with the national result. The Southern, South and Central-West regions, on the other hand, presented higher percentages in comparison with the country's average. All regions showed an increase in the number of households served by garbage collection between 2000 e 2017 (Figure 1.9).




Source: Based on BRASIL (2016); IBGE (2018d).

*Figure 1.9. Proportion (%) of households served by garbage collection by regions*

## 1.4.2 Economic, agricultural and energy circumstances

Brazil is a developing country with a complex and dynamic economy. It is an urban-industrial country, with a strong agricultural sector contributing significantly for both domestic and global economies. In addition, its electric mix is clean, and the energy mix is transitioning to be predominantly based on renewable energies. In 2018, the Brazilian GDP totaled BRL 6.83 trillion, a 13.9% increase in relation to 2015, when the country was ranked by the International Monetary Fund (IMF) as the world's 9th largest economy, in gross numbers (when countries are compared without taking into account their number of inhabitants).

Brazil has set a global benchmark in sustainable agriculture by establishing an integrated approach to the landscape, adopting sustainable practices in lands that are suitable for farming and encouraging environmental regularization of rural properties. The Brazilian Forest Code is one of the most advanced pieces of environmental legislation in the world. As a general rule, the law establishes that at least 80% of the area of rural properties in the Amazon must be allocated to conservation and sustainable use of natural resources, meaning that rural producers are allowed to use a maximum of 20% of the land in their properties. In the Cerrado biome this percentage is 35%, and 20% in the remaining biomes.

In 2018, the Brazilian agricultural sector contributed with approximately 21% of the country's total GDP, with exports hitting a record-breaking nominal level of USD 101.7 billion, a 5.9% growth compared to 2017 (Cepea, 2018), out of a total national agricultural production value of BRL 343.5 billion, an 8.3% growth compared to 2017. This figure corresponds to 227.5 million tons of grains (cereals, pulses, oilseeds), besides other commodities (IBGE 2018e).

In addition to its relevant share of the GDP, according to the Center for Advanced Studies on Applied Economics (Cepea, for its acronym in Portuguese), the sector is crucial to the balance of trade, accounting for more than 40% of total exports. It employs 20% of Brazil's total occupied population, which is equivalent to 18.2 million people. Out of the total individuals employed by the sector, 45% work directly in primary production. According to the Agricultural Census, five million Brazilian households are involved in producing food, fiber, and energy. This clearly reflects the importance of sustainability in its three pillars – environmental, economic and social.

The country's strategies by encouraging technology research and development towards a sustainable tropical agriculture have led to increased productivity per hectare, followed by economic and population growth. Adoption of these technologies by rural producers has allowed for more constant food supply throughout the year, thus guaranteeing more stable prices for the consumer, not to mention better food quality. In a scenario of mounting climate uncertainty, Brazil has been establishing strategies to guarantee domestic and global food security.

Regarding energy circumstances, Brazil has the cleanest energy mix and electricity mix among the largest global consumers. The Domestic Energy Supply (OIE for its acronym in Portuguese) in 2019 was 294 million toe (tons of oil equivalent), slightly higher than in 2018, which was 288.4 million toe. A breakdown of the energy mix for 2018 and 2019 shows a significant increase in the share of renewable sources, from 45.5% in 2018 to 46.1% in 2019 (Table 1.2). This accounts for a 2.8% increase in the supply from renewable sources compared to the previous year, compared to a 0.3% increase in non-renewable sources during the same period.

Brazil's share of renewables in its energy mix is currently 4.3 times larger than the average in OECD countries and 3.3 times larger than the average for the rest of the world. A study conducted by the International Energy Agency revealed that Brazil would reach the share of 44.3% of renewable energies in its energy mix by 2023, but the country exceeded that share as early as in 2018 (MME, 2020e).

With regard to the generation of electric energy, in 2018-2019 wind energy supply increased by 15.5% and hydro generation rose by 2.3%. Photovoltaic solar generation deserves special notice, since it reported a significant increase of 92% in this period. So, the country's electricity mix remains primarily based on renewable sources, with the prospect of increasing its share over the next few years given the growing competitiveness of wind and solar sources. Brazil has a share of 83% of renewable sources in its electricity mix, i.e., 2.9 times larger the average in OECD countries and almost 3.1 times larger than the average for the rest of the world (MME, 2020e).

As far as bioenergy is concerned, sugarcane products have stood out. The total bioenergy supply in 2019 was 93.9 Mtoe, which accounts to 31.9% of the Brazilian energy mix and represents an increase compared to 2018, which was 31.4%. In the transportation sector, a highlight is the increased share of ethanol in the light vehicle segment. In 2019, ethanol production was 35.2 million $m^3$, up 5.6% over 2018. Biodiesel production in 2019 increased by 10.7% over 2018, thus confirming the growth trend of previous years.

*Table 1.2. Share (%) of renewable and non-renewable sources in the energy mix*

| *DOMESTIC ENERGY SUPPLY SOURCES* | *SHARE (%)* | | |
|---|---|---|---|
| | 2010 | 2018 | 2019 |
| Non-Renewable | **54.7** | **54.5** | **53.9** |
| OIL AND OIL BY-PRODUCTS | 37.7 | 34.4 | 34.4 |
| NATURAL GAS | 10.3 | 12.4 | 12.2 |
| MINERAL COAL AND COKE | 5.2 | 5.7 | 5.3 |

| *DOMESTIC ENERGY SUPPLY SOURCES* | *SHARE (%)* | | |
|---|---|---|---|
| | 2010 | 2018 | 2019 |
| URANIUM ($U_3O_8$) | 1.4 | 1.4 | 1.4 |
| OTHER NON-RENEWABLE (a) | - | 0.6 | 0.6 |
| RENEWABLE | **45.3** | **45.5** | **46.1** |
| WATER | 14.1 | 12.6 | 12.4 |
| WOOD AND CHARCOAL | 9.5 | 8.8 | 8.7 |
| SUGARCANE BY-PRODUCTS | 17.7 | 17.3 | 18.0 |
| OTHER RENEWABLE SOURCES (b) | 3.8 | 6.8 | 7.0 |
| TOTAL | **100.0** | **100.0** | **100.0** |

(a) Blast, steel and sulfur furnace gases; (b) bleach, biodiesel, wind, solar, rice husk, biogas, wood waste, charcoal gas and elephant grass.
Source: Based on MME (2020e; MME, 2011).

*Table 1.3. Share (%) of renewable and non-renewable sources in the energy mix.*

| *DOMESTIC ENERGY SUPPLY SOURCES* | *SHARE (%)* | | |
|---|---|---|---|
| | 2015 | 2018 | 2019 |
| NON-RENEWABLE | **24.5** | **17.0** | **17.0** |
| WATER | 58.4 | 61.1 | 61.1 |
| SUGARCANE BAGASS | 5.5 | 5.6 | 5.7 |
| WIND POWER | 3.5 | 7.6 | 8.6 |
| SOLAR | 0.010 | 0.54 | 1.02 |
| OTHER RENEWABLE | 2.4 | 3.0 | 2.8 |
| OIL | 4.2 | 1.5 | 1.1 |
| NATURAL GAS | 12.9 | 8.6 | 9.3 |

| DOMESTIC ENERGY SUPPLY SOURCES | SHARE (%) | | |
|---|---|---|---|
| | 2015 | 2018 | 2019 |
| COAL | 3.1 | 2.2 | 2.4 |
| NUCLEAR | 2.4 | 2.5 | 2.5 |
| OTHER NON-RENEWABLE | 2.0 | 1.9 | 1.9 |
| IMPORTATION | 5.6 | 5.5 | 3.8 |
| TOTAL | **100.0** | **100.0** | **100.0** |

Source: Based on MME (2020e; MME, 2016).

## 1.5. RELEVANT INSTITUTIONAL ARRANGEMENTS FOR THE IMPLEMENTATION OF THE CONVENTION IN BRAZIL

Brazil plays a relevant role in climate change global governance. At the international level, Brazil's leading role was marked by the United Nations Conference on Environment and Development, (Earth Summit ECO-92). Brazil was the first country to sign the Convention, which was ratified by the National Congress on 28 February 1994. In 2012, the country confirmed the importance of the theme by hosting Rio+20. Moreover, as Party to the UNFCCC, the country fulfills its commitment to prepare and submit its National Communication (NCs) based on the guidelines provided by the Conference of the Parties (COP) for non-Annex I Parties (Decision 17/CP.8). In this regard, the Government of Brazil has successfully submitted its First, Second and Third (TCN) National Communications. An important contribution is provided by the several research programs conducted by Brazil's Science and Technology (S&T) system, with the significant engagement of the Brazilian Research Network on Global Climate Change (Rede CLIMA). Scientific research helps bridge information gaps identified in the previous NCs, while contribute significantly for the development of climate knowledge and its repercussions at the regional and national levels.

Within the scope of international climate agreements, the country ratified the Kyoto Protocol on 23 August 2002[23], and the Protocol gained legal force in Brazil in the form of Legislative Decree No. 144 in 2002. In 2009, the Conference in Copenhagen (COP 15/MOP 5) marked the conclusion of a two-year process of negotiations on a new climate agreement, initiated with the Bali Action Plan. On that occasion, Brazil indicated its national voluntary commitment for the Nationally Appropriate Mitigation Actions (NAMAs), in which it established a reduction of greenhouse gas emissions of 36.1% to 38.9% by 2020, formalized by Law No. 12,187 of 29 December in the same year. Considering these developments, the Paris Agreement was approved by 195 countries, including Brazil, in 2015, at the 21st Conference of the Parties (COP21) of the UNFCCC.

The repercussions of these actions in the national context are countless. Brazil has established projects, activities, programs and political actions in order to monitor and mitigate emissions, as well as monitor impacts and adapt to climate change. Brazil's NAMAs include, but are not limited to: reductions in deforestation in the Amazon and Cerrado

[23] *Available in Portuguese at: http://www.mma.gov.br/clima/convencao-das-nacoes-unidas/protocolo-de-quioto.html*

biomes; restoration of degraded grazing land; increased area for integrated crop-livestock system and no-till farming; biological nitrogen fixation; improved energy efficiency actions.

A set of regulatory frameworks and management tools has since been improved in the country. As a result, government programs and initiatives for the follow-up of the implementation of actions and emission reductions have either been enforced or are under development.

Regarding financing of mitigation and adaptation activities, the country has implemented innovative mechanisms, such as the Climate Fund and the Amazon Fund. The Climate Fund has the purpose of ensuring resources to support projects or studies and for the financing of projects that have as their objective the mitigation of climate change. The Amazon Fund aims at raising donations for nonrecoverable investments in actions of prevention, monitoring and combating deforestation and to promote the conservation and sustainable use of forests, especially in the Amazon biome. The Climate Fund and the Amazon Fund have jointly supported 302 projects, with investments mounting BRL 1.9 billion.

In order to meet the broad and diversified set of initiatives for mitigation and adaptation to climate change, the Government put together a cross-cutting institutional arrangement through coordinated activities at different levels (national and subnational), as presented below.

## 1.5. 1 The Interministerial Committee on Climate Change (CIM)

The Interministerial Committee on Climate Change (CIM, for its acronym in Portuguese) has a permanent nature and was reinstituted by Decree No. 10,145/2019[24]. Within this framework, it is up to the CIM to establish guidelines, arrange and coordinate the implementation of the country's public actions and policies related to climate change. Panel 1.12 presents a summary of its key elements.

*Panel 1.12. Key elements of the Interministerial Committee on Climate Change (CIM).*

| The Interministerial Committee on Climate Change | |
|---|---|
| **Legal framework** | Decree No. 10,145/2019. |
| **Objective:** | Provides for the Interministerial Committee on Climate Change. |
| **Purpose** | The Interministerial Committee on Climate Change (CIM), of a permanent nature, has the purpose of establishing guidelines, arranging and coordinating the implementation of the country's public actions and policies related to climate change: Paragraph 1. Pursuant to the provisions of the caput, the public policies, development plans and government programs of the Federal Executive Branch shall be harmonized with the guidelines and recommendations established by CIM resolutions; Paragraph 2. In order to promote synergy and convergence among climate change policies and other public policies without prejudice to the institutional competences provided for in Law 13,844 of 18 June 2019, the CIM shall be previously consulted on matters related to climate change actions, plans and policies and the commitments made by the country regarding the theme, in particular proposals for projects started by the Federal Executive Branch; Paragraph 3. The CIM shall promote dialogue with the National Congress, subnational governments, society, the business sector and the scientific-academic sector. |

[24] *The original Decree nº 6.263/2007 was revoked by the Decree nº 10.223/2020. Available in Portuguese at: <http://www.planalto.gov.br/ccivil_03/_ato2019-2022/2019/decreto/D10145.htm >*

| The Interministerial Committee on Climate Change | |
|---|---|
| **Competencies** | Under the terms of this Decree, among other actions to achieve the objectives of public actions and policies related to climate change, the CIM's responsibilities include, but are not limited to: I) define guidelines for the Brazilian Government action policies related to climate change, including its role in the United Nations Framework Convention on Climate Change (UNFCCC), enacted by Decree No. 2,652, of 1 July 1998, and associated instruments; II) coordinate and direct policies in federal bodies that directly or indirectly impact national greenhouse gas emissions or removals and the country's capacity to adapt to the effects of climate change, without prejudice to the respective institutional competencies; III) deliberate on the country's strategies for the elaboration, implementation, financing, monitoring, assessment and updating of policies, plans and actions related to climate change, among which: the subsequent Nationally Determined Contributions- NDCs in the scope of the Paris Agreement, enacted by Decree No. 9,073, of 5 June 2017, and their updates; IV) monitor the implementation of the country's NDC in the scope of the Paris Agreement, as well as transparency and information provision activities, in compliance with UNFCCC decisions ; V) propose updates to the National Policy on Climate Change (PNMC, for its acronym in Portuguese); VI) establish guidelines and elaborate proposals for economic and finance mechanisms to be adopted in order to enable the implementation of climate change policies' strategies, aiming at promoting efficiency and efficacy in the use of resources and maximizing policy benefits and outcomes; VII) assure coherence between the PNMC and the actions, measures and policies that directly or indirectly impact national greenhouse gas emissions and removals, and the country's capacity to adapt to climate change, without prejudice to the respective institutional competencies; and VIII) promote policies, plans and actions related to climate change, among which the subsequent NDCs to the Brazilian society. |
| **Institutional arrangement** | The CIM shall have a deliberative body in the form of a Council of Ministers, composed by: I) Chief of Staff of the Presidency, who will be the Council's Chair; II) Ministry of Foreign Affairs; III) Ministry of the Economy; IV) Ministry of Agriculture, Livestock and Supply; V) Ministry of Regional Development; VI) Ministry of Mines and Energy; VII) Ministry of Science, Technology and Innovations; VIII) Ministry of the Environment; and IX) Ministry of Infrastructure. Incumbents may be substituted by their Executive Secretaries or by the Secretary-General, in the case of the Ministry of Foreign Affairs. |

Source: Based on BRAZIL (2020).

### 1.5.2 National Committee for the Reducing Emissions from Deforestation and Forest Degradation, Conservation of Forest Carbon Stocks, Sustainable Forest Management and Enhancement of Forest Carbon Stocks (CONAREDD+)

The National Committee for the Reducing Emissions from Deforestation and Forest Degradation, Conservation of Forest Carbon Stocks, Sustainable Forest Management and Enhancement of Forest Carbon Stocks (CONAREDD+) was established by Decree No. 10,144/2019, which revoked Decree No. 8,576, of 26 November 2015 and Articles 2 and 3 of Decree No. 6,527, of 1 August 2008. Panel 1.13 summarizes the Committee's objectives, competencies and institutional arrangement.

*Panel 1.13. Key elements of the National REDD+ Committee*

| National REDD+ Committee | |
|---|---|
| **Legal framework** | Decree No. 10,144/2019 (Revokes Decree No. 8,576, of 26 November 2015; and Art. 2 and 3 of Decree No. 6,527, of 1 August 2008). |
| **Objective:** | Institutes the National Committee for the Reducing Emissions from Deforestation and Forest Degradation, Conservation of Forest Carbon Stocks, Sustainable Forest Management and Enhancement of Forest Carbon Stocks (CONAREDD+), with the purpose of coordinating, overseeing and monitoring the implementation of the National REDD+ Strategy, and coordinating the elaboration of eligibility conditions to REDD+ results-based payments and actions in Brazil, accredited by the UNFCCC. |
| **Definition** | For the purposes of this Decree, REDD+ results-based payments mean payments from multiple sources, in recognition of reduced emissions measured, reported and verified from policies, programs, projects and actions undertaken on multiple scales. |
| **Competencies** | CONAREDD+ is the implementation and advisory body of States, the Federal District and the Ministry of the Environment, created to formulate guidelines and issue resolutions on: I) implementing the REDD+ National Strategy; II) considering and respecting REDD+ safeguards; III) REDD+ results-based payments in Brazil, accredited by the United Nations Framework Convention on Climate Change; IV) allocation of reduced emissions, including the definition of percentage for federal bodies, according to their competences, and for forest carbon private initiative programs and projects; V) eligibility to access REDD+ results-based payments owed to the country; VI) fundraising by REDD+ results-based payment eligible entities; VII) the use of REDD+ results-based payment raised by eligible entities; VIII) regulation of standards and technical methodologies for the development of REDD+ projects and actions; and IX) formulation, regulation and structuring of financial and market mechanisms to promote and encourage the reduction of REDD+ emissions, based on the provisions of Articles 5, 6, 8 and 9 of Law No. 12,187, of 29 December 2009. |
| **Institutional arrangement** | CONAREDD+ is composed of representatives and their deputies of the following bodies: I) Ministry of the Environment, which will coordinate it and take on Executive Secretariat functions; II) Ministry of Foreign Affairs; III) Ministry of the Economy; IV) Ministry of Agriculture, Livestock and Supply; V) Ministry of Science, Technology and Innovations; VI) one representative from environmental state bodies, who must be an official occupying an effective or commission-paid position, to be chosen from among those indicated by the States, by drawing lots; and VII) one representative of the Brazilian organized civil society, represented by the Executive Secretary of the Brazilian Forum on Climate Change. |

Source: Based on BRAZIL (2020).

### 1.5.3 Executive Committee for the Control of Illegal Deforestation and Recovery of Native Vegetation

The recent improvements in the institutional framework for the implementation of the Convention in Brazil also led to creation of the Executive Committee for the Control of Illegal Deforestation and Recovery of Native Vegetation by Decree No. 10,142/2019. The committee is a collegiate policy-making body towards reducing illegal deforestation and recovering native vegetation. Its competencies, legal framework and institutional arrangement are described in Panel 1.14.

*Panel 1.14. Key elements of the Executive Committee for the Control of Illegal Deforestation and Recovery of Native Vegetation*

| **Executive Committee for the Control of Illegal Deforestation and Recovery of Native Vegetation** | |
|---|---|
| **Legal framework** | Decree No. 10,142/2019 (Revokes the Decree dated 3 July 2003; the Decree dated 15 March 2004; Art. 3 and 4 of the Decree dated 15 September 2010; and Art. 7 and 8 of Decree No. 8,972, of 23 January 2017). |
| **Objective:** | Institutes the Executive Committee for the Control of Illegal Deforestation and Recovery of Native Vegetation within the scope of the Ministry of the Environment. |
| **Competencies** | The Executive Committee for the Control of Illegal Deforestation and Recovery of Native Vegetation is a collegiate policy-making body towards reducing illegal deforestation and promoting the recovery of native vegetation, with the following competencies: I) propose plans and guidelines, and integrate strategic actions for the prevention and control of illegal deforestation and recovery of native vegetation in the biomes; II) coordinate and monitor the implementation of action plans for the prevention and control of illegal deforestation in the biomes, as provided for in item III of the caput of Article 6 of Law No. 12,187, of 29 December 2009; III) coordinate and monitor the implementation of the National Policy for the Recovery of Native Vegetation and the National Plan for the Recovery of Native Vegetation; IV) coordinate the development and implementation of initiatives related to the forest sector in the scope of Brazil's Nationally Determined Contributions; V) propose priorities for the application of resources aimed at reducing illegal deforestation and increasing native vegetation areas; VI) propose measures to strengthen the Government's role in strategic actions to achieve the objectives established by policies and plans provided for in items II and III; VII) propose partnerships between bodies and agencies of the federal, state and municipal public administration, private agencies and civil society; and VIII) promote joint actions to produce, harmonize, and disclose official information related to deforestation, land use and cover, and fires. |
| **Institutional arrangement** | I) representative of the Ministry of the Environment, which will coordinate and take on Executive Secretariat functions; II) representative of the Ministry of Agriculture, Livestock and Supply; III) representative of the Ministry of Science, Technology and Innovations; IV) representative of the Ministry of Defense; V) representative of the Ministry of Economy; VI) representative of the Ministry of Justice and Public Security; and VII) representative of the Ministry of Regional Development. |

Source: Based on BRAZIL (2020).

### 1.5.4 General Coordination of Climate Science and Sustainability of the Ministry of Science, Technology and Innovations (MCTI)

According to Ordinance No. 217 of 25 January 2019, which approves the Rules of Procedure of internal MCTI bodies and the discloses the demonstrative framework of commission-paid positions and appointed positions, the General Coordination of Climate Science and Sustainability (CGCL, for its acronym in Portuguese) acts as part of the organizational structure of the Secretariat of Scientific Research and Training (SEPEF, for its acronym in Portuguese). The CGCL's competencies are described in Panel 1.15.

*Panel 1.15. Competences- General Coordination of Climate Science and Sustainability (CGCL)*

| Competences | Description: |
|---|---|
| I | Advise the Department of Science Policies and Programs (DEPPC, for its acronym in Portuguese) on policy-making and defining strategies for the implementation of programs, actions and activities, aiming at scientific and technology development and innovation in the areas of Meteorology, Climatology and Climate Change. |
| II | Coordinate, implement and monitor the implementation of the National Strategy in Science, Technology and Innovation (ENCTI, for its acronym in Portuguese), thus contributing for the implementation of public policies within the scope of its competencies. |
| III | Support and coordinate Research, Development and Innovation (RD&I) programs and projects within the scope of its competencies. |
| IV | Technically coordinate and participate in coordination actions between the Ministry and domestic and foreign institutions, aiming at scientific and technology development within the scope of its competencies. |
| V | Monitor and participate in activities, meetings, commissions, committees, national and international councils and fora in matters within the scope of its competencies. |
| VI | Monitor, advise and support the implementation of treaties, international conventions and protocols, particularly UNFCCC and the Vienna Convention for the Protection of the Ozone Layer. |
| VII | Participate in the formulation, implementation and monitoring of international cooperation policies and programs that strengthen actions within the scope of its competencies. |
| VIII | Coordinate actions for raising and managing the resources allocated to foster capacity-building, research, technology development, and innovation, within the scope of its competencies. |
| IX | Technically advise the Secretariat in preparing and reviewing the Multi-year Plan and the Annual Budget. |
| X | Coordinate strategic activities toward the country's development, via Science, Technology and Innovation Action Plans within the scope of its competencies and in accordance with the National Science, Technology and Innovation Strategies and Sustainable Development Goals. |
| XI | Exercise other competencies that are eventually attributed within the scope of its competencies. |

Source: Based on MCTIC (2019).

The CGCL coordinates the elaboration of National Communications and Biennial Update Reports, and is also responsible for the National Emissions Registry System (SIRENE, for its acronym in Portuguese), the government's official instrument for Measurement, Reporting and Verification (MRV) of anthropogenic greenhouse gas (GHG) emissions. It implemented the "Mitigation Options of GHG Emissions in Key Sectors in Brazil" project, and is currently implementing the "Technology Needs Assessment for the Implementation of Climate Action Plans in Brazil" project. It is an important support pillar to Rede CLIMA's activities, and provides inputs for public policy-making. In addition, it is a member of CIM, REDD+, and the Executive Committee for the Control of Illegal Deforestation and Recovery of Native Vegetation, besides supporting the Brazilian Forum on Climate Change (FBMC, for its acronym in Portuguese) with technical inputs in its different thematic chambers.

Finally, it must be noted that the CGCL acts as the Designated National Authority (DNA) for the Technology Mechanism of the Convention, as well as has participated in the Brazilian delegation during negotiations under the UNFCCC and its subsidiary bodies, and evaluation and special reports review, as well as meetings of the Intergovernmental Panel on Climate Change (IPCC).

### 1.5.5 General Coordination of Climate Change and Environment of the Ministry of Agriculture, Livestock and Supply (MAPA)

Decree No. 9,667, of 2 January 2019, which approves the new Rules of Procedure and the Demonstrative Framework of the commission-paid positions and appointed positions at the Ministry of Agriculture, Livestock and Supply (MAPA, for its acronym in Portuguese), among other resolutions, provides for[25] the competencies of each Secretariat and Department regarding climate change in the organizational structure of MAPA. Within this framework, it is up to the Secretariat for Innovation, Rural Development and Irrigation to plan, foster, provide guidance, coordinate, enforce and assess the activities related to climate change impacts within the scope of MAPA (Art. 38 – II); it is up to the Department of Sustainable Production and Irrigation to propose and implement plans, programs, projects, actions and activities towards adaptation and mitigation of climate change impacts (Art. 41 – I), and, it is up to the Department of Technical, Sanitary and Phytosanitary Issues, under the Secretariat of Trade and International Relations (SCRI, for its acronym in Portuguese), to provide guidance to MAPA on international issues and processes related to environmental sustainability, climate, and climate change in agriculture; social issues related to animal welfare, forests, and other non-tariff matters; as well as deliberate on official requirements and matters of interest to agriculture, livestock, aquaculture and fisheries (Art. 45).

Structural changes led to the creation of these three new Secretariats/Departments, which were assigned attributions from units that were under other areas of the Federal Government – such as the Ministries of the Environment and Social Development, the Special Secretariat of Family Agriculture and Rural Development, the Office of the Chief of Staff, and the Secretariat of Social Mobility and Cooperativism. As per this new structure, the Secretariat for Innovation, Rural Development and Irrigation is responsible for promoting the sustainability of agricultural production systems through the promotion of technology innovation, the adoption of conservative production systems, including low carbon emission systems and irrigated farming systems. Moreover, the Brazilian Agricultural Research Corporation (Embrapa, for its acronym in Portuguese), under Mapa, is responsible for coordinating the Brazilian agricultural research and its technology development, involving other domestic and state institutions, aiming at promoting productive technology suited to the Brazilian tropical and subtropical reality.

In this regard, the Plan for Low Carbon Emission in Agriculture (ABC Plan), as one of the sectoral plans prepared in accordance with Article 3 of Decree No. 7,390/2010 – substituted by Decree No. 9,578/2018, aims at expanding the area under sustainable and resilient agricultural production systems that ensure the sustainable development of agriculture and support the reduction of GHG emissions.

*See item 4.1.6 for more information on the ABC Plan*

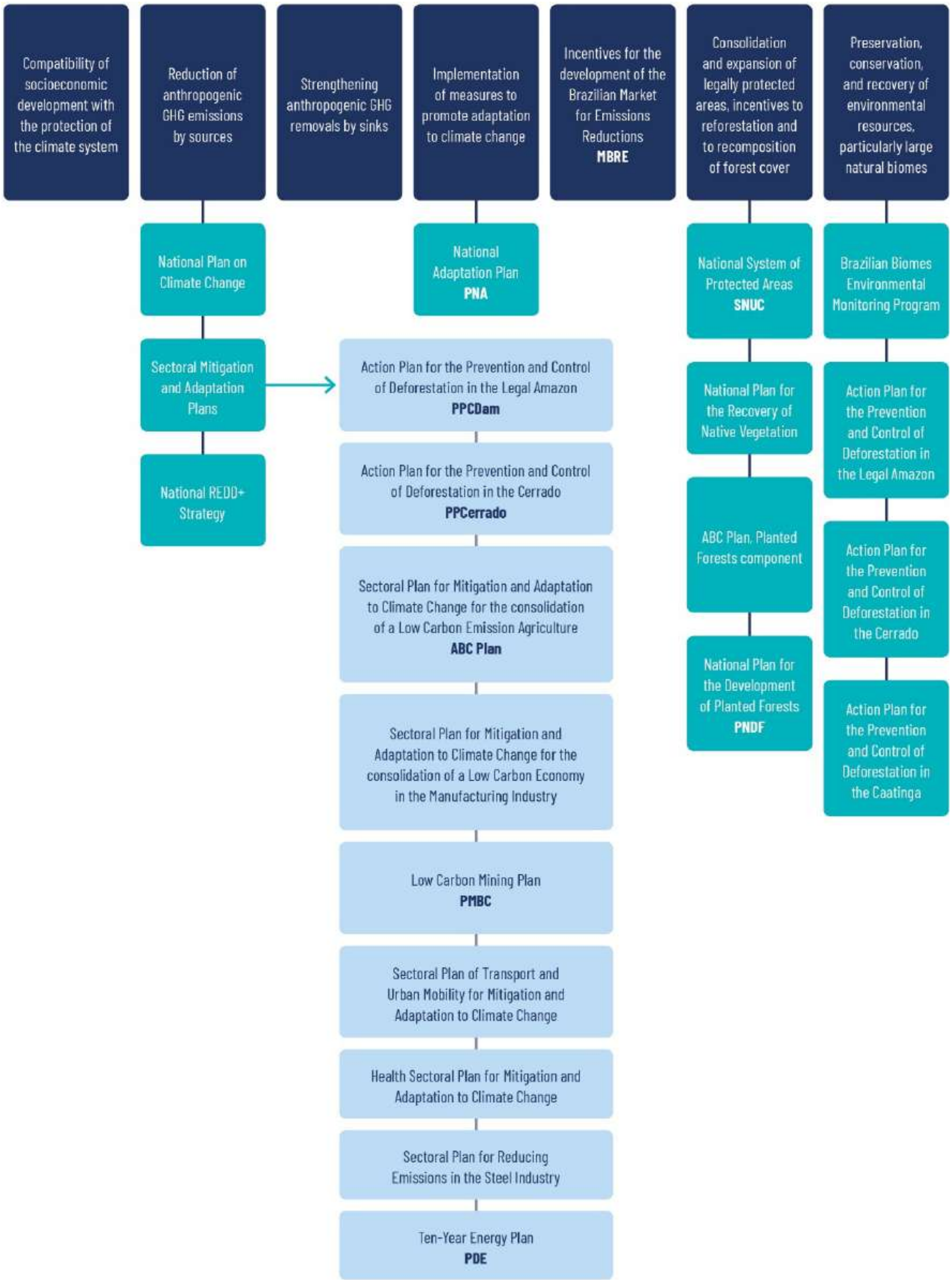
[25] *Alters Decree No. 6,464, of 27 May 2008.*

## 1.6. NATIONAL POLICY ON CLIMATE CHANGE (PNMC) AND BRAZIL'S NATIONALLY DETERMINED CONTRIBUTION (NDC) TO THE PARIS AGREEMENT

Among the regulatory frameworks and management tools aimed at implementing the UNFCCC in the country, the National Policy on Climate Change (PNMC, for its acronym in Portuguese) stands out, as it established the legal framework to tackle climate change in Brazil by 2020. Its main characteristics and components, as well as its institutional arrangement, are summarized in Panel 1.16 and Figure 1.10.

*Panel 1.16. Key elements of the National Policy on Climate Change (PNMC).*

| | |
|---|---|
| Legal Framework | Law No. 12,187/2009. |
| Goals | To promote sustainable development while protecting the climate system; to reduce greenhouse gas emissions from different sources, as well as to strengthen removals of these gases by sinks; to implement measures to adapt to climate change; to preserve, conserve and recover natural resources; to consolidate and expand legally protected areas; and to foster the development of a Brazilian Emissions Reduction Market. The objectives of the National Policy on Climate Change must be in line with sustainable development in order to pursue economic growth, eradication of poverty, and reduction of social inequalities. |
| National Voluntary Commitment | Expected reduction of greenhouse gas emissions ranging from 36.1% to 38.9% expected for 2020 (BAU - Business As Usual). |
| Instruments | Instruments under the PNMC include the National Plan on Climate Change; the National Fund on Climate Change; the Action Plans for the Prevention and Control of Deforestation – Amazon, Cerrado; Plans for Mitigation and Adaptation in Agriculture, Energy, and Charcoal, as well as Brazil's National Communication to the UNFCCC. Policy instruments also include, but are not limited to, resolutions of the Interministerial Committee on Climate Change (CIM), fiscal and tax measures, credit and financing facilities, research programs by development agencies, and financial and economic measures related to mitigation and adaptation to climate change. |
| Regulation | Decree No. 7,390/2010, which sets forth the expected emissions for 2020, and the National Voluntary Sector-Specific Commitment - revoked by Decree No. 9,578/2018. |
| Governance and institutional arrangements | The institutional instruments, within the governmental scope, are the Interministerial Committee on Climate Change (CIM for its acronym in Portuguese) and the Commission for the Coordination of Meteorology, Climatology and Hydrology Activities (CMCH for its acronym in Portuguese). The current governance of the CIM is provided for by Decree No. 10,145, of November 28, 2019, which establishes, among others, its jurisdiction and composition. The CIM functions on a standing basis and is intended to establish guidelines, design and coordinate public actions and climate change policies. The CIM's deliberative body – the Board of Ministers – is comprised of 9 Ministers of State: I - Chief of Staff of the Presidency of the Republic, who will act as the chair of the Committee; II - Minister of Foreign Affairs; III - Minister of the Economy; IV - Minister of Agriculture, Livestock and Food Supply; V - Minister of Regional Development; VI - Minister of Mines and Energy; VII - Minister of Science, Technology and Innovations; VIII - Minister of the Environment; and IX - Minister of Infrastructure.<br>At the civil society level, the Brazilian Forum on Climate Change (FBMC) and the Brazilian Research Network on Global Climate Change (Rede CLIMA) are also institutional instruments to assist in the implementation of the Convention. |




Source: Based on MMA (2009).

*Figure 1.10. Institutional arrangement of the National Policy on Climate Change (PNMC).*

Brazil deposited the Instrument of Ratification of the Paris Agreement in September 2016, in which the country pledged to adopt measures to reduce GHG emissions through its Nationally Determined Contribution (NDC) (MRE, 2016) (Panel 1.17). Moreover, the country ratified the Doha Amendment to the Kyoto Protocol in December 2017 (SF, 2017).

*Panel 1.17. Key elements of Brazil's Nationally Determined Contribution to the Paris Agreement.*

| NDC | Information |
|---|---|
| **Contribution** | To reduce its GHG emissions by 37% below 2005 levels, by 2025. |
| **Subsequent indicative contribution** | To reduce its GHG emissions by 43% below 2005 levels, by 2030. |
| **Type** | Absolute target in relation to a base year. |
| **Coverage** | 100% of the territory, economy-wide, including $CO_2$, $CH_4$, $N_2O$, perfluorocarbons, hydrofluorocarbons and $SF_6$. |
| **Reference point** | 2005. |
| **Timeframe** | single-year target for 2025; indicative values for 2030 for reference purposes only. |
| **Metrics** | 100-year Global Warming Potential (GWP-100) using IPCC AR5 values (IPCC, 2014). |
| **Methodological approaches, including those for estimating and accounting for anthropogenic greenhouse gas emissions, and as appropriate, removals** | Inventory-based approach for estimating and accounting for anthropogenic greenhouse gas emissions and removals. The contribution takes into account the role of conservation units and indigenous lands as forest managed areas, in accordance with the applicable IPCC guidelines on the estimation of emission removals. |
| **Use of markets** | Brazil reserves its position in relation to the possible use of any market mechanisms that may be established under the Paris agreement. The Brazilian Government also emphasizes that any transfer of units from mitigation results achieved in Brazil shall be subject to prior and informed consent of the Federal Government. Brazil will not recognize the use by other Parties of any units resulting from mitigation outcomes achieved in the Brazilian territory that have been acquired through any mechanism, instrument or arrangement established outside the Convention, its Kyoto Protocol or its Paris agreement. |

Source: Based on UNFCCC (2015); MCTIC (2017, 2017a); FBMC (2018).

Also considering the commitment made by the NDC, which refers to the institutional arrangements for the implementation of the Climate Convention in the country from 2020 onwards, it is important to emphasize that it was necessary to revisit them in Decree No. 10,140/2019 to 10,145/2019.

## 1.7. INSTITUTIONAL ARRANGEMENTS FOR ELABORATING NATIONAL COMMUNICATIONS ON PERMANENT BASES

*See item 1.5.4 for more information on the CGCL*

The Ministry of Science, Technology and Innovations (MCTI), via the General Coordination of Climate Science and Sustainability (CGCL, for its acronym in Portuguese), is the body responsible for implementing the Enabling Activity Project that assists the Brazilian Government in the preparation of its National Communications and Biennial Update Reports (BUR), in line with the Brazilian Cooperation Agency (ABC, for its acronym in Portuguese). This project, under a modality of National Implementation, was funded through international resources from the Global Environment Facility (GEF) and is supported by the United Nations Development Programme (UNDP) as an implementing agency.

Therefore, this Fourth National Communication (4NC) was coordinated by the CGCL, which also acted as the implementing agency of projects that resulted in the preparation of the previous National Communications, submitted to the UNFCCC in 2004, 2010 and 2016.

Since the beginning of the project, meetings with Government representatives have been held on a regular-basis to update and discuss the methodologies adopted, the progress and results achieved, aiming at keeping all Ministries involved with the climate agenda informed on the progresses and challenges faced while implementing the project.

Within the project scope, a *Project Management Unit* – PMU was created, composed of the National Director, National Coordinator and Technical Coordinator. The project's permanent team is composed of the technical coordinator, supervisors, analysts, experts, a translator, and a project assistant, who work directly with the national management and coordination. This team was hired with GEF funds, which were additionally used to enter into partnerships and hire consultancies to develop various analyses. MCTI officials have also contributed with administrative assistance and expert advice for technical issues (Figure 1.11).

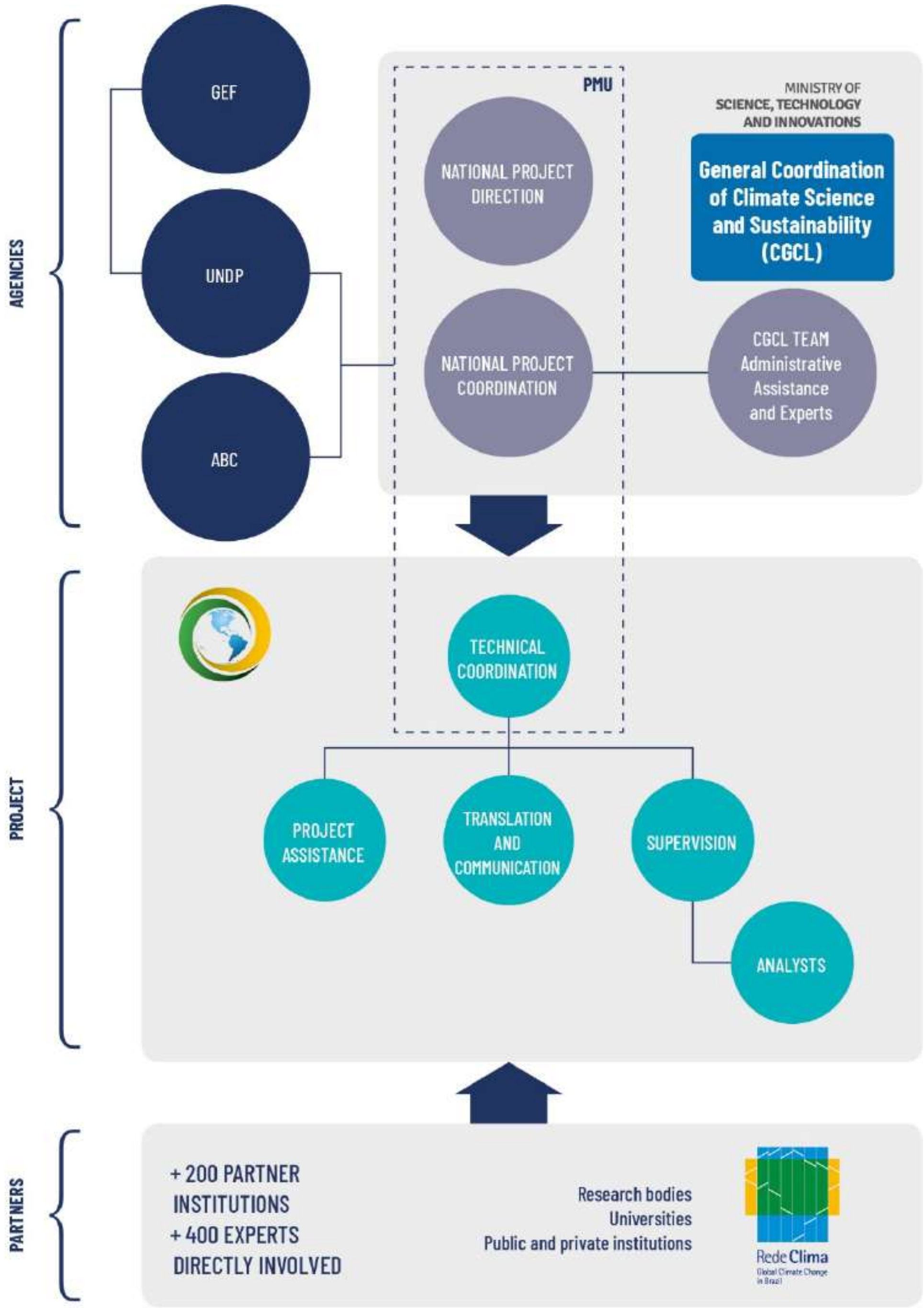



*Figure 1.11. Institutional arrangement for elaborating Brazil's Fourth National Communication*

The development of the 4NC counted on the relevant engagement of hundreds of domestic experts under several public and private institutions, such as universities, research institute and bodies, businesses and associations that have a direct contribution by providing data and developing analyses. In addition to these, other institutions were indirectly involved – they provided official national data available on public platforms.

Regarding academic and research contribution towards the 4NC, as was the case in the Third National Communication (TCN), the Brazilian Research Network on Global Climate Change (Rede CLIMA) has a significant participation, in partnership with other researchers associated to several research groups, such as the National Science and Technology Institutes (INCTs, for its acronym in Portuguese). For the fourth inventory of this Communication, the engagement of this network, with the involvement of sub-network researchers, who supported data updating, production of factors and parameters, and further discussions towards adjusting methodological premises for the sectors inventoried, is of note. The National Inventory's technical scientific coordination counted on researchers of the Federal University of Rio de Janeiro (UFRJ), the Federal Institute of Alagoas (IFAL), the University of Brasilia (UnB) and several offices of the Brazilian Agricultural Research Corporation (Embrapa), such as Embrapa – Environment; Embrapa Rice and Beans; Embrapa Agrobiology; Embrapa Forests; Embrapa Dairy Cattle; Embrapa Cattle Southeast; Embrapa Center for Temperate Climate; Embrapa Swine and Poultry; Embrapa Soils; among others. For the Industrial Processes and Product Use sector, whose data and parameters are largely sourced from the private sector, the contribution of the Federal University of Rio de Janeiro team was offered for cross-section discussions in the Energy sector.

*See item 3.1 for more information on the integrative approach*

For the 4NC chapter regarding impact, vulnerability and adaptation assessments, it was possible to count on the technical-scientific coordination of experts of the National Center for Monitoring and Early Warnings of Natural Disasters (CEMADEN, for its acronym in Portuguese), UnB, the National Institute for Space Research (INPE, for its acronym in Portuguese), UFRJ and IFAL. Furthermore, it is worth mentioning that these academic representatives are responsible for the elaboration of unpublished studies, developed from the best available science, to evaluate the impacts and regional vulnerabilities through an integrative approach from the perspective of warming level. Due to the crosscutting nature of these studies, the multidisciplinary collaboration among representatives of nearly all Rede CLIMA sub-networks secured the achievement of an integrated standpoint, especially for the analysis of adaptation options. It is expected that the result of these analyses will serve as input for discussions on the revision of the National Adaptation Plan. Finally, the engagement of Rede CLIMA's Public Policies sub-network stood out in contributing to the discussions on national circumstances and the mitigation and adaptation measures in progress in the country (Figure 1.12).

*See item 5.2.16 for more information on Rede CLIMA*

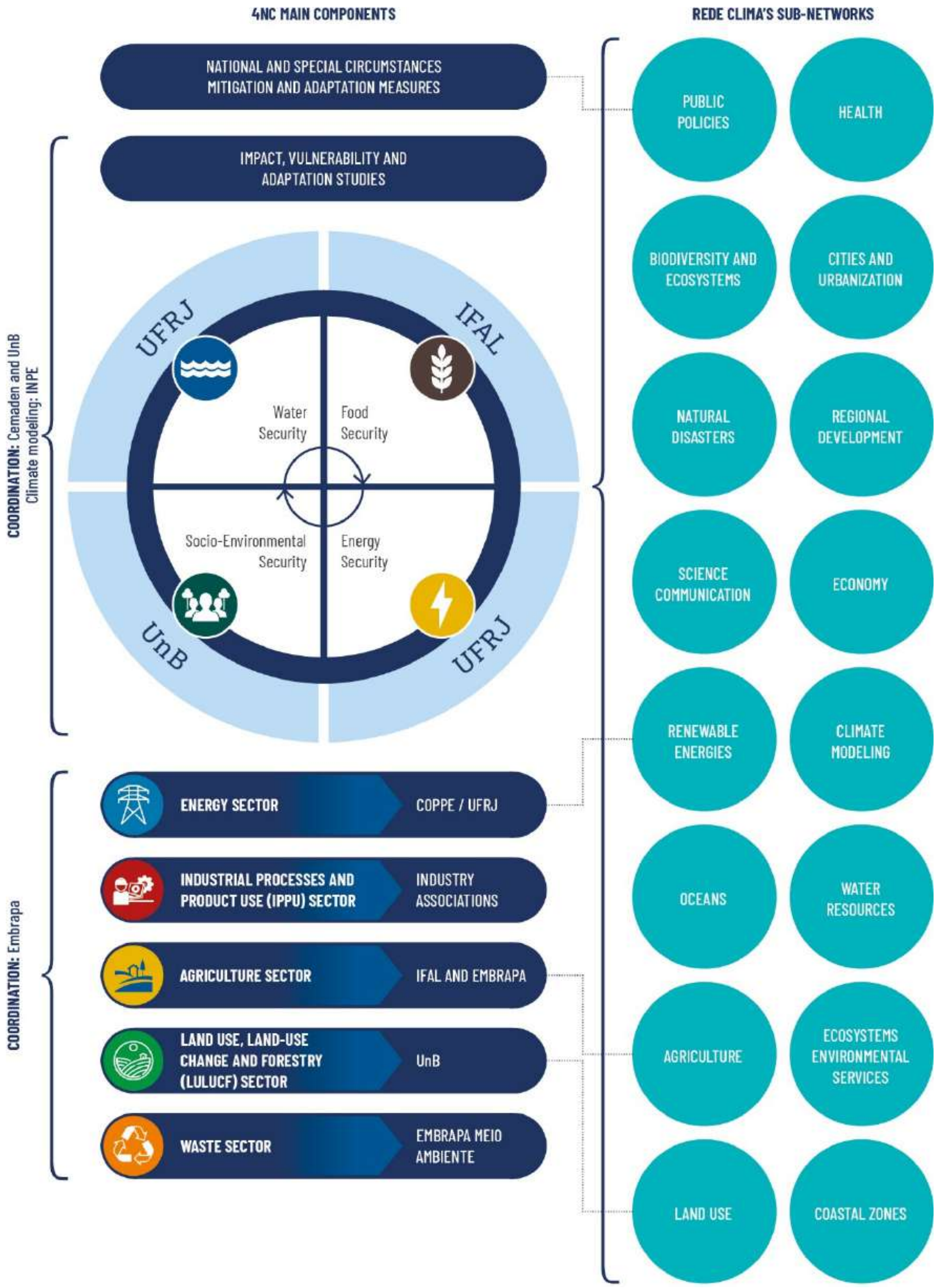



*Figure 1.12. Institutional arrangement for the technical-scientific coordination of the 4NC*

In terms of quality assurance (QA) and quality control (QC) procedures adopted by the project, the main parties involved were the CGCL, the project team, partners, experts not directly involved with the work, and government representatives. Technical outcomes were reviewed based on the planning of activities and formalization of partnerships, then, adjusted and validated by the project's technical team. In order to optimize quality control (QC) activities, strategies were additionally adopted by the project itself or by the partners. One example was the creation of a biome mapping validation committee for the National Inventory, hired by the project.

Once completed, the technical reports, such as sectoral reference inventory reports, were submitted to public consultation with experts as part of quality assurance (QA). The feedback received in this process, characterized by the participation of individuals who were not involved in developing the studies, was duly analyzed by the technical team, who incorporated improvements as appropriate. The consolidated version of the 4NC was validated and approved by representatives of the ministries involved (Figure 1.13).

Finally, the Ministry of Foreign Affairs (MRE, for its acronym in Portuguese) acts as the National Focal Point, with the mission of promoting the coordination of the Brazilian Government with the UNFCCC, as well as being responsible for the official submission of the Fourth National Communication.

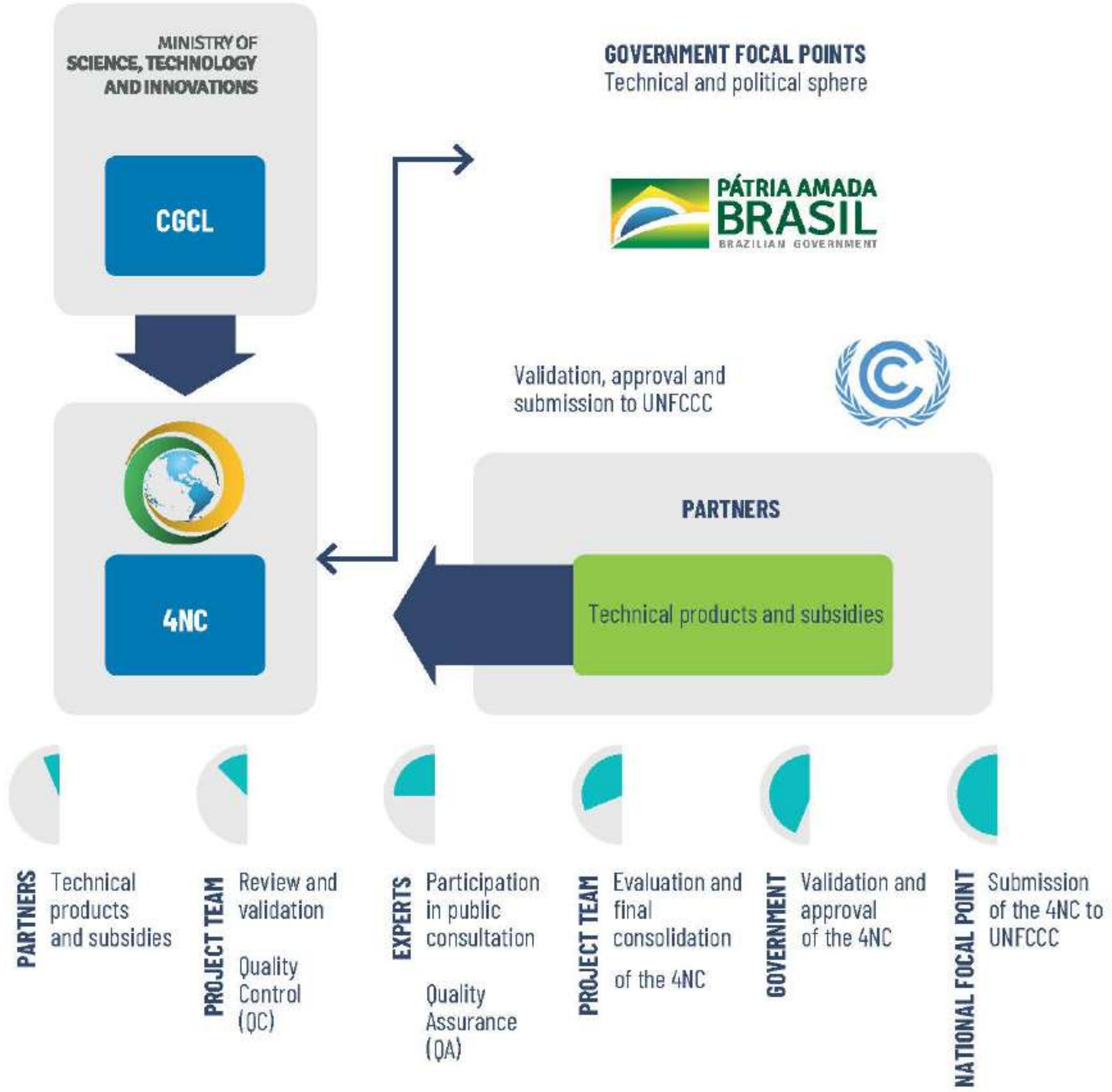



*Figure 1.13. Quality assurance (QA) and quality control (QC) procedures of Brazil's Fourth National Communication*

### 1.7.1 Financial, Technical and Capacity-Building Difficulties Associated with the Preparation of the National Communication

Regarding the financial aspects for the elaboration of the 4NC, there were no budget restrictions due to the correct estimate of funds for the BRA/16/G31 Project and the high USD to BRL rate during project implementation. It must be noted that the resources provided by GEF were pivotal to ensure the structuring of the project team, the entering into of partnerships and the hiring of consultancies and services – without which it would not be feasible to meet the objectives set out in the project document.

In terms of capacity-building, it is worth mentioning the support received by the UNFCCC's Consultative Group of Experts (CGE), through the conduction of regional technical training as a contribution to improve the team's knowledge on the methodology for the preparation of emission inventories, the emission factor database (EFDB) and the IPCC inventory development software. Most importantly, the significant opportunity offered to representatives of the project's technical team to be accredited, via an on-line course offered by the UNFCCC, as experts in the "2006 IPCC Guidelines for National Greenhouse Gas Inventories - IPCC 2006" is of note. Despite all the opportunities provided by the Secretariat and CGE, the lack of an official communication channel that would facilitate access to UNFCCC and IPCC experts to address questions raised during the development of activities was noted.

Conduction of the project's activities required, above all, a great effort by the MCTI, the project team and the UNDP to overcome the various administrative and technical challenges encountered at different stages of the work. At first, the need to identify the appropriate instruments to enter into partnerships and their respective administrative processes caused delays in the effective commencement of technical activities. This was a situation that happened to all components, but more so to the National Inventory, for which it is increasingly timely to establish a national arrangement that ensures institutional coordination, on a permanent basis, for the appropriate updating and provision of official statistical data, emission parameters and factors, according to the appropriate definition of functions and responsibilities assigned for each body, in order to meet the demands of the estimating national GHG emissions and removals.

Other difficulties were observed during the collaborative work, usually resulting from the effort to advance knowledge. In this regard, in some situations, the limiting factor was the lack of data from third parties, which were not shared in a timely manner to be incorporated in the studies. The important engagement of the technical-scientific staff with advanced expertise in specific areas of studies is also of note, given that due to their primary institutional duties, they were not able to fully commit to the Project's activities. Nevertheless, the engagement of Rede CLIMA, initiated at the TCN, was kept and they contributed with scientific rigor to the elaboration of the National GHG Inventory and to the development of impacts and vulnerabilities studies.

In particular, the implementation of a methodology for the Land Use, Land-Use Change and Forestry (LULUCF) sector, considering the extent of the Brazilian territory and the diversity of its biomes, as well as the identification of new land-use structures, brought challenges associated with the complexity of the analyses for the classification of spatially-explicit land-use conversion, which required the structuring of a large technical team specialized in mapping as well as many hours of work dedicated to the analysis and validation of the extensive volume of data. In addition, infrastructure limitations may also be listed as part of the challenges that made it difficult, at times, to acquire advanced technology for the proper implementation of the project's activities related to the construction of future climate scenarios.

Lastly, it should be noted that the Project Management Unit has been able to incorporate and register important information to maintain the level of excellence of the Brazilian NCs published so far, which will certainly contribute to a more fluid and even more robust implementation of future editions

# CHAPTER 2

## SUMMARY

# 2 NATIONAL INVENTORY OF EMISSIONS AND REMOVALS OF GREENHOUSE GASES

## 2.1 INTRODUCTION

Brazil periodically presents its national inventory of anthropogenic emissions by sources and anthropogenic removals by sinks of all greenhouse gases (GHG) not controlled by the Montreal Protocol (hereafter referred to as Inventory), to the extent that their capacities allow, as their commitment to update these estimates and report to the United Nations Framework Convention on Climate Change (UNFCCC). In addition to the Inventory pertaining to National Communications, Brazil provides an updated report of its emissions and removals in the Biennial Update Reports (BUR).

***Inventory of GHGs not controlled by the Montreal Protocol***

*As determined by the UNFCCC, the Inventory must include anthropogenic GHG emissions and removals not controlled by the Montreal Protocol. For this reason, CFCs and HCFCs are not considered, which, although they are also GHG, deplete the ozone layer and, therefore, are monitored by the Montreal Protocol.*

The GHGs estimated in this Inventory were carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride ($SF_6$). Other gases, such as carbon monoxide (CO), nitrogen oxides ($NO_x$) and other non-methane volatile organic compounds (NMVOCs), are indirect GHG, and their anthropogenic emissions have been included whenever possible, as encouraged by the UNFCCC.

***Indirect GHG***

*Referring to precursor gases, which can influence the concentration of some GHGs, mainly tropospheric ozone.*

This Inventory presents emissions from 1990 to 2016, with an update to the Third Inventory, which presented emissions from 1990 to 2010 (BRASIL, 2016). The methodology used in this Inventory reflects the technical and scientific advances consolidated in the “2006 Guidelines of the Intergovernmental Panel on Climate Change (IPCC) for National Inventories of Greenhouse Gas Emissions” (*2006 IPCC Guidelines for National Greenhouse Gas Inventories* – IPCC, 2006).

Due to the various sources of anthropogenic GHG emissions, the Inventory is organized according to the activities contemplated in the following sectors: Energy; Industrial Processes and Product Use (IPPU); Agriculture; Land Use, Land-Use Change and Forestry (LULUCF); and Waste (as shown in Figure 2.1). The removal of GHG is accounted for only in the LULUCF sector, because of the increase in the carbon stock, for example, the growth of vegetation.

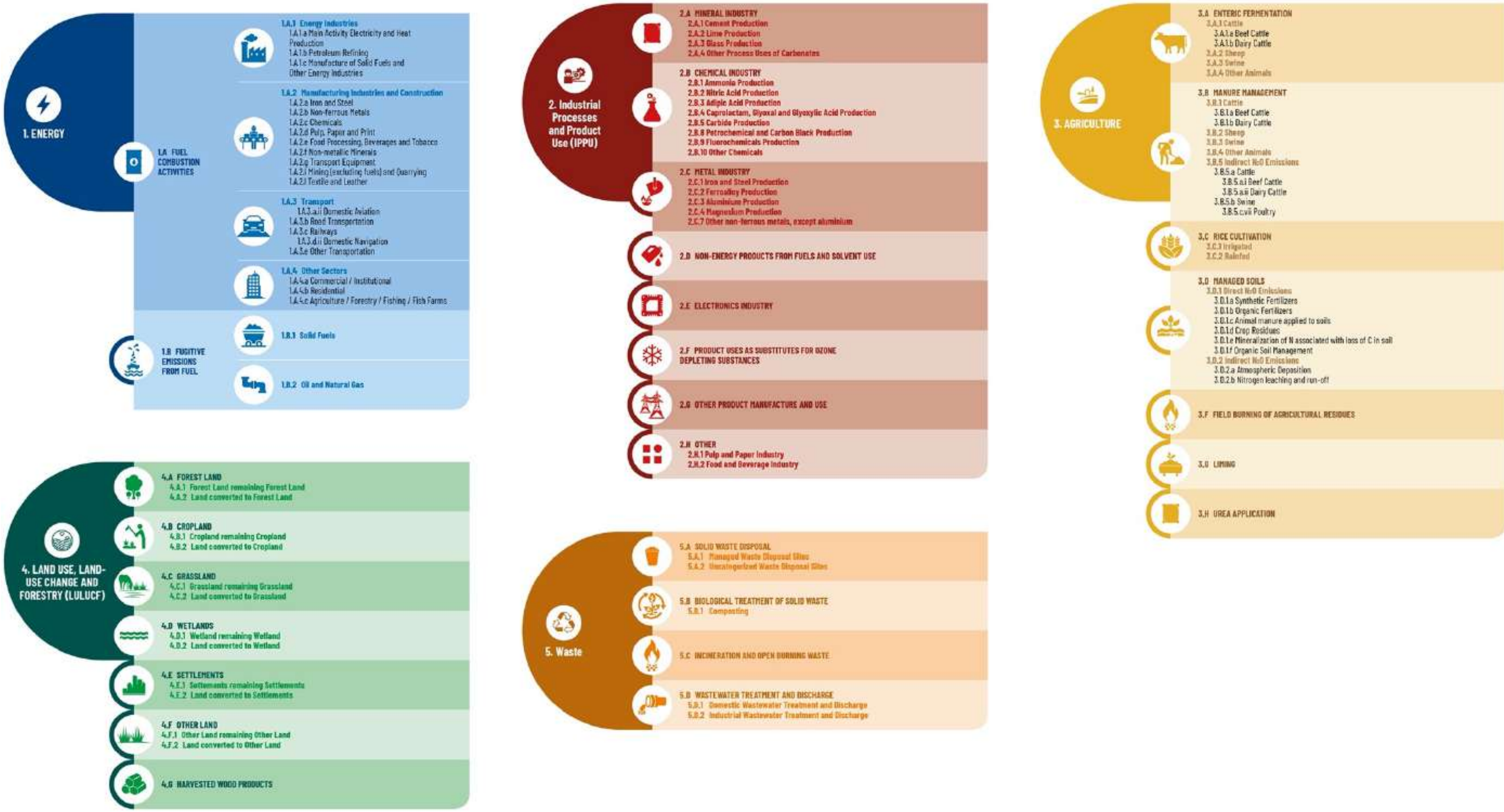


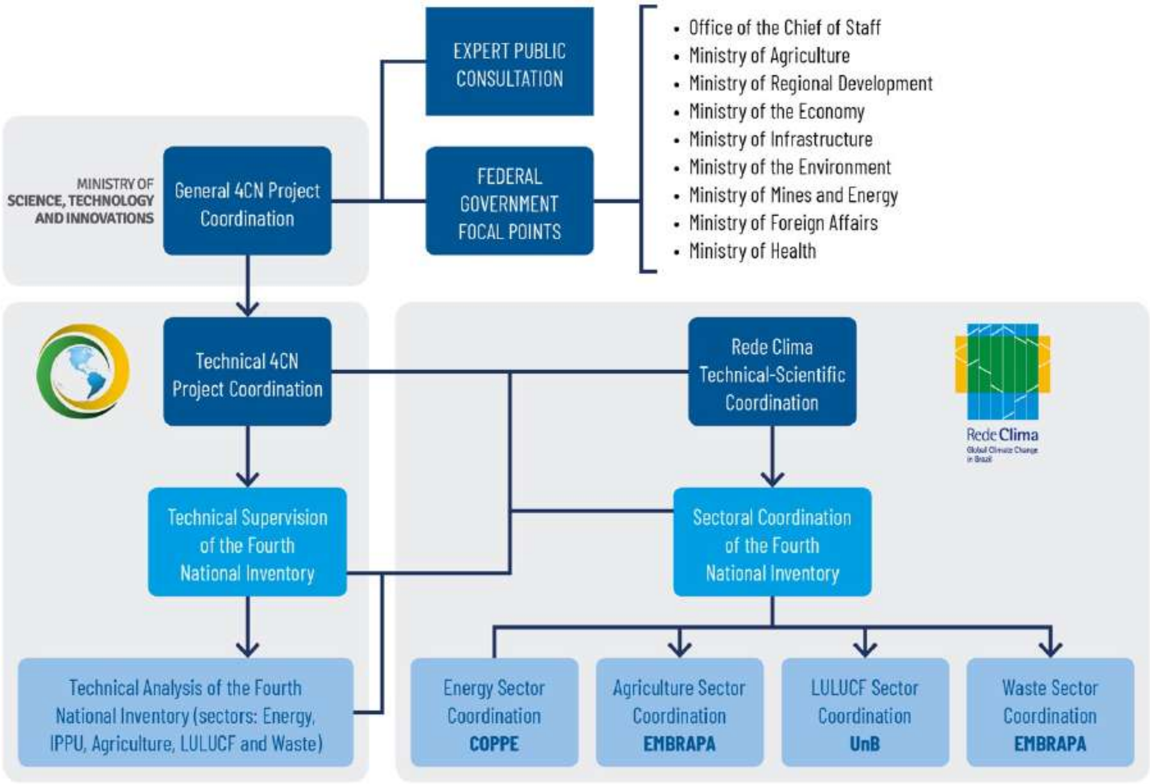

Figure 2.1. Structure of the sectors inventoried in the Fourth GHG Inventory of Brazil

### 2.1.1 Institutional arrangements for the preparation of the Inventory

The elaboration of the Fourth Inventory represented a collective and multidisciplinary effort, which involved about 185 institutions and over 300 specialists from all regions of the country. The Ministry of Science, Technology, and Innovations (MCTI), through the work of the General Coordination of Climate Science and Sustainability (CGCL), is responsible for coordinating the preparation of the Inventory and plays a relevant role in the articulation of the different working groups, that contribute to the survey of sectoral information. The organization chart in Figure 2.2 shows the institutional arrangement and shows the complexity of articulation between the different players involved in the process of preparing this Inventory.

Due to its scope and specificity, the elaboration of the Fourth Inventory involved an important part of the Brazilian scientific and business community, in addition to several government institutions, class associations, third sector organizations, universities and research centers, represented, in large part, by the Brazilian Research Network on Global Climate Change (Rede CLIMA). Due to the scope of the activities pertinent to the IPPU sector, it did not have specific technical-scientific coordination, but it did use the contact and subsidies from the main industrial associations, in addition to having the engagement of the scientific community in the topics covered, integrated with the Energy sector.

*See **item 5.2.16** for more information about Rede CLIMA.*




| | Energy Sector | IPPU Sector | Agriculture Sector | LULUCF Sector | Waste Sector |
|---|---|---|---|---|---|
| Rede CLIMA Focal Points | 2 | 1 | 13 | 4 | 3 |
| Experts | 43 | 22 | 72 | 120 | 41 |
| Institutions directly involved | 11 | 7 | 33 | 34 | 12 |
| Institutions indirectly involved | 10 | 21 | 7 | 20 | 6 |

Figure 2.2. Institutional arrangement for the elaboration of the Fourth GHG Inventory

## 2.1.2 Inventory planning and management

The Inventory cycle begins with the establishment of partnerships responsible for generating and collecting data, developing and surveying parameters, updating estimates, and compiling the results in reference reports. The cycle follows the steps described in Figure 2.3 and ends with planning for improvements for the next cycle.

The Inventories of Brazil are archived as a set of spreadsheets in the MCTI institutional network, in addition to metadata used throughout the process, from scientific articles to the spatial database used in the LULUCF sector. The sectoral reference reports, which transparently describe the methodological details, with an indication of the data sources and assumptions adopted, are also filed by the MCTI. These reports are made publicly available on the website at the National Emissions Registry System (SIRENE)[1], together with the emission results of all GHG not controlled by the Montreal Protocol. In this sense, it is possible, through SIRENE, to access the historical series of emissions referring to the published results of national inventories, and the data of graphs and tables can be exported in different formats.

*See **item 5.1.2**., for more information about SIRENE.*

[1] *Available at: https://sirene.mctic.gov.br*

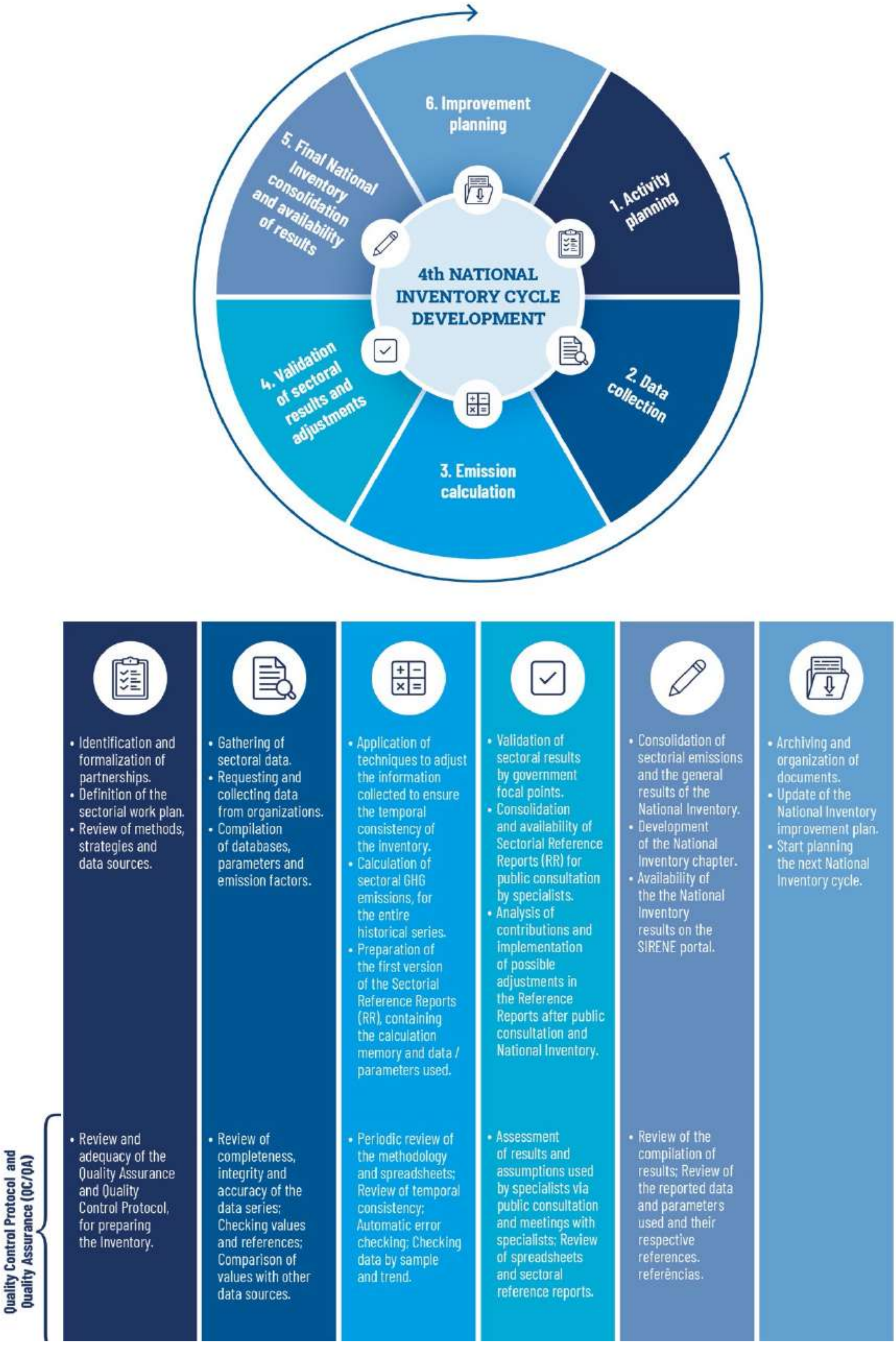



Figure 2.3. Cycle for the elaboration of Brazil's GHG Inventory

### 2.1.3 Methods and main sources of information

The preparation of this Inventory complied with the guidelines for the preparation of the National Communications of the non-Annex I Parties to the UNFCCC, established by Decision 17/CP.8. According to this Decision, the inventories of developing countries must, at a minimum, be prepared following the IPCC guidelines. In this Inventory, Brazil has committed to the application of the 2006 IPCC Guidelines for National Greenhouse Inventories (IPCC, 2006) that had already been partially used in the Third Inventory. Thus, it is understood that the country has improved its estimates, which makes it possible to improve planning and subsidies for making decisions about GHG mitigation actions.

The IPCC methodologies for quantifying emissions are divided into 3 levels (or Tiers) that correspond to the methodological complexity and the representation of the particularities of each country. Tier 1 is considered the basic method, using standard emission factors (default) indicated by the IPCC methodology itself, the intermediate Tier 2, and the more demanding Tier 3 in terms of nationally obtained data requirements. Tiers 2 and 3 are considered to be more accurate estimation methods.

For this inventory, the different Tiers were used, their application for the various categories can be understood in the sectoral details presented in the Tables with information on the "methodological levels applied according to gas" (Panels 2.2, 2.5, 2.8, 2.9, 2.15).

For the Fourth Inventory, there was the inclusion of emission categories, updating of some methodological assumptions, and changes in the equations, parameters, and/or emission factors used, mainly resulting from the implementation of the IPCC 2006, as shown in Panel 2.1.

Panel 2.1. Methodological updates and improvements for the Fourth Inventory

| Sector | Methodological updates and improvements |
|---|---|
| 1. Energy | ● Compatibility of the emission categories of the sector, according to the classification indicated by the IPCC 2006;<br>● Improvement of parameters and models used to estimate emissions in Domestic Aviation (1.A.3.a) and Road Transportation (1.A.3.b);<br>● Inclusion of emissions from coking plants in the Energy Industries;<br>● Exclusion of $CO_2$ emissions related to spontaneous combustion in tailing piles, in the Coal Mining and Handling category (1.B.1.a), given the national conditions analyzed. |
| 2. IPPU | ● Other Process Uses of Carbonates (2.A.4): shift to the category of end use, when relevant (iron and steel);<br>● Inclusion of a new subcategory: Ceramics (2.A.4.a);<br>● Ammonia production (2.B.1): $CO_2$ discount used in urea production;<br>● Update of the emission factor for ethylene production;<br>● Use of the industry's carbon balance in the Iron and Steel Production category (2.C.1);<br>● Inclusion of new subsector Electronics industry (2.E);<br>● Reformulation of the calculation model for Refrigeration and Air Conditioning (2.F.1). |
| 3. Agriculture | ● Inclusion of the subsectors: Liming (3.G) and Urea Application (3.H), in accordance with the sector structure indicated by the IPCC 2006 and with UNFCCC recommendations;<br>● Managed Soils (3.D):<br>o Inclusion of the category Mineralization of N associated with loss of C in soil (3.D.1.e), in accordance with the sector structure indicated by the IPCC 2006;<br>o Emissions due to the contribution of N from pasture biomass incorporated into the soil at the time of renewal, and the roots of crops are now counted as a source of $N_2O$ in Crop Residues (3.D.1.d), in accordance with the sector structure indicated by the IPCC 2006;<br>o Inclusion of the sugar and alcohol industry filter cake in Organic Fertilizers (3.D.1.b), as well as the use of synthetic fertilizers in rice cultivation, in Synthetic Fertilizers (3.D.1.a);<br>● Enteric Fermentation (3.A) and Manure Management (3.B): for the cattle animal category, there was a greater breakdown by type of confinement, age, and animal sex. For the swine and poultry categories, there was a breakdown by productive purpose. Also, in Manure |

| Sector | Methodological updates and improvements |
|---|---|
| | Management (3.B), indirect $N_2O$ emissions were included, following the IPCC 2006 implementation;<br>● Field burning of agricultural residues (3.F): implementation of specific emission factors for the national reality;<br>● Change/update of the database and parameters used to estimate emissions in the Agriculture sector. |
| 4. LULUCF | ● Inclusion of the Harvested Wood Products category (4.G), following the sector structure indicated by the IPCC 2006;<br>● Liming (3.G) transfer for the Agriculture sector, following UNFCCC recommendations;<br>● Review of the methodology for estimating removal by protected natural (or managed, for the Inventory) vegetation and by secondary vegetation;<br>● Update of activity data: new maps for the Atlantic Forest biome, for all evaluated years; improvements to the 1994 and 2002 maps of the Cerrado biome; mapping of severely degraded pastures in the Cerrado and Amazon biomes for 2016; spatial detailing by type of cultivation (perennial, semi-perennial and annual) in 2016;<br>● Update of emission and removal factors: i) review of carbon stocks and the representativeness of phytophysiognomies in all biomes, based on a new map of past natural vegetation; ii) above-ground biomass estimate for the Amazon biome, based on airborne LiDAR data; iii) spatialization of carbon stocks in the Cerrado biome, based on ecoregions; iv) revision of the organic carbon alteration factors of pasture soils (natural, planted in good conditions and planted in poor conditions), crops (direct and conventional planting) and reforestation. |
| 5. Waste | ● Inclusion of the subsector Biological Treatment of Solid Waste (5.B), following the sector structure indicated by the IPCC 2006;<br>● Inclusion of the category Open Burning of Waste (5.C.2), in the subsector Incineration and Open Burning of Waste (5.C), following the sector structure indicated by the IPCC 2006;<br>● Change/update in the database and parameters used to estimate emissions in the Waste sector. |

### 2.1.4 Quality assurance and quality control procedures

The main objective of the quality assurance and quality control plan (QA/QC) is to ensure that the Inventory is following the principles of good practice, which guide the preparation and dissemination of inventories, namely: transparency, accuracy, comparability, consistency, and completeness.

By definition, Quality Control (QC) is a system of routine technical activities to assess and maintain the quality of the inventory while it is being compiled. Quality Assurance (QA) is a planned system of review procedures, conducted by actors not directly involved in the inventory development and compilation process.

In order to meet the criteria for good QC practices recommended by the IPCC, checks were performed on activity data, parameters, emission factors and calculations. For this, validation procedures and activities were established, according to the progress in the development of the products, until the elaboration of the sectoral reference reports.

The QA process consisted of making sectoral reference reports available for public consultation to specialists, for external technical evaluation. The resulting comments, suggestions, recommendations and observations were recorded, replied and incorporated, when relevant.

Specifically, for the LULUCF sector, a strategy complementary to the established standard QA was adopted, due to the complex process of generating activity data for this sector (i.e., land-use conversion and land cover matrices) given the size and regional characteristics of the national territory. In this sense, a Scientific Validation Committee was created, formed by specialists from each biome. The committee's activities took place from the validation of land use and land cover maps elaborated in previous Inventories, to the selection of satellite images, technical assistance during the elaboration of the updated map for 2016, and validation and analysis of the accuracy of the map made in Fourth Inventory. The involvement of experts in mapping each Brazilian biome contributed to better represent the dynamics of use and coverage of national land. Also, experts from each biome validated the factors applied for the estimates, as well as the sector's results.

### 2.1.5 Uncertainty analysis

The estimates of anthropogenic emissions and removals of GHG presented in this Inventory are subject to uncertainties due to several causes, from the inaccuracy of basic data to the incomplete knowledge of the processes that originate the emissions or removals of GHG. According to the 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 fully eliminated. However, the main objective must be to produce accurate estimates, which are neither underestimated nor overestimated, and increasingly accurate, as far as possible.

According to IPCC 2006, the analysis of uncertainties should help to prioritize national efforts that will make it possible to reduce the uncertainty of future inventories, in addition to guiding decisions regarding methodological choices.

Inventory uncertainty is associated with data from each activity, as well as emission factors and other parameters used in the estimates. The quantification of the uncertainty of each data is as much or more difficult to evaluate information as the desired information itself.

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

The error propagation method (Approach 1) at the national level was used for the calculation of uncertainties, for the last year of the Inventory (2016), for all sectors. Except for 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 from the analysis of the uncertainties of all estimated gases, and not just the three most important ones - $CO_2$, $CH_4$, and $N_2O$ - which make up 99.6% of the total $CO_2e$ in 2016.

The quantitative results of the uncertainty analysis are shown in Table 2.1.

Table 2.1. Results of the uncertainty analysis in 2016, Fourth Inventory

| Sectors | Uncertainty by gas in 2016 (%) | | | | | |
|---|---|---|---|---|---|---|
| | $CO_2$ | $CH_4$ | $N_2O$ | PFCs | HFCs | $SF_6$ |
| Energy | 3 | 45 | 32 | - | - | - |
| IPPU | 3 | 76 | 40 | 20 | 31 | 54 |
| Agriculture | 29 | 16 | 65 | - | - | - |

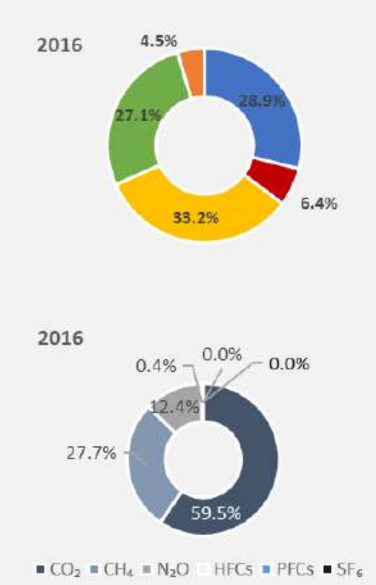
| Sectors | Uncertainty by gas in 2016 (%) | | | | | |
|---|---|---|---|---|---|---|
| | $CO_2$ | $CH_4$ | $N_2O$ | PFCs | HFCs | $SF_6$ |
| LULUCF | 73 | 33 | 40 | - | - | - |
| Residues | 70 | 12 | 26 | - | - | - |
| Uncertainty by gas | 31 | 13 | 56 | 20 | 31 | 54 |
| Uncertainty (2016) | 20 | | | | | |

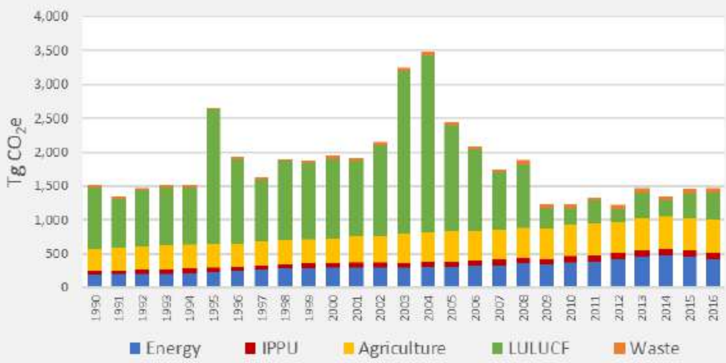
## 2.2 GREENHOUSE GAS EMISSIONS AND REMOVALS FROM BRAZIL

Total GHG emissions from Brazil, in 2016, totaled 1,467 Tg $CO_2e$ (see Panel 2.1) and represented an increase of 19.4% compared to emissions in 2010 (Figure 2.4), the last year of the historical series presented in the Third National Communication.

*See the **Appendix I** to check the tables with all results per gas, in mass units, for all sectors and the entire historical series (1990 to 2016)*

Proportionally, the Agriculture sector contributed 33.2% of total national emissions in 2016 (see Panel 2.2), the Energy sector with 28.9%, and the LULUCF sector with 27.1% (Figure 2.4). The IPPU and Waste sectors contributed smaller emissions, representing 6.4% and 4.5%, respectively.




| Sector | 1990 | 1995 | 2000 | 2005 | 2010 | 2016 | Variation 2010-2016 |
|---|---|---|---|---|---|---|---|
| | ---- Tg $CO_2e$ ---- | | | | | | ----- % ----- |
| **Energy** | 192.8 | 231.0 | 288.2 | 313.4 | 374.7 | 423.6 | **13.1** |
| **IPPU** | 53.6 | 64.0 | 73.8 | 78.9 | 87.1 | 93.4 | **7.2** |
| **Agriculture** | 329.5 | 359.2 | 370.1 | 438.0 | 458.1 | 487.0 | **6.3** |
| **LULUCF** | 907.5 | 1,966.8 | 1,175.0 | 1,564.1 | 252.5 | 397.4 | **57.4** |
| **Waste** | 26.2 | 34.3 | 42.6 | 51.6 | 56.7 | 66.0 | **16.4** |
| **TOTAL** | **1,509.6** | **2,655.2** | **1,949.6** | **2,445.9** | **1,229.0** | **1,467.3** | **19.4** |

Figure 2.4. Total GHG emissions from 1990 to 2016 in Tg of $CO_2e$

In 2016, Brazilian emissions were 873,272 Gg $CO_2$; 19,333.2 Gg $CH_4$, and 586.09 Gg $N_2O$, which represented 59.5%, 27.7%, and 12.4% of the total Inventory in $CO_2e$. Between 2010 and 2016, total $CO_2$, $CH_4$, and $N_2O$ emissions increased by 30.3%, 3.8%, and 10.7%, respectively.

HFCs totaled 5,728 Gg $CO_2e$, PFCs 273 Gg $CO_2e$ and $SF_6$ was estimated at 295 Gg $CO_2e$, which together represented 0.4% of total emissions in 2016 (Figure 2.5). Emissions of indirect GHG were also assessed, in 2016 2,547.7 Gg of $NO_x$ were estimated; 24,044.1 Gg of CO; and 3,241.0 Gg of NMVOC.

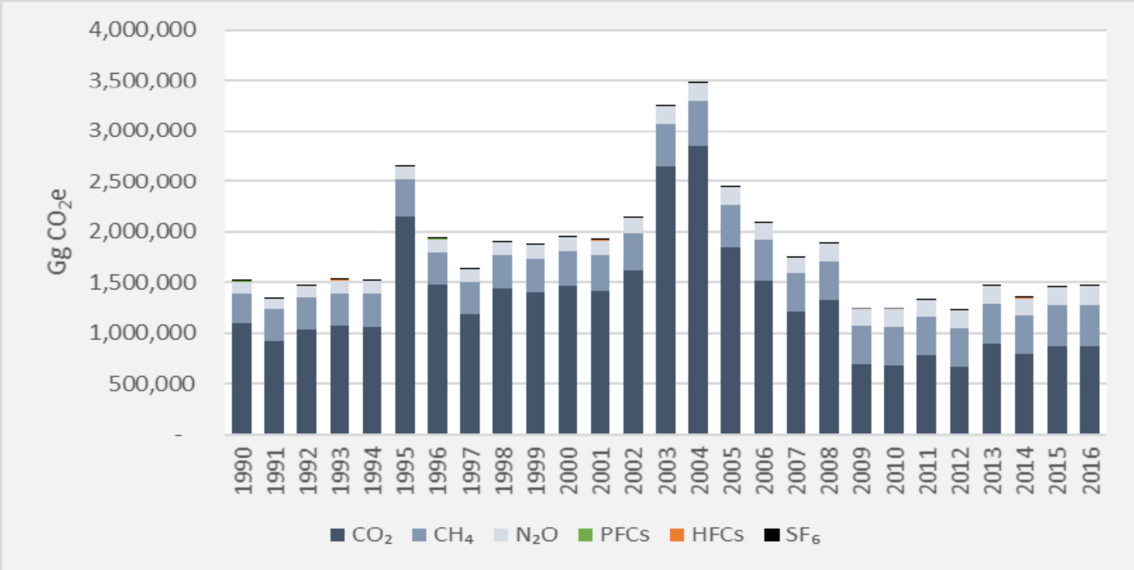



Figure 2.5. Result of the evolution of GHG emissions in Gg $CO_2e$ from 1990 to 2016.

For the period from 1990 to 2016, there is a significant decrease in emissions from 2004 on, with the observation of relative stability in emissions for the most recent period from 2010 to 2016.

Most of the increase in total emissions between 2010 and 2016, (61%) was due to the increase in emissions in LULUCF. Next came contributions from increases in the Energy (20%), Agriculture (12%) Waste (4%), and IPPU (3%) sectors.

*Box 2.1:* National emissions considering other metrics of GWP (SAR and AR5) and GTP (AR5)

According to Decision 17/CP.8 of the UNFCCC, the results of the inventory must be presented in absolute gas units. If the country chooses to report its emissions in $CO_2$ equivalents ($CO_2e$), it could use the Global Warming Potential (GWP) values for a 100-year horizon, published in the Second IPCC Assessment Report (SAR) (IPCC, 1995). All analyses and results presented in $CO_2e$ in this chapter used the GWP metric of the SAR (100 years).

GWP is a measurement of how much heat a given amount of a greenhouse gas retains in the atmosphere in relation to the same amount of $CO_2$, in a given time horizon. It is expressed as a factor that, multiplied by the mass of the gas, results in an equivalent mass of $CO_2$ ($CO_2e$).

Although the use of GWP-SAR is suggested for inventories from non-Annex I countries, the IPCC's subsequent assessment reports presented new values for the GWP of gases. From the IPCC Fifth Assessment Report (AR5) (IPCC, 2013), the most recent publication on the topic, the values for the Global Temperature Potential (GTP) were presented for the first time in English), which Brazil also considers relevant.

According to the IPCC, GTP is characterized by being a metric based on temperature change, that is, it is related to the variation of the average temperature of the global surface, in a selected time horizon, in response to a pulse of GHG emissions.

According to the IPCC (2013), "the most appropriate metric and time horizon will depend on which aspects of climate change are considered most important for a particular use. No metric can accurately compare all the consequences of different emissions and all have limitations and uncertainties ". The IPCC further states that the GTP metric is more suited for policies based on global warming containment targets, while the GWP is not directly related to a temperature limit Thus, the GTP would be the most consistent metric for monitoring measures that aim to contain the increase in the global average temperature below 2°C considering pre-industrial levels.

Table 2.2 shows the values of the gas coefficients associated with the different metrics. Table 2.3 shows the final $CO_2e$ results with other most recent metrics - GWP-AR5 and GTP-AR5 (IPCC, 2013).

Table 2.2. Factors for GWP (100 years) and GTP (100 years)

| Gas | GWP<br>100 years<br>SAR-1995 | GWP<br>100 years<br>AR5-2014 | GTP<br>100 years<br>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 |

| Gas | GWP 100 years SAR-1995 | GWP 100 years AR5-2014 | GTP 100 years AR5-2014 |
|---|---|---|---|
| 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 2.3. Results of the Fourth Inventory, in $CO_2e$, with GWP (SAR and AR5) and GTP (AR5) metrics.

| GWP (SAR) | 1990 | 1995 | 2000 | 2005 | 2010 | 2016 |
|---|---|---|---|---|---|---|
| | ---------- Gg $CO_2e$ ---------- | | | | | |
| 1. Energy | 192,809 | 230,983 | 288,164 | 313,396 | 374,671 | 423,580 |
| 2. IPPU | 53,553 | 63,965 | 73,758 | 78,883 | 87,101 | 93,359 |
| 3. Agriculture | 329,510 | 359,245 | 370,116 | 437,959 | 458,091 | 487,005 |
| 4. LULUCF | 907,520 | 1,966,770 | 1,175,013 | 1,564,054 | 252,508 | 397,357 |
| 5. Waste | 26,194 | 34,257 | 42,578 | 51,618 | 56,672 | 65,954 |
| TOTAL | 1,509,585 | 2,655,220 | 1,949,629 | 2,445,909 | 1,229,043 | 1,467,255 |
| GWP (AR5) | 1990 | 1995 | 2000 | 2005 | 2010 | 2016 |
| | ---------- Gg $CO_2e$ ---------- | | | | | |
| 1. Energy | 196,118 | 233,681 | 290,986 | 317,209 | 377,818 | 426,279 |
| 2. IPPU | 53,503 | 63,600 | 73,148 | 78,198 | 87,352 | 93,597 |
| 3. Agriculture | 394,660 | 430,465 | 440,610 | 520,056 | 538,345 | 567,043 |
| 4. LULUCF | 916,026 | 1,983,628 | 1,186,864 | 1,579,549 | 258,274 | 403,141 |
| 5. Waste | 33,976 | 44,550 | 55,412 | 67,269 | 73,966 | 86,484 |
| TOTAL | 1,594,283 | 2,755,924 | 2,047,020 | 2,562,280 | 1,335,754 | 1,576,544 |

| GTP (AR5) | 1990 | 1995 | 2000 | 2005 | 2010 | 2016 |
|---|---|---|---|---|---|---|
| | Gg $CO_2$e | | | | | |
| 1. Energy | 182,643 | 222,086 | 278,508 | 300,642 | 362,290 | 411,890 |
| 2. IPPU | 52,693 | 62,744 | 71,410 | 75,524 | 84,057 | 88,034 |
| 3. Agriculture | 119,537 | 128,482 | 137,298 | 162,928 | 178,403 | 198,043 |
| 4. LULUCF | 878,072 | 1,908,883 | 1,134,166 | 1,510,668 | 232,364 | 377,231 |
| 5. Waste | 6,330 | 8,098 | 10,098 | 12,128 | 13,157 | 14,487 |
| TOTAL | 1,239,276 | 2,330,292 | 1,631,480 | 2,061,890 | 870,272 | 1,089,684 |

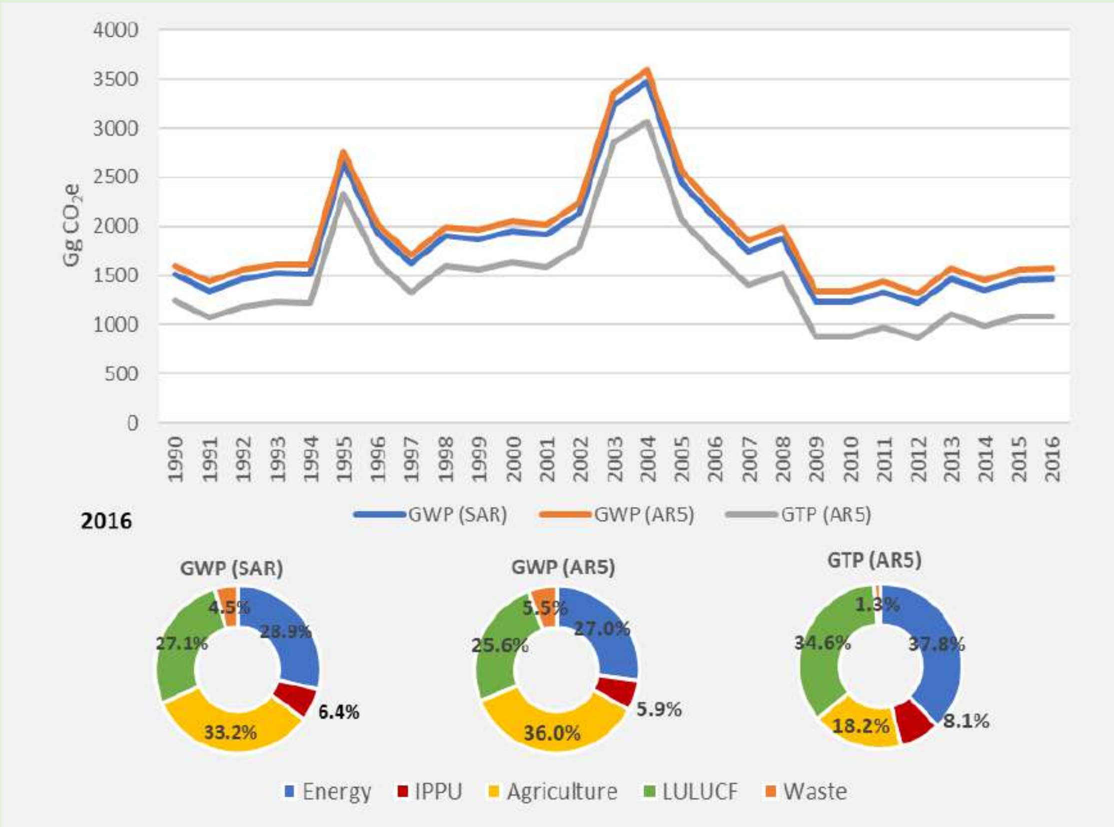



Figure 2.6. Evolution of emissions in $CO_2$e in GWP-SAR, GWP-AR5 and GTP-AR5 metrics, from 1990 to 2016

## 2.2.1 $CO_2$ emissions

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

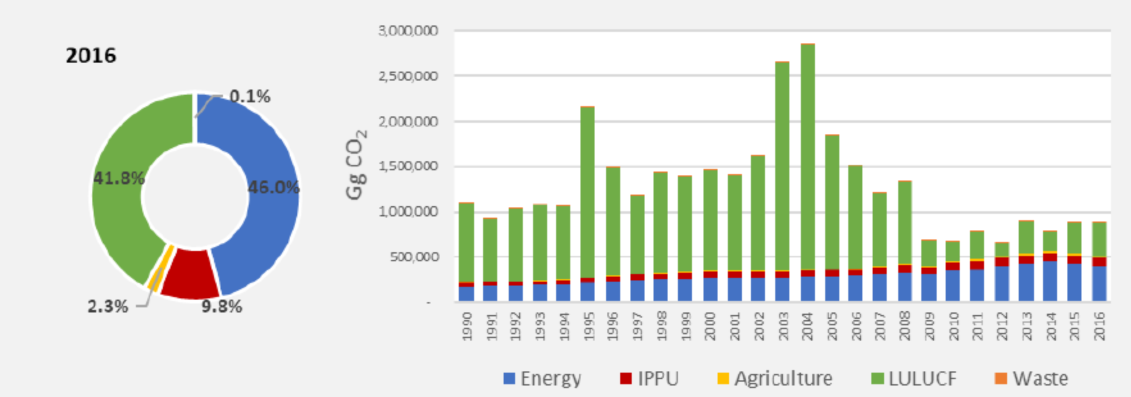
In Brazil, since 2005, there was a significant reduction in emissions from the LULUCF sector, mainly related to the decrease in deforestation, which contributed to the increase of the relative participation of the Energy sector in the total $CO_2$ emissions for 2016. It is worth mentioning the high participation of renewable energy in the Brazilian energy matrix, the generation of electricity from hydroelectric plants, the use of ethanol in road transport, and the use of sugarcane bagasse and charcoal in industry[2]. Figure 2.7 summarizes the net $CO_2$ emissions in Brazil, by sector.

In 2016, $CO_2$ emissions from the Energy sector represented 46.0% of total $CO_2$ emissions, with an increase of 13.8% in comparison to the emissions in 2010. Only the Transport category, which involves all modes, was responsible for 22.9% of national $CO_2$ emissions in 2016.

Emissions from the IPPU sector accounted for 9.8% of total $CO_2$ emissions in 2016, with iron and steel production, the main emitting source, contributing 5.0% of national $CO_2$ emissions. From 2010 to 2016, IPPU emissions increased by 4.7%.

The Agriculture sector contributed 2.3% of the country's $CO_2$ emissions, related to liming and urea application in agriculture. Net emissions from the LULUCF sector represented 41.8% of total $CO_2$ emissions in 2016, with emissions from the Forest Land converted to Grassland category (4.C.2.a) being the most representative.

The Waste sector contributed 0.1% to $CO_2$ emissions in 2016, mainly due to incineration and open burning of waste (0.06% of national $CO_2$ emissions).




| Sectors | 1990 | 1995 | 2000 | 2005 | 2010 | 2016 | Variation 2010-2016 |
|---|---|---|---|---|---|---|---|
| | Gg $CO_2$ | | | | | | % |
| **Energy** | 177,046 | 216,613 | 272,173 | 292,351 | 352,903 | 401,690 | **13.8** |
| **IPPU** | 45,192 | 53,139 | 64,506 | 67,660 | 82,049 | 85,943 | **4.7** |
| **Agriculture** | 9,771 | 6,765 | 10,645 | 9,975 | 13,698 | 19,732 | **44.1** |
| **LULUCF** | 860,893 | 1,875,495 | 1,110,480 | 1,479,731 | 220,461 | 365,404 | **65.7** |
| **Waste** | 533 | 585 | 926 | 1,108 | 1,154 | 504 | **-56.4** |
| **TOTAL** | **1,093,435** | **2,152,596** | **1,458,729** | **1,850,825** | **670,265** | **873,272** | **30.3** |

Figure 2.7. National $CO_2$ emissions, all sectors, from 1990 to 2016

[2] *$CO_2$ emissions related to the combustion of biomass are not accounted for in the Energy sector, since they are related to the balance of the carbon stock associated with the change in land use in the LULUCF sector.*

## 2.2.2 $CH_4$ emissions

National $CH_4$ emissions came from agricultural activities, from changing land use and coverage, from waste treatment, from some industrial processes, in addition to the extraction and refining of oil and natural gas.

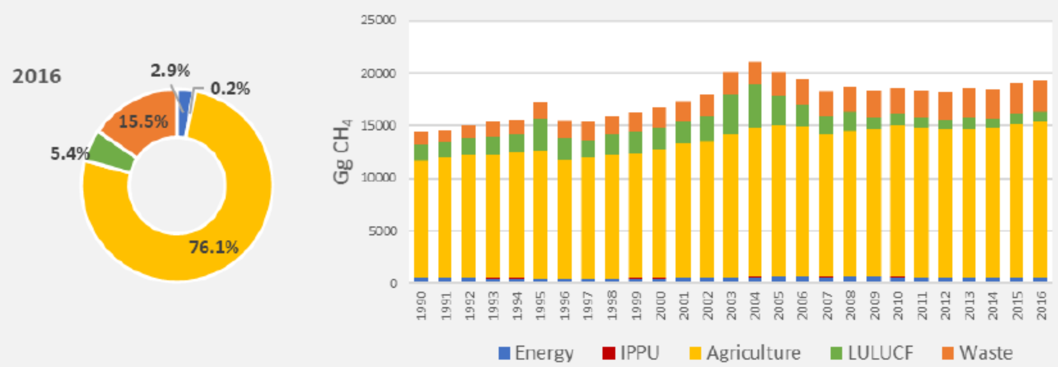
In the Energy sector, $CH_4$ emissions occur due to imperfect fuel combustion and also due to $CH_4$ leakage during the production and transportation of natural gas and coal mining processes. $CH_4$ emissions from the Energy sector represented 2.9% of total $CH_4$ emissions in 2016, an 8.6% decrease compared to 2010 emissions.

In the IPPU sector, $CH_4$ emissions occur during the production of petrochemicals but have a small share in Brazilian emissions, 0.2%.

The Agriculture sector had a 76.1% share in $CH_4$ emissions in 2016. In that year, $CH_4$ emissions associated with enteric fermentation (eructation) of the national herd were estimated at 13,462.5 Gg, representing 91.5% of emissions from the sector, an increase of 1.6% in relation to 2010, an insignificant value when compared to the increase in livestock and livestock productivity that occurred in the country. The remaining emissions are related to manure management, the cultivation of rice (irrigated, which has most of the cultivated area in the country), and the field burning of agricultural residues, the latter with a reduction of 72.8% of emissions compared to 2010.

In the LULUCF sector, $CH_4$ emissions occur due to the burning of biomass associated with the dynamics of land use and cover. These emissions represented 5.4% of the total $CH_4$ emissions in 2016.

Emissions from the Waste sector represented 15.5% of total $CH_4$ emissions in 2016, with the solid waste disposal being the activity that most contributed to the sector's emissions.




| Sectors | 1990 | 1995 | 2000 | 2005 | 2010 | 2016 | Variation 2010-2016 |
|---|---|---|---|---|---|---|---|
| | Gg $CH_4$ | | | | | | % |
| Energy | 543.3 | 463.9 | 496.7 | 660.4 | 609.6 | 557.1 | **-8.6** |
| IPPU | 42.9 | 37.7 | 41.0 | 51.1 | 41.9 | 34.5 | **-17.6** |
| Agriculture | 11,102.7 | 12,179.7 | 12,208.4 | 14,352.9 | 14,406.5 | 14,715.7 | **2.1** |
| LULUCF | 1,520.1 | 2,996.2 | 2,111.6 | 2,760.2 | 1,036.8 | 1,037.2 | **0.0** |
| Waste | 1,145.2 | 1,510.7 | 1,878.9 | 2,287.2 | 2,523.1 | 2,988.7 | **18.5** |
| **TOTAL** | **14,354.3** | **17,188.2** | **16,736.8** | **20,111.8** | **18,617.9** | **19,333.2** | **3.8** |

Figure 2.8. National $CH_4$ emissions of all sectors, from 1990 to 2016

## 2.2.3 $N_2O$ emissions

National $N_2O$ emissions resulted from the application of synthetic and organic fertilizers to the soil, as well as the treatment of domestic effluents, fossil fuels and biomass combustion, industrial processes, and changes in land use and coverage.

$N_2O$ emissions in the Energy sector represented 5.6% of total $N_2O$ emissions in 2016, basically due to imperfect fuel combustion.

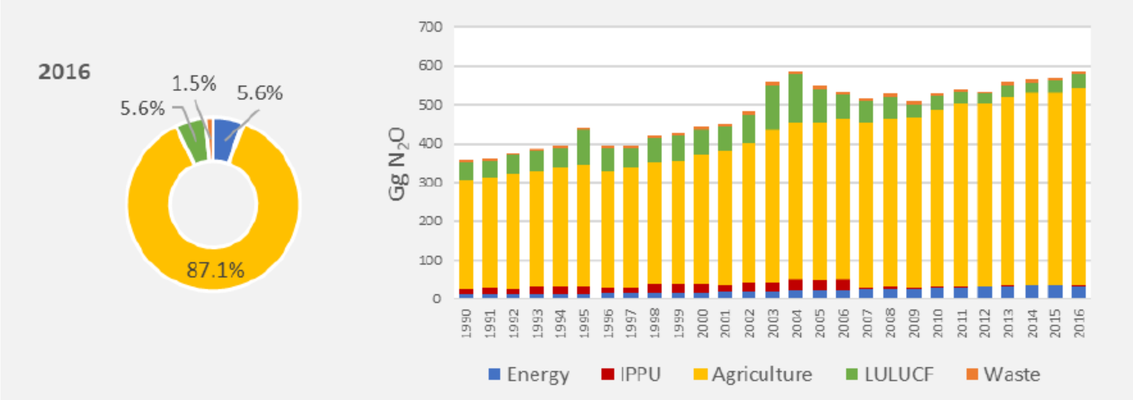
In the IPPU sector, $N_2O$ emissions occur during the production of nitric acid and adipic acid - greatly reduced in these two cases due to the Clean Development Mechanism (CDM) projects, implemented since 2007 to reduce emissions - and in production of metals. Together, these activities accounted for 0.2% of total $N_2O$ emissions in 2016.

$N_2O$ emissions from the Agriculture sector corresponded to 510.46 Gg in 2016, representing 87.1% of the country's emissions of this gas. In the sector, direct emissions from managed soils accounted for 74.4%, and indirect emissions, accounted for 22.3%, while emissions from the manure management and the field burning of agricultural residues corresponded to 3.1% and 0.2% of the total, respectively.

In the LULUCF sector, $N_2O$ emissions occur due to the burning of biomass associated with the dynamics of land use and cover. These emissions represented 5.6% of the total $N_2O$ emissions in 2016.

In the Waste sector, $N_2O$ emissions occur, basically, due to the presence of nitrogen in human consumption protein, which ends up being released into the soil or bodies of water. In 2016, the contribution to the total issuance was 1.4%. A smaller fraction comes from the incineration of waste, with 0.1%.

Figure 2.9 summarizes $N_2O$ emissions in Brazil, by sector.




| Sectors | 1990 | 1995 | 2000 | 2005 | 2010 | 2016 | Variation 2010-2016 |
|---|---|---|---|---|---|---|---|
| | ------------------------------ Gg $N_2O$ | | | | | -------------------------- | ----- % ----- |
| Energy | 14.04 | 14.93 | 17.94 | 23.15 | 28.92 | 32.88 | **13.7** |
| IPPU | 11.55 | 18.20 | 20.73 | 23.79 | 1.51 | 1.27 | **-15.4** |
| Agriculture | 279.30 | 311.96 | 332.56 | 408.30 | 457.60 | 510.46 | **11.6** |
| LULUCF | 47.43 | 91.47 | 65.12 | 85.03 | 33.14 | 32.81 | **-1.0** |
| Waste | 5.20 | 6.28 | 7.08 | 7.99 | 8.17 | 8.67 | **6.2** |
| **TOTAL** | **357.52** | **442.84** | **443.43** | **548.25** | **529.34** | **586.09** | **10.7** |

Figure 2.9. National $N_2O$ emissions, of all sectors, from 1990 to 2016.

## 2.2.4 Emissions of HFCs, PFCs and $SF_6$

HFCs, PFCs, and $SF_6$ are gases that do not originally exist in nature but are synthesized solely by human activities. The main contribution of this family of gases came from the use of HFC-134a in the air conditioning and refrigeration subsector, with fugitive emissions estimated at 4,058.2 t HFC-134a in 2016 (98% of HFCs emissions, in $CO_2e$). From 2010 to 2016, HFC emissions increased by 99%, an increase like that observed in the rest of the world, due to the replacement of CFC gases, which destroy the ozone layer, combined with the greater use of refrigeration and air conditioning.

PFC emissions ($CF_4$ and $C_2F_6$) occur during the primary process of aluminium production, being estimated at 38.1 t $CF_4$ and 2.8 t $C_2F_6$ in 2016 (91% and 9% of PFCs emissions, respectively, in $CO_2e$), although a marginal amount of $CF_4$ emissions has been estimated in the electronics industry. From 2010 to 2016, PFC emissions decreased by 54% due to the deactivation of part of the aluminium production industries.

$SF_6$ emissions were estimated only through gas leaks in high voltage electrical equipment and, in 2016, totaled 12.3 t. From 2010 to 2016, $SF_6$ emissions increased by 22%.

Table 2.4 summarizes emissions of HFCs, PFCs and $SF_6$, in $CO_2e$.

Table 2.4. Emissions of HFCs, PFCs and $SF_6$ (in $CO_2e$)

| Gas | Sector | 1990 | 1995 | 2000 | 2005 | 2010 | 2016 | Var. 2010-16 |
|---|---|---|---|---|---|---|---|---|
| | | Gg $CO_2e$ | | | | | | % |
| HFC-23 | 2.B. Chemical Industry | 1,407 | 1,791 | NO | NO | NO | NO | NA |
| | 2.E. Electronics Industry | NO | NO | NO | NO | 0 | 0 | 356% |
| HFC-32 | 2.F. Product Uses as Substitutes for ODS | NO | NO | NO | NO | NO | 47 | NA |
| HFC-125 | 2.F. Product Uses as Substitutes for ODS | NO | NO | 4 | 6 | 12 | 238 | 1832% |
| HFC-134a | 2.F. Product Uses as Substitutes for ODS | NO | NO | 495 | 1,190 | 2,835 | 5,368 | 89% |
| HFC-143a | 2.F. Product Uses as Substitutes for ODS | NO | NO | 6 | 10 | 20 | 53 | 170% |
| HFC-152a | 2.F. Product Uses as Substitutes for ODS | NO | NO | 0 | 24 | NO | NO | NA |
| HFC-227ea | 2.F. Product Uses as Substitutes for ODS | NO | NO | NO | NO | 5 | 17 | 280% |
| HFC-365mfc | 2.F. Product Uses as Substitutes for ODS | NO | NO | NO | NO | 0 | 5 | 1665% |
| $CF_4$ | 2.C. Metal Industry | 1,964 | 1,989 | 952 | 805 | 535 | 248 | -54% |
| | 2.E. Electronics Industry | NO | NO | NO | NO | 0 | 0 | 356% |

| Gas | Sector | 1990 | 1995 | 2000 | 2005 | 2010 | 2016 | Var. 2010-16 |
|---|---|---|---|---|---|---|---|---|
| | | Gg $CO_2e$ | | | | | | % |
| $C_2F_6$ | 2.C. Metal Industry | 242 | 242 | 108 | 95 | 59 | 26 | -56% |
| $SF_6$ | 2.C. Metal Industry | 138 | 241 | 246 | 455 | NO | NO | NA |
| | 2.G. Other Product Manufacture and Use | 130 | 128 | 154 | 190 | 241 | 295 | 22% |

NO — not occurring
Obs: The variation percentages (2010 to 2016) refer to the non-rounded results of the emissions.

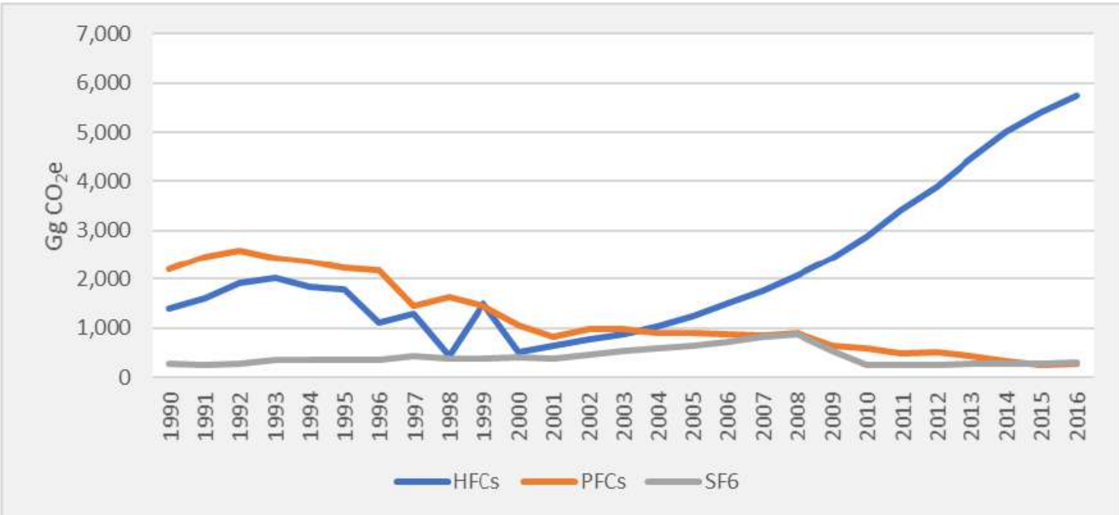



Figure 2.10. Total emissions of HFCs, PFCs and $SF_6$, in Gg of $CO_2e$

## 2.2.5 Indirect Greenhouse Gases

Indirect GHG, or precursors, contribute to the formation of tropospheric ozone[3], which, in turn, is a greenhouse gas. They were not accounted for in $CO_2e$, given the lack of metrics associated with them by the IPCC. The indirect GHG inventoried were: CO (carbon monoxide), $NO_x$ (nitrogen oxides), and NMVOC (non-methane volatile organic compounds).

CO and $NO_x$ emissions are almost entirely the results of imperfect fuel combustion. For CO, the main sources were the burning of biomass in the LULUCF sector and fossil fuels in the Energy sector; for $NO_x$, the importance of these two sectors is reversed. A small portion of CO emissions results from production processes, basically from aluminium production; concerning $NO_x$, some emission occurs in the IPPU sector, in the production of nitric acid and aluminium.

CO emissions mostly occurred in the LULUCF sector, followed by the Energy sector; emissions are completed by the IPPU and Agriculture sectors. These emissions were estimated at 24,044 Gg in 2016, having decreased by 9% since 2010, mainly due to the reduction of sugarcane burning, the advance of mechanized harvesting, as well as the new vehicle pollution controls.

[3] *Located in the lowest layer of the atmosphere.*

The Energy sector emitted most of the $NO_x$ emissions followed by the LULUCF sector, in addition to the IPPU and Agriculture sectors with much smaller shares. $NO_x$ emissions were estimated at 2,548 Gg in 2016, 5% less since 2010, mainly due to new vehicle pollution controls and also due to the mechanization of the sugarcane harvest.

NMVOC emissions are mostly the result of the use of solvents, but they also result from the imperfect fuels combustion or industrial processes. NMVOC emissions in 2016 were estimated at 3,241 Gg, 19% less than in 2010, mainly due to the reduction in the use of solvents.

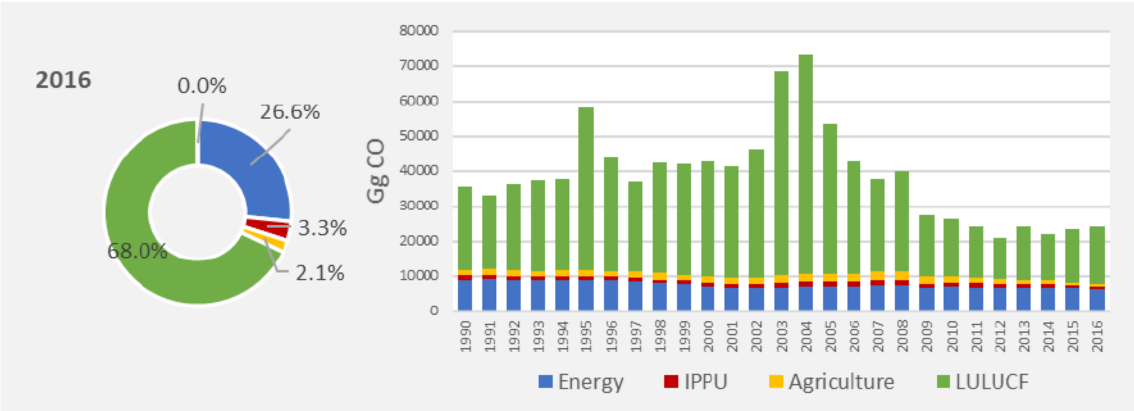



Figure 2.11. CO Emissions, from 1990 to 2016

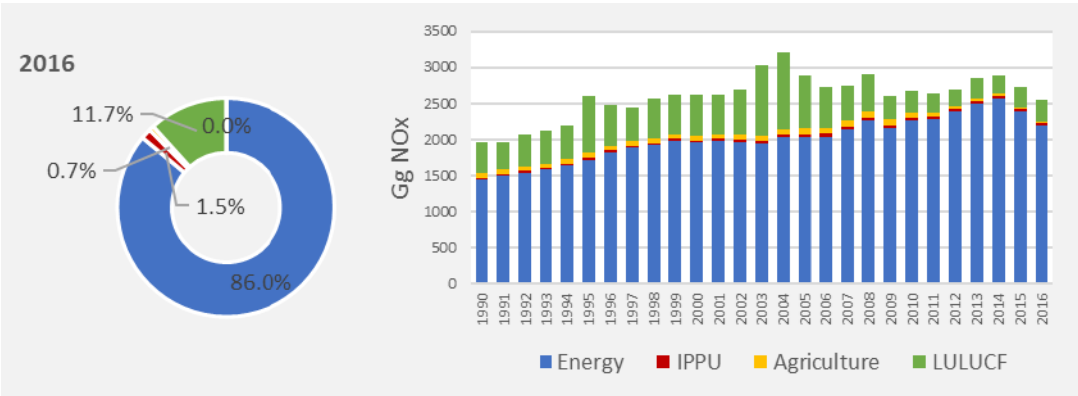



Figure 2.12. $NO_x$ emissions, from 1990 to 2016

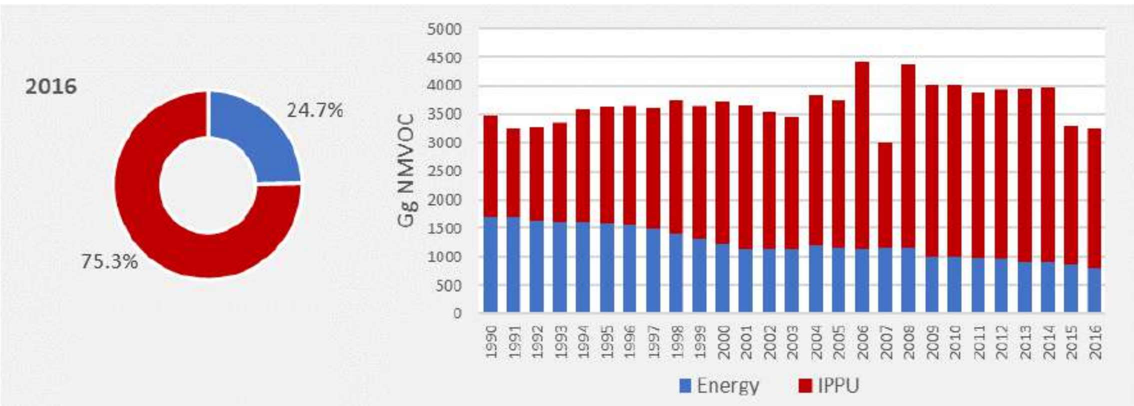



Figure 2.13. NMVOC emissions, from 1990 to 2016

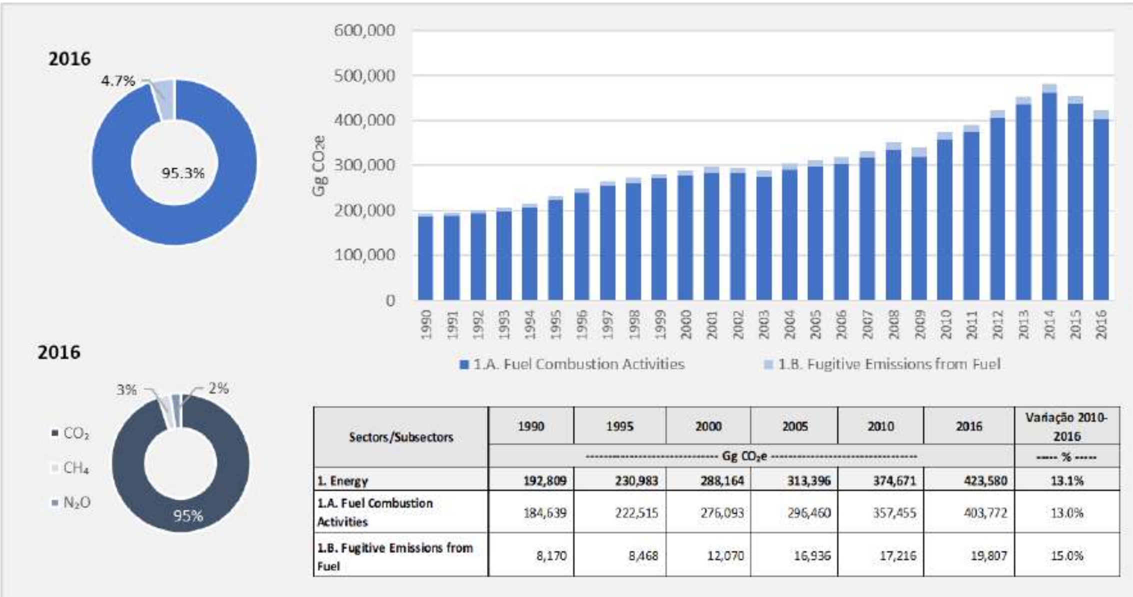
## 2.3 ENERGY SECTOR (1)

The activities of the Energy sector related to GHG emissions estimated in national inventories are exploration and conversion of primary energy sources (energy products provided by nature in its direct form, e.g., oil, natural gas, mineral coal, etc.); fuel transmission and distribution; and use of fuels in facilities and equipment.

The inventoried gases for the sector were $CO_2$, $CH_4$, $N_2O$, in addition to indirect GHG — CO, $NO_x$, and NMVOC. The main subsectors in Energy are Fuel Combustion Activities (1.A) and Fugitive Emissions from Fuel (1.B). The $CO_2$ Transport and Storage (1.C) subsector was not considered in this Inventory, as Petrobras, despite having units in operation in Brazil with $CO_2$ injection for Enhanced Oil Recovery (EOR), did not record the occurrence of $CO_2$ storage activity in the period from 1990 to 2016.

*See the **Appendix I** to check the tables with all results per gas in mass unit, for all sectors and the entire historical series (1990 to 2016)*

Estimates of emissions in the Energy sector totaled 423,580 Gg $CO_2$e in 2016, which reflected an increase of 13% in relation to the sector's $CO_2$e emissions in 2010 (Figure 2.14). The Fuel Combustion Activities subsector (1.A) contributed most of the emissions and represented 95% of the sector's $CO_2$e emissions, while the Fugitive Emissions from Fuel subsector (1.B) represented 5%.




| Sectors/Subsectors | 1990 | 1995 | 2000 | 2005 | 2010 | 2016 | Variação 2010-2016 |
|---|---|---|---|---|---|---|---|
| | Gg $CO_2$e | | | | | | % |
| **1. Energy** | **192,809** | **230,983** | **288,164** | **313,396** | **374,671** | **423,580** | **13.1%** |
| **1.A. Fuel Combustion Activities** | 184,639 | 222,515 | 276,093 | 296,460 | 357,455 | 403,772 | 13.0% |
| **1.B. Fugitive Emissions from Fuel** | 8,170 | 8,468 | 12,070 | 16,936 | 17,216 | 19,807 | 15.0% |

Figure 2.14. Emissions of the Energy sector, in $CO_2$e, by subsector from 1990 to 2016

For 2016, 96% of the $CO_2$ emissions in the sector came from Fuel Combustion Activities (1.A). The Transport category (1.A.3) was the most representative, due to the prevalence of this activity in the country, contributing 50% of $CO_2$ emissions. For $CH_4$ and $N_2O$, emissions from the Fuel Combustion Activities subsector corresponded to 67% and 99%, respectively.

According to the IPCC 2006 methodology, $CO_2$ emissions from the consumption of biomass fuels are reported but are not counted in the sector's total emissions.

## 2.3.1 Methodological aspects of the sector

The methods for calculating emissions followed the IPCC 2006[4]. For data on fuel consumption and transformation, the National Energy Balance (BEN) (EPE, 2019) was used. For Tier 2 modeling of non-$CO_2$ gases, the breakdown of fuel consumption between final energy destinations was made using the three editions of the Useful Energy Balance (BEU)[5], available in Brazil for 1983, 1993, and 2004. For the remaining years, interpolations and extrapolations were made with the existing data. In the case of air transport and road transportation (driving force), the modeling provided that the estimates were even more detailed and incorporated the technologies[6]. Panel 2.2 shows the sources of information used in each category.

[4] *Intergovernmental Panel on Climate Change (IPCC). IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme. Vol. 2, Energy (IPCC, 2006).*

[5] *The Useful Energy Balance (BEU) allows processing the sectoral information of BEN, of energy consumption, to obtain estimates of the Final Energy destined for the Final Uses: Driving Force, Process Heat, Direct Heating, Refrigeration, Lighting, Electrochemistry and Other Uses and, based on the yields of the first energy transformation process, estimate the Useful Energy (EPE, 2019).*

[6] *Details available in the Reference Reports: Fuel Burning Activities - Sectoral Approach, Civil Aviation and Road Transport.*

Panel 2.2. Methodological levels applied by gas and references of the Energy sector

| Subsector | Category | Subcategories | Estimated gases and methodologies | | | | | | References | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $CO_2$ | $CH_4$ | $N_2O$ | CO | $NO_x$ | NMVOC | Activity Data | Emission Factors |
| 1.A. Fuel Combustion Activities | 1.A.1. Energy Industries | 1.A.1.a. Main Activity Electricity and Heat Production | T2 | T2 | T2 | T2 | T2 | T2 | National Energy Balance – BEN (EPE, 2019); Useful Energy Balance – BEU (1983,1993 and 2004). | Volume 2, Chapter 2 (IPCC, 2006); Volume 2 (IPCC, 1996); EMEP/EEA Air Pollutant Emission Inventory Guidebook (EMEP/EEA, 2013 and 2017); specific for firewood and charcoal (BRASIL, 2016). |
| | | 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 | | |

| Subsector | Category | Subcategories | Estimated gases and methodologies | | | | | | References | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $CO_2$ | $CH_4$ | $N_2O$ | CO | $NO_x$ | NMVOC | Activity Data | Emission Factors |
| | | 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. Transport Equipment | T2 | T2 | T2 | T2 | T2 | T2 | | |
| | | 1.A.2.i. Mining (excluding fuels) and Quarrying | T2 | T2 | T2 | T2 | T2 | T2 | | |
| | | 1.A.2.l. 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 Database (BIMTRA); average times for each step in the LTO cycle (ICAO, 2011; FOI, 2013); average times for APU standard operations for aircraft (ACRP, 2012); National Energy Balance — BEN (EPE, 2019). | Volume 2, Chapter 3 (IPCC, 2006); ANAC (2020). |

| Subsector | Category | Subcategories | Estimated gases and methodologies | | | | | | References | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $CO_2$ | $CH_4$ | $N_2O$ | CO | $NO_x$ | NMVOC | Activity Data | Emission Factors |
| | | 1.A.3.b. Road Transportation | T2 | T3 | T3 | T3 | T3 | T3 | Active fleet: vehicle sales and scrapping curve (ANFAVEA, 2019; ABRACICLO, 2019; BRASIL, 2002; BRASIL, 2010; BRASIL, 2014; IBTS, 2019); Fuel Consumption (CETESB, 2019; BRASIL, 2014; IBTS, 2019); and Intensity of use (BRASIL, 2014; GONÇALVES & D´AGOSTO, 2017; CETESB, 2019) | Volume 2, Chapter 3 (IPCC, 2006); BRASIL (2014); CETESB (2019) |
| | | 1.A.3.c. Railways | T2 | T2 | T2 | T2 | T2 | T2 | National Energy Balance – BEN (EPE, 2019); Useful Energy Balance – BEU (1983,1993 and 2004). | Volume 2, Chapter 2 (IPCC, 2006); Volume 2 (IPCC, 1996); EMEP/EEA Air Pollutant Emission Inventory Guidebook (EMEP/EEA, 2013 and 2017); specific for firewood and charcoal (BRASIL, 2016). |
| | | 1.A.3.d. Domestic Navigation | T2 | T2 | T2 | T2 | T2 | T2 | | |
| | | 1.A.3.e. Other Transportation | T2 | T2 | T2 | T2 | T2 | T2 | | |
| | 1.A.4. Other Sectors | 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, and Fish Farms | T2 | T2 | T2 | T2 | T2 | T2 | | |

| Subsector | Category | Subcategories | Estimated gases and methodologies | | | | | | References | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $CO_2$ | $CH_4$ | $N_2O$ | CO | $NO_x$ | NMVOC | Activity Data | Emission Factors |
| | 1.A.5. Non-Specified | 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 by the Brazilian Coal Association (ABCM, 2019) | Volume 2, Chapter 4 (IPCC, 2006) |
| | | 1.B.1.b. Uncontrolled Combustion, and Burning Coal Dumps | NO | NO | NO | NO | NO | NO | | |
| | | 1.B.1.c. Solid Fuel Transformation | 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 | Results of GHG emissions by Petrobras; Production and refining data by the National Oil, Natural Gas and Biofuels Agency (ANP, 2019); processed load from the National Energy Balance (EPE, 2019). | Industries protocols and sources of emissions of categories |
| | | 1.B.2.b. Natural Gas | T2, T3 | T2, T3 | T2, T3 | NE | NE | NE | | |

Note: Method applied (IPCC, 2006) — T1: *Tier* 1; T2: *Tier* 2; T3: *Tier* 3.
Notation keys: NA — not applicable; NO — not occurring; NE — not estimated.

The main source of data for the $CO_2$, $CH_4$, and $N_2O$ emission factors was the IPCC 2006. In the case of non-$CO_2$ gases ($CH_4$, $N_2O$, CO, $NO_x$, and NMVOC), emissions do not depend only on the type of fuel used, but also the combustion technology employed and the operating conditions. Thus, the more accurate calculation of emissions of these gases requires more disaggregated data and detailed methodology (Tier 2 and Tier 3). Some emission factors used for $CH_4$ and $N_2O$ were obtained from the EMEP/EEA Air Pollutant Emission Inventory Guidebook, in its 2013 and 2016 editions (EMEP/EEA, 2013 and 2017). In the absence of adequate emission factors in the aforementioned guidelines, those of the IPCC 1996 were maintained.

The non-$CO_2$ gas emission factors used in the estimates of the Domestic Aviation (1.A.3.a) and Road Transportation (1.A.3.b) categories varied over the period of the Inventory and were obtained by modeling in Tier 3a and Tier 3, respectively. These models were used for the breakdown with a greater level of detail than the estimates of the other categories. Average emission factors for fuels were obtained from the models in Tier 3a and Tier 3, for each year inventoried.

Some of the activity data and emission results were not subject to disaggregation in the Inventory. This information was obtained in an aggregated way and was thus reported. Panel 2.3 shows the emission allocations for the subcategories that could not be broken down in the Energy sector.

Panel 2.3. Categories for which the values were included elsewhere (IE) in the Energy Sector

| IPCC Codes | Previous categories | Allocation |
|---|---|---|
| 1.A.1.a.i | Electricity Generation | 1.A.1.a Main Activity Electricity and Heat Production |
| 1.A.1.a.ii | Combined Heat and Power Generation (CHP) | 1.A.1.a Main Activity Electricity and Heat Production |
| 1.A.1.a.iii | Heat Plants | 1.A.2 Manufacturing Industries and Construction |
| 1.A.1.c.i | Manufacture of Solid Fuels | 1.A.1.c Manufacture of Solid Fuels and Other Energy Industries |
| 1.A.1.c.ii | Other Energy Industries | 1.A.1.c Manufacture of Solid Fuels and Other Energy Industries |
| 1.A.2.h | Machinery | 1.A.2.g Transport Equipment |
| 1.A.2.j | Wood and Wood Products | 1.A.2.d Pulp, Paper and Print |
| 1.A.2.k | Construction | 1.A.2.g Transport Equipment |
| 1.A.2.m | Non-specified Industry | 1.A.2.g Transport Equipment |
| 1.A.3.e.ii | Off-road | Sectorally distributed in the National Energy Balance |
| 1.A.4.c.i | Stationary | 1.A.4.c Agriculture / Forestry / Fishing / Fish Farms |
| 1.A.4.c.ii | Off-road Vehicles and Other Machinery | 1.A.4.c Agriculture / Forestry / Fishing / Fish Farms |
| 1.A.4.c.iii | Fishing (mobile combustion) | 1.A.4.c Agriculture / Forestry / Fishing / Fish Farms |

| IPCC Codes | Previous categories | Allocation |
|---|---|---|
| 1.A.5.b.ii | Mobile (Water-borne Component) | 1.A.4.a Commercial / Institutional |
| 1.B.2.biii.2 | Production (Natural Gas) | 1.B.2.a.iii.2 Production and Upgrading (Oil) |

For some subcategories, it was not possible to calculate emissions, mainly due to a lack of information. In Panel 2.4, the subcategories for which GHGs were not estimated in the Energy sector were compiled.

Panel 2.4. Subcategories not estimated (NE) for the Energy Sector.

| IPCC Codes | Subcategories | Notes |
|---|---|---|
| 1.A.3.b.v.i | Urea-based Catalysts | Emissions not considered due to the lack of national information. |
| 1.B.1.a.i.3 | Abandoned Underground Mines | There is not enough information to characterize abandoned mines in the country, in order to estimate emissions after the end of its activities. |
| 1.B.2.a.iii.1 | Exploration (Oil) | Until the Fourth Inventory, Petrobras did not have enough information for the emissions of these subcategories to be estimated. |
| 1.B.2.a.iii.5 | Distribution of Oil Products | |
| 1.B.2.b.iii.1 | Exploration (Natural Gas) | |
| 1.B.2.b.iii.5 | Distribution (Natural Gas) | |

## Comparison between the Reference and the Sectoral approaches

The calculation of GHG emissions for fossil fuels combustion must be prepared based on two approaches, according to the IPCC 2006: the Reference Approach (top-down methodology) and the Sectoral Approach (bottom-up methodology). The emissions that integrate the accounting of national inventories are those carried out with the Sectoral Approach. The more simplified Reference Approach consists of calculating emissions from aggregated data on the supply of fuels. For this, the concept of apparent consumption is used: the production of primary fuels and the import of primary and secondary fuels are added, and the export of primary and secondary fuels, *bunkers*[7] and the variation in stock (which can be positive or negative). From this result, $CO_2$ emissions are estimated based on the carbon content of fuels.

For the Sectoral Approach, information on fuel consumption by the Energy sector is used, which is multiplied by the corresponding emission factors. The calculation of $CO_2$ emissions with the two approaches can lead to different results, but it is used as quality control of the results of the sector. According to IPCC 2006, differences above 5% are considered significant and must be investigated and explained.

[7] *In the Sectoral Approach, emissions from international bunkers must be calculated and reported, however they are not counted in the country's total.*

For the Fourth Inventory, an average percentage variation of 1.7% was observed between the Reference Approach and the Sectoral Approach, for the historical series from 1990 to 2016, with an absolute maximum of 3.7% in 1998. In 2016, the difference between the two approaches was -0.1%, according to Table 2.5.

Table 2.5. Comparison between Reference and Sector approaches in the Energy sector

| Year | Reference Approach (Gg $CO_2$) | Sectoral Approach (Gg $CO_2$) | Difference |
|---|---|---|---|
| 1990 | 174,697 | 170,855 | 2.2% |
| 1991 | 180,552 | 174,530 | 3.5% |
| 1992 | 184,171 | 179,832 | 2.4% |
| 1993 | 190,501 | 185,032 | 3.0% |
| 1994 | 199,495 | 193,483 | 3.1% |
| 1995 | 213,954 | 210,030 | 1.9% |
| 1996 | 232,839 | 226,662 | 2.7% |
| 1997 | 248,007 | 241,647 | 2.6% |
| 1998 | 257,084 | 248,026 | 3.7% |
| 1999 | 264,100 | 256,773 | 2.9% |
| 2000 | 266,109 | 262,738 | 1.3% |
| 2001 | 278,428 | 269,687 | 3.2% |
| 2002 | 273,030 | 267,097 | 2.2% |
| 2003 | 262,993 | 259,898 | 1.2% |
| 2004 | 279,238 | 275,107 | 1.5% |
| 2005 | 283,974 | 279,894 | 1.5% |
| 2006 | 287,083 | 285,827 | 0.4% |
| 2007 | 299,812 | 298,680 | 0.4% |
| 2008 | 318,148 | 317,169 | 0.3% |
| 2009 | 302,768 | 300,476 | 0.8% |
| 2010 | 344,435 | 339,596 | 1.4% |
| 2011 | 357,952 | 356,153 | 0.5% |
| 2012 | 387,867 | 387,400 | 0.1% |
| 2013 | 422,113 | 418,400 | 0.9% |
| 2014 | 445,837 | 443,238 | 0.6% |
| 2015 | 420,273 | 418,006 | 0.5% |
| 2016 | 385,396 | 385,850 | -0.1% |

## *International bunker*

According to IPCC 2006, emissions resulting from fuels combustion in international activity (bunker), for which there is still no criterion for the division of responsibilities, should not be counted in national inventories but must be reported for purposes of composition of the global data. These emissions are related to flights and maritime and fluvial transport that leave one country and arrive in another. For this Inventory, the subcategories that have emissions linked to bunkers were:

- 1.A.3.a.i. International aviation
- 1.A.3.d.i. International navigation

- **International aviation**

For the estimation of bunker emissions in aviation from 2005 to 2016, information related to aviation kerosene consumed on international flights was used, based on bottom-up modeling (ANAC, 2020). The division into domestic flights and bunker was not necessary in the case of aviation gasoline, since this energy source is conventionally used in small aircraft that operate on domestic routes. The calculation of emissions from 1990 to 2004 was carried out based on BEN bunker consumption information, adjusted by the overlap technique to maintain the temporal consistency of the historical series, and considered the implicit emission factors obtained in 2005 (from bottom-up modeling).

Figure 2.15 shows the evolution of emissions in $CO_2e$ for national and international aviation.

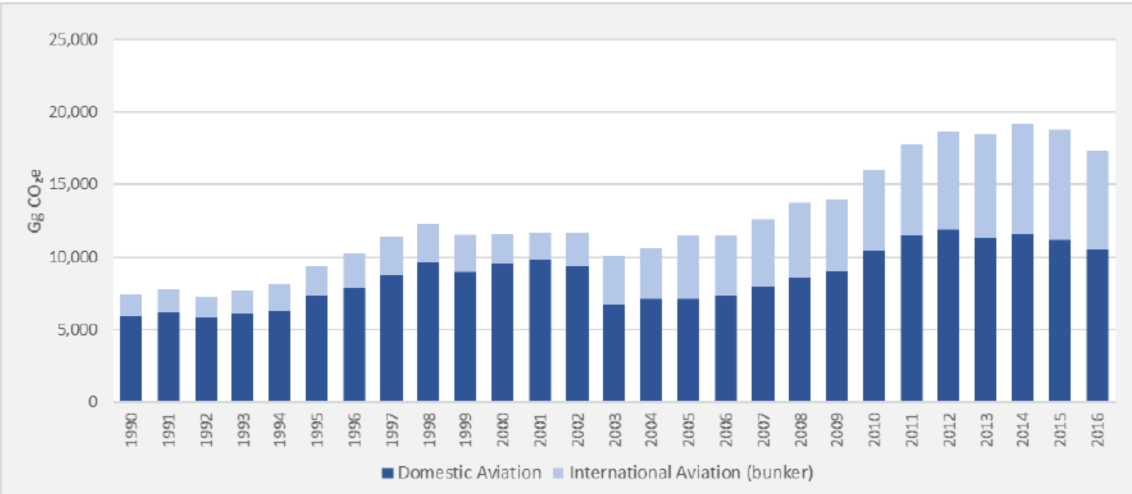



Figure 2.15. Historical series of $CO_2e$ emissions for domestic aviation and bunker, from 1990 to 2016

- **International navigation**

For the calculation of emissions related to international navigation, the consumption of bunker fuel oil and diesel oil indicated in BEN, referring to international waterway transportation, were considered. From the consumption of these fuels, specific emission factors were applied. Figure 2.16 shows the evolution of $CO_2e$ emissions for national and international navigation.

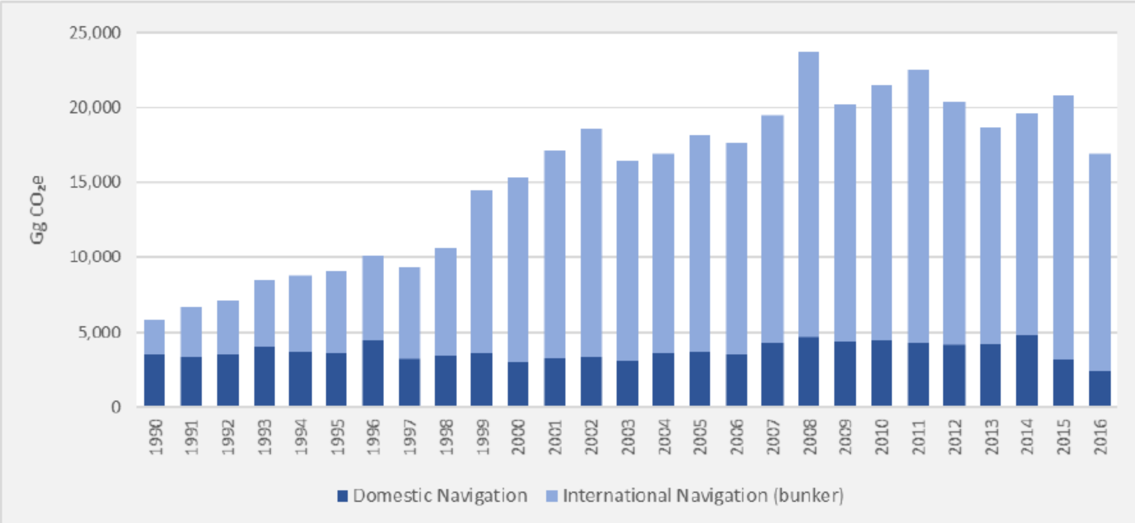



Figure 2.16. Historical series of $CO_2e$ emissions for domestic navigation and bunker, from 1990 to 2016

## *Non-energy fuels*

In order to avoid double counting, emissions from non-energy use of fuels are not accounted for in the Energy sector and their emissions were allocated to IPPU, as described below:

- Metal Industry: fuels used as reductants in the iron and steel, ferroalloy, and non-ferrous industries. It should be noted that the values of petroleum coke, bituminous coals, coal coke, and charcoal are considered to be reductants, whose final use is in direct heating, according to the Useful Energy Balance (BEU).
- Non-energy fuel and solvent products: fuels such as asphalt, lubricants, solvents, and other non-energy petroleum products, specified in BEN.
- Chemical Industry: all fuels accounted for as “final non-energy consumption” in BEN, except for those included in the item above.

## 2.3.2 Fuel Combustion Activities (1.A)

In the Fuel Combustion Activities subsector (1.A), emissions from the oxidation of carbon contained in fuels are accounted for during their final use, or in the generation of electricity. The gases considered in this subsector were $CO_2$, $CH_4$, and $N_2O$, in addition to indirect GHG (CO, $NO_x$, and NMVOC).

In 2016, this subsector totaled 403,772 Gg $CO_2e$. The Transport category (1.A.3) had the largest share, with 51.1% of the total $CO_2e$ emitted in 2016. Energy Industries (1.A.1) and Manufacturing Industries and Construction (1.A.2) corresponded to 19.5% and 18.6%, respectively. From 2010 to 2016, the total emissions of the subsector increased by 13% in $CO_2e$.

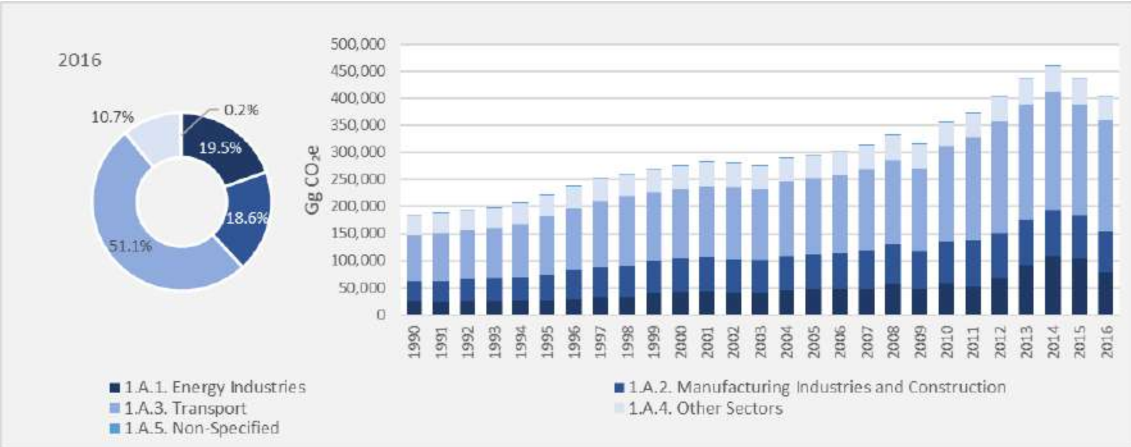



Figure 2.17. Emissions from Fuel Combustion Activities (1.A), in $CO_2e$, by category from 1990 to 2016

In the Energy Industries category (1.A.1), the most representative emissions in 2016 were due to the fuels combustion for electricity generation, which corresponded to 54.4% of the category.

For the Manufacturing Industries and Construction category (1.A.2), energy consumption in the non-metallic minerals industry represented the largest share in the category's GHG emissions in 2016 (with 25.7%), followed by industry chemical products (18.8%), and non-ferrous metals (12%).

In Transport (1.A.3), road transport participated with 91.5% of the total emissions of the category in 2016. Of these, heavy trucks and buses represented 55.3%, and automobiles participated with 35.9%.

In 2016, for the Other Sectors category (1.A.4), the residential sector contributed 56.1% of emissions, mainly due to the use of firewood for cooking.

The category indicated as Non-Specified (1.A.5) mainly referred to the aviation component, due to fuel consumption in helicopters, small aircraft, and military aircraft, not included in the Transport category (1.A.3).

## 2.3.3 Fugitive Emissions from Fuel Production (1.B)

GHGs emitted accidentally or intentionally during the extraction, processing, storage, and transportation of fossil fuels until their final use, are referred to as fugitive emissions. In this way, the Fugitive Emissions from Fuel Production subsector, or just Fugitive Emissions (1.B), is related to the emissions from fuel production systems, with the exception of fuel combustion contributions.

In Brazil, these emissions refer to the mining and processing of coal (1.B.1.a Coal Mining and Handling), in addition to those associated with the extraction, transportation, and processing of oil and natural gas (1.B.2 Oil and Natural Gas). In 2016, emissions from this subsector totaled 19,807 Gg $CO_2$e, an increase of 15% in comparison to the result of 2010.

Given the national characteristics, for Coal Mining and Handling (1.B.1.a) only $CH_4$ was estimated, and for the Oil and Natural Gas category (1.B.2), $CO_2$, $CH_4$, and $N_2O$ were considered.

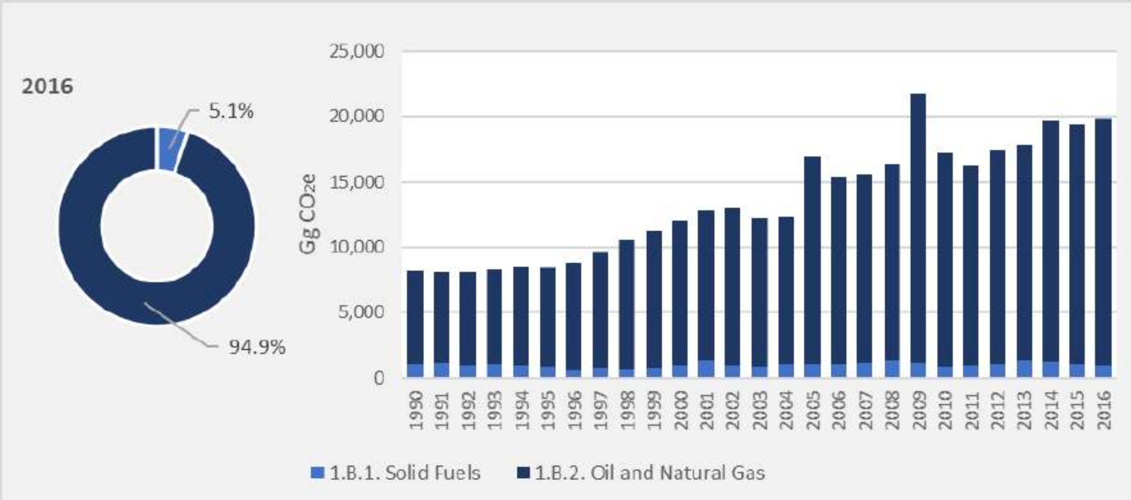



Figure 2.18. Emissions from the Fugitive Emissions subsector (1.B), in $CO_2$e, by category from 1990 to 2016

The Solid Fuels category (1.B.1), fully represented by the Coal Mining and Handling sub-category (1.B.1.a), contributed, in 2016, with 5.1% of the total $CO_2$e emissions of the subsector. Emissions in this subcategory refer to mining operations and mineral coal processing and include fugitive $CH_4$ emissions from surface and underground mines, in addition to post-mining activities. The amount of $CH_4$ released during mining depends on the classification of the coal, the depth in which it is found, its gas content, and the mining method.

In 2016, the Underground Mines subcategory (1.B.1.a.i) was responsible for 90.9% of $CO_2$e emissions in the Solid Fuels category (1.B.1), with the remainder corresponding to Surface Mines (1.B.1.a.ii).

The Oil and Natural Gas category (1.B.2) represented 94.9% of the $CO_2$e emissions in the subsector (1.B), with 94.7% of the emissions in this category being related to Oil (1.B.2.a) and 5.3% to Natural Gas (1.B.2.b) in 2016. Of the gases estimated in the subsector (1.B), $CO_2$ represented 80% of emissions in 2016, followed by $CH_4$ with 19.7%, and $N_2O$ with 0.3%.

Emissions in the Oil and Natural Gas category (1.B.2) include fugitive $CH_4$ emissions during the extraction of oil and natural gas, their transportation and distribution in pipelines and ships, and their processing in refineries. $CO_2$, $CH_4$, and $N_2O$ emissions from flares on oil and natural gas extraction platforms and refinery units are also considered. $CO_2$ emissions from fuel burning in flares, or non-useful combustion, are included as fugitive emissions, even if they are the result of combustion, but are associated with loss and not useful fuel consumption. The use of oil and natural gas, or their derivatives, to supply energy for internal use in energy production and transportation is considered as combustion and, therefore, treated in the Fuel Combustion Activity subsector (1.A.).

## 2.4 INDUSTRIAL PROCESSES AND PRODUCT USE SECTOR (2)

Emissions related to activities in the Industrial Processes and Product Use (IPPU) sector are those resulting from productive processes in industries, including the non-energy consumption of fuels as a raw material. The fuel combustion for energy purposes is reported in the Energy sector (1.A).

The following subsectors were considered: 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 the sector were: $CO_2$, $CH_4$, $N_2O$, and $SF_6$; those belonging to the family of HFCs (hydrofluorocarbons) - HFC-23, HFC-32, HFC-125, HFC-134a, HFC-143a, HFC-152a, HFC-227ea, and HFC-365mfc; and PFCs (perfluorocarbons) - $CF_4$ and $C_2F_6$. The use of $NF_3$ (nitrogen trifluoride) has not been identified in the country.

Estimates of emissions from the IPPU sector totaled 93,359 Gg of $CO_2e$ in 2016, which indicated an increase of 7% compared to 2010, as shown in Figure 2.19. The Metal Industry subsector (2.C) contributed most of the emissions, with a 52% representation of the sector's $CO_2e$ emissions in 2016. The Mineral Industry subsector (2.A) was the second most representative, with 31%.

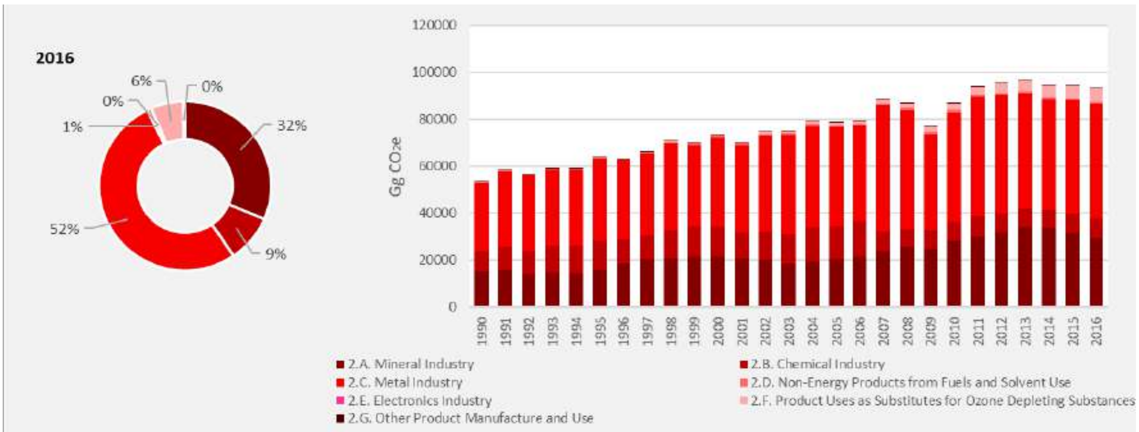
For 2016, $CO_2$ emissions represented 92% of the sector's total (in $CO_2e$), with the contribution of the Metal Industry (2.C) and Mineral Industry (2.A) subsectors of 56% and 34%, respectively.

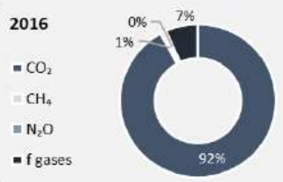
Following $CO_2$, there was the participation of HFCs gases, with 6% of the sector, with emphasis on the subsector Product Uses as Substitutes for Ozone Depleting Substances (2.F), which represented almost 100% of them.

*See the **Appendix I** to check the tables with all results per gas in mass unit, for all sectors and the entire historical series (1990 to 2016)*

$CH_4$ had a 0.8% share of the sector's GHG emissions in 2016, 65% of which came from the Metal Industry subsector (2.C) and 35% from the Chemical Industry subsector (2.B).

$N_2O$ accounted for 0.4% of emissions in 2016, divided between the Chemical Industry subsector (2.B), with 66%, and the Metal Industry subsector (2.C), with 34%.




| Sector/ Subsector | 1990 | 1995 | 2000 | 2005 | 2010 | 2016 | Variation 2010-2016 |
|---|---|---|---|---|---|---|---|
| | Gg $CO_2e$ | | | | | | ----- % ----- |
| **2.A. Mineral Industry** | **53,553** | **63,965** | **73,758** | **78,883** | **87,101** | **93,359** | **7.2%** |
| 2.B. Chemical Industry | 15,171 | 16,149 | 21,702 | 20,444 | 28,359 | 29,373 | 3.6% |
| 2.C. Metal Industry | 8,744 | 12,070 | 12,744 | 14,164 | 8,012 | 8,422 | 5.1% |
| 2.D. Non-Energy Products from Fuels and Solvent Use | 28,988 | 35,148 | 38,028 | 42,194 | 46,817 | 48,778 | 4.2% |
| 2.E. Electronics Industry | 520 | 470 | 624 | 661 | 800 | 763 | -4.6% |
| 2.F. Product Uses as Substitutes for Ozone Depleting Substances | - | - | - | - | 0.09 | 0.41 | 355.8% |
| 2.G. Other Product Manufacture and Use | - | - | 505 | 1,231 | 2,872 | 5,728 | 99.4% |
| 2.G. Fabricação e Uso de Outros Produtos | 130 | 128 | 154 | 190 | 241 | 295 | 22.3% |

Figure 2.19. Emissions from the Industrial Processes and Use of Products sector, in $CO_2e$, by subsector, from 1990 to 2016

The share of emissions from PFCs and $SF_6$ were equal, 0.3% each, the first being almost entirely due to the production of aluminium and the second due to the Manufacture and Use of Other Products Manufacture and Use (2.G), more specifically in electrical equipment.

## 2.4.1 Methodological aspects of the sector

The methods for calculating emissions were as indicated in IPCC 2006[8]. For the indirect greenhouse gas emission factors, for which there are no updates, the IPCC 1996[9]. Whenever possible, parameters or emission factors available in the national literature, such as in the production of ceramics, or used in industry, as occurred in the production of iron and steel, in cement and the chemical industry, to portray the reality of the country and avoid the use IPCC default values. The data obtained from official sources were complemented by information from the productive sector, through their class associations.

Access to activity data and other parameters in the IPPU sector presented particular challenges, as it often involves the confidentiality of companies' information regarding technological processes or even the quantity of their production. For some subsectors, such as cement, aluminium, and iron and steel production, the quantities produced were available in official publications, such as in the IBGE Automatic Recovery System - SIDRA (IBGE, 2017b), BEN (EPE, 2019) and Statistical Yearbooks of the Metal Sector and the Non-Metallic Transformation Sector (MME, 2019), possibly without the desired refinement for application in the Inventory. To complement the information related to some parameters and emission factors of these subsectors, industrial associations were important, either for access to their publications or for direct contact with companies.

For the Cement Production (2.A.1) and Aluminium Production (2.C.3) subsectors, aggregated information was obtained from industrial associations regarding the most accurate estimates (Tier 3), for specific years, of associated companies. In the absence of these values, extrapolations were performed with the available data. For the Iron and Steel Production subsector (2.C.1), data collected by Instituto Aço Brasil from its associates allowed a general carbon balance to calculate $CO_2$ (Tier 2).

In the Chemical Industry (2.B), for the production of Nitric Acid (2.B.2) and Adipic Acid (2.B.3), the existence of projects under the Clean Development Mechanism (CDM)[10] allowed access to data detailed information of companies, based on published reports for monitoring GHG reduction operations.

Details of the methodologies, parameters, emission factors, and sources of information used in each category of the IPPU sector are presented in Panel 2.5.

[8] *Intergovernmental Panel on Climate Change (IPCC). IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme. Vol. 3, Industrial Processes and Product Use (IPCC, 2006).*

[9] *Intergovernmental Panel on Climate Change (IPCC). Revised IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme. Vol. 3, Industrial Processes and Product Use (IPCC, 1996).*

[10] *CDM web-page, available at: https://cdm.unfccc.int/Projects/projsearch.html.*

Panel 2.5. Methodological levels applied by gas references of the IPPU sector

| 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.A. Mineral Industry | 2.A.1. Cement Production | T3 | NA | NA | NA | NA | NA | NA | NA | NA | Total clinker production (SNIC, 2013). | Data from SNIC (2013), with the latest actual calculation of emission factors conducted in 2010. From 2011, the implicit factor was the average for 2008-2010. |
| | 2.A.2. Lime Production | T2 | NA | NA | NA | NA | NA | NA | NA | NA | Production of quicklime and hydrated lime (ABPC, 2014). As of 2015, the values for 2014 have been maintained. Average composition of limes according to the variation allowed by Brazilian standards. | Volume 3, Chapter 2 (IPCC, 2006) |
| | 2.A.3. Glass Production | T3 | NA | NA | NA | NA | NA | NA | NA | NA | Glass production according to the Statistical Yearbook – Non-Metallic Transformation Sector (MME, 2019). Following the latest data (2011), calculation of production was based on IBGE's trend indexes for "23.1 Manufacture of glass and glass products". | Stoichiometry of chemical processes, based on the average composition of glass raw material, according to the Yearbook, with emission factors from Volume 3, Chapter 2 (IPCC, 2006) |

| 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.A.4. Other Process Uses of Carbonates | T2 | NA | NA | NA | NA | NA | NA | NA | NA | Ceramics: Production (IBGE, 2017b), breakdown of national production according to the Yearbook of Statistics of the Non-Metallic Transformation Sector (MME, 2019) and the Brazilian Ceramics Association (ABCERAM, 2019); Sodium carbonate: Production, import and export (ABIQUIM, 2014); Magnesite: Data from the Mineral Summary (ANM, 2016) and 2001 Brazilian Mineral Balance (ANM, 2001). | For ceramics, several publications that differentiated the parameters according to the characteristics of the various states and regions of Brazil were considered. Stoichiometry of chemical processes; Volume 3, Chapter 2 (IPCC, 2006) |
| 2.B. Chemical Industry | 2.B.1. Ammonia Production | T3 | NA | NA | NA | NA | NA | NA | NA | NA | Ammonia production (ABIQUIM, 2014); Urea (IBGE, 2017b), for years prior to 2005, in conjunction with ABIQUIM data from 2005 to 2007. | National specific factor, excluding $CO_2$ 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). Subsequently, by monitoring CDM projects (UNFCCC, 2019). | Data by Abiquim (2009) and from CDM project monitoring (UNFCCC, 2019). |
| | 2.B.3. Adipic Acid Production | NA | NA | T3 | T1 | T1 | NA | NA | NA | NA | Production up to 2010 (ABIQUIM, 2008, 2012). Subsequently, by monitoring CDM projects (UNFCCC, 2019). | Data by Abiquim (2012) and from CDM project monitoring (UNFCCC, 2019). |

| 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.4. Caprolactam, Glyoxal and Glyoxylic Acid Production | NA | NA | T1/ NO | NA | NA | NA | NA | NA | NA | ABIQUIM (2014) | Volume 3, Chapter 3 (IPCC, 2006) |
| | 2.B.5. Carbide Production | T1 | NO | NA | NA | NA | NA | NA | NA | NA | Specific information about the plant up to 2007, with complementary information up to 2010 (ABIQUIM, 2012); and repeated information up to 2016. | Plant specific information up to 2007; 2008-2010 ABIQUIM (2012); repeated information up to 2016. |
| | 2.B.6. Titanium Dioxide Production | NA | NA | NA | NA | NA | NA | NA | NA | NA | | |
| | 2.B.7. Soda Ash Production | NA | NA | NA | NA | NA | NA | NA | NA | NA | | |
| | 2.B.8. Petrochemical and Carbon Black Production | T1 | T1 | NA | NA | T1 | T1 | NA | NA | NA | ABIQUIM (2020). | Volume 3, Chapter 3 (IPCC, 2006) |

| 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. Fluorochemicals Production | NA | NA | NA | NA | NA | NA | T1 | NA | NA | Prozon (1999) | Volume 3, Chapter 3 (IPCC, 2006) |
| 2.C. Metal Industry | 2.C.1. Iron and Steel Production | T2 | T1 | T1 | NA | NA | NA | NA | NA | NA | Brazil Steel Institute (IABR, 2017) | $CO_2$: carbon balance (IABR, 2020). Non-$CO_2$: Volume 2, Chapter 2 (IPCC, 2006) |
| | 2.C.2. Ferroalloy Production | T2 | T1 | NA | NA | NA | NA | NA | NA | NA | National Energy Balance — BEN (EPE, 2019) | Volume 3, Chapter 4 (IPCC, 2006) |
| | 2.C.3. Aluminium Production | T1/ T2/ T3 | NA | NA | T1 | T1 | NA | NA | T1/ T2/ T3 | NA | ABAL (2019) | $CO_2$ and PFCs: ABAL (2019); non-$CO_2$: IPCC (1996) |
| | 2.C.4. Magnesium Production | T1 | NA | NA | NA | NA | NA | NA | NA | T1 | RIMA Industrial (2009). From 2005, by monitoring CDM projects (UNFCCC, 2019). | Volume 3, Chapter 4 (IPCC, 2006) |
| | 2.C.5. Lead Production | IE | NA | NA | NA | NA | NA | NA | NA | NA | | |
| | 2.C.6. Zinc Production | NA | NA | NA | NA | NA | NA | NA | NA | NA | | |

| 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.C.7. Other (non-ferrous metals, except aluminium and magnesium) | T1 | NA | NA | NA | NA | NA | NA | NA | NA | National Energy Balance — BEN (EPE, 2019) | Volume 3, Chapter 4 (IPCC, 2006) |
| 2.D Non-Energy Products from Fuels and Solvent Use | 2.D.1. Use of Lubricants | T1 | NA | NA | NA | NA | NA | NA | NA | NA | National Energy Balance — BEN (EPE, 2019) | Volume 3, Chapter 5 (IPCC, 2006) |
| | 2.D.2. Use of Paraffin Wax | IE | NA | NA | NA | NA | NA | NA | NA | NA | | |
| | 2.D.3. Other | T1 | NA | NA | NA | NA | T1 | NA | NA | NA | National Energy Balance — BEN (EPE, 2019) | IPCC (1996) |
| 2.E. Electronics Industry | 2.E.1. Integrated Circuit or Semiconductor | NA | NA | NA | NA | NA | NA | IE | IE | NO | | |
| | 2.E.2. TFT Flat Panel Display | NA | NA | NA | NA | NA | NA | IE | IE | NO | | |
| | 2.E.3. Photovoltaic Panels | NA | NA | NA | NA | NA | NA | NE | NE | NO | | |

| 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.E.4. Heat Transfer Fluid | NA | NA | NA | NA | NA | NA | NO | NO | NO | | |
| | 2.E.5. Other | NA | NA | NA | NA | NA | NA | T2a | T2a | NO | Foreign trade statistics - Comex Stat (ME, 2019) | Volume 3, Chapter 6 (IPCC, 2006) |
| 2.F. Product Uses as Substitutes for Ozone Depleting Substances | 2.F.1. Refrigeration and Air Conditioning | NA | NA | NA | NA | NA | NA | T2a | NO | NA | Foreign trade statistics - Comex Stat (ME, 2019), IBGE (2017b), ELETROS (2019) | Volume 3, Chapter 7 (IPCC, 2006) |
| | 2.F.2. Foam Agents | NA | NA | NA | NA | NA | NA | T2a | NO | NA | Foreign trade statistics - Comex Stat (ME, 2019) | Volume 3, Chapter 7 (IPCC, 2006) |
| | 2.F.3. Fire Protection | NA | NA | NA | NA | NA | NA | T2a | NO | NA | Foreign trade statistics - Comex Stat (ME, 2019) | Volume 3, Chapter 7 (IPCC, 2006) |
| | 2.F.4. Aerosols | NA | NA | NA | NA | NA | NA | T2a | NO | NA | Foreign trade statistics - Comex Stat (ME, 2019) | Volume 3, Chapter 7 (IPCC, 2006) |
| | 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 | | |

| 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.G. Other Product Manufacture and Use | 2.G.1. Electrical Equipment | NA | NA | NA | NA | NA | NA | NA | NO | T1 | MCT National Survey (2009) | Volume 3, Chapter 8 (IPCC, 2006) |
| | 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 | NA | NA | T1 | NA | NA | NA | IBA (2019) | IPCC (1996) |
| | 2.H.2. Food and Beverage Industry | NA | NA | NA | NA | NA | T1 | NA | NA | NA | Food in general and beers: IBGE (2017b); Sugar: UNICA (2019); Wine: IBRAVIN (2019), UVIBRA (2019), post-2004 (IBGE, 2017b). | IPCC (1996) |
| | 2.H.3. Other | NA | NA | NA | NA | NA | NA | NA | NA | NA | | |

Note: Method applied (IPCC, 2006) — T1: *Tier* 1; T2: *Tier* 2; T3: *Tier* 3.
Notation keys: NA — not applicable; NO — not occurring; NE — not estimated; IE— included elsewhere

Some of the activity data and emission results were not subject to disaggregation in the Inventory, therefore, this information was obtained in aggregate and was thus reported. Panel 2.6 presents the allocation of emissions from categories that could not be broken down, in the IPPU Sector.

Panel 2.6. Categories for which the values were included elsewhere (IE) in the IPPU Sector

| Previous categories | Allocation |
|---|---|
| 2.C.5. Lead Production | 2.C.7. Other (non-ferrous metals, except aluminium and magnesium) |
| 2.D.2. Use of Paraffin Wax | 2.E.5. 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 due to the lack of information. Panel 2.7 compiled the subcategories for which GHGs were not estimated in the IPPU sector.

Panel 2.7. Categories not estimated (NE) in the Inventory for the IPPU sector

| Categories not estimated | Notes |
|---|---|
| 2.E.3. Photovoltaic Panels | Production (since 2012) still considered to be very incipient |
| 2.E.4. Heat Transfer Fluid | Production still considered to be very incipient until 2016 |
| 2.F.5. Solvents | Data could not be obtained due to the large number of possible variations in this area and other uses for the same substances |
| 2.G.3. $N_2O$ from Product Uses | Data are not available in the country |

## 2.4.2 Mineral Industry (2.A)

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

In 2016, the Mineral Industry (2.A) emitted 29,373 Gg $CO_2$, which corresponded to 31% of the sector's $CO_2e$ emissions (Figure 2.20). The main emissions were linked to the Cement Production category (2.A.1), which emitted 21,238 Gg $CO_2$ and contributed 72% of the subsector's emissions. Then, the Lime Production (2.A.2), with emissions of 6,071 Gg $CO_2$, represented 21% of emissions. In 2016, emissions from the Mineral Industry subsector (2.A) were 3.6% higher than those estimated in 2010. However, there was a sharp increase in emissions between 2011 and 2013, reversing the trend from 2014 on.

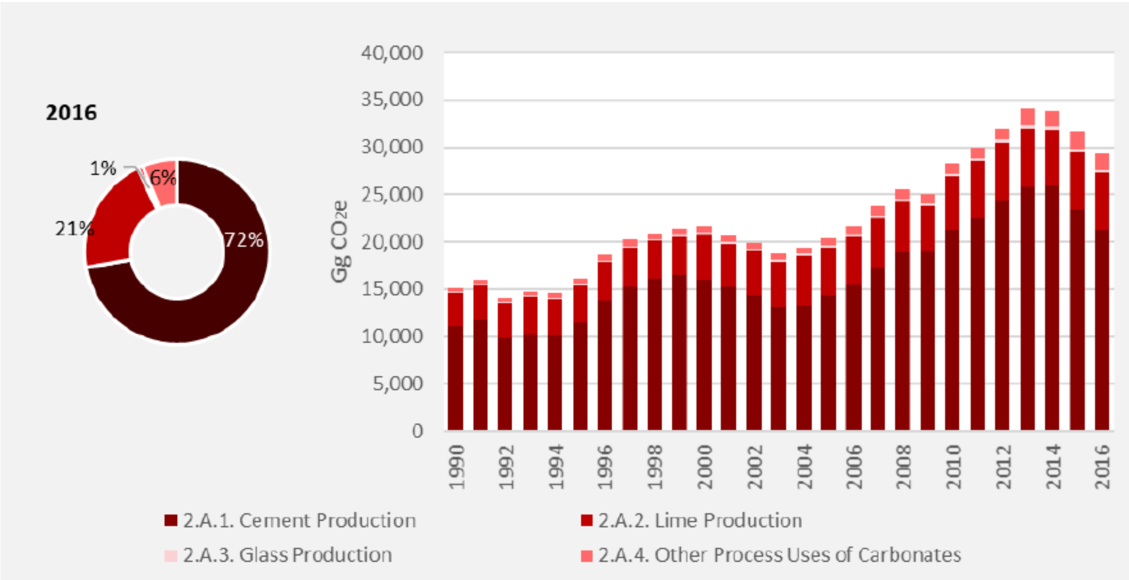



Figure 2.20. Emissions from the Mineral Industry (2.A), in $CO_2e$, by category, from 1990 to 2016

## 2.4.3 Chemical Industry (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); Fluorochemicals 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 activity.

In 2016, the Chemical Industry (2.B) had emissions of 8,422 Gg $CO_2e$, or 9% of the sector's emissions, with an increase of 5.1%, compared to 2010 (Figure 2.21). The Petrochemical and Carbon Black Production category (2.B.8) was the most representative, and corresponded to 91% of the total subsector (2.B). The petrochemical products that had their emissions estimated were: Methanol, Ethene (or Ethylene), Dichloroethane and Vinyl Chloride (MVC), Ethene Oxide, Acrylonitrile, and Calcinated Petroleum Coke.

Next, emissions from Ammonia Production (2.B.1), Nitric Acid Production (2.B.2), and Adipic Acid Production (2.B.3) were the most representative, with 5%, 2 %, and 1%, respectively.

Between 2010 and 2016, among the emissions of the Chemical Industry subsector (2.B), $CO_2$ emissions grew by 5.8%, $CH_4$ emissions by 1.8% and NMVOC emissions by 7.8%. During this period, $N_2O$ emissions fell 9.2%, CO, 49% and $NO_x$, 21%.

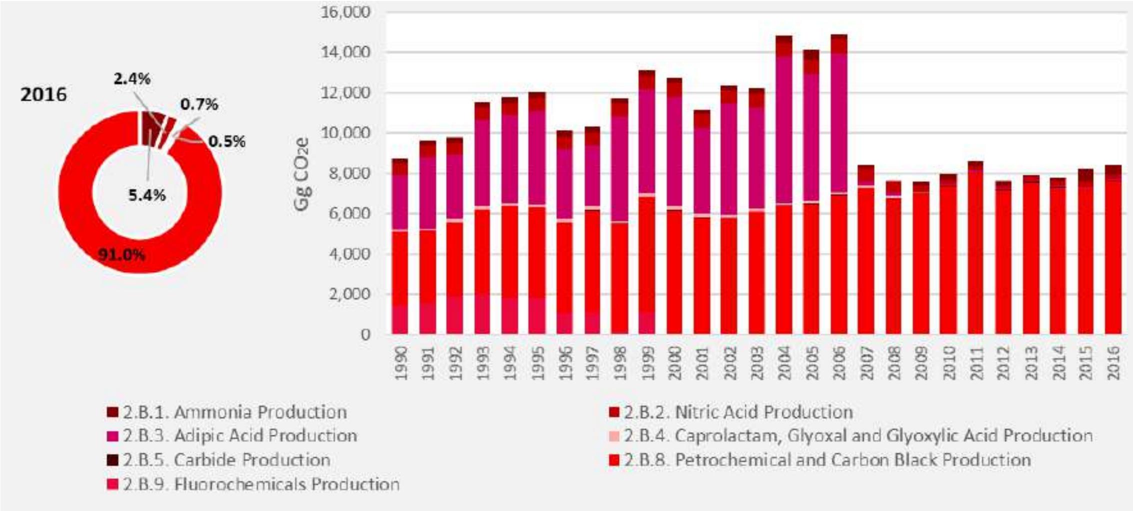



Figure 2.21. Chemical Industry emissions (2.B), in $CO_2e$, by category, from 1990 to 2016

Concerning $CO_2$, it is observed that, throughout the period, the main emitting category was the Petrochemicals and Carbon Black Production (2.B.8) and that, in 2016, contributed 94% of the emissions of this gas in the subsector. In this category, emissions related to the production of Ethene stood out (81% of the category).

In the case of $CH_4$, total emissions refer 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 Ammonia Production (2.B.1) categories, which represented 77% and 23% in 2016, respectively.

About 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 77%, 19%, and 4.6%, respectively, in 2016. Finally, NMVOC emissions came from the category Other Chemicals (2.B.10) and the Petrochemical and Carbon Black Production (2.B.8), with contributions of 81% and 19%, respectively, in 2016.

### 2.4.4 Metal Industry (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); Aluminium production (2.C.3); Magnesium Production (2.C.4); and Other (non-ferrous metals, except aluminium and magnesium) (2.C.7), the latter also including emissions from Lead Production (2.C.5). There is no GHG emission in the Zinc Production category (2.C.6) because, in Brazil, reductants are not used in this process.

In 2016, 48,778 Gg $CO_2e$ were emitted in the subsector[11], which corresponded to 52% of the sector's emissions (Figure 2.22). From 2010 to 2016, emissions from the Metal Industry (2.C) increased by 4.2%.

[11] *According to the IPCC 2006 methodology, $CO_2$ emissions from the consumption of biomass fuels are reported but are not counted in the sector's total emissions.*

The most representative category in the subsector was Iron and Steel Production (2.C.1), responsible for 91% of emissions. The categories Ferroalloys Production (2.C.2), Aluminium Production (2.C.3) and Other (non-ferrous metals, except aluminium and magnesium) (2.C.7) corresponded to 2%, 3%, and 4%, respectively.

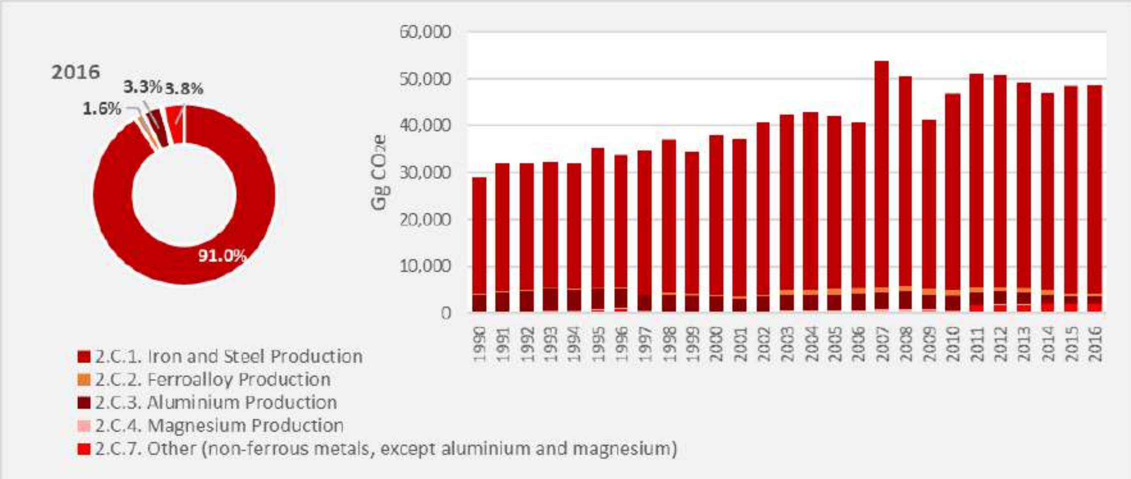



Figure 2.22. Emissions of the Metallurgical Industry (2.C), in $CO_2e$, by category, from 1990 to 2016

Concerning $CO_2$, it can be seen that the main emitting category was Iron and Steel Production (2.C.1) with a 91% contribution in 2016. Most $CO_2$ emissions from steelmaking occurred during the production of pig iron in the blast furnace, that is, in the iron ore reduction step. The categories Ferroalloys Production (2.C.2), Aluminium Production (2.C.3) and Other (non-ferrous metals, except aluminium and magnesium) (2.C.7) corresponded to 2%, 3%, and 4%, respectively, either by reducing raw materials or by consuming anodes.

$CH_4$ and $N_2O$ emissions came from Iron and Steel Production (2.C.1); while CO and $NO_x$ were related to Aluminium Production (2.C.3).

### 2.4.5 Non-Energetic Fuel and Solvent Products (2.D)

Emissions from the Non-Energy Products of Fuels and Solvents (2.D) are related to the categories Use of Lubricants (2.D.1) and Other (2.D.3). Emissions associated with the Use of Paraffin Wax (2.D.2) were included in the category Other (2.D.3).

In 2016, the subsector emitted 763 Gg $CO_2$ and represented 1% of the total emissions of this sector. From 2010 to 2016, emissions of Non-Energy Products from Fuels and Solvent Use (2.D) decreased by 4.6%. The Use of Lubricants category (2.D.1) represented 84% of the total subsector. In this category, emissions resulting from the use of lubricants in machinery and equipment are estimated, only when burned in engines, with the remainder being stored definitively. Emissions in the Other category (2.D.3), which complements the subsector, are related to the non-energy use of tar.

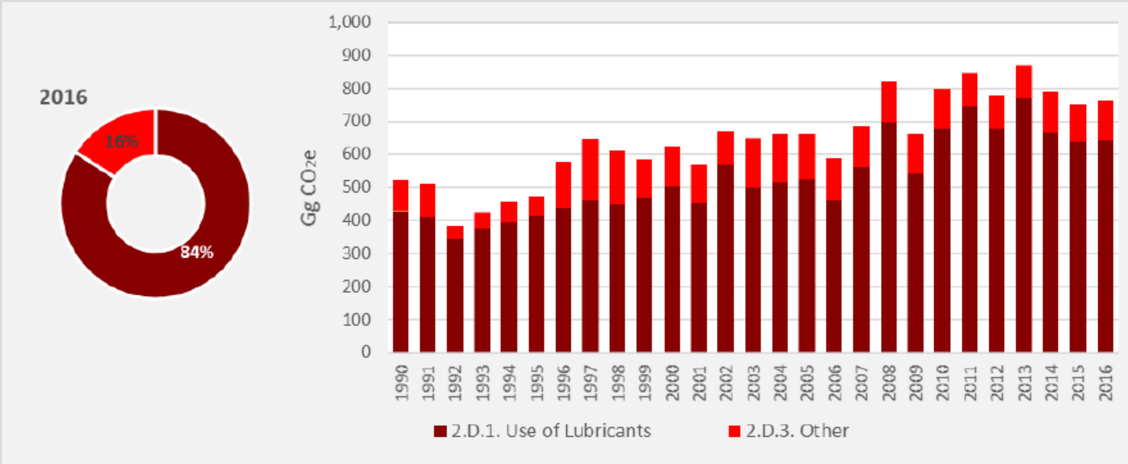



Figure 2.23. Emissions of Non-Energy Products from Fuels and Solvents (2.D), in $CO_2e$, by category, from 1990 to 2016

## 2.4.6 Electronics Industry (2.E)

The Electronics Industry subsector (2.E) includes advanced electronics manufacturing processes, such as integrated circuits or semiconductors, flat-screen display with thin-film transistors (TFT), photovoltaic panels, heat transfer fluid, among others. These processes use fluorinated compounds and, for this Inventory, the emissions of HFC-23 ($CHF_3$) and $CF_4$ were identified and estimated.

Due to the impossibility of data disaggregation, the emissions related to the Integrated Circuit or Semiconductor (2.E.1) and TFT Flat Panel Display (2.E.2) categories were reported in the category Other (2.E.5). The manufacture of photovoltaic panels in Brazil (emissions reported in the category Photovoltaic Panels - 2.E.3) started in 2012 and is still in its initial stage, and it was not possible to estimate the emissions related to this process. In Brazil, there are no emissions related to the Heat Transfer Fluid category (2.E.4).

## 2.4.7 Product Uses as Substitutes for Ozone Depleting Substances (2.F)

Hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) replace ozone-depleting substances, which are controlled by the Montreal Protocol. There are several areas of application of these substances, such as refrigeration and air conditioning, fire suppression, aerosol propellants and foams. Some categories in 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 Agents (2.F.2), Fire Protection (2.F.3), and Aerosols (2.F.4). Although emissions related to Solvents (2.F.5) may exist, even in small quantities, were not estimated, since the uses in this category are very specific in certain electronic assembly and precision mechanics companies. In this subsector, activity data and parameters cannot be obtained directly, as there is no reporting obligation on the part of companies, which requires the use of support models and grouped import information for these substances.

The Subsector Product Uses as Substitutes for Ozone Depleting Substances (2.F) emitted 5,728 Gg $CO_2e$ in 2016 and contributed 6% of the sector's emissions. In 2010, emissions from this subsector were 2,872 Gg

$CO_2e$. In Figure 2.24, it can be seen that the Refrigeration and Air Conditioning category (2.F.1) represented almost the totality of the subsector's emissions, with a contribution of 98% in 2016, complemented by Aerosols (2.F.4), Foam Agents (2.F.2), and Fire Protection (2.F.3), with contributions of 1.3%, 0.4% and 0.3% for the subsector's emissions, respectively.

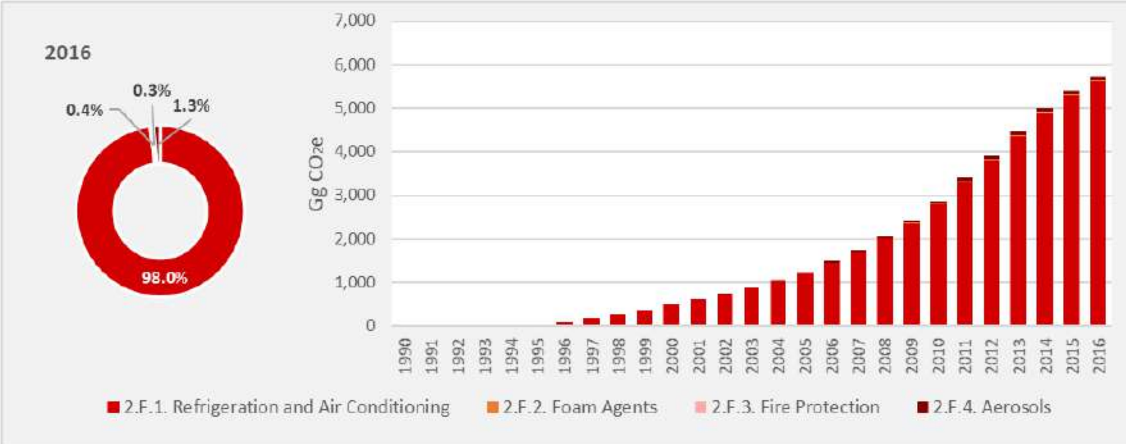



Figure 2.24. Emissions from the Uses of Products as Substitutes for Ozone Depleting Substances (2.F), in $CO_2e$, by category, from 1990 to 2016

In 2016, HFC-134a gas was the most representative of the subsector, with 94% of the total in $CO_2e$, in which the Vehicle Air Conditioning, Refrigeration Equipment, and Chillers (coolers) categories contributed 85%, 10% and 2, 6%, respectively. The second most emitted gas in 2016 was HFC-125, with 4.1%, mainly due to the Air Conditioning category, which corresponded to 79% of emissions in this subsector.

### 2.4.8 Other Product Manufacture and Use (2.G)

The Other Product Manufacture and Use (2.G) subsector includes emissions from the use of $SF_6$, PFC, and $N_2O$ in applications based on the different physical properties of these substances, such as the high $SF_6$ dielectric constant, the stability of PFCs, and the anesthetic effects of $N_2O$. For this Inventory, only $SF_6$ emissions were estimated due to its use in electrical energy equipment, referring to the Electrical Equipment category (2.G.1). There are no national emissions of $SF_6$ and PFCs from Other Products Uses (2.G.2) and the $N_2O$ from Product Uses categories (2.G.3) has not been estimated, due to the need for a more in-depth assessment of the data.

In 2016, emissions from the Other Product Manufacture and Use (2.G) subsector were estimated at 295 Gg $CO_2e$ and represented 0.3% of the sector's total emissions. In relation to 2010, these emissions increased by 22%. All emissions are related to the Electrical Equipment category (2.G.1).

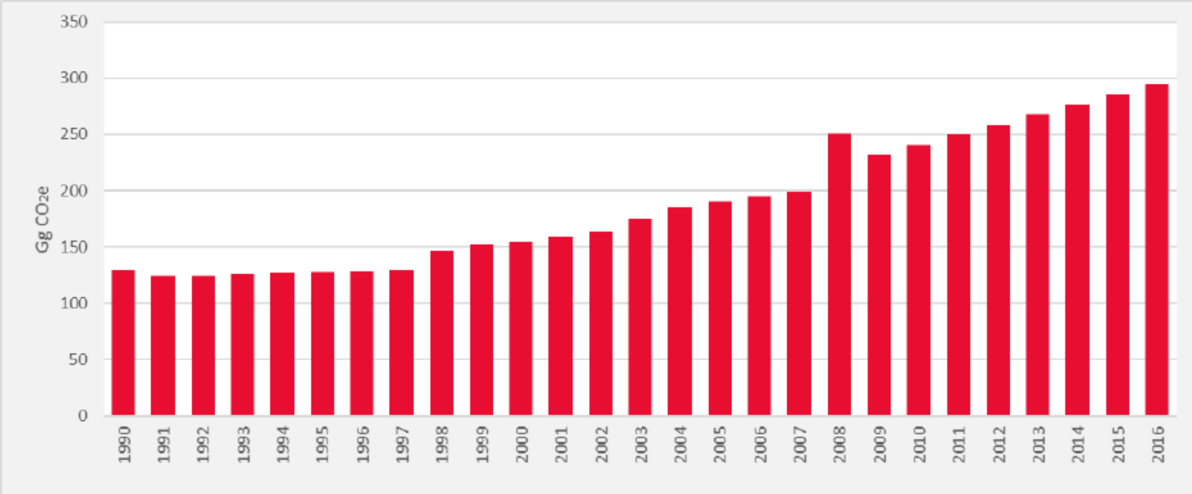



Figure 2.25. $SF_6$ emissions in the Electrical Equipment category (2.G.1), from 1990 to 2016

## 2.4.9 Other (2.H)

In this subsector, emissions related to the Pulp and Paper Industry (2.H.1) and Food and Beverage Industry (2.H.2) categories, which emit only indirect GHG, are reported. In the Pulp and Paper Industry category (2.H.1), emissions related to the national pulp and paper production process were CO, $NO_x$, and NMVOC, which represented 9% of the subsector's emissions in 2016. In Food and Beverage Industry (2.H.2) 91% of NMVOC emissions in the subsector occurred in 2016, with a contribution of 53% from the production of sugar and 29% from the production of distillates.

## 2.5 AGRICULTURE SECTOR (3)

The Agriculture sector comprises emissions from livestock and agricultural activities and includes $CH_4$, $N_2O$, and $CO_2$ gases, in addition to indirect GHG (CO, $NO_x$, and NMVOC)[12]. According to the IPCC 2006 methodology, the subsectors covered are Enteric Fermentation (3.A), Manure Management (3.B), Rice Cultivation (3.C), Managed Soils (3.D), Field Burning of Agricultural Residues (3.F), Liming (3.G) and Urea Application (3.H).

*See the **Appendix I** to check the tables with all results per gas in mass unit, for all sectors and the entire historical series (1990 to 2016)*

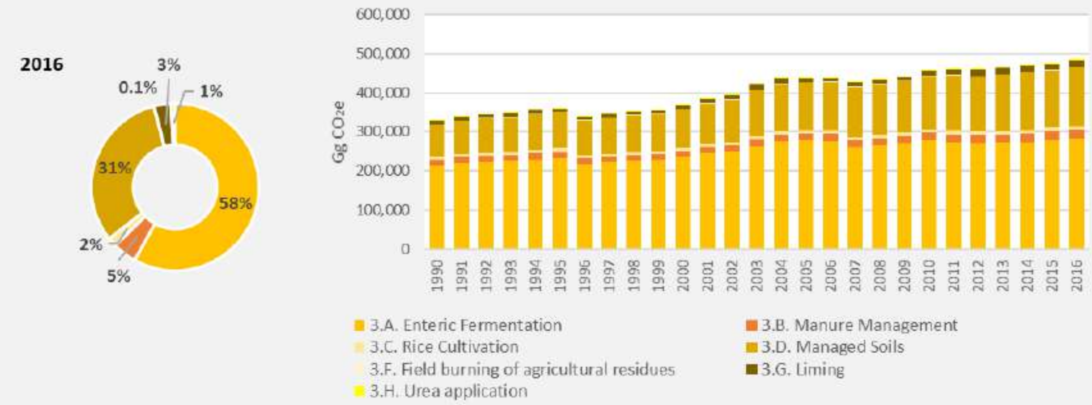
The sector's emissions totaled 487,005 Gg $CO_2e$ in 2016, an increase of 6.3%, compared to 2010. The Enteric Fermentation subsector (3.A) presented an emission of 282,713 Gg $CO_2e$ in 2016, while the Emissions from Managed Soils (3.D) were 153,065 Gg $CO_2e$. The other subsectors contributed with the rest of the sector's emissions.

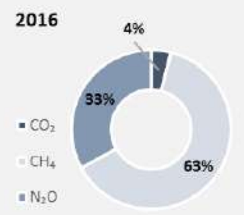
As shown in Figure 2.26, $CH_4$ emissions are the most representative for the sector and come mainly from the subsector Enteric Fermentation (3.A). Then there are $N_2O$ emissions, whose main emission source was the Managed Soils Subsector (3.D). $CO_2$ represented a new accounting for emissions for the Agriculture sector, which accounted for 4% of the sector's total emissions, mainly related to the application of lime in the soil (Liming - 3.G).

Livestock farming is an economic activity of national relevance, and the main parameters used to estimate its emissions refer to the population, the type of feedlot, digestibility, weight, and animal productivity. Agricultural emissions are mainly related to the agricultural production process and the use of nitrogen fertilizers, while emissions and removals resulting from the conversion processes of land use and cover and soil management are accounted for in the LULUCF sector (4).

It is especially noteworthy that, because of efforts made to adopt more efficient and sustainable production practices and systems, through the implementation of the Sectoral Climate Change Mitigation and Adaptation Plan for the Consolidation of a Low Carbon Emission Economy in Agriculture (*Plano ABC*), the sector has contributed to a significant reduction in emissions in the country. However, since the methodology for national inventories does not include, in a systemic way, the balance of flows and stocks within agricultural production systems, the results achieved with the transformation of 50 million hectares into sustainable production systems (see Box 2.2), over the course of 10 years of this public policy, do not appear explicitly in the historical series.

[12] *Indirect greenhouse gases are accounted for only in the Burning Agricultural Waste subsector (3.F).*




| Sector/ Subsector | 1990 | 1995 | 2000 | 2005 | 2010 | 2016 | Variation 2010-2016 |
|---|---|---|---|---|---|---|---|
| | Gg $CO_2e$ | | | | | | % |
| **3. Agriculture** | **329,510** | **359,245** | **370,116** | **437,959** | **458,091** | **487,005** | **6.3%** |
| **3.A. Enteric Fermentation** | 213,743 | 233,373 | 235,669 | 278,118 | 278,253 | 282,713 | 1.6% |
| **3.B. Manure Management** | 14,335 | 16,011 | 15,340 | 17,736 | 19,617 | 22,616 | 15.3% |
| **3.C. Rice Cultivation** | 6,954 | 8,654 | 7,733 | 8,097 | 8,095 | 8,369 | 3.4% |
| **3.D. Managed Soils** | 83,012 | 92,597 | 99,098 | 121,910 | 136,557 | 153,065 | 12.1% |
| **3.F. Field burning of agricultural residues** | 1,696 | 1,844 | 1,630 | 2,123 | 1,871 | 509 | -72.8% |
| **3.G. Liming** | 9,141 | 5,845 | 9,444 | 8,097 | 11,292 | 15,844 | 40.3% |
| **3.H. Urea application** | 631 | 920 | 1,201 | 1,878 | 2,406 | 3,888 | 61.6% |

Figure 2.26. Agriculture sector emissions, in $CO_2e$, by subsector from 1990 to 2016

*Box 2.2.* The productive efficiency of beef and dairy cattle in Brazil

The elaboration of the Fourth GHG Emissions Inventory for the Agriculture sector relies on the commitment of the national scientific community concerning the choice of parameters and definition of emission and removal factors more accurate to the reality of the country. This has allowed Brazil to consistently reflect the efforts of the Agriculture sector to produce more efficiently and sustainably, reducing emissions in the sector.

In recent years, a set of public policies aimed at the livestock sector, summed to scientific research and technological development, in addition to the entrepreneurship of rural producers, have resulted in increased national productivity. This sets up a promising outlook for this sector of great economic relevance for the country. Among the outstanding actions, we can mention the advances in the adoption of technologies and production systems such as integrated systems like crop-livestock-forest and their combinations, no-tillage system, biological nitrogen fixation, treatment of animal manure, recovery of degraded pastures, among others that contribute to the improvement of the productive processes of tropical agriculture.

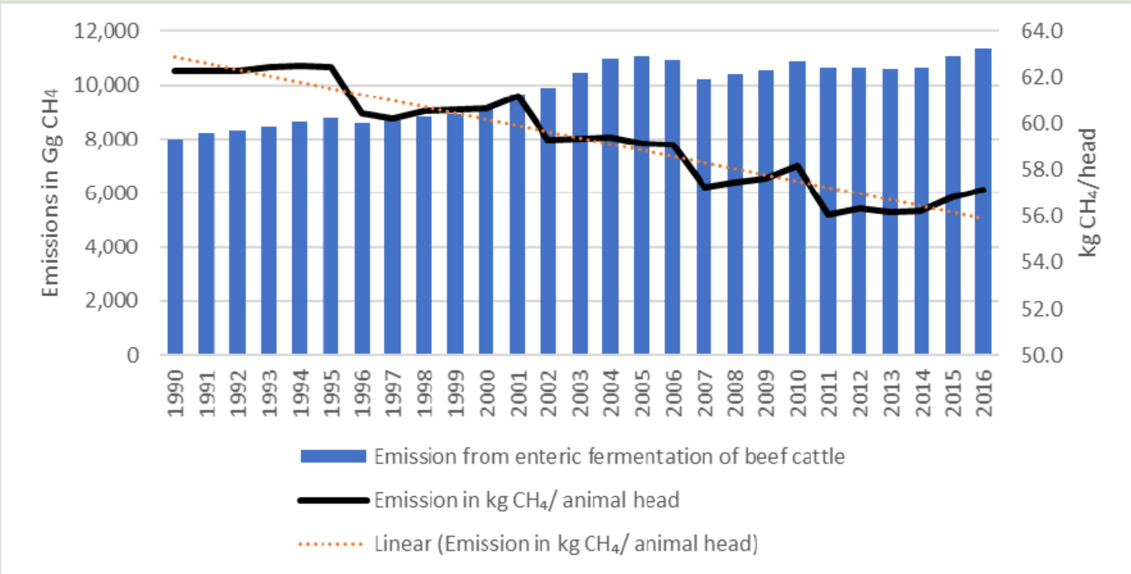
***Herd and productivity***

Holder of the largest commercial cattle herd in the world, with an average annual production of close to 9.1 million tons of meat in 2016 (ABIEC, 2019), Brazil is the second-largest producer in the world and the leader in meat exports - an important contribution to world food security. This performance comes from a 48% growth in the number of animals (from 1990 to 2016), represented by a herd of 218 million animals in 2016 (IBGE, 2018), about 80% for beef purposes.

The Agriculture sector contributed, in 2016, with 33% of Brazilian emissions (in $CO_2$ equivalent). The most relevant source for emissions in this sector is enteric fermentation. In 2016, this subsector represented

19% of the country's total GHG emissions and 76% of $CH_4$ emissions, from the Fourth National Inventory (as seen in Figure 2.26).

The analysis of $CH_4$ emission from enteric fermentation per head of beef cattle shows a reduction of 8.2% between 1990 and 2016 (Figure I), although the sector's historical series shows an increase in emissions due to the increase in the herd. The reduction in $CH_4$ emissions from enteric fermentation per head of beef cattle is directly related to the 7.6% increase in the digestibility rate[13] of the forages consumed by the herd (from 55.6% to 59.8%)[14], which has a direct influence on the intensity of emissions emitted by each animal. Studies carried out in Brazil show that, in recent years, the improved digestibility of the diet of ruminants, directly favored the productive efficiency of the herd, improving food intake and weight gain, and as a co-benefit diluted GHG emission per product. In this way, digestibility can be considered an indicator of the advancement of the productive efficiency of the Brazilian herd directly related to the reduction of emissions per head as shown in Figures I and IV.




Source: Based on IBGE (2018).

Figure I. $CH_4$ emissions from enteric fermentation of the beef herd, and emission per animal head (expressed in kg/head/year), for the period from 1990 to 2016, in Brazil.

Plant genetic improvement can also be mentioned as an excellent strategy, which in addition to improving digestibility, results in improved herd productivity. Cultivars that are more resistant to pests and diseases, with greater productivity, palatability, better nutritional qualities, and selected for different Brazilian biomes are part of this technological package. The use of complementary technologies was also important for an adequate productive response, such as liming, fertilization, electric or conventional fences, drinking fountains, control of invasive plants, management of pasture, adjustments of animal loads, provision of forage for the dry season or cold, irrigation, etc.

The public policies developed since 1990, added to technological and scientific development, as well as the entrepreneurship of rural producers, printed a different picture to the usual one, in case there were no

13 The digestibility rate is commonly expressed as the percentage (%) of the amount of crude energy (GE) in the food not excreted in the animals' feces. Variations in the digestibility of the animal diet result in large variations in the estimated feed needed to meet the needs of the animals (IPCC, 2006).

14 Digestibility average of the national beef herd.

changes (business as usual). These efforts resulted in a reduction of more than 8% of enteric methane per head of beef cattle from 1990 to 2016, as illustrated in Figure II.

Figure II represents the difference in emissions of kg $CH_4$/head/year between the ex-post A situation, without the adoption of public policies and effective technologies for the livestock sector, and ex-post B, with the implementation of the changes, showing an increase in animal productivity and a positive change in the scenario of emissions in Brazil, compared to the ex-ante situation.

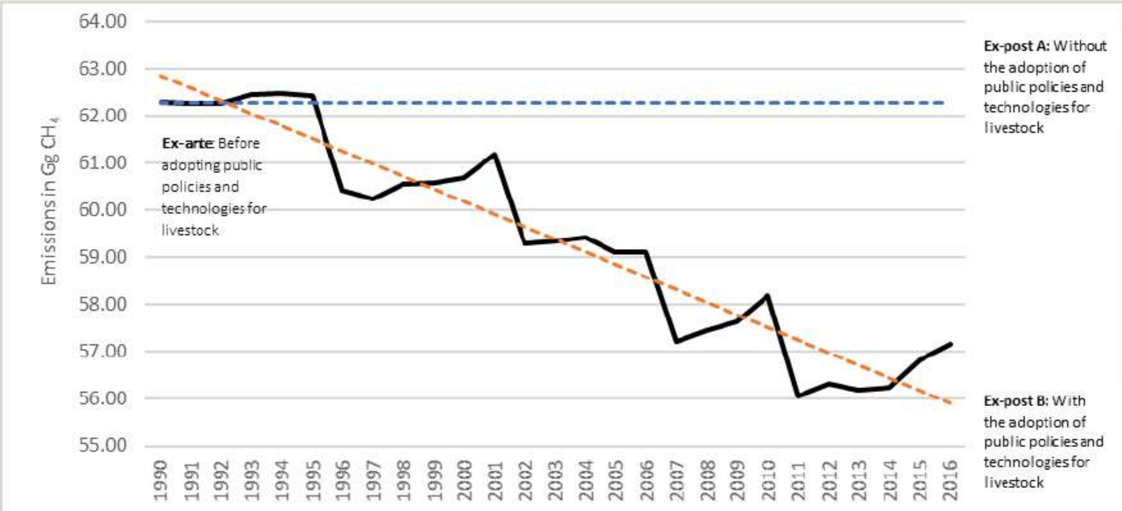
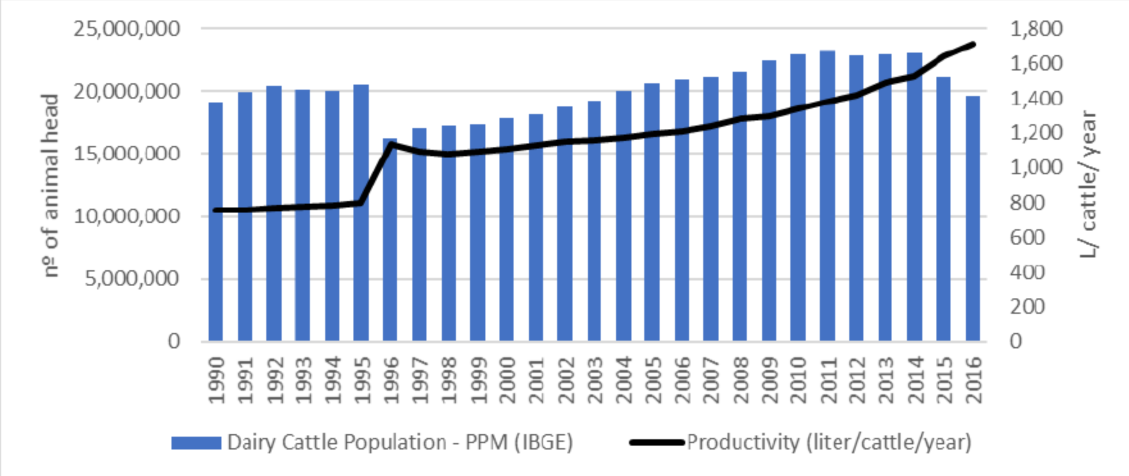



Figure II. Emission per animal head of beef cattle (expressed in kg/head/year), for the period from 1990 to 2016, in Brazil and the difference in emissions between the ex-post A situation, without adoption of public policies and technologies and ex-post B with the adoption of public policies and technologies, both compared to the ex-ante situation, before the adoption of public policies and technologies for livestock.

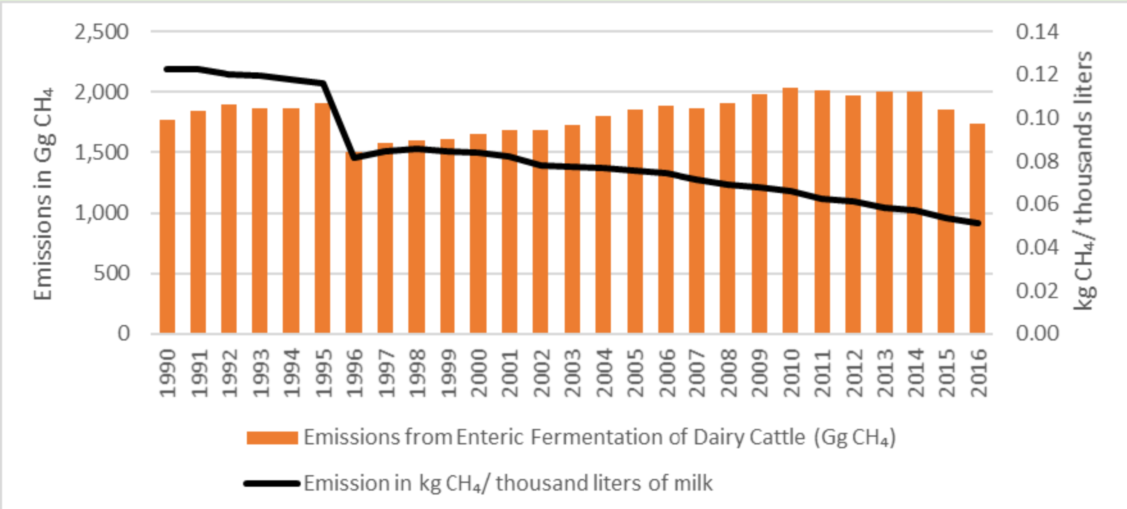
In the historical series analyzed, dairy cattle also shows productivity improvement. From 1990 to 2016, while the number of dairy cows increased by 2.6% (Figure III), milk production increased by 133%, that is, milk productivity (liters produced per cow, per year) increased by 127% (IBGE, 2018).




Source: Based on IBGE (2018).

Figure III. Population[15] of dairy cattle and milk productivity (expressed in liters/head/year), for the period of 1990 to 2016, in Brazil.

In terms of $CH_4$ emission, dairy cattle decreased by 2% from 1990 to 2016. When considering the emission of $CH_4$ per liter of milk produced, there is a decrease of 58% in the same period (Figure IV). This is due to the increase in the share of high production cows in the national dairy herd (from 1% to 30%), and to the 11.3% increase in the digestibility of forages (from 61.4% to 68.4%), in the same period, a similar situation to that occurred in beef cattle.




Source: Based on IBGE (2018).

Figure IV. $CH_4$ emissions from enteric fermentation of dairy cattle herd, and emission per liter of milk produced (expressed in kg / thousand liters milk/year), for the years 1990 to 2016, in Brazil.

According to Herrero et al. (2013), the intensity of GHG emissions differs between geographic regions and production systems and is mainly influenced by the efficiency of feed conversion (quantity of food

[15] In 1996, the animal population was corrected, due to the implementation of the 1996 Agriculture and Livestock Census (IBGE, 1996)

consumed per unit of product), which improves with the quality of the animal diet, in digestibility and protein content. Therefore, improving the quantity and quality of food will result in improved production and animal feed efficiency, thus reducing GHG emissions (particularly $CH_4$) per unit of animal product, whether meat or milk (HRISTOV et al., 2013). Even with technological advances, the total gross emissions of a region or country are expected to increase if the number of heads increases more than the avoided emissions of a stabilized herd (LATAWIEC et al. 2014).

Brazil has been committed and advanced in increasing animal productivity and efficiency, through the implementation of public policies that promote the improvement of herd and forage plant genetics, digestibility, animal comfort, early slaughter, efficient reproduction strategies, better efficiency pastures, the use of technologies for the treatment of animal waste, among other actions. These initiatives have helped to promote sustainable and low-carbon livestock farming in the country, showing a promising trend for the coming years.

Additionally, the country has advanced in the improvement and transparency of emission estimates in each edition of the National Inventory, seeking for new scientific research, the use of emission and removal parameters and factors that reflect national conditions. This effort results in greater accuracy of national emissions and encourages the continuity of scientific advances, contributing to the development of national and world science.

### 2.5.1 Methodological aspects of the sector

Estimates of emissions from the Agriculture sector were based on the methodology indicated in IPCC 2006[16]. The calculation of emissions considered national data, such as animal population, consumption of synthetic and organic fertilizers, agricultural production, technologies used for manure management, among others. Most activity data were obtained from official sources. The parameters, emission factors, and other activity data were obtained or calculated from national and international literature, as shown in Panel 2.8.

Tier 1 methodology was adopted for Enteric Fermentation (3.A) emissions in the categories of swine, buffaloes, sheep, goats, horses, mules, and asses, using the IPCC 2006 default emission factors. For bovine cattle, the most representative animal category in the sector, Tier 2 was used, which allowed a more detailed approach compared to other animal categories, in addition to considering specific factors and parameters for each state or region of the country. For this animal category, a breakdown was performed between beef cattle (by type of feedlot, age, and sex) and dairy cattle (by high and low production).

For emissions from Manure Management (3.B), the same animal breakdown of enteric fermentation was adopted, with greater detail of the swine and inclusion of the poultry category. Tier 2 methodology was used for these last two categories, with a breakdown by productive purpose. The swine animal category was broken down into industrial and subsistence swine, used for breeding, lactation, and finishing purposes. For the poultry category, there was a breakdown between hens and laying hens; roosters, chicks and chickens, and quails. For the indirect emissions of this subsector (category added in this edition of the Inventory, due to the implementation of the IPCC 2006), Tier 1 was used.

Emissions from Rice Cultivation (3.C) were estimated using the Tier 1 and Tier 2 methodologies, due to the detailed activity data and/or the availability of emission factors from the validated sites. Thus, Tier 2 was

[16] *Intergovernmental Panel on Climate Change (IPCC). IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme. Vol. 4, Agriculture, Forestry and Other Land Use (IPCC, 2006).*

adopted for the emission estimates of the states of Rio Grande do Sul and Santa Catarina, as they represent the largest portion of rice production in the country and have local emission factors. Tier 1 was used for the other Federative Units.

For emissions from Managed Soils (3.D), Tier 1 and Tier 2 methodologies were used. Concerning organic fertilizers and the deposition of manure directly into the soil, the same animal breakdown was adopted for the Manure Management (3.B). For this Inventory, due to the implementation of IPCC 2006, the filter cake emissions from the sugar and alcohol industry were included in the Organic Fertilizers category (3.D.1.b), as well as the use of synthetic fertilizers in rice cultivation. Additionally, $N_2O$ emissions from crop roots and emissions from nitrogen (N) from pasture biomass, incorporated into the soil at the time of its renovation, are now counted in the Crop Residues category (3.D.1.d). Another category included was Mineralization of N associated with loss of C in soil (3.D.1.e).

Emissions from the Prescribed Burning of Savannas subsector (3.E) were not estimated (NE), because the differentiation of savanna burning by anthropic or natural causes, as well as the monitoring of the dynamics of these fires over the years in the national territory, is not a simple activity and requires the development of a more complex methodology, which ensures the proper association of fires with the respective causes.

The Tier 2 approach was adopted for the Field Burning of Agricultural Residues (3.F) estimates, in which the emission factors, the straw/stem ratio, and the combustion factor were specific for the sugarcane culture. The amount of biomass available for combustion and the percentage of production submitted to burning (when mechanized harvesting is not used) were specific for each Federative Unit and year.

Emissions from Liming (3.G) and Urea Application (3.H) used the Tier 1 methodology, due to the low representativeness in the sector's emissions.

Panel 2.8. Methodological levels applied by gas and references from the Agriculture sector

| Subsector | Category | Subcategories | Estimated gases and methodologies | | | | | | References | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $CO_2$ | $CH_4$ | $N_2O$ | CO | $NO_x$ | NMVOC | Activity Data | Emission Factors |
| 3.A. Enteric Fermentation | 3.A.1. Cattle | 3.A.1.a Beef Cattle | NA | T2 | NA | NA | NA | NA | Animal population data from Municipal Livestock Production - PPM, by Unit of the Federation from 1990 to 2016 (IBGE, 2018a), 1996 and 2006 Agricultural Census (IBGE, 1996; 2006) and Anualpec (FNP, 1997; 2001; 2005; 2013). | · Volume 4, Chapter 10 (IPCC, 2006);<br>· Calculation of parameters and factors used to estimate emissions of cattle categories was based on extensive scientific literature for each Unit of the Federation and year for the following parameters: weight, feed digestibility, pregnancy rate, fat content of milk and average daily milk production. |
| | | 3.A.2.b Dairy Cattle | NA | T2 | NA | NA | NA | NA | | |
| | 3.A.2. Sheep | | NA | T1 | NA | NA | NA | NA | Animal population data from Municipal Livestock Production - PPM, by Unit of the Federation from 1990 to 2016 (IBGE, 2018a). | Default EF IPCC (2006). Volume 4, Chapter 10 (IPCC, 2006). |
| | 3.A.3. Swine | | NA | T1 | NA | NA | NA | NA | | |
| | 3.A.4. Other Animals | 3.A.4.a. Buffalos | NA | T1 | NA | NA | NA | NA | | |
| | | 3.A.4.b. Goats | NA | T1 | NA | NA | NA | NA | | |
| | | 3.A.4.c. Equines | NA | T1 | NA | NA | NA | NA | | |
| | | 3.A.4.d. Mules | NA | T1 | NA | NA | NA | NA | | |
| | | 3.A.4.e. Asses | NA | T1 | NA | NA | NA | NA | | |
| | 3.B.1. Cattle | 3.B.1.a. Beef Cattle | NA | T2 | T2 | NA | NA | NA | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.B. Manure Management | | 3.B.1.b. Dairy Cattle | NA | T2 | T2 | NA | NA | NA | Animal population data from Municipal Livestock Production - PPM, by Unit of the Federation from 1990 to 2016 (IBGE, 2018a), 1996 and 2006 Agricultural Census (IBGE, 1996; 2006) and Anualpec (FNP, 1997; 2001; 2005; 2013). Data from SESI (2019) and ABPA (2019) were also used for swine categories. | Cattle, Swine and Poutry:<br>· Volume 4, Chapter 10 (IPCC, 2006);<br>· Calculation of parameters and factors used to estimate emissions was based on extensive scientific literature for each Unit of the Federation, year and animal category for the following parameters: weight, feed digestibility, excretion rates, manure management system, etc.<br><br>Other animals: Default EF IPCC (2006). Volume 4, Chapter 10 (IPCC, 2006). |
| | 3.B.2. Sheep | | NA | T1 | NO | NA | NA | NA | | |
| | 3.B.3. Swine | 3.B.3.a. Swine, Breeding | NA | T2 | T2 | NA | NA | NA | | |
| | | 3.B.3.b. Swine, Suckling/nursery | NA | T2 | T2 | NA | NA | NA | | |
| | | 3.B.3.c. Swine, Finishing | NA | T2 | T2 | NA | NA | NA | | |
| | 3.B.4. Other Animals | 3.B.4.a. Buffalos | NA | T1 | NO | NA | NA | NA | | |
| | | 3.B.4.b. Goats | NA | T1 | NO | NA | NA | NA | | |
| | | 3.B.4.c. Equines | NA | T1 | NO | NA | NA | NA | | |
| | | 3.B.4.d. Mules | NA | T1 | NO | NA | NA | NA | | |
| | | 3.B.4.e. Asses | NA | T1 | NO | NA | NA | NA | | |
| | | 3.B.4.f. Poultry | NA | T1 | T1 | NA | NA | NA | | |
| | 3.B.5. Indirect $N_2O$ emissions | 3.B.5.a. Cattle | NA | NA | T1 | NA | NA | NA | | |
| | | 3.B.5.b. Other | NA | NA | T1 | NA | NA | NA | | |
| 3.C. Rice Cultivation | 3.C.1. Irrigated | 3.C.1.a. Continuously flooded | NA | T1, T2 | NA | NA | NA | NA | · Annual harvested area of rice (stratified by water regime): Embrapa | Default EF IPCC (2006). Volume 4, Chapter 5 (IPCC, 2006); Emission factors and other parameters determined locally (Embrapa |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 3.C.1.b. Intermittently flooded | NA | T1, T2 | NA | NA | NA | NA | Arroz e Feijão (2018); DCI/IRGA (IRGA, 2018);<br>· Cultivation period of rice, by Unit of Federation and year (stratified by seeding system): Embrapa (2018);<br>Obs: for Santa Catarina state, the following regional data were used - annual harvested area of rice (stratified by water regime): Embrapa Arroz e Feijão (2018) and Epagri (2019). Cultivation period of rice: Epagri (2019). | Arroz e Feijão, 2018; YAN et al., 2005; Epagri, 2019). |
| | 3.C.2. Rainfed | | NA | NO | NA | NA | NA | NA | | |
| 3.D. Managed Soils | 3.D.1. Direct $N_2O$ Emissions | 3.D.1.a. Synthetic Fertilizers | NA | NA | T2 | NA | NA | NA | Total amount of synthetic N fertiliser and urea delivered to end consumers in Brazil from 1990 to 2016 (ANDA, 2018).<br>Obs: For estimation of annual amount of synthetic fertiliser N applied to rice area, was considered that only urea is applied to flooded rice, and only the South Region of Brazil has harvested area of rice with significant production and productivity, to consider a relevant application of synthetic fertilizer (ANDA, 2018; Embrapa Arroz e Feijão, 2018, IRGA, 2018 e IBGE, 2019). | Volume 4, Chapter 11 (IPCC, 2006). |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 3.D.1.b. Organic Fertilizers | NA | NA | T1, T2 | NA | NA | NA | Data on the production of ethanol and sugar from by-products of vinasse and filter cake produced in Brazil were obtained from the Sugarcane Industry Association (UNICA, 2019).<br>Animal population data from Municipal Livestock Production - PPM, by Unit of the Federation from 1990 to 2016 (IBGE, 2018a); 1996 and 2006 Agricultural Census (IBGE, 1996; 2006); Anualpec (FNP, 1997; 2001; 2005; 2013); SESI (2019) and ABPA (2019). " | Volume 4, Chapter 11 (IPCC, 2006); Paredes et al. (2014); (2014); Parameters to estimate 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); Factors of direct emission of $N_2O$ from vinasse and filter cake applied to sugarcane crops: Oliveira et al. (2013); Siqueira Neto et al. (2016); Sousa Neto (2012).<br>The definition of weight, excretion rates and disposal of manure for the individual livestock categories was based on extensive literature for each Unit of the Federation and year." |
| | | 3.D.1.c. Animal manure applied to soils | NA | NA | T1, T2 | NA | NA | NA | Animal population data from Municipal Livestock Production - PPM Unit of the Federation from 1990 to 2016 (IBGE, 2018a); 1996 and 2006 Agricultural Census (IBGE, 2006); Anualpec (FNP, 1997; 2001; 2005; 2013); SESI (2019) and ABPA (2019). | · Volume 4, Chapter 11 (IPCC, 2006). Bastos (2018);<br>· The definition of weight, excretion rates and manure management system for the individual livestock categories was based on extensive literature for each Unit of the Federation and year. |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 3.D.1.d. Crop Residues | NA | NA | T1, T2 | NA | NA | NA | "· Data on productivity and annual harvested area of the main agricultural crops in Brazil, by Unit of Federation and year from IBGE - Agricultural Production by City - 1990 a 2016 (IBGE, 2018b);<br>· Annual harvested area of rice (by Unit of Federation and year): Embrapa Arroz e Feijão (2018); DCI/IRGA (IRGA, 2018);<br>· Data on grassland remaining grassland and grassland coverted to other uses and its associated biomass (by Unit of Federation and year) were based on data generated by the sector “Land Use, Land Use Change and Forestry (LULUCF)” for the Fourth National Inventory. " | Volume 4, Chapter 11 (IPCC, 2006). Parameters to calculate the amount of N in pasture 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 | NA | Mineralized N was calculated from the multiplication of 1/R and the amount of organic carbon in the soil lost as a result of 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 sector “Land Use, Land Use Change and Forestry (LULUCF)” for the Fourth National Inventory. | Volume 4, Chapter 11 (IPCC, 2006). |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 3.D.1.f. Organic Soil Management | NA | NA | T2 | NA | NA | NA | Map of Brazil's Soils, IBGE (2001). In addition to the organic soil areas, maps with areas under different uses of the "Land Use, Land Use Change and Forestry (LULUCF)" sector for the Fourth National Inventory were used. | Volume 4, Chapter 11 (IPCC, 2006). |
| | 3.D.2. Indirect $N_2O$ Emissions | 3.D.2.a. Atmospheric deposition | NA | NA | T1, T2 | NA | NA | NA | Same data used in Synthetic Fertilizers (3.D.1.a.), Organic Fertilizers (3.D.1.b.) and Animal manure applied to soils (3.D.1.c.). | Volume 4, Chapter 11 (IPCC, 2006). |
| | | 3.D.2.b. Nitrogen leaching and run-off | NA | NA | T1, T2 | NA | NA | NA | · Same data used in Synthetic Fertilizers (3.D.1.a.), Organic Fertilizers (3.D.1.b.), Animal manure applied to soils (3.D.1.c.), Mineralization of N associated with loss of C in soil (3.D.1.e.) and Crop Residues (3.D.1.d.).<br>· Formulation of maps containing areas where the excess rainfall in relation to potential evapotranspiration exceeded the available water capacity of the soil, based on data from INMET (2019) and Xavier (2019). | Volume 4, Chapter 11 (IPCC, 2006). |
| 3.E. Prescribed Burning of Savannas | | | NE | NE | NE | NE | NE | NA | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.F. Field burning of agricultural residues | 3.F.1. Sugarcane | | NA | T2 | T2 | T2 | T2 | NA | · Mass available for combustion (MB): Specific values for each municipality and reference year were calculated from data from Municipal Agricultural Production - PAM (IBGE, 2018b);<br>· Cultivated varieties: Braga et al (2017); RIDESA (2018);<br>· Straw/stalk ratio: average values per Unit of the Federation: Hassuani et al. (2005); Franco et al. (2007); Tasso Junior et al. (2011); Marques and Pinto (2013); and Ivo et al. (2015). | · Combustion factor ($C_f$): Volume 4, Chapter 5 (IPCC, 2006);<br>· Emission Factor ($G_{ef}$): $CH_4$: Yokelson et al. (2008) / CO: Yokelson et al. (2008); Lopes and Carvalho (2009); and França et al., (2012) / $NO_x$: França et al. (2012) / $N_2O$: IPCC (2006); Andreae and Merlet (2001). |
| | 3.F.2. Cotton | | NA | T1 | T1 | T1 | T1 | NA | Mass available for combustion (MB): Specific value for each Unit of the Federation and reference year (BRASIL, 2015). | Combustion factor ($C_f$) and Emission factor (Gef): Volume 4, Chapter 5 (IPCC, 2006). |
| 3.G. Liming | | | T1 | NA | NA | NA | NA | NA | Data on limestone production and consumption for each Unit of the Federation from 1990 to 2016, from the Brazilian Association of Limestone Producers (ABRACAL, 2018). | Volume 4, Chapter 11 (IPCC, 2006). |
| 3.H. Urea application | | | T1 | NA | NA | NA | NA | NA | Data on the apparent consumption of urea for each Unit of the Federation from 1990 to 2016, from ANDA – National Association for the Dissemination of Fertilizers (ANDA, 2018). | Volume 4, Chapter 11 (IPCC, 2006). |
| 3.I. Other | | | NO | NA | NA | NA | NA | NA | | |

Note: Method applied (IPCC, 2006) — T1: *Tier* 1; T2: *Tier* 2; T3: *Tier* 3. Notation keys: NA — not applicable; NO — not occurring; NE — not estimated.

## 2.5.2 Enteric Fermentation (3.A)

This subsector includes $CH_4$ emissions generated by animal enteric fermentation. The animal categories that present this physiological process and had their emissions estimated were: ruminant animals - cattle, buffaloes, sheep, goats; non-ruminants - equines, asses, mules; and monogastric - swine.

The main factor influencing emissions in this subsector is the animal population, whose variation modulates $CH_4$ emissions (see Panel 2.2). Other factors that influence these emissions, and vary according to the animal category and age, are feed digestibility - which depends on the quality of the food consumed -, the animal weight and the $CH_4$ conversion factor - corresponding to the percentage of energy consumed by the animal that is converted to that gas. For dairy cattle, other parameters that also influence emissions are milk production, milk fat content, and pregnancy rate (see Panel 2.2).

In 2016, emissions from Enteric Fermentation (3.A) totaled 282,713 Gg $CO_2e$, while in 2010 they were 278,253 Gg $CO_2e$ (Figure 2.27). The Beef Cattle subcategory (3.A.1.a) accounted for 84.3% of the subsector's issuance portion, while the Dairy Cattle subcategory (3.A.1.b) accounted for 12.9%, with a decrease of 14.4% in 2016, when compared to 2010. This decrease is due to the increase in milk productivity in the country and, consequently, the growth of high production cows in the milk herd in recent years. The other animal categories had a smaller representation, with 7,880 Gg $CO_2e$ or 2.8% of the subsector in 2016.

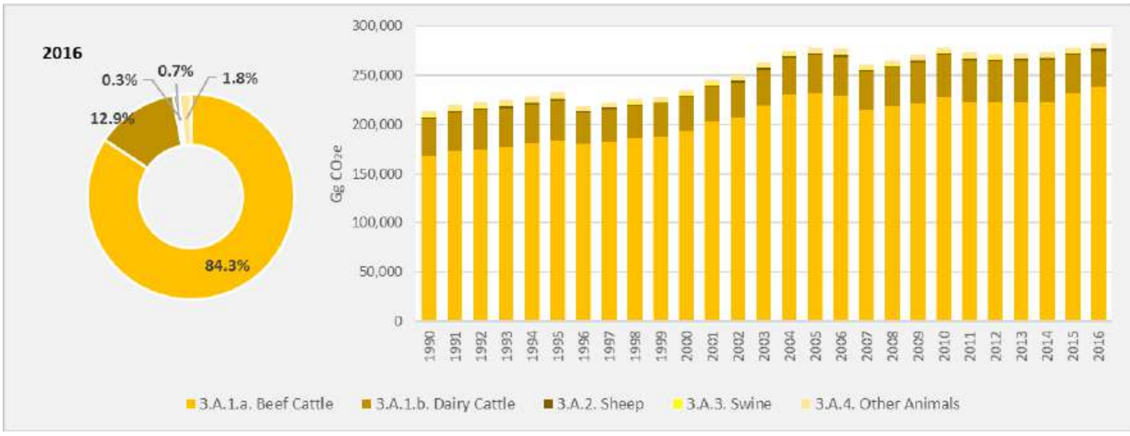



Figure 2.27. Emissions of Enteric Fermentation (3.A), in $CO_2e$, of the main animal categories, from 1990 to 2016

## 2.5.3 Manure Management (3.B)

Manure management comprises $CH_4$ and $N_2O$ emissions resulting from animal categories used for productive purposes in Brazil: cattle (beef and milk), swine, sheep, goats, asses, mules, horses, buffaloes, and poultry.

$CH_4$ emission occurs during the decomposition of manure under anaerobic conditions (in the absence of oxygen), during its treatment or disposal, and is influenced by the amount of manure generated and the type of treatment system adopted. It is estimated that between 2010 and 2016 around 9.3 million $m^3$ of animal manure for biogas production were treated in Brazil, resulting in a reduction in $CH_4$ emissions due to manure management. The emission of $N_2O$ occurs directly, through the nitrification and denitrification of Nitrogen (N) contained in the waste, and indirectly, through the volatilization of ammonia during the treatment and disposal of animal waste. Between 2010 and 2016, 9.3 million $m^3$ of animal manure were treated in Brazil by biodigestion, resulting in a mitigation of 105,186 Gg $CO_2e$ with the use of biogas (MARIANI, 2019).

Figure 2.28 shows that emissions from Manure Management (3.B) totaled 22,616 Gg $CO_2e$ in 2016, while in 2010 they were 19,617 Gg $CO_2e$. The share of cattle and swine was 45% and 38%, respectively. Indirect $N_2O$ Emissions from atmospheric deposition (subcategory 3.B.5) represented 11% of the total emission, in $CO_2e$. In terms of participation by gas, in 2016, $CH_4$ was the most representative, with 78% of the total $CO_2e$, while $N_2O$ emissions contributed with 22%.

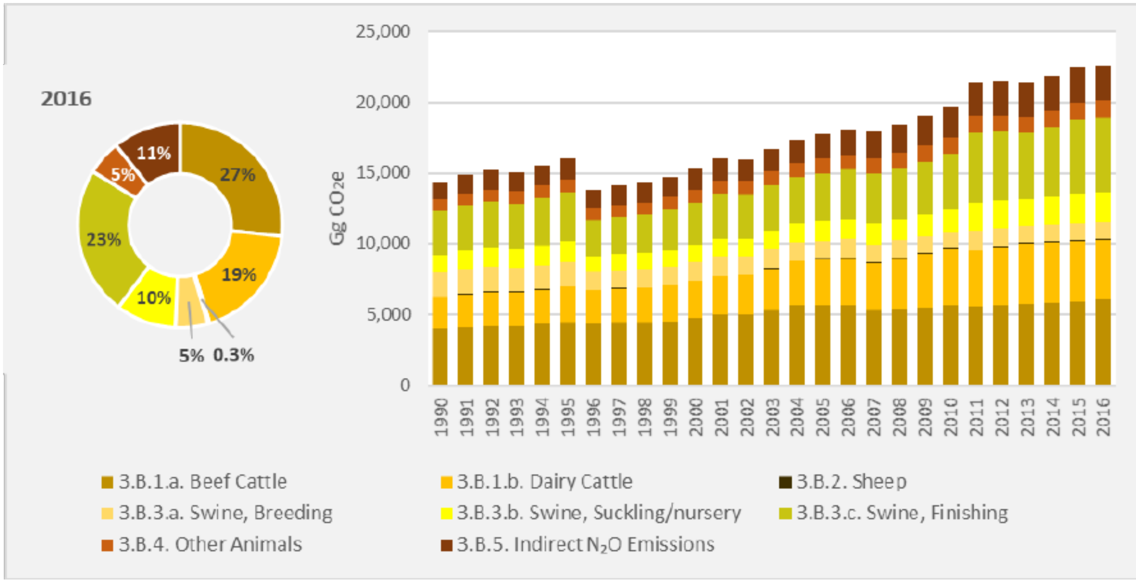



Figure 2.28. Emissions from Manure Management (3.B), in $CO_2e$, of the main animal categories from 1990 to 2016

## 2.5.4 Rice Cultivation (3.C)

Emissions from rice cultivation refer to $CH_4$ gas[17] and are associated with the system irrigated by soil flooding, which creates anaerobic conditions for the decomposition of organic matter, leading to the generation of $CH_4$. In Brazil, rice production is developed in irrigated and dryland systems[18], which accounted, in 2016, for 71.2% and 28.8% of the cultivated area, respectively (EMBRAPA, 2018).

In 2016, emissions from Irrigated Rice Cultivation (3.C.1) were estimated at 8,369 Gg $CO_2e$, that is, 3.4% higher than in 2010. Emissions are associated with the area cultivated in an irrigated system, as well as the amount of organic material brought to the soil. That same year, 95.5% of the emissions came from the cultivation of Irrigated rice with Continuous Flooding (3.C.1.a), and the rest of the emissions (4.5%) from the Irrigated with Intermittent Flooding system (3.C.1.b), as shown in Figure 2.29.

For the state of Rio Grande do Sul, the largest national grain producer, distinct emission factors were considered for soil tillage systems (conventional, early tillage, and other systems), therefore, emissions were also influenced by the temporal variation of the representativeness of these systems. In Santa Catarina, in turn, variations in emissions also suffered some influence from changes in the water regime,

[17] *$N_2O$ emissions from rice cultivation are reported in the subsector "Managed Soils (3D)", as recommended by IPCC 2006.*

[18] *The scale factor (SFw) that considers the water regime during the growing period is null for upland or dryland rice crops (IPCC, 2006).*

the type and time of incorporation of organic material into the soil, in addition to the length of the rice-growing period.

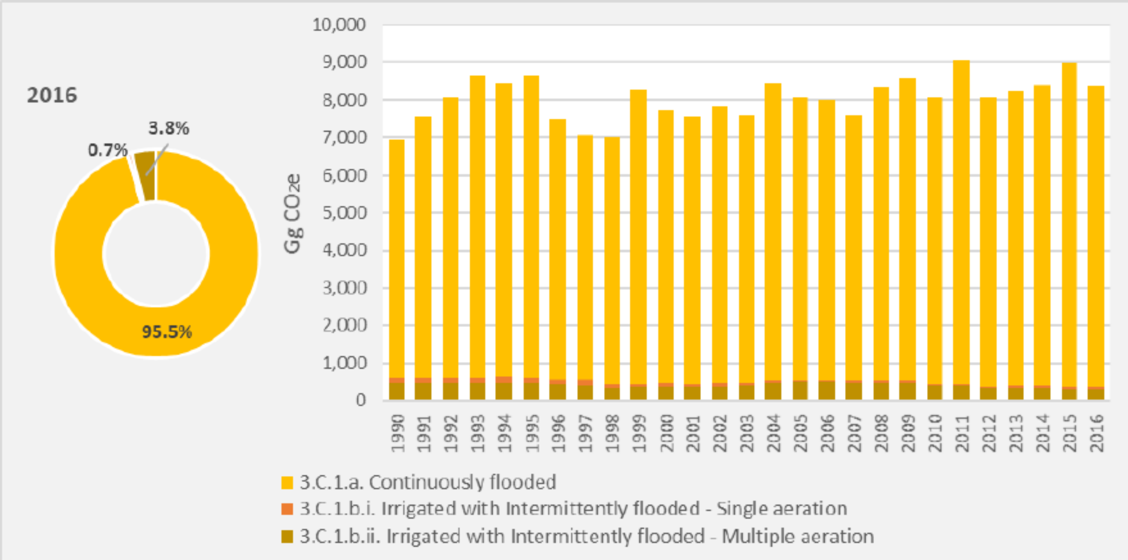



Figure 2.29. $CH_4$ emissions from rice cultivation (3.C), with the main types of irrigation, from 1990 to 2016

## 2.5.5 Managed Soils (3.D)

This subsector comprises direct and indirect $N_2O$ emissions, resulting from the application of nitrogen fertilizers (synthetic and organic - of animal origin), deposition and incorporation of crop harvest residues and the renewal of pastures, deposition of animal manure directly into the soil (unmanaged manure), nitrogen mineralization resulting from the loss of soil organic matter, and the management of organic soils. These emissions are due to the nitrification and denitrification process by increasing the amount of Nitrogen (N) in the soil, due to the use of inputs and the management of plants and soil, which results in direct and indirect $N_2O$ emissions. However, the adoption of biological nitrogen fixation, replacing the use of nitrogen fertilizers, in Brazil has contributed to an important 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 Gg $CO_2e$ in the country (MANZATTO et al., 2020).

Emissions from Managed Soils (3.D) totaled 153,065 Gg $CO_2e$ in 2016 (Figure 2.30) and were largely produced (77%) by Direct $N_2O$ Emissions (3.D.1). Of the direct emissions, the category of Animal Manure Applied to Soils (3.D.1.c) was the most representative, with 37.8%. Then, the Crop Residues category (3.D.1.d) represented 19.8% and included emissions from permanent and temporary crops. Indirect $N_2O$ emissions (3.D.2), which occur after the deposition of volatilized and Nitrogen leaching and run-off, corresponded to 23.0% of the total subsector in 2016. In 2010, the emissions of this subsector were 136,557 Gg $CO_2e$.

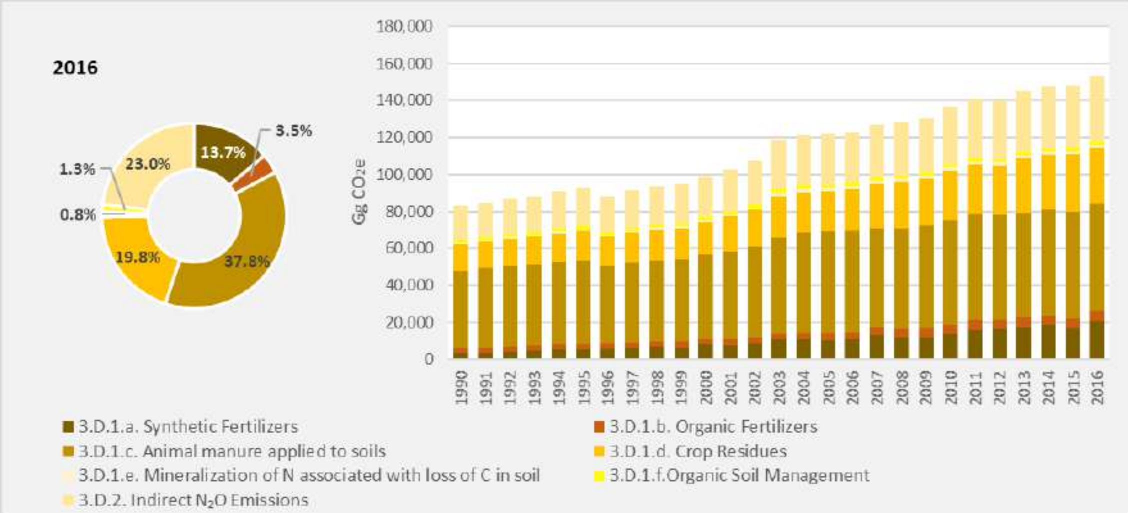



Figure 2.30. Emissions from Managed Soils (3.D), in $CO_2e$, from the main emission categories, from 1990 to 2016

## 2.5.6 Field Burning of Agricultural Residues (3.F)

The Field Burning of Agricultural Residues subsector (3.F) accounted for $CH_4$ and $N_2O$[19], emissions, resulting from the burning carried out in the pre-harvest of sugarcane and the post-harvest of herbaceous cotton, the latter occurring until 1994.

In 2016, emissions from this subsector were estimated at 509 Gg $CO_2e$. From 2010 to 2016, there was a 72.8% reduction in emissions from burning sugarcane residues in the country, despite the 12.6% increase in the harvested area. This is due to the transition process from manual harvesting, which uses fire, to mechanized harvesting (mainly in the state of São Paulo), as seen from 2007, in Figure 2.31. $N_2O$ and $CH_4$ emissions represented 53% and 47% of the subsector's total $CO_2e$ in 2016, respectively.

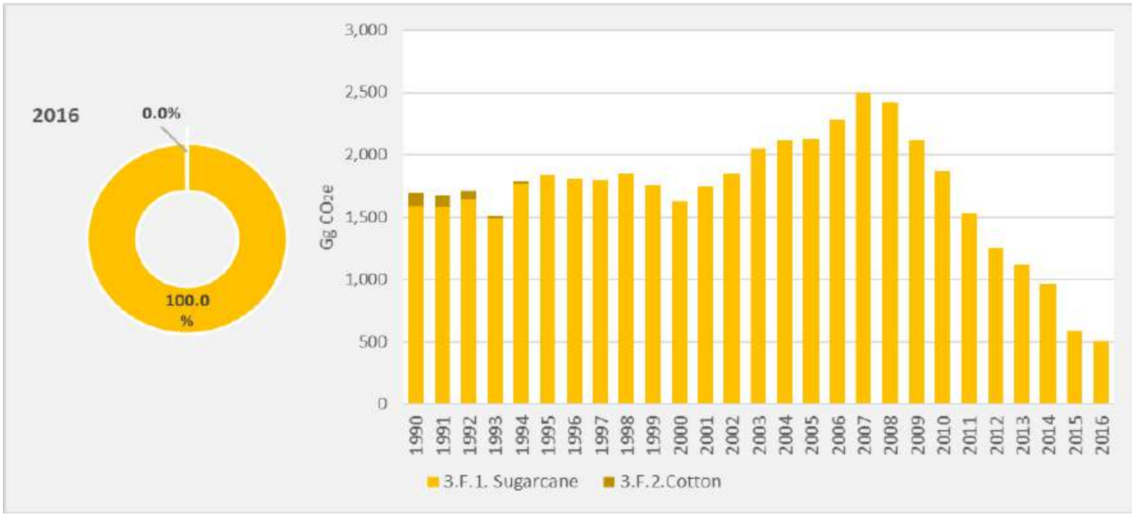



Figure 2.31. Emissions from Field Burning of Agricultural Residues (3.F), in $CO_2e$, of the main agricultural crops, from 1990 to 2016

[19] *According to IPCC 2006, the $CO_2$ emitted is not counted, as it is already considered in the absorption of CO2 in the photosynthesis of the next harvest. In addition to direct gases, subsector 3.F includes the accounting for indirect greenhouse gases CO and NOx.*

### 2.5.7 Liming (3.G)

Liming emissions include only $CO_2$. In Brazil, the use of limestone (dolomite) has been increasingly used to supply Calcium (Ca) and Magnesium (Mg) to plants and, mainly, to reduce the acidity characteristic of their soils. Calcium stimulates the growth of roots, aiding in the efficiency of plants in the search for water and nutrients in the soil. It is essential for healthy soil, as it increases the microbial activity of the soil resulting in greater mineralization of organic matter and biological nitrogen fixation. However, after being added, limestone releases carbonate that reacts in the soil, with the release of $CO_2$ into the atmosphere.

$CO_2$ emissions from liming totaled 15,844 Gg of $CO_2$ in 2016. Emissions from this subsector are mainly related to the consumption of limestone for agricultural purposes, and in this way, they followed the technification trend of national agriculture, as shown in Figure 2.32. In 2010, liming emissions were 11,292 Gg $CO_2$.

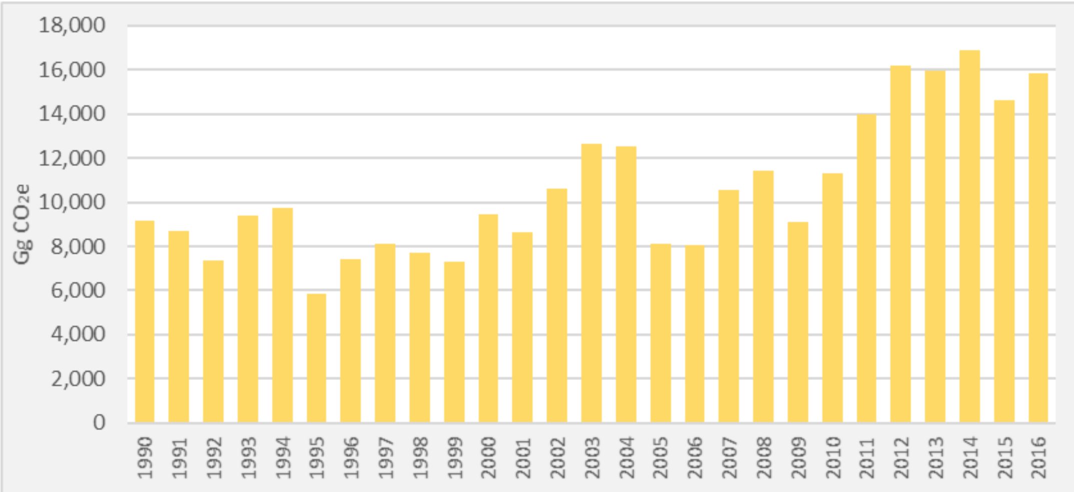



Figure 2.32. Emissions from Liming (3.G), in $CO_2$, from 1990 to 2016

### 2.5.8 Urea Application (3.H)

In Brazil, urea is widely used as an organic fertilizer and, as in Liming, its application generates $CO_2$ emissions. Urea has carbon in its constitution and, when applied to the soil, it undergoes the hydrolysis process, which generates ammonia for plants and $CO_2$ that goes into the atmosphere.

In 2016, emissions from the Urea Application totaled 3,888 Gg $CO_2$, while in 2010 it was 2,406 Gg $CO_2e$.

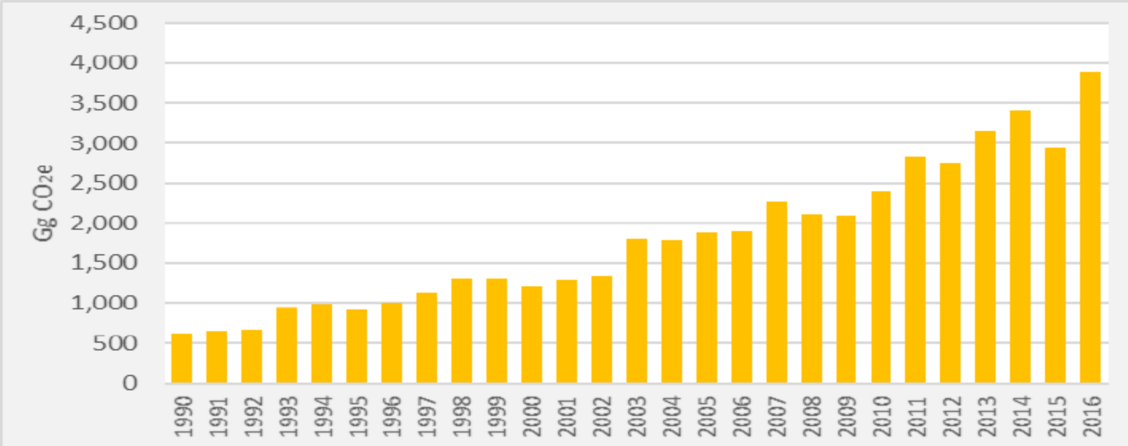



Figure 2.33. Emissions from the Urea Application (3.H), in $CO_2$, from 1990 to 2016

## 2.6 LAND USE, LAND-USE CHANGE, AND FORESTRY SECTOR (4)

The Land Use, Land-Use Change, and Forestry (LULUCF) sector presents anthropogenic emissions by sources and removals by $CO_2$ sinks from carbon loss or gain (C) associated with land use and cover changes. Additionally, emissions of $CH_4$ and $N_2O$ and indirect GHG (CO and $NO_x$) arising from the burning of biomass associated with the dynamics of land use and cover are estimated. $CO_2$ emissions and removals by Harvested Wood Products, that is, products manufactured/processed after wood harvesting wood, such as paper, sawn wood, wood panels, among others, are also considered.

The subsectors of the LULUCF sector are: Forest Land (4.A), Cropland (4.B), Grassland (4.C), Wetland (4.D), Settlement (4.E), Other Lands (4. F), and Harvested Wood Products (4.G), according to the IPCC 2006 guidelines.

For this sector, the results are represented by net emissions or removals. These estimates are the result of the balance between gross emissions (of $CO_2$ by Harvested Wood Products and non-$CO_2$ and $CO_2$ associated with land use and cover change) and $CO_2$ removals (due to land use and cover change, soil management, and Harvested Wood Products). When gross emissions are greater than removals, there are net emissions; when removals are greater than gross emissions, there are net removals.

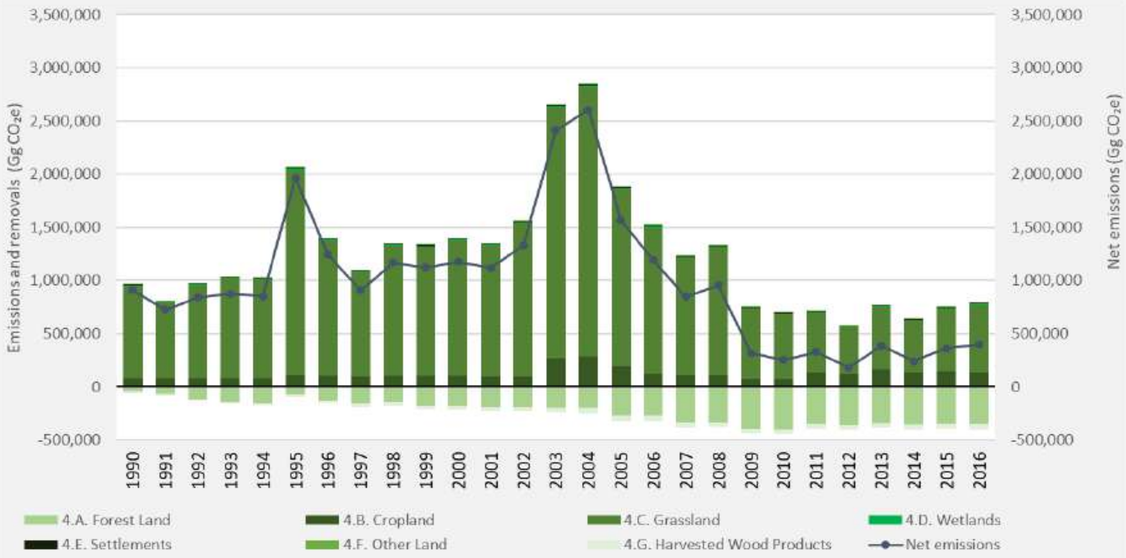
*To learn more about the Action Plans for Prevention and Control of Deforestation, see **items 4.1.3 and 4.1.4.***

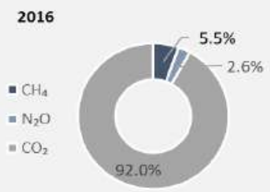
The net emissions of the LULUCF sector totaled 397,357 Gg $CO_2e$ in 2016. It is worth mentioning that the Action Plans for Prevention and Control of Deforestation contributed to the reduction of emissions in this sector since 2005. Moreover, since 2010, *Plano ABC* was implemented, which, between 2010 and 2018, recovered 23 million hectares of degraded pasture, whose removals are not fully accounted for in this National Inventory due to methodological limitations. In terms of participation by gas, $CO_2$ contributed 92% in 2016, that is, 365,404 Gg of total net emissions, while $CH_4$ (21,782 Gg $CO_2e$) and $N_2O$ (10,172 Gg $CO_2e$) emissions represented 5% and 3%, respectively (Figure 2.34).

In 2016, the sector's most representative emissions came from the Grassland subsector (4.C) (640,377 Gg $CO_2e$), while the largest removals were from the Forest Land (4.A) subsector, which contributed -347,821 Gg $CO_2e$. On the other hand, the subsector Grassland (4.C) provided areas for other subsectors such as Cropland, Secondary Forest, and Reforestation. In 2016, 9.8 million hectares of pasture started to be occupied by annual, perennial, and semi-perennial crops and another 4 million were left to regenerate (3.1 million hectares) or were reforested (1.8 million hectares), resulting in a removal of -192,852.1 Gg $CO_2$ since 2010.

*See the **Appendix I** to check the tables with all results per gas in mass unit, for all sectors and the entire historical series (1990 to 2016)*

$CH_4$ and $N_2O$ emissions, resulting from the burning of biomass associated with the dynamics of land use and cover, came mainly from the Grassland subsector (4.C), which contributed with 18,104 Gg $CO_2e$ (or 83%) and 8,273 Gg $CO_2e$ (or 81%) of emissions of these gases in the sector, respectively, in 2016.




| Sector/ Subsector | 1990 | 1995 | 2000 | 2005 | 2010 | 2016 | Variation 2010-2016 |
|---|---|---|---|---|---|---|---|
| | ---------- Gg $CO_2e$ ---------- | | | | | | ----- % ----- |
| **4. Land Use, Land-Use Change and Forestry (LULUCF)** | **907,520** | **1,966,770** | **1,175,013** | **1,564,054** | **252,508** | **397,357** | **57.4%** |
| **4.A Forest Land** | -44,069 | -76,309 | -182,004 | -269,310 | -400,026 | -347,821 | -13.1% |
| **4.B Cropland** | 78,966 | 113,788 | 100,491 | 195,786 | 71,337 | 132,999 | 86.4% |
| **4.C Grassland** | 869,132 | 1,927,119 | 1,274,147 | 1,665,616 | 615,043 | 640,377 | 4.1% |
| **4.D Wetlands** | 6,385 | 10,540 | 9,619 | 12,268 | 6,252 | 8,596 | 37.5% |
| **4.E Settlements** | 6,862 | 9,916 | 8,588 | 7,052 | 4,354 | 5,068 | 16.4% |
| **4.F Other Land** | 1,268 | 2,414 | 1,712 | 4,999 | 2,481 | 8,911 | 259.2% |
| **4.G Harvested Wood Products** | -11,025 | -20,697 | -37,539 | -52,357 | -46,933 | -50,772 | 8.2% |

Figure 2.34. LULUCF sector emissions, in $CO_2e$, by subsector, from 1990 to 2016

## 2.6.1 General methodological aspects of the sector

Estimates of $CO_2$ emissions and removals due to land use and land cover change and Harvested Wood Products, as well as non-$CO_2$ gases emissions, were based on the methodology suggested in the IPCC 2006[20].

*To learn more about Brazilian biomes, see* ***item 1.1.***

To better represent the carbon stock variations in its territory, the country estimated emissions and removals from the LULUCF sector by biome (Panel 2.9). For this, a spatial database was created composed of satellite images and layers of information highlighted in Figure 2.35. It is worth mentioning that natural formations protected, that is, within a Conservation Unit (UC) or Indigenous Land (TI), were classified as managed[21] and, therefore, had their $CO_2$ removals accounted for.

By crossing these layers of spatial information, more than 23 million polygons were generated, each representing a conversion of land use and cover for the periods evaluated (1994-2002, 2002-2010 and 2010-2016), which were presented in land use conversion matrices, by period (Tier 2) (Figure 2.35).

Each land use and cover were associated with carbon emission and removal factors for the different pools (above and below-ground living biomass, dead organic matter, and soil). Values published in scientific

[20] *Intergovernmental Panel on Climate Change (IPCC). IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme. Vol. 4, Agriculture, Forestry and Other Land Use. (IPCC, 2006).*

[21] *According to the IPCC, managed areas are those that have relevant ecological, economic, and/or social interests.*

articles and national data for each biome were prioritized, adopting the IPCC 2006 default factors only when national information was not available (Tier 1 and 2). Thus, it was possible to estimate gross emissions and removals of vegetation, emissions and removals from the soil and, therefore, the net emissions and removals of each biome, by period.

Annual estimates of gross vegetation emissions were modulated based on available deforestation rates, by biome. $CO_2$ removals by protected natural formations were annualized based on the date of creation of the UC or TI. The removals from other land use and cover conversions were distributed equally for each year of the evaluated period, as well as the emissions and removals from the soil.

For the period between 1990 and 1994, the data produced in the scope of the Initial Communication of Brazil (BRASIL, 2004) were used, with updating of carbon stock factors and carbon sequestration of secondary vegetation.

$CO_2$ emissions and removals by Harvested Wood Products (4.G) were calculated based on the IPCC 2006 atmospheric flow methodology (Tier 1) (Panel 2.9).

Estimates for non-$CO_2$ gases ($CH_4$, $N_2O$, CO, and $NO_x$) in this sector were performed based on the conversion of natural vegetation for anthropogenic use. It is considered that, after the removal of part of the original biomass in the form of firewood for the manufacture of furniture or use as fuel, it is burned (Table 2.9).

***Conversion for anthropogenic use***

*Conversions from natural vegetation (protected or not) to reforestation (planted forest), secondary vegetation, pasture, agriculture, settlement, reservoir, mining and exposed soil were considered.*

It is worth noting that the emissions and removals of mineral soils and organic soils from the LULUCF sector were not disaggregated and non-$CO_2$ emissions from the Cropland remaining Cropland (4.B.1) category were included (IE) in the Field Burning of Agricultural Residues subsector (3.F) of the Agriculture sector.

Monitoring the dynamics of fires and plant regeneration over the years covered by this inventory is not simple, as it requires access to satellite images with greater frequency, in addition to specific scientific data for the association of vegetation growth rates. Furthermore, the association of fires with anthropogenic causes is not trivial, assuming then the premise that fires occur only in cases where land use and cover conversion is effectively observed, not being estimated (NE) under other conditions.

$CO_2$ emissions and removals from Cropland remaining Cropland (4.B.1) were not accounted for due to the lack of spatialized data by type of cultivation for periods before 2016. Although Severely Degraded Pastures (APD) were mapped in 2016, $CO_2$ removals were counted only for areas converted from uses other than pasture to well-managed pastures, for the entire historical series. These estimates were made based on the application of factors of alteration of organic carbon in the soil, proportionally stratified, by Federative Unit, in relation to the quality of pastures (natural / planted in good conditions / planted in poor conditions).

Figure 2.35 presents a summary of the methodology for estimating emissions and removals from the LULUCF sector. Panel 2.9 presents the methodological Tiers applied by gas and references from the LULUCF sector.

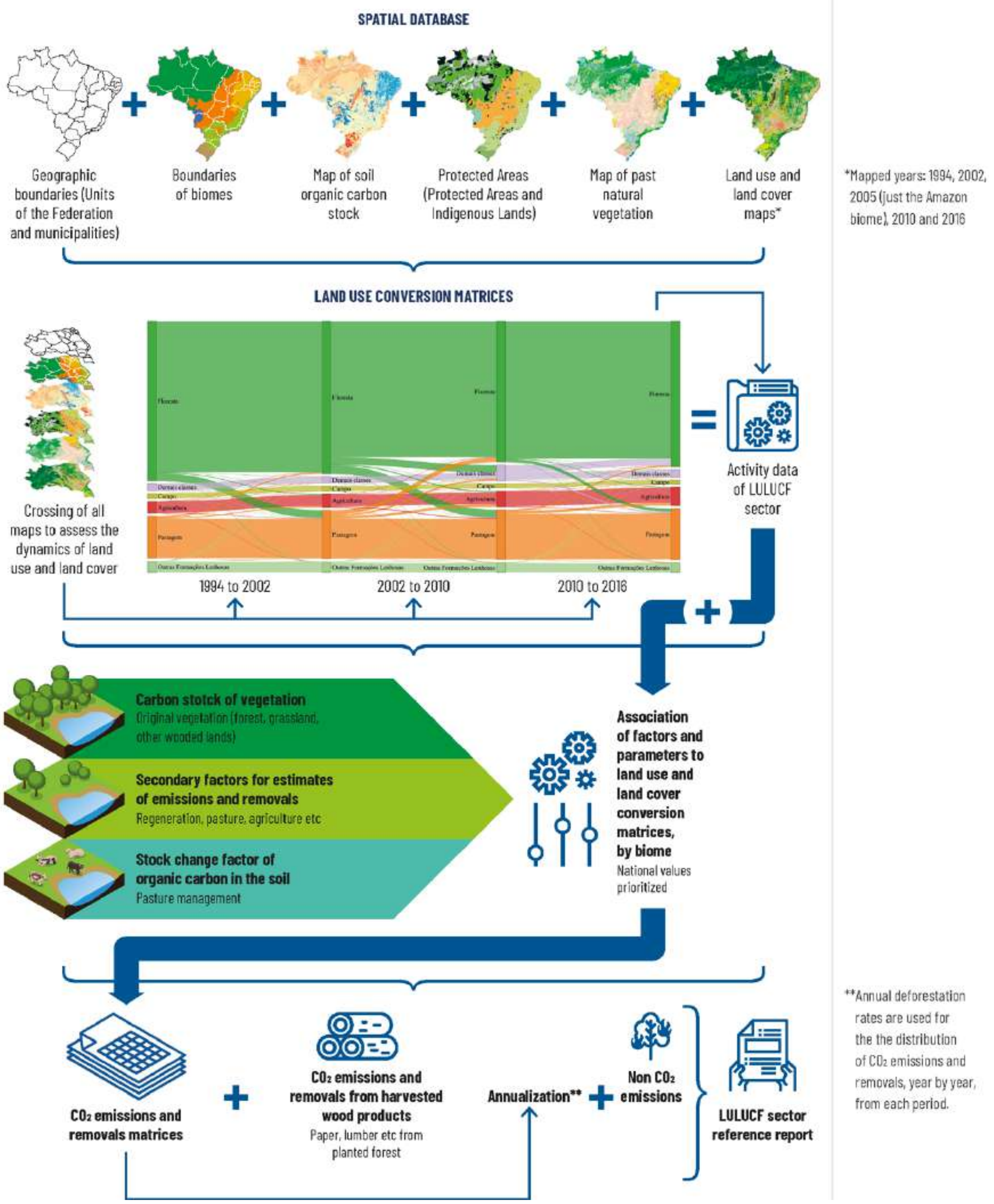



Figure 2.35. Flowchart of the methodology used to prepare the National Inventory of the LULUCF sector

Panel 2.9. Methodological levels applied by gas and reference in the LULUFC sector.

| Subsector | Category | Subcategories | Estimated gases and methodologies | | | | | | References | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $CO_2$ | $CH_4$ | $N_2O$ | CO | $NO_x$ | NMVOC | Activity Data | Emission Factors |
| 4.A. Forest Land | 4.A.1. Forest Land remaining Forest Land | | T1, T2 | T1, T2 | T1, T2 | T1, T2 | T1, T2 | T1, T2 | Land use conversion matrices considering mapped years (1994-2002, 2002-2010, and 2010-2016), generated according to Approach 3 (IPCC, 2006) and based on the following spatial information:<br>• Boundaries of Units of the Federation and municipalities (IBGE, 2017a);<br>• Boundaries of biomes (IBGE, 2004);<br>• Map of soil organic carbon stock (IBGE, 2004; EMBRAPA, 2003; BERNOUX et al., 2002);<br>• Protected Areas (ICMBio Protected Areas and FUNAI Indigenous Lands);<br>• Map of past natural vegetation (adapted from IBGE, 2017a); | • Carbon stock of biomass from the past natural vegetation for all pools (above-ground, below-ground, and dead organic matter, consisting of standing and fallen dead wood, and litter) based on field data and scientific literature. In the absence of national data, reasons and/or default values of IPCC were applied (dead wood from IPCC, 2003, and below-ground from IPCC, 2006). For the Amazon biome, airborne LiDAR data (EBA/CCST-INPE) were used. The carbon content of dry forest biomass was 47% for all pools, with the exception of litter (46%) (IPCC, 2006; OMETTO et al., 2006). As for grassland vegetation and other wooded lands, 47% were considered for biomass above and below-ground, 50% for dead wood and 40% for litter (IPCC, 2006). |
| | 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 | NA | NA | NA | NA | NA | | |
| | | 4.A.2.c Wetland converted to Forest Land | T1, T2 | NA | NA | NA | NA | NA | | |
| | | 4.A.2.d Settlement 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 | IE | | |
| | 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 | T1, T2 | | |

| Subsector | Category | Subcategories | Estimated gases and methodologies | | | | | | References | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $CO_2$ | $CH_4$ | $N_2O$ | CO | $NO_x$ | NMVOC | Activity Data | Emission Factors |
| | | 4.B.2.b Grassland converted to Cropland | T1, T2 | T1, T2 | T1, T2 | T1, T2 | T1, T2 | T1, T2 | • Maps of land use for 1994, 2002, 2005 (the Amazon biome only), 2010, and 2016 on a scale of 1:250,000 based on medium resolution satellite imagery covering the following categories: Managed Forest (within a protected area), Unmanaged Forest, Secondary Forest, Selective Logging (for the Amazon biome only), Reforestation, Managed Grassland (within a protected area), Unmanaged Grassland, Secondary Grassland, Pasture, Agriculture, Settlement, Wetland, Artificial Reservoirs, Rock, Sand Dunes, Exposed Soil, Mining, and Unobserved Areas (clouds and/or shadows in satellite imagery).<br><br>Complementary data on land use:<br><br>- crop type areas (annual or perennial) by Unit of the | • Soil organic carbon stock: methodology by Bernoux et al. (2002) adapted to vegetation maps (IBGE, 2004), and soil maps (EMBRAPA, 2003).<br><br>• Data on stock/removal from biomass in pastures, croplands, secondary vegetation and protected natural vegetation were obtained from scientific literature; in some cases, IPCC default values were used (IPCC, 2006). Categories such as Settlement, Exposed Soil, Mining, Artificial Reservoirs, Sand Dunes, and Rock had their carbon stock associated with zero.<br><br>• Factors of organic carbon change in the soil: obtained from data from national field data for reforestation, croplands (no-till planting vs. conventional planting) and pastures (natural/ planted under good conditions/planted under poor conditions/severely degraded pastures). |
| | | 4.B.2.c Wetland converted to Cropland | T1, T2 | NA | NA | NA | NA | NA | | |
| | | 4.B.2.d Settlement 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 | | |
| 4.C Grassland | 4.C.1 Grassland remaining Grassland | | T1, T2 | NE | NE | NE | NE | NE | | |
| | 4.C.2 Land converted to Grassland | 4.C.2.a Forest Land converted to Grassland | T1, T2 | T1, T2 | T1, T2 | T1, T2 | T1, T2 | T1, T2 | | |
| | | 4.C.2.b Cropland converted to Grassland | T1, T2 | NA | NA | NA | NA | NA | | |
| | | 4.C.2.c Wetland converted to Grassland | NO | NA | NA | NA | NA | NA | | |
| | | 4.C.2.d Settlement converted to Grassland | NO | NA | NA | NA | NA | NA | | |

| Subsector | Category | Subcategories | Estimated gases and methodologies | | | | | | References | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $CO_2$ | $CH_4$ | $N_2O$ | CO | $NO_x$ | NMVOC | Activity Data | Emission Factors |
| | | 4.C.2.e Other Land converted to Grassland | T1, T2 | NA | NA | NA | NA | NA | Federation according to IBGE for each year mapped (for a breakdown of the Agriculture for the years prior to 2016);<br>- planted forest area by species and Unit of the Federation according to IBÁ (for a breakdown of the Reforestation);<br>- area by Unit of the Federation and type of planting system (conventional or no-tillage) according to IBGE (2017a) (for factors of organic carbon change in the soil);<br>- area per Unit of the Federation of pasture conditions (natural, planted under good conditions, planted under poor conditions) according to IBGE (2017a) (for factors of organic carbon change in the soil). | • Combustion factors: obtained from the scientific literature, by biome and type of vegetation.<br>• Non-$CO_2$ gas emission factors: default (IPCC, 2006), differentiated by type of vegetation. |
| 4.D Wetland | 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 | T1, T2 | | |
| | | 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 | NA | NA | NA | NA | 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 Settlement | 4.E.1 Settlement remaining Settlement | | NA | NA | NA | NA | NA | NA | | |
| | 4.E.2 Land converted to Settlement | 4.E.2.a Forest Land converted to Settlement | T1, T2 | T1, T2 | T1, T2 | T1, T2 | T1, T2 | T1, T2 | | |

| Subsector | Category | Subcategories | Estimated gases and methodologies | | | | | | References | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $CO_2$ | $CH_4$ | $N_2O$ | CO | $NO_x$ | NMVOC | Activity Data | Emission Factors |
| | | 4.E.2.b Cropland converted to Settlement | T1, T2 | NA | NA | NA | NA | NA | Data for annualization of gross emissions:<br>- PRODES for the Amazon (INPE, 2019a);<br>- Atlas of Forest Remnants from the Atlantic Forest to the Atlantic biome (FUNDAÇÃO SOS MATA ALÂNTICA; INPE, 2019);<br>- PRODES for Cerrado (INPE, 2019b);<br>- PMDBBS for Caatinga, Pampa and Pantanal Wetlands (MMA, 2012).<br><br>Data for calculating emissions of non-$CO_2$ gases from burning biomass:<br>- Firewood and roundwood from logging (IBGE, 2016) | |
| | | 4.E.2.c Grassland converted to Settlement | T1, T2 | T1, T2 | T1, T2 | T1, T2 | T1, T2 | T1, T2 | | |
| | | 4.E.2.d Wetland converted to Settlement | NA | NA | NA | NA | NA | NA | | |
| | | 4.E.2.e Other Land converted to Settlement | T1, T2 | T1, T2 | T1, T2 | T1, T2 | T1, T2 | T1, T2 | | |
| 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 Wetland converted to Other Land | NE | NA | NA | NA | NA | NA | | |

| Subsector | Category | Subcategories | Estimated gases and methodologies | | | | | | References | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $CO_2$ | $CH_4$ | $N_2O$ | CO | $NO_x$ | NMVOC | Activity Data | Emission Factors |
| | | 4.F.2.e Settlement converted to Other Land | NE | NA | NA | NA | NA | NA | | |
| 4.6 Harvested Wood Products | | | T1 | T1 | T1 | T1 | T1 | T1 | • Production, import and export of sawn wood, wood panels, paper and paperboard (FAO, 2019).<br>• Waste originating from wood, paper and paperboard, and residues from parks and gardens. | Unit conversion factors (density, carbon fraction and carbon factor) from IPCC 2006 default values for i) wood harvested, industrial harvest, sawn wood, wood pulp, chips, particles, firewood, wood residues; ii) charcoal; iii) wood panels; iv) paper and cardboard, pulp, recycled fiber pulp and recycled paper. |

Note: Method applied (IPCC, 2006) — T1: Tier 1; T2: Tier 2; T3: Tier 3.
Notation keys: NA — not applicable; NO — not occurring; IE — included elsewhere; NE — not estimated

### 2.6.2 Forest Land (4.A)

This subsector is mainly characterized by the density of trees in the upper stratum of the canopy of vegetation formations, where some trees can reach heights up to or above 50 m (IBGE, 2012). Both natural and planted forests are considered. The subsector Forest Land (4.A) is divided into the categories Forest Land remaining Forest Land (4.A.1) and Land converted to Forest Land (4.A.2), which consider national subdivisions (Table 2.10). $CO_2$ emissions and removals are linked to the loss or gain of carbon by changing land use and cover, for all pools (above and below-ground living biomass, dead organic matter, and soil). $CH_4$ and $N_2O$ emissions are linked to the conversion process from natural vegetation to reforestation.

Panel 2.10. National subdivision of the Forest land subsector

| Subsector | Subdivision according to national peculiarities | Description |
|---|---|---|
| Forest | Managed Forest | Natural forest, where human action did not cause significant changes in characteristics, classified based on the map of past natural vegetation and also on its phytophysiognomy. It is in a protected area (UC or TI) and, therefore, its $CO_2$ removals are accounted for, based on a scientific survey, when they remain with the same coverage between the evaluated periods. |
| | Unmanaged Forest | Natural forest, where human action did not cause significant changes in characteristics, classified based on the map of past natural vegetation and also on its phytophysiognomy. Emissions and removals are only accounted for when converted to anthropogenic use. $CO_2$ removals are not counted when it remains intact between the periods evaluated since there is no anthropic intervention. |
| | Secondary Forest | Classified based on the map of natural past vegetation and resulting from a process of natural regeneration associated with previous anthropogenic use, for example, agricultural cultivation or pasture. |
| | Selective Logging | Identified only in the Amazon biome; consists of the removal of trees in native forests, which may be associated with the practice of sustainable forest management, regulated and authorized by competent bodies, as well as the practice of selective predatory harvesting, which consists of unsustainable logging over time and without authorization from competent bodies. |
| | Reforestation | Planted forests, in monoculture, mostly composed 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 2016, the Forest Land subsector (4.A) totaled -347,821 Gg $CO_2$ net removal, while in 2010 it was -400,026 Gg $CO_2e$.

Net removals from the category Forest Land remaining Forest Land (4.A.1) (-310,643 Gg $CO_2$e) contributed 89% of net removals in 2016, while the category Land converted to Forest Land (4.A.2) contributed with the others 11% (-37,178 Gg $CO_2$e) (Figure 2.36).

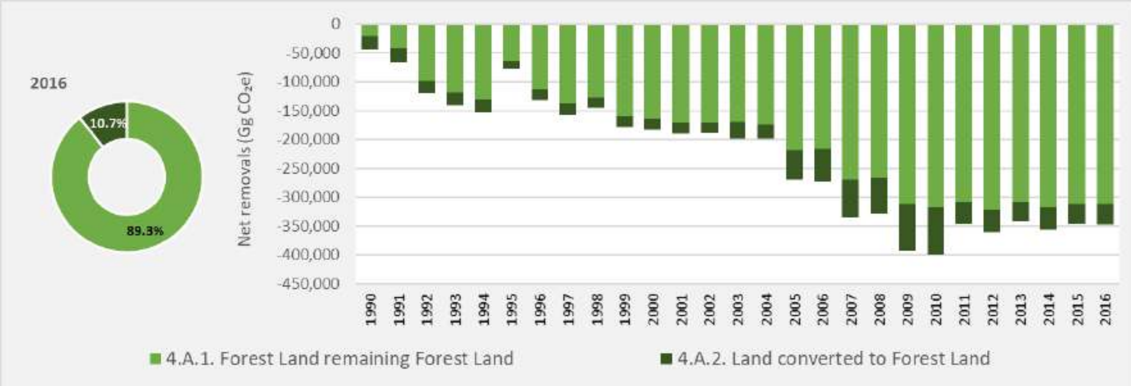



Figure 2.36. Net removals of the categories of the Forest Land subsector (4.A), in $CO_2$e, from 1990 to 2016.

## 2.6.3 Cropland (4.B)

The Cropland subsector (4.B) comprises areas cultivated with temporary, perennial, or semi-perennial crops. Also included in this category are lands that are set aside before being cultivated again. This subsector includes the categories of Cropland remaining Cropland (4.B.1) and Land converted to Cropland (4.B.2), which consider national subdivisions (Panel 2.11). $CO_2$ emissions and removals are linked to carbon loss or gain by changing land use and land cover, for all pools (above and below-ground living biomass, dead organic matter, and soil), while $CH_4$ and $N_2O$ are linked to the process of converting natural vegetation to agriculture.

Panel 2.11. National sub-division of the Cropland subsector

| Subsector | Subdivision according to national peculiarities | Description |
|---|---|---|
| Cropland | Annual Agriculture | Areas intended for crops that have an annual production cycle, which culminates in the death of the plant after harvesting. This category includes areas for horticulture and cultivation of soy, rice, beans, corn, cotton, tubers, etc. |
| | Perennial Agriculture | Areas intended for crops that produce over several years, without the need for new planting after harvesting. Perennial crops include trees and shrubs, mainly represented by fruit trees, such as citrus, banana, coconut, coffee, among others. |
| | Semi-perennial Agriculture | In Brazil, this type of cultivation is represented by sugar cane, which is harvested several times before there is a new planting. Semi-perennial crops can produce for a period ranging from five to six years, depending on the management applied. |

The Cropland subsector (4.B) resulted in a net emission of 132,999 Gg $CO_2$e in 2016, while in 2010 it was 71,337 Gg $CO_2$e (Figure 2.37).

The only category accounted for in this sector was Land converted to Cropland (4.B.2). The subcategories Forest Land converted to Cropland (4.B.2.a) and Grassland converted to Cropland (4.B.2.b) contributed 76,252 Gg $CO_2$e and 56,747 Gg $CO_2$e, respectively, to the net emissions of this category in 2016. The Other Land to Cropland subcategory (4.B.2.e) contributed to the removal of -0.77 Gg $CO_2$e (Figure 2.37).

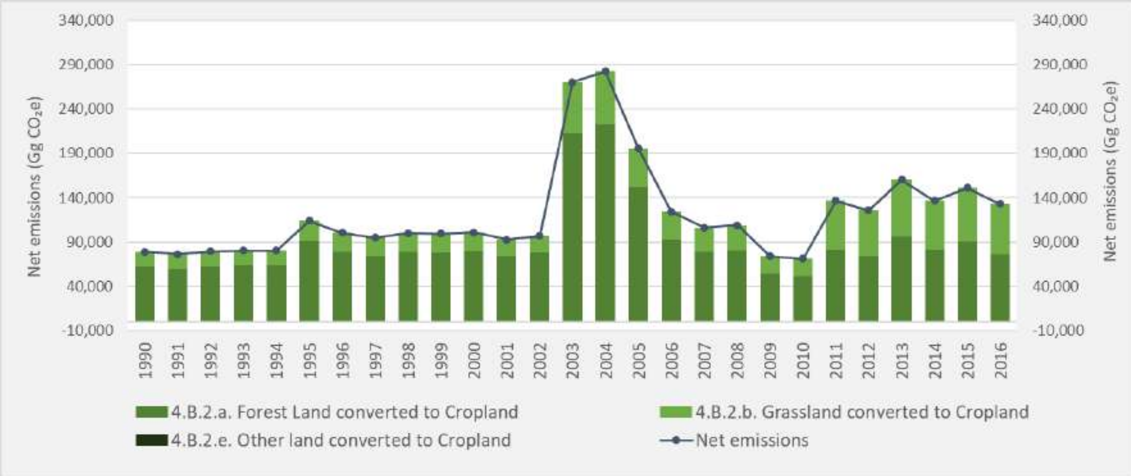



Figure 2.37. Net emissions and removals of the subcategories of the Land converted to Cropland category (4.B.2) of the Cropland subsector (4.B), in $CO_2$e, from 1990 to 2016.

## 2.6.4 Grassland (4.C)

The Grassland subsector (4.C) includes natural grassland, natural and planted pastures, and Other Wooded Land. The grassland is characterized by areas with a predominance of herbaceous and shrubby vegetation, where the incidence of sunlight occurs directly on the soil or lower strata since there is no canopy densification in these environments (IBGE, 2012). The insertion of Other Wooded Land in this subsector considered the definition used in the Forest Resources Assessment (FRA) by FAO (2015), which classifies them as formations that do not fall under the Forest Land subsector, which cover more than 0.5 hectares with trees greater than 5 meters and a canopy cover of 5 to 10%, or with trees capable of reaching these limits, or with a combined cover of shrubs and trees above 10%.

This subsector is divided into the Grassland remaining Grassland category (4.C.1) and Land converted to Grassland category (4.C.2), which consider national characteristics (Panel 2.12). $CO_2$ emissions and removals are linked to the loss or gain of carbon by changing land use and land cover, including soil management, for all pools (above and below-ground living biomass, dead organic matter, and soil). Severely Degraded Pastures (APD) were mapped in 2016. $CO_2$ removals were counted only for areas converted from uses other than pasture to well-managed pastures, for the entire historical series, using factors of alteration of soil organic carbon weighted by the quality of the pastures. Regarding $CH_4$ and $N_2O$ emissions, these are specifically linked to the conversion process from natural vegetation to pasture.

Panel 2.12. National subdivision of the Grassland subsector

| Subsector | Subdivision according to national peculiarities | Description |
|---|---|---|
| Grassland | Managed Field | Natural grassland, where human action has not caused significant changes in characteristics, classified based on the map of past natural vegetation also in relation to its phytophysiognomy. It is located in a protected area (UC or IT) and, therefore, its $CO_2$ removals are accounted for, based on a scientific survey, when they remain with the same coverage between the evaluated periods. |
| | Unmanaged Grassland | Natural grassland, where human action did not cause significant changes in characteristics, classified based on the map of past natural vegetation also in relation to its phytophysiognomy. Emissions and removals are only accounted for when converted to human use. $CO_2$ removals are not counted when it remains with the same coverage between the periods evaluated since there is no anthropic intervention. |
| | Secondary Grassland | Classified based on the map of past natural vegetation and resulting from a natural regeneration process associated with previous anthropogenic use, for example, agricultural cultivation or pasture. |
| | Pasture | Areas intended for grazing, which can be composed of both grazable fields of native origin (natural pastures) and planted (mostly species of exotic grasses). The joining of areas (natural and planted) occurred, mainly, due to the spectral similarity observed in the satellite images, especially in areas of degraded pastures or with great seasonal variation. In biomes such as Pampa and Pantanal, there is extensive use of natural pastures. In biomes such as the Amazon and Cerrado, cultivated pastures predominate. |
| | Severely Degraded Pasture | They are pasture areas with advanced biological degradation, characterized mainly by the presence of exposed soil and low productivity. |
| | Managed Other Wooded Land | Other Wooded Land, with an intermediate structure between Forest and Grassland, where human activity has not caused significant changes in characteristics. Classified based on the map of past natural vegetation and their phytophysiognomy. It is located in a protected area (UC or TI) and, therefore, its $CO_2$ removals are accounted for, based on a scientific survey, when they remain with the same coverage between the evaluated periods. |
| | Unmanaged Other Wooded Land | Other Wooded Land, with an intermediate structure between Forest and Grassland, where human activity has not caused significant changes in characteristics. Classified based on the map of past natural vegetation and their phytophysiognomy. Emissions and removals are only accounted for when converted to anthropogenic use. $CO_2$ removals are not counted when it remains with the same coverage between the periods evaluated since there is no anthropogenic intervention. |

| Subsector | Subdivision according to national peculiarities | Description |
|---|---|---|
| | Secondary Other Wooded Land | Classified based on the map of past natural vegetation and resulting from a natural regeneration process associated with previous anthropogenic use, for example, agricultural cultivation or pasture. |

Net $CO_2$ emissions from the Grassland subsector (4.C) totaled 640,377 Gg $CO_2e$ in 2016, and 615,043 Gg $CO_2e$ in 2010.

The Grassland remaining Grassland category (4.C.1) contributed to a net removal of -3,421 Gg $CO_2e$ for this subsector in 2016. This removal does not account for the Severely Degraded Pasture area in 2010 that was recovered and turned into a well-managed pasture area in 2016. According to estimates by FERREIRA JUNIOR (2020), 26,8 million hectares were recovered between 2010 and 2018 in Brazil.

The Land converted to Grassland category (4.C.2) emitted 643,799 Gg $CO_2e$ in 2016, with the subcategories Forest Land converted to Grassland (4.C.2.a) and Cropland converted to Grassland (4.C.2.b) contributed 641,068 Gg $CO_2e$ and 2,741 Gg $CO_2e$. The Other Land converted to Grassland subcategory (4.C.2.e) contributed to a net removal of -11 Gg $CO_2$ (Figure 2.38).

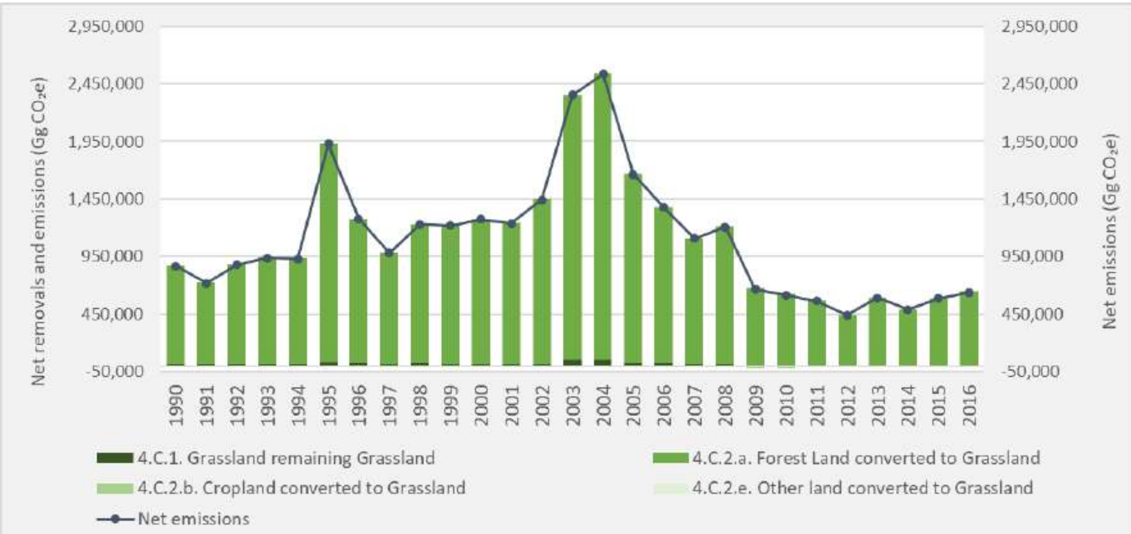



Figure 2.38. Net emissions and removals of categories and subcategories of the Grasslands subsector (4.C), in $CO_2e$, from 1990 to 2016

### 2.6.5 Wetland (4.D)

The Wetland subsector (4.D) comprises regions of marshes (formation in coastal areas), swamps, peatlands or waters of natural or artificial regime, permanent or temporary, stagnant or flowing, sweet, brackish or salty (excluding the oceans). This subsector comprises the categories Wetland remaining Wetlands (4.D.1) and Land converted to Wetland (4.D.2), according to the national subdivisions (Panel 2.13). $CO_2$, $CH_4$, and $N_2O$ emissions are linked to the conversion process from natural vegetation to reservoir, specifically.

Panel 2.13. National sub-division of the Wetland subsector

| Subsector | Subdivision according to national peculiarities | Description |
|---|---|---|
| Wetlands | Water | Natural lentic (lakes) and lotic (rivers) bodies of water, from the spring areas where the watercourses have small dimensions, to the large rivers, such as the Amazon and São Francisco. These areas are not counted as Managed Land for the Inventory, since they do not suffer anthropogenic interference. |
| | Reservoir | Bodies of water created by anthropogenic activities, such as artificial lakes and flooded areas for the construction of hydroelectric plants and human supply. |

The Wetland (4.D) subsector contributed 8,596 Gg $CO_2e$ of GHG emissions in 2016, which came only from the Land converted to Wetland category (4.D.2). In 2010, the net emissions of this subsector were 6,252 Gg $CO_2e$ (Figure 2.39).

The Forest Land converted to Wetland subcategory (4.D.2.a) contributed 89% (7,659 Gg $CO_2e$) of net emissions in the category Land converted to Wetland (4.D.2), followed by the subcategories Grassland converted to Wetland (4.D.2.c), which contributed 10% (853 Gg $CO_2e$), and Cropland converted to Wetlands (4.D.2.b), which contributed 1% (84 Gg $CO_2e$) (Figure 2.39).

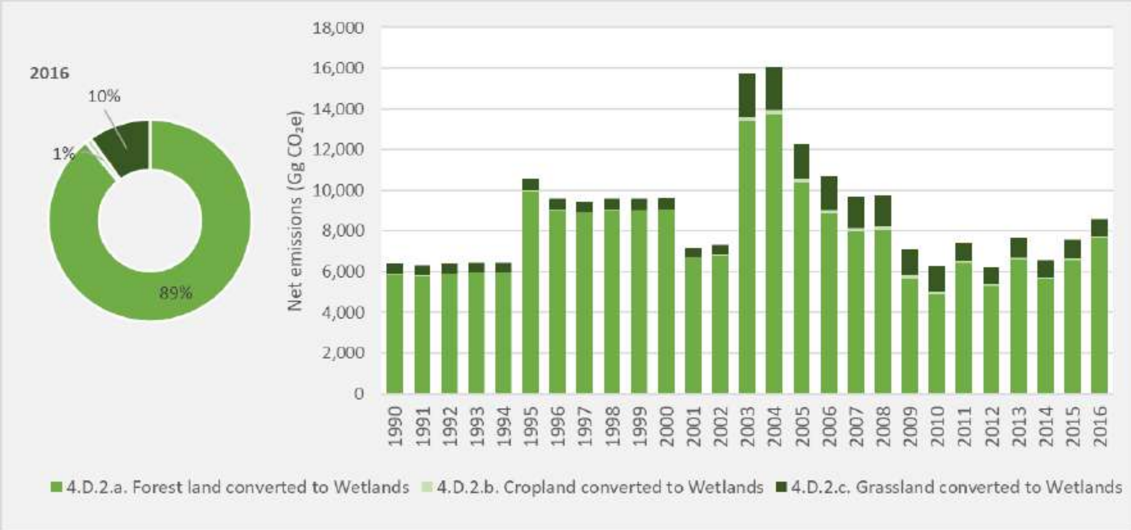



Figure 2.39. Net emissions of subcategories of the Land converted to Wetland (4.D.2) category of the Wetland (4.D) subsector, in $CO_2e$, from 1990 to 2016

## 2.6.6 Settlement (4.E)

The Settlement subsector (4.E) is characterized by the presence of typical housing structures (buildings and agglomerations of residences), industrial constructions, and routes for locomotion of people and means of transport. This subsector is divided into the categories: Settlement remaining Settlement (4.E.1) and Land converted to Settlement (4.E.2). $CO_2$, $CH_4$, and $N_2O$ emissions are linked to the process of converting natural vegetation to Settlement, specifically.

2016 GHG emissions from the Settlement subsector (4.E) corresponded to 5,068 Gg $CO_2e$, originating only from the Land converted to Settlement category (4.E.2), and in 2010 emissions were 4,354 Gg $CO_2e$ (Figure 2.40).

The most representative subcategories in 2016 were Forest Land converted to Settlement (4.E.2.a), which emitted 2,594 Gg $CO_2e$ and contributed 51%, and Grassland converted to Settlement (4.E.2.c), which emitted 2,106 Gg $CO_2e$ and represented 42% of emissions in the Land converted to Settlement category (4.E.2) (Figure 2.40). The subcategory Agriculture converted to Settlement (4.E.2.b) contributed with the remaining 7%, with an emission of 367 Gg $CO_2e$.

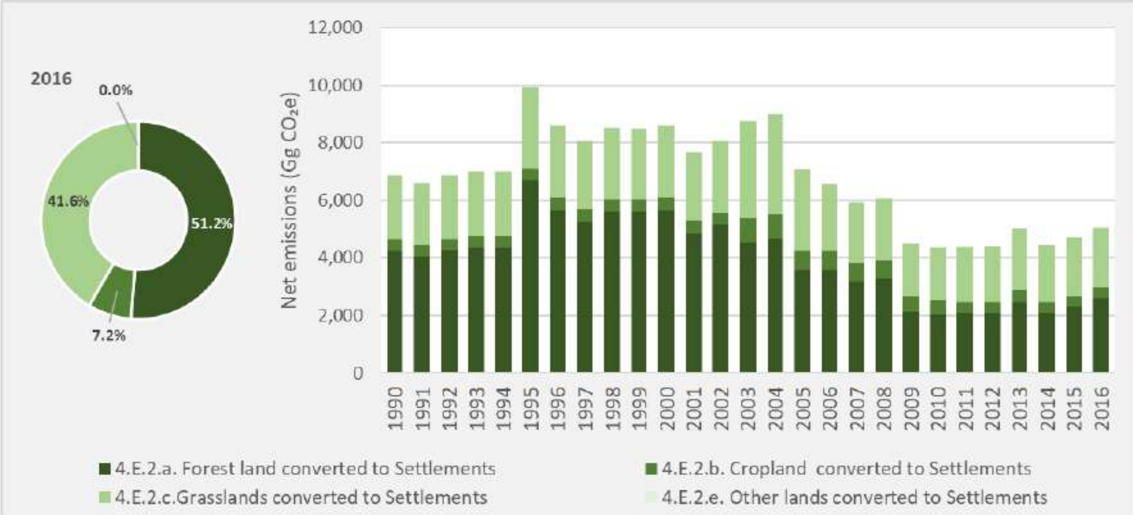



Figure 2.40. Net emissions of the subcategories of the Land converted to Settlement category (4.E.2) of the Settlement (4.E) subsector, in $CO_2e$, from 1990 to 2016

## 2.6.7 Other Land (4.F)

The Other Land subsector (4.F) includes natural areas, such as dunes and rocky outcrops, and human-impacted areas, such as exposed soil and mining, according to subdivisions adopted by the country (Panel 2.14). This subsector comprises the categories Other Land remaining Other Land (4.F.1) and Land converted to Other Land (4.F.2). $CO_2$, $CH_4$, and $N_2O$ emissions are linked to the conversion process from natural vegetation to mining and exposed soil, specifically.

Panel 2.14. National subdivision of the Other Land subsector

| Subsector | Subdivision according to national peculiarities | Description |
|---|---|---|
| Other Lands | Managed Dunes | Natural areas composed only of sand, without vegetation cover, located in protected areas (UC or TI). |
| | Unmanaged Dunes | Natural areas composed only of sand, without vegetation cover, outside protected areas. |
| | Managed Rocky Outcrops | Areas where there is a natural exposure of rocks on the soil surface, without vegetation cover, located in protected areas (UC or TI). |
| | Unmanaged Rocky Outcrops | Areas where natural exposure of rocks on the soil surface occurs, without vegetation cover, outside protected areas. |
| | Mining | Areas for the extraction of minerals for commercial use, mainly characterized by the total removal of native vegetation. |
| | Exposed Soils | Areas without native or exotic vegetation cover, subject to erosion and loss of soil fertility due to the action of abiotic |

| Subsector | Subdivision according to national peculiarities | Description |
|---|---|---|
| | | agents (such as leaching). The exposed soils are usually originated from activities such as deforestation and burning. |
| | Areas not observed | Areas that could not be classified due to the presence of clouds and their shadows, which compromised the analysis of the satellite images available. |

This subsector emitted 8,911 Gg $CO_2e$ in 2016, originating only in the category Land converted to Other Land (4.F.2), which emitted 2,481 Gg $CO_2e$ in 2010.

The Forest Land converted to Other Land subcategory (4.F.2.a) had the largest share in net emissions in this category in 2016, corresponding to 94% (8,419 Gg $CO_2e$). The subcategory Grassland converted to Other Land (4.F.2.c) participated with 5% (470 Gg $CO_2e$) and the subcategory Cropland converted to Other Land (4.F.2.b), with 0.2% (21 Gg $CO_2e$) (Figure 2.41).

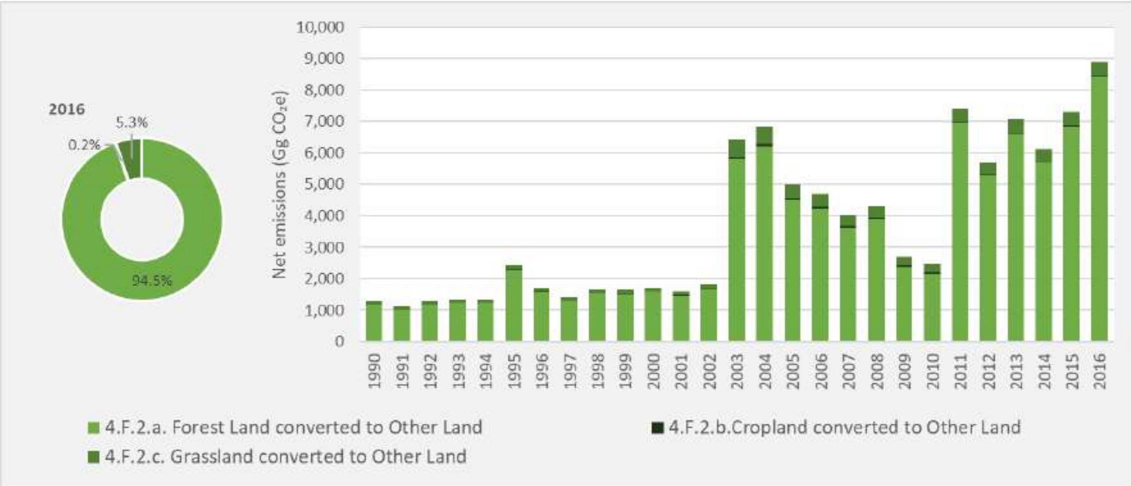



Figure 2.41. Net emissions of the subcategories of the Land converted to Other Land category (4.F.2) of the Other Land subsector (4.F), in $CO_2e$, from 1990 to 2016

## 2.6.8 Harvested Wood Products (4.G)

The Harvested Wood Products subsector (4.G) considers $CO_2$ emissions and removals from products originating from raw materials from planted forests, such as solid wood, panels, paper, and paperboard. $CO_2$ emissions are the result of the decomposition of these products[22] (accounted for in the consuming country), while $CO_2$ removals reflect the growth of reforestation (accounted for in the producing country).

For 2016, the removal corresponding to the harvested wood was -485,804 Gg $CO_2$ for planted forests, and the gross emission was 435,032 Gg $CO_2$. As a result, the balance of the contribution of Harvested Wood Products was a net removal of - 50,772 Gg $CO_2$ in 2016 (Figure 2.42).

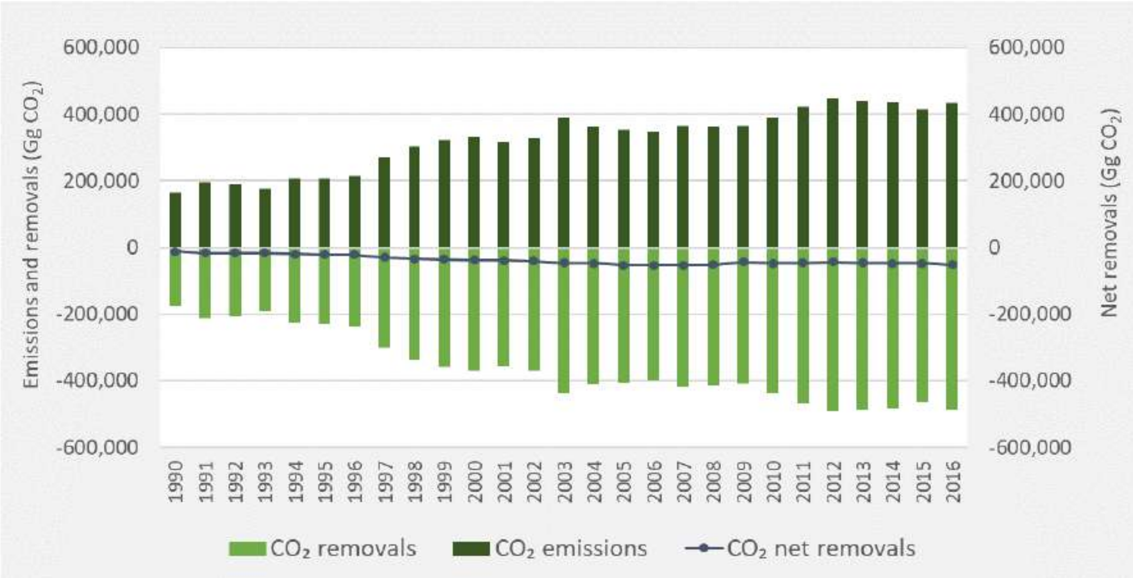



Figure 2.42. Gross emissions, removals, and net $CO_2$ removals from the Harvested Wood Products subsector (4.G), from 1990 to 2016.

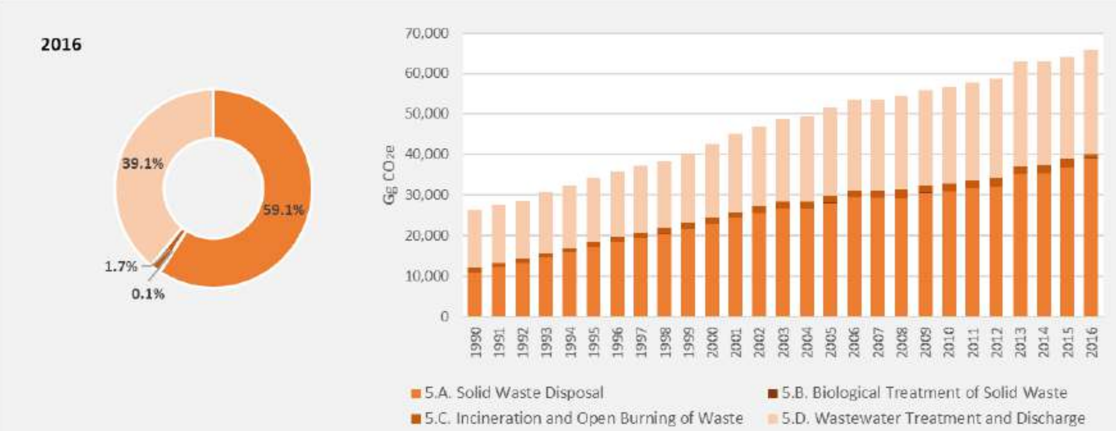
[22] *Emissions of non-$CO_2$ gases associated with the decomposition process are accounted for in the Waste sector.*

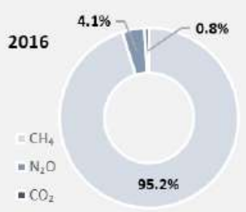
## 2.7 WASTE SECTOR (5)

The Waste sector comprises emissions from the disposal and treatment of solid and liquid waste, and includes $CH_4$, $N_2O$, and $CO_2$ emissions from four subsectors, according to the IPCC 2006 methodology: 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). The sector's emissions are mainly due to the anaerobic degradation process occurring at the final destination of solid waste in managed or in uncategorized landfills, as well as the discharge of wastewater that has undergone or not some treatment process.

*See the **Appendix I** for the tables with all results per gas in mass unit, for all sectors and the entire historical series (1990 to 2016)*

The sector's emissions totaled 65,954 Gg $CO_2e$ in 2016, an increase of 16.4%, compared to 2010. The Solid Waste Disposal subsector (5.A) was the one that most contributed to the sector's emissions in 2016, with 39,001 Gg $CO_2e$ or 59.1% of the total. Wastewater Treatment and Discharge (3.D) emitted 25,794 Gg $CO_2e$ in 2016 and was responsible for 39.1% of the sector's total. The other subsectors contributed a smaller share of emissions, as shown in Figure 2.43.




| Sector/ Subsector | 1990 | 1995 | 2000 | 2005 | 2010 | 2016 | Variation 2010-2016 |
|---|---|---|---|---|---|---|---|
| | Gg $CO_2e$ | | | | | | % |
| **5. Waste** | **26,194** | **34,257** | **42,578** | **51,618** | **56,672** | **65,954** | **16.4%** |
| **5.A. Solid Waste Disposal** | 10,978 | 17,177 | 22,820 | 28,022 | 30,877 | 39,001 | 26.3% |
| **5.B. Biological Treatment of Solid Waste** | 19 | 30 | 36 | 47 | 43 | 56 | 32.0% |
| **5.C. Incineration and Open Burning of Waste** | 1,027 | 1,139 | 1,581 | 1,837 | 1,840 | 1,102 | -40.1% |
| **5.D. Wastewater Treatment and Discharge** | 14,169 | 15,912 | 18,142 | 21,713 | 23,912 | 25,794 | 7.9% |

Figure 2.43. Emissions from the Waste sector, in $CO_2e$, by subsector, from 1990 to 2016

As shown in Figure 2.43, the main gas emitted by the sector was $CH_4$ (95.1%), with Solid Waste Disposal (5.A) being the most significant emission source, followed by Wastewater Treatment and Discharge (5.D), corresponding to 62.1% and 37.0% of the sector's total $CH_4$ emissions, respectively. $N_2O$ and $CO_2$ gases represented a smaller share of emissions in terms of $CO_2e$ (4.1% and 0.8%, respectively).

### 2.7.1 Methodological aspects of the sector

Emission estimates were made based on the methodology recommended in IPCC 2006 [23], and were calculated with official national data, such as urban and rural population, generation of municipal solid waste and health services, type of solid waste disposal sites, variables climatic conditions of municipalities, gravimetric composition of residues, routes or systems for discharging domestic and industrial wastewater, fraction of sewage treatment, wastewater treatment technologies, industrial production and organic load per product unit.

Panel 2.15 presents 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, with emphasis on 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 Biological Treatment of Waste emissions (5.B), Tier 1 was used for Composting (5.B.1), as this category was not very representative in terms of emissions.

For the Open Incineration and Burning of Waste (5.C) subsector, the Tier 2 methodology was used for $CO_2$ emissions, and Tier 1 methodology was used for the other inventoried gases. For emissions by Wastewater Treatment and Discharge (5.D), Tier 2 was used for $CH_4$ and Tier 1 for $N_2O$.

[23] *Intergovernmental Panel on Climate Change (IPCC). IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme. Vol. 5, Waste. (IPCC, 2006).*

Panel 2.15. Methodological levels applied by gas and references from the Waste sector

| Subsector | Category | Subcategories | Estimated gases and methodologies | | | | | | References | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $CO_2$ | $CH_4$ | $N_2O$ | CO | $NO_x$ | NMVOC | Activity Data | Emission Factors |
| 5.A. Solid Waste Disposal | 5.A.1. Managed Waste Disposal Sites | | NA | T2 | NA | NA | NA | NA | Demographic data: Demographic Census (1970; 1980; 1991; 2000; 2010), Population Estimates (1992-1995; 1997-1999; 2001-2009; 2011-2016) and Population Count (1996; 2007) (IBGE, 2010; 2015); Gap estimated for the 1970s and 1980s and 1994 based on a grade 2 polynomial model; $CH_4$ recovered: Projects under the Clean Development Mechanism (UNFCCC, 2019). | Data on the total population (urban and rural populations) with waste disposal service, from the National Sanitation Information System - SNIS (MCID, 2018) and Brazilian Institute of Research and Statistics (IBGE) (IBGE, 1980; 1983; 2008). Grade 2 polynomial model based on IBGE data (1980; 1983; 2008) and SNIS data (2003-2016; MCID, 2018) on the total population served with MSW collection and the collected mass; The type of solid waste disposal in each municipality was obtained from information on the final disposal site of all municipalities in Brazil (MMA, 2015) and the year in which the disposal site started operating (MCID, 2018); National literature review on the gravimetric composition of solid |
| | 5.A.2.Unmanaged Waste Disposal Sites | | NA | IE | NA | NA | NA | NA | | |
| | 5.A.3. Uncategorized Waste Disposal Sites | | NA | T2 | NA | NA | NA | NA | | |

| **Subsector** | **Category** | **Subcategories** | **Estimated gases and methodologies** | | | | | | **References** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | **$CO_2$** | **$CH_4$** | **$N_2O$** | **CO** | **$NO_x$** | **NMVOC** | **Activity Data** | **Emission Factors** |
| | | | | | | | | | | waste, for each Unit of the Federation and year; Volume 3, Chapter 3 (IPCC, 2006). |
| 5.B. Biological Treatment of Solid Waste | 5.B.1. Composting | | NA | T1 | T2 | NA | NA | NA | Same data from the Solid Waste Disposal subsector (5.A). | Volume 3, Chapter 4 (IPCC, 2006). |
| | 5.B.2. Anaerobic digestion[24] | | NO | NO | NA | NA | NA | NA | | |
| 5.C. Incineration and Open Burning of Waste | 5.C.1. Waste Incineration | 5.C.1.a. Biogenic | T2a | NA | T1 | NA | NA | NA | Amount of incinerated waste from the health sector obtained from the population of the municipalities where collection and collected mass are available (IBGE, 2008). Gaps filled from the linear interpolation of these data. | Volume 3, Chapter 5 (IPCC, 2006). |
| | | 5.C.1.b. Non-Biogenic | T2a | NA | T1 | NA | NA | NA | | |

[24] *The Anaerobic Digestion category (5.B.2) was not counted, since this technology is still incipient in Brazil.*

| Subsector | Category | Subcategories | Estimated gases and methodologies | | | | | | References | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $CO_2$ | $CH_4$ | $N_2O$ | CO | $NO_x$ | NMVOC | Activity Data | Emission Factors |
| | 5.C.2. Open Burning of Waste | | T2a | T1 | NA | NA | NA | NA | Data on the total population from Demographic Census (1991, 2000 and 2010) (IBGE, 2010) and from the National Household Sample Survey - PNAD (IBGE, 2015) (intermediate years to the Census) and gaps for years 1994 and 2016 were estimated. | Volume 3, Chapter 5 (IPCC, 2006). |
| 5.D. Wastewater Treatment and Discharge | 5.D.1. Domestic Wastewater Treatment and Discharge | | NA | T2 | T1 | NA | NA | NA | Data on urban populations from Units of the Federation were estimated annually by simple bivariate linear regression between population of IBGE - Census intervals (IBGE, 1970; 1980; 1991; 2000; 2010). Rural population | Volume 3, Chapter 6 (IPCC, 2006); The treatment and discharge systems from PNSB in Brazil (IBGE, 2008) were classified, with a simple linear interpolation between periods according to default values (IPCC, 2006); FAO data (2009) on protein consumption, with simple linear interpolation in the data gaps; The amount of sludge was calculated based on BOD |

| Subsector | Category | Subcategories | Estimated gases and methodologies | | | | | | References | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $CO_2$ | $CH_4$ | $N_2O$ | CO | $NO_x$ | NMVOC | Activity Data | Emission Factors |
| | | | | | | | | | estimate based on the difference between total and urban populations. The data on treatment and discharge systems were obtained from PNAD (1992-1993, 1995-1999, 2001-2009 and 2011-2015) (IBGE, 2015) and from the IBGE - Population Census (1991, 2000 and 2010) (IBGE, 2010). The share of the population served with each treatment technology estimated from data from the National Basic Sanitation Survey - PNSB (IBGE, 2008). | generation factors of sludge by BOD treated in each treatment technology found in domestic literature (Andreoli; Von Sperling; Fernandes, 2001); Volume 3, Chapter 6 (IPCC, 2006). |
| | 5.D.2. Industrial Wastewater | | NA | T2 | NA | NA | NA | NA | Industrial production data: Sugar and Ethanol (UNICA, | Organic load values used: Sugar: 21 and 82 (CTC, 1995; ANA, 2009); Ethanol: 146 (ANA, 2009); |

| Subsector | Category | Subcategories | Estimated gases and methodologies | | | | | | References | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $CO_2$ | $CH_4$ | $N_2O$ | CO | $NO_x$ | NMVOC | Activity Data | Emission Factors |
| | Treatment and Discharge | | | | | | | | 2019); Raw milk (IBGE, 2018a); Pasteurized milk, (ABLV, 2019); Cellulose (IBA; 2019); Beer, Slaughter of poultry, and Slaughter of cattle (IBGE, 2017b). | Cellulose: 19 (SUHR, 2015); Volume 3, Chapter 6 (IPCC, 2006); Calculation of sludge data was based on BOD generation factors of sludge by BOD treated in each treatment technology found in domestic literature (Andreoli; Von Sperling; Fernandes, 2001). |

Note: Method applied (IPCC, 2006) — T1: Tier 1; T2: Tier 2; T3: Tier 3.

Notation keys: NA — not applicable; NO — not occurring; IE — included elsewhere, NE — not estimated.

According to IPCC 2006[25], the description of final disposal sites indicates a classification for landfills (5.A.1 - Managed Sites) but does not specify classification for controlled landfills and dumps. Thus, controlled landfills and landfills were classified as “Not Categorized” (5.A.3), since there are not enough features on these sites to enable classification in any other category.

## 2.7.2 Solid Waste Disposal (5.A)

The Solid Waste Disposal subsector (5.A) includes only $CH_4$ emissions that occur during the anaerobic decomposition of organic matter deposited in landfills (Managed Waste Disposal Sites - 5.A.1), controlled landfills, and dumps (Uncategorized Waste Disposal Sites - 5.A.3). Emissions from Solid Waste Disposal vary mainly with the quality of the disposal site, the population size, the quantity, and the gravimetric composition of the deposited waste.

Emissions associated with Solid Waste Disposal (5.A) accounted for 39,001 Gg $CO_2e$ in 2016, an increase of 26.3% compared to 2010 (Figure 2.44). The disposal of waste in Managed Waste Disposal Sites (5.A.1) represented 47.1% in 2016, and had an increase of 43%, compared to the emissions of 2010. This fact is due to the increase in the population served with services of waste collection and the increased deposition of this waste in landfills (average from 35% in 1990 to 51% in 2016), whose $CH_4$ generation capacity is greater than in controlled landfills and dumps. Emissions in Uncategorized Waste Disposal Sites (5.A.3) accounted for 52.9% and increased by 14.2%, compared to emissions in 2010. In qualitative terms of gravimetric composition, "food waste" and "paper and cardboard" were the main components in $CH_4$ generation due to the disposal of municipal solid waste in landfills and dumps, accounting for 60.6% and 32.4% of the total emission generated, respectively.


Figure 2.44. Emissions from Solid Waste Disposal (5.A), in $CO_2e$, by emission category, from 1990 to 2016

$CH_4$ estimates have already taken into account the reduction in emissions due to landfill gas recovery and burning, which contributed to a 7.3% decrease in the total emissions of the subsector in 2016. The recovered $CH_4$ was accounted for from the results submitted by CDM projects registered with the UNFCCC. This $CH_4$ recovery started to occur in 2003, the year in which the first project was submitted and approved.

[25] *Intergovernmental Panel on Climate Change (IPCC). IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme. Vol. 5, Waste, chapter 3, Tab 3.1 (IPCC, 2006).*

### 2.7.3 Biological Treatment of Solid Waste (5.B)

The Biological Treatment of Solid Waste subsector (5.B)[26] accounted for $CH_4$ and $N_2O$ emissions associated with Composting (5.B.1). Composting is an aerobic process, and its emission is related to the amount, type, and composition of the organic waste deposited. Emissions related to the composting of solid urban waste were estimated at 56 Gg $CO_2e$ in 2016, which reflected an increase of 32% compared to 2010 (Figure 2.45) and is mainly due to the increase in the composting of organic solid waste in Brazil in that period. $CH_4$ and $N_2O$ emissions represented 53% and 47% of total $CO_2e$ in 2016, respectively.

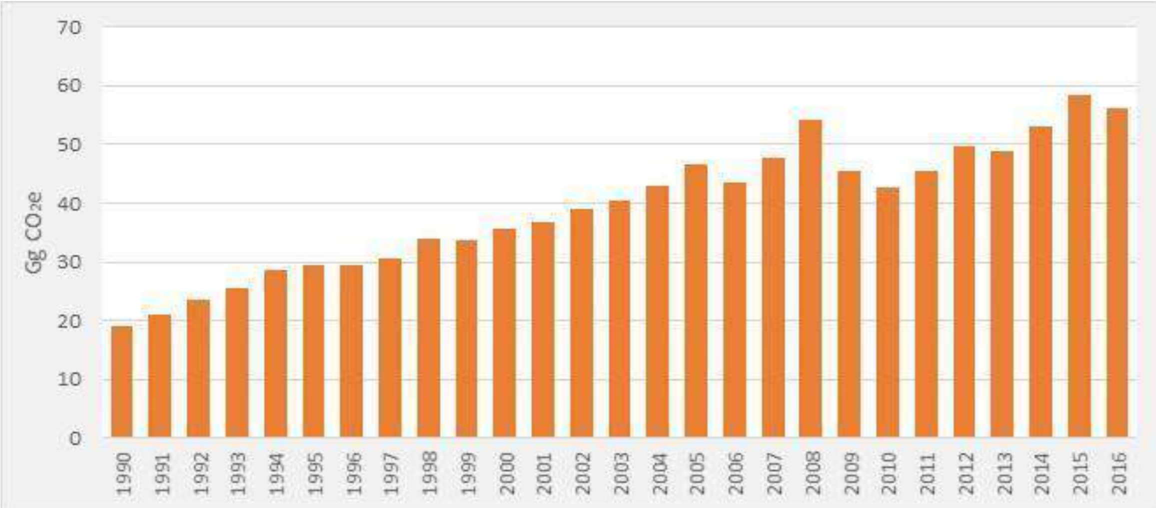



Figure 2.45. Emissions from Biological Treatment of Waste (5.B), in $CO_2e$, from 1990 to 2016

### 2.7.4 Incineration and Open Burning of Waste (5.C)

The Incineration and Open Burning of Waste subsector (5.C) comprises $CH_4$, $N_2O$, and $CO_2$ emissions resulting from the waste combustion process, whether controlled or not. In the case of open burning, the combustion of fossil carbon, a substance present mainly in plastic packaging, is responsible for the emission of $CO_2$ into the atmosphere and, as it is a process of combustion carried out in an uncontrolled environment, it emits a small fraction of carbon in the form of $CH_4$ due to inefficiency in aeration.

The subsector's emissions accounted for 1,102 Gg $CO_2e$ in 2016 (Figure 2.46) and were mostly from the category Open Burning of Waste (5.C.2) (89%). There was a 40% decrease in emissions, compared to 2010, mainly due to the increase in plastic recycling in this period, which allowed a smaller increase in the fossil carbon burned.

Emissions from the Waste Incineration (5.C.1), totaled 120 Gg $CO_2e$ in 2016, or 11% of the subsector. In this category, emissions from the incineration of waste from health services, which occur in compliance with national environmental legislation, were considered. Emissions from the category Open Burning of Waste (5.C.2) totaled 982 Gg $CO_2e$. In Brazil, the practice of burning waste in the open is still widely used, especially by the population that is not served by the selective garbage collection system. In 2016, the subsector's $CH_4$, $N_2O$, and $CO_2$ emissions represented 44%, 10%, and 46%, respectively.

[26] *Biological Treatment of Solid Waste subsector (5.B) was included in this edition of the Inventory, due to the implementation of IPCC 2006.*

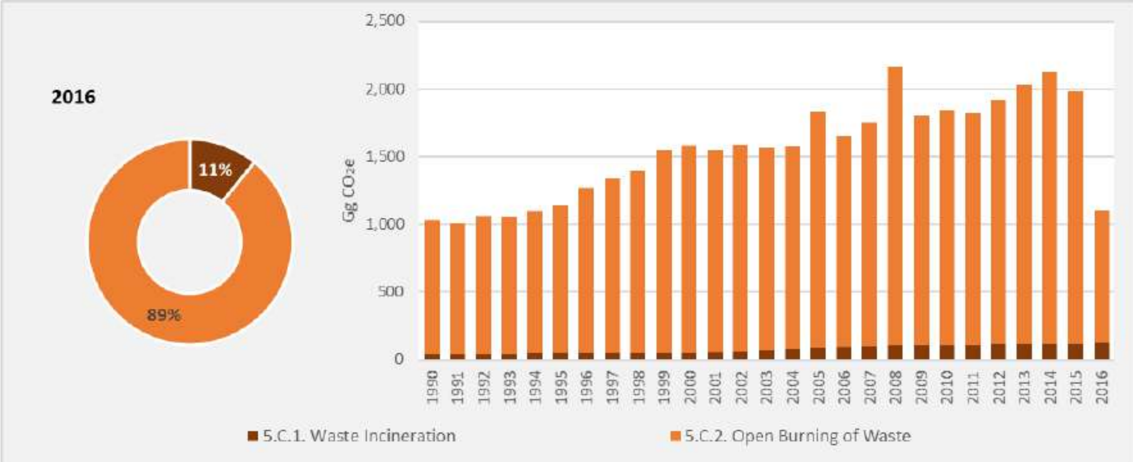



Figure 2.46. Emissions from Incineration and Burning of Solid Waste (5.C), in $CO_2e$, by category of emission, from 1990 to 2016

## 2.7.5 Wastewater Treatment and Discharge (5.D)

The Wastewater Treatment and Discharge subsector (5.D) accounts for $CH_4$ and $N_2O$ emissions from the Domestic Wastewater (5.D.1) and Industrial Wastewater (5.D.2) systems. $CH_4$ emissions occur in anaerobic environments and are related to the amount of degradable organic material present in the effluent, as well as the temperature of the place and the type of treatment used. $N_2O$ emissions are associated with the degradation of nitrogen present in the effluent, through the process of nitrification and denitrification.

Emissions from Wastewater Treatment and Discharge (5.D) were estimated at 25,794 Gg $CO_2e$ in 2016, an increase of 7.9% compared to 2010. The Domestic Wastewater category (5.D.1) was the most representative, with emission of 21,397 Gg $CO_2e$, or 83% of the subsector's emissions (Figure 2.47). These emissions increased by 4.6% compared to the 2010 results, and are directly related to population growth, expansion of the sewage collection and treatment network in states and municipalities, and the organic matter present in the effluent, expressed as Biochemical Oxygen Demand (BOD), since these are the main variables that influence them.

For the Industrial Wastewater category (5.D.2), emissions in 2016 were estimated at 4,398 Gg $CO_2e$ (17% of the subsector), an increase of 27% compared to 2010. It is worth noting that the milk production activity raw and pasteurized accounted for more than half of the emissions in this category until 2003 when the contribution of the animal slaughtering activity (poultry, swine and, mainly, cattle) became the most representative.

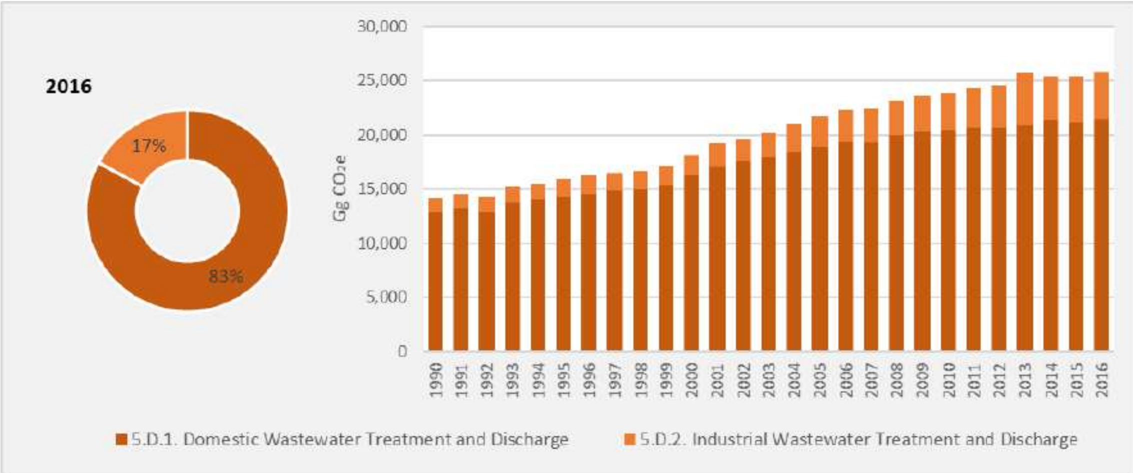
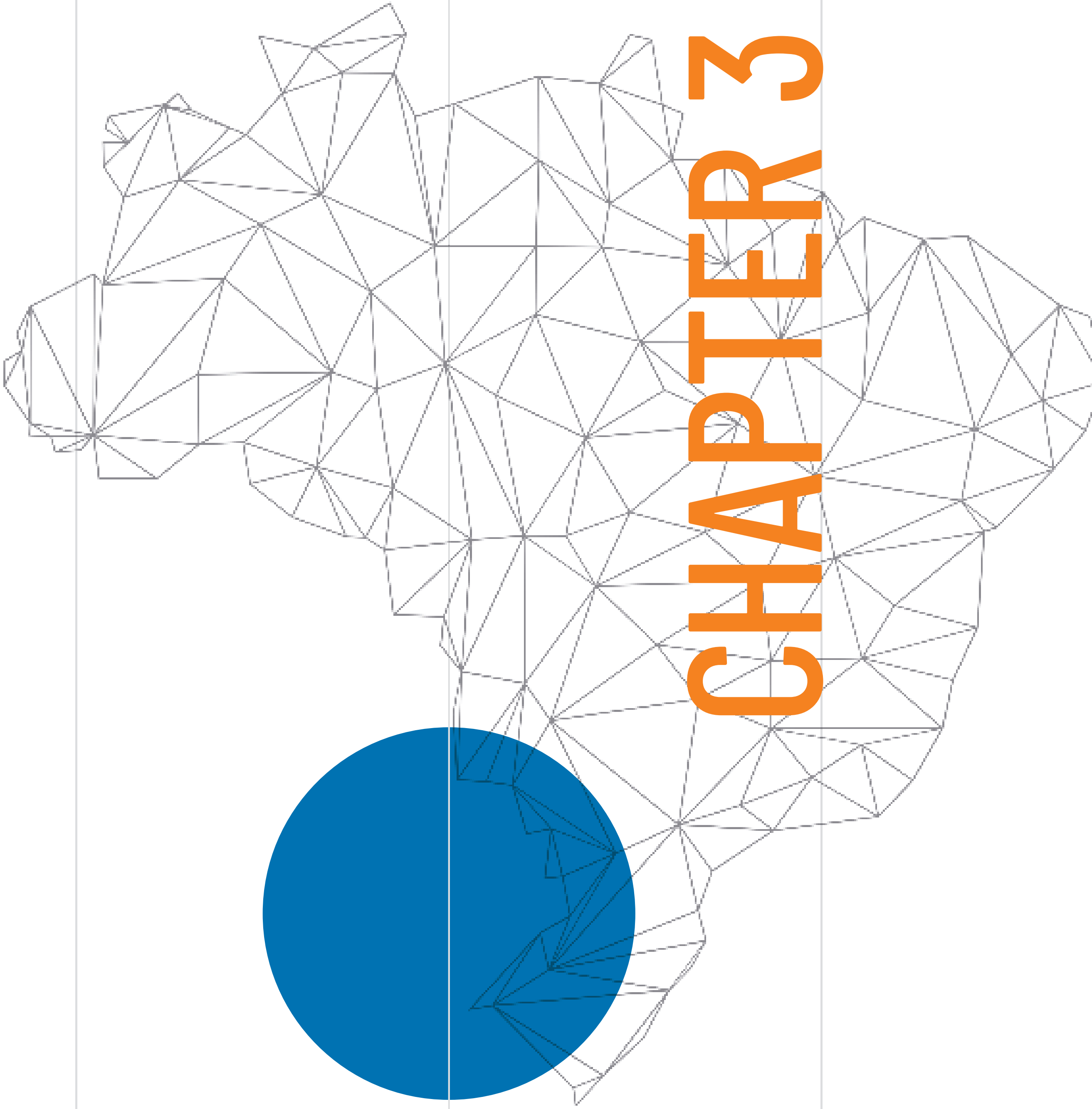



Figure 2.47. Emissions from Wastewater Treatment and Discharge (5.D), in $CO_2e$, by emission category, from 1990 to 2016

# CHAPTER 3



## SUMMARY

3. IMPACTS, VULNERABILITY AND ADAPTATION TO CLIMATE CHANGE

## 3.1 CONTEXT AND APPROACH

The adaptation matter has become increasingly relevant worldwide, as climate-related impacts become more visible, reflecting on its gradual incorporation to the political agenda of many countries, especially starting from 2011, with the establishment of the Cancun Framework for Adaptation (CAF), during COP16.

The **adaptation to climate change** is the adjustment process from natural and human systems to current and future climates and their effects. In human systems, the adaptation aims at moderating or avoiding potential damages and exploring helpful opportunities. In some natural systems, human interventions may facilitate the adjustment to the expected climate changes and their effects (IPCC, 2014, p.05).

In compliance with that tendency, the growth of Brazil's adaptation agenda resulted in the launching of the National Climate Change Adaptation Plan (PNA).

PNA (2016) advises that a satisfactory and coordinated implementation of the sector and thematic risk management strategies, prioritizing food, nutritional, water, and energy security areas must be ensured, considering the synergies and the transversality of the subjects within the many economic sectors, employing coordinating public policies, adopting both horizontal and vertical governance principles.

*To learn more about PNA, see **item 4.1.5**.*

The implementation of adaptation actions has the potential to synergically contribute to the progress of the Sustainable Development Goals (SDGs), which are part of the 2030 Agenda of the United Nations (UN) between 2016-2030. According to UNFCCC (2017), integrating the adaptation agenda and the 2030 Agenda with the the Sendai Framework[1] for Disaster Risk Reduction may provide a basis for a sustainable, low-carbon development, and for strengthening resilience[2] to climate change.

### INTEGRATED APPROACH

Intending that the integration of climate policies in Brazil be capable to articulate sectors that historically have very specific action outlines, having in mind that there are complex, multidimensional interactions among the different governance levels, from local to global when it comes to mitigation and adaptation to climate change (Adelle e Russel, 2013; Mickwitz et al, 2009; Weiz et al., 2017).

The **integrated approach** combines the theoretical concept of water-energy-food nexus, with aspects related to **sustainable livelihoods**, climate risks, and environmental security (Milhorance & Bursztyn 2019).

As a way to foster an integrated perspective in equating key issues for society[3], different approaches rise, seeking methodological strategies for integrated analyses, and the identification of interdependences and synergies. Some of these proposals had been employed (Milhorance & Bursztyn, 2019) to guide the Impacts, Vulnerability, and Adaptation studies (IVA) elaborated in this 4NC.

The 4NC IVA studies were therefore structured from water, energy, food, and socioenvironmental securities, according to the concepts described below:

[1] *International document related to the reduction of disasters, adopted in 2015 by UN member States on the Sendai Convention (Japan), with goals to be reached by 2030.*

[2] *Capability from social, economic, and environmental systems in dealing with dangerous events, tendencies, or disturbances, responding or reorganizing themselves in ways that maintain their key function, identity, and structure, while also safeguarding their capability to adapt, learn, and transform (IPCC, 2014).*

[3] *Hagemann e Kirschke, 2017; Howells e Rogner, 2014; Pahl-Wostl, 2017; Scott, 2017; Weitz et al., 2017; Ringler, Bhaduri e Lawford, 2013; Castro e Bursztyn, 2019; Araújo et al., 2019.*

WATER SECURITY indicates the appropriate availability of both quantity and quality of water for health, livelihoods, ecosystems, and production, associated with an acceptable level of water-related risks regarding people, economy, and the environment (Grey & Sadoff, 2007).

ENERGY SECURITY involves securing the supply of energy services, minimizing interruptions, with an affordable price within a market and energy system that promotes efficiency and sustainability; that is also sufficiently flexible, and prepared to tackle with and recover from sudden, extreme events, of any kind, or in any time frame.

FOOD SECURITY is defined as the state in which "everyone in every moment has physical, social, and economic access to sufficient, safe and nutritional food to afford their respective food needs and preferences for an active and healthy life" (FAO 2014 apud FAO 1996).

SOCIOENVIRONMENTAL SECURITY is the condition whereby human existence, in all its features, by interacting with ecosystems and benefiting from their services, ensures a decent, suitable life, without undermining the other living beings and ecosystems, whose integrity and intrinsic value must be acknowledged.

Securities are related not only to the availability of resources, but also to sustainability-based elements – accessibility and fair distribution of resources to the population, environmental protection, and economic development – and involve political, conjunctural, and institutional matters. It means an evolution over sectoral approaches (IISD, 2013; Ringler, Bhaduri e Lawford, 2013, p.617; Simpson e Jewitt, 2019).

The materialization of the proposal of an integrated approach on IVA studies implied two integration levels: one within the scope of each security; and the other among securities.

Regarding the first level, it is considered that there is a multitude of sectors and subjects within each security, as well as different impacts and risks threaded and conditioned by both climate and non-climate-related features, acting cross-sectionally, but distinctively on the territory. Thus, the outcomes from each security were consolidated by analyses from the same territorial perspectives, corresponding to each terrestrial biome (Amazon, Cerrado, Caatinga, Atlantic Forest, Pampa, and Pantanal), with specific inferences to cities, coastal zones, and oceans as well.

Furthermore, regarding each security's scope, to assess climate-related impacts and risks in the country, aiming to support adaptation strategies, the studies brought data on observed impacts in conjunction with profiling of future scenarios. These scenarios were developed with the support of climate models, information that was embedded in each security according to more appropriate methodologies for each knowledge field.

Regarding the second integration level, it intended to identify inter-relations among securities, as well as synergies and trade-offs among potential adaptation options[4]. Regarding adaptation, it has been adopted a participatory options' survey and assessment process, with several experts from different co-related areas on the subjects tackled in each security.

Finally, the IVA security analyses occurred according to the following development sequence:

| Context | Impacts and Vulnerabilities | Adaptation |
|---|---|---|
| Conceptualization<br>National Relevance and for the adaptation<br>Governance | Observed Impacts<br>Conditioning factors and Impact Chain<br>Key impacts' assessment<br>Integrated Analysis | Adaptation Options<br>Synergies and trade-offs among adaptation options |

Figure 3.1. 4NC IVA studies development sequence by securities.

[4] *Synergies can be understood as relations where adaptation actions leverage one another. On the other hand, tradeoffs are considered whenever adaptation actions minimize certain risks, simultaneously aggravating others, generating choice conflicts.*

## 3.2 Climate Change in Brazil

### 3.2.1 Climate Modeling Program in Brazil

#### Global Climate Models

Climate-related risks and impact assessment is based on the use of climate models, whose scenarios lead to a better understanding of the current and the future climate, to subsidize adaptation strategies.

To carry out future climate projections, terrestrial system models are conditioned by scenarios of greenhouse gas emissions (GHG). The greenhouse gas emissions' Representative Concentration Pathways (RCPs) were proposed by the Intergovernmental Panel on Climate Change (IPCC), representing four possible concentration scenarios that are co-related to radiative forcings (amount of warming) by the end of the century (2.6, 4.5, 6.0 and 8.5 watts per $m^2$) (IPCC, 2014).

One must consider that there are two uncertainty sources associated with these scenarios. The first uncertainty source involves the future pathway of greenhouse gas emissions in the atmosphere. This is strongly influenced by human decisions on the desired social, economic, and environmental course. The second stems from the fact that mathematical models are imperfect representations of the real world.

Using model simulation ensembles allow effects from different uncertainty sources to be analyzed, providing plausible projections on climate change. In this context, the international initiative of the Coupled Model Intercomparison Project[5] (CMIP) stands out, whose goal is to gather in a standardized way the outcomes from climate models produced by the many climate modeling groups worldwide, which are widely used by scientific institutions, including IPCC. The fifth and last IPCC assessment report (AR5, 2014) was subsidized by information from CMIP5.

Since the Third IPCC Assessment Report was issued, in 2001, there is an increasingly greater understanding of the expected climate standards for the 21st century. Precipitation at high latitudes likely rises, while reductions are probable on most subtropical continental regions, continuing with the patterns observed in recent tendencies.

#### Regional modeling in Brazil

To analyze how climate change occurs at a regional level, it is necessary to enhance the spatial resolution of the Global Climate Models (GCMs), which generally have a resolution on the order from one to two hundred kilometers, and/or using regionalization techniques (known as downscaling) to translate the information provided by the GCMs in a finest spatial scale (AMBRIZZI et al. 2019).

Nationwide, in this context, the projects that stand out are CLARIS-LPB (European/South American Network to assess Climate Change and Impact Studies in La Plata Basin) (BOULANGER et al. 2010), CREAS (Regional Climate Change Scenarios for South America[6]) (Marengo e Ambrizzi, 2006; Ambrizzi et al., 2007; Marengo et al. 2009) and CORDEX (Coordinated Regional Climate Downscaling Experiment[7]). Such initiatives served as the basis for developing the climate modeling program in Brazil, and to subsidize the production of Brazil's Second National Communication (SNC) to the United Nations Framework Convention on Climate Change (UNFCCC).

[5] *CMIP is an international project organized in 1995 by the Working Group of Couple Modelling (WGCM) from the World Climate Research Programme (WCRP).*

[6] *In Portuguese, "Cenários Regionais de Mudanças Climáticas para a América do Sul."*

[7] *To learn more, see: http://cordex.org/*

The Third National Communication (TNC) gathered future regionalized projections from Eta regional model, with the spatial scale of 20 km lat-lon, nestled in/receiving data from the English Hadley Centre Global Environmental Model (HadGEM2-ES), the Japanese global Model for Interdisciplinary Research on Climate (MIROC5), and BESM (Brazilian Earth System Model) with different greenhouse gas effect concentration scenarios in the atmosphere (RCP 4.5 and 8.5). These results supported the PNA formulation (2016).

Eta regional model was set up on CPTEC in 1996, to complement numerical weather forecast, later being applied in long-term weather forecasts.

WARMING LEVEL APPROACH. To the Fourth National Communication (4NC), intending to pursue greater compliance to the Paris Agreement and the IPCC reports, has adopted a Specific Warming Level approach (SWL), having as parameters 1.5 °C, 2 °C e 4 °C (Morice et al. 2012) (see BOX 3.1).

*BOX 3.1* Specific Warming Level (SWL)

In 2010, UNFCCC's COP16 in Cancun formalized the aim of limiting to 2 °C the rise of the global average temperature. Later, in 2015, the Paris Agreement was approved during COP21, and it seeks to limit the rise of global average temperature up to 1.5 °C over pre-industrial levels, by the end of the twentieth-first century. It is further considered that, according to IPCC (2018), human activities have already caused around 1.0 °C global warming (probable variation from 0.8 °C to 1.2 °C).

The concept of Specific Warming Level (SWL) represents the global average anomaly variation of the air temperature in the surface regarding the pre-industrial period (approximately 1870-1899), in other words, temperature rise or reduction over the years regarding such period. That methodology intends to gauge the impacts derived from man-made activities coupled with the climate's natural variability.

In the last decade, a growing number of studies had been developed, considering the different global average warming levels on a regional and local scale (James and Washington, 2013; Vautard et al., 2014; Dequé et al., 2016; Nikulin et al., 2018; Lennard et al., 2018). In general, these studies reveal that the regional temperature standards are not determined by global average SWLs only, that it also strongly depends on the region and time of the year. Also, the warming extent at the level of 1.5 °C, 2 °C or higher (global average) can be greater than these values at the local level, leading to more severe and extreme climate conditions than it could be, including other aspects aside from temperature, as precipitation, extreme events, sea level, etc., than if it were considered the global standard only.

Another equally important aspect is quantifying the impacts associated with the average global temperature rise in 1.5 °C and 2 °C, aiming at analyzing whether there is a significant reduction in climate risks between the two levels, showing that the benefits of limiting global warming to 1.5 °C (although the most pessimistic scenarios indicate warming levels of 4 °C or more by the end of the century). Tebaldi et al. (2015) highlight that the most prominent negative effects of the increment in 0.5 °C can be seen mostly in extreme events. For example, the probability of occurring extreme events due to the rise in the global air temperature average in 2 °C is almost double than in 1.5 °C (Fischer; Knutti, 2015).

It has been therefore sought to analyze possible implications for the country, arising from future climate scenarios where global average warming of 1.5 °C, 2 °C, and 4 °C (or simply SWL1.5, SWL2, and SWL4) are reached. It has been considered that, as SWLs escalate, bigger changes can be expected, which will probably give rise to even more noticeable impacts.

## 3.2.2 CURRENT CLIMATE

The analysis on current climate tendencies in Brazil has been carried out together with the discussions of possible changes in climate variability with emphasis on air temperature and precipitation considering the period 1980 – 2018, from observational data.

For trend analyses involving temperature weather variable (minimum and maximum temperature, and TX90p climate index) it was used CPC/NOAA's data set (Climate Prediction Center/ National Oceanic and Atmospheric Administration – https://www.cpc.ncep.noaa.gov/). On the other hand, for the analyses involving precipitation and RX5day and CDD indices, it has been used CHIRPS precipitation database (Rainfall Estimates from Rain Gauge and Satellite Observations – https://www.chc.ucsb.edu/data/chirps). The calculation of temperature and precipitation extreme climate indices derived its foundations from the methodologies described in the document Climate Data Operators (CDO). The definition of these climate indices belongs to the European Climate Assessment project (ECA), while the CDO software was developed by the Max Planck Institute for Meteorology, from Germany, representing a set of operators to standardized climate data process.

The atmospheric circulation over South America (SA) presents characteristic monsoon patterns (MARENGO et al., 2012), besides that, the precipitation over the Southern Amazon and the Southern and Midwestern regions from Brazil have a well-defined annual cycle, that is, two distinct phases: "humid" and "dry". Despite that characteristic, there is a high spatial and temporal variability of the precipitation across the country, with peculiarities related to climate variability.

In the Northern Amazon sector, rainy equatorial weather is noted with almost no dry season. However, the Amazonian region presents a significant spatial and seasonal pluviosity heterogeneity as a whole, and it also has the highest national annual rainfall total – over 2,000 mm/year (ESPINOZA, 2015). Meanwhile, in the semiarid Northeastern region of Brazil, the annual average precipitation varies between 400 and 800 mm, with mean temperatures over 23°C, potential evapotranspiration around 2,000 mm/year (MOSCATI; GAN, 2007). On the other hand, the Brazilian South presents subtropical weather with high temperatures in summer and low in the winter, and an annual rainfall index around 1,200 mm.

It is also considered that climate changes at a regional or smaller scale are influenced not only by the global climate change, but also by local factors associated with surface processes, like urbanization, deforestation, and the overall changes in land use; aside from higher scales spatial and temporal climate phenomena, such as El Niño and La Niña, the Atlantic Multidecadal Oscillation (AMO) and the Pacific Interdecadal Oscillation (PIO). Thus, part of the tendencies detected in the precipitation, for example, can be explained by the climate system's decadal/interdecadal variations. However, another percentage may be a consequence of the current rise observed in the global average temperature due to man-made activities, as discussed by PBMC (2014).

## MAIN OBSERVED TENDENCIES

It is quite noticeable that the minimum and maximum temperatures (Figure 3.22, columns 1 and 2) present a warming tendency, around 0.5 °C per decade in nearly every country region and every season of the year, especially the Midwestern portion (Mato Grosso, Tocantins, Goiás, and Western Bahia, Minas Gerais, and São Paulo) and the Northern region on winter and spring, where gains are up to 1 °C/decade. Cooling tendency up to 0.5 °C/decade is noted, more punctually, mainly in the Brazilian eastern range of the Northeast and in the far south from Brazil.

It is noted a rise in the number of days with extreme maximum temperature (TX90p – number of days with temperature over the percentile 90) (Figure 3.2, column 4) in the analyzed period (1980-2018). The increase is higher than 30% per decade nearly in the whole country, highlighting central portion areas, North, and northern Northeast, for presenting expressive increases in all time scales, mostly on winter (June/July/August – JJA) and spring (September/October/November – SON), where the upward trend is over 90%.

Different from the temperatures, the annual precipitation tendency (Figure 3.2, column 3) highlights great spatial variability. An increase of annual precipitation, mostly in the country's far north from the Northern region, in the middle east from the Northeast, and in the South.

In the annual average for summertime (December/January/February – DJF), it is noted an increase up to 5 mm/decade. An opposing pattern is checked in the North southwest, with total reductions around 20 mm over the past four decades, that is, on summertime months, it rains 20 mm less in average compared to what it was observed at the beginning of the period. Considering that in summertime we have the period with the greatest precipitation volume on the North and the fact that during that season, the region strongly contributes to rainfall regimes in the Mid-West and Southeast, that negative trend is also seen in the regions stated, especially in the states of Goiás, Minas Gerais, and Espírito Santo, where that reduction is more prominently seen.

The Northeast stands out with a reduction up to 5 mm/decade, that is, up to 20 mm over the decades analyzed on annual average as to autumn season (March/April/May – MAM), and slightly positive increase (lower than 3 mm/decade) in summer (DJF) and winter (JJA). It is noteworthy that over the MAM quarter, we have, climatologically, the rainy season in the north portion of that region. Therefore, a significant precipitation reduction over that period may strongly impact the socioeconomic sectors over the following months.

Therefore, throughout all seasons, there is a negative precipitation trend in most parts of the country's central, Southeastern and Northeastern regions, with a positive increase in the north range of the North and parts from the South. These behaviors become clearer on an annual accumulated, whereby it is noted a more remarkable positive trend pattern over the past decades in the far north from the Northern region (up to 40 mm), in the Brazilian South (up to 20 mm), and areas from the states of Mato Grosso and Mato Grosso do Sul, yet less pronounced. On the other hand, in other country areas, comprising the states from the Northeast, Southeast, the state of Goiás, and the south of Tocantins, it is noted a negative trend around 20 mm in these areas.

About the **extreme precipitation events** (RX5day – maximum rain accumulated in five days) (Figure 3.2, column 5), we see an annual positive increment mostly in the east of the Northeastern region, in the state of Bahia, in the east of the Southeastern Region, in most of the Mid-West region (except the state of Goiás), and interspersed areas in the Northern region. In these areas, the rainfall totals in extreme events had an addition of around 8 to 40 mm in the past decades. The greatest magnitudes are seen on the east from the Northeast, where a positive trend persistence is seen also in seasonal scales, mostly during winter (June/July/August). It suggests that the slight increase in precipitation trend to that Northeastern range, over the aforementioned quarter (Figure 3.22, column 3), is possibly associated with these increments on extreme precipitation events.

About the **events of consecutive dry days** (CDD – the maximum number of consecutive dry days, with precipitation < 1 mm) (Figure 3.2, column 6), we see an upward trend mainly in winter and spring seasons at the South range from the North, north, and west from the Northeast, and Mid-West and Southeast, pointing to a possible intensification of the dry season in these areas. The steep addition in the trend of consecutive dry days is also evident in the annual field to these areas and the Northeastern region as a whole.

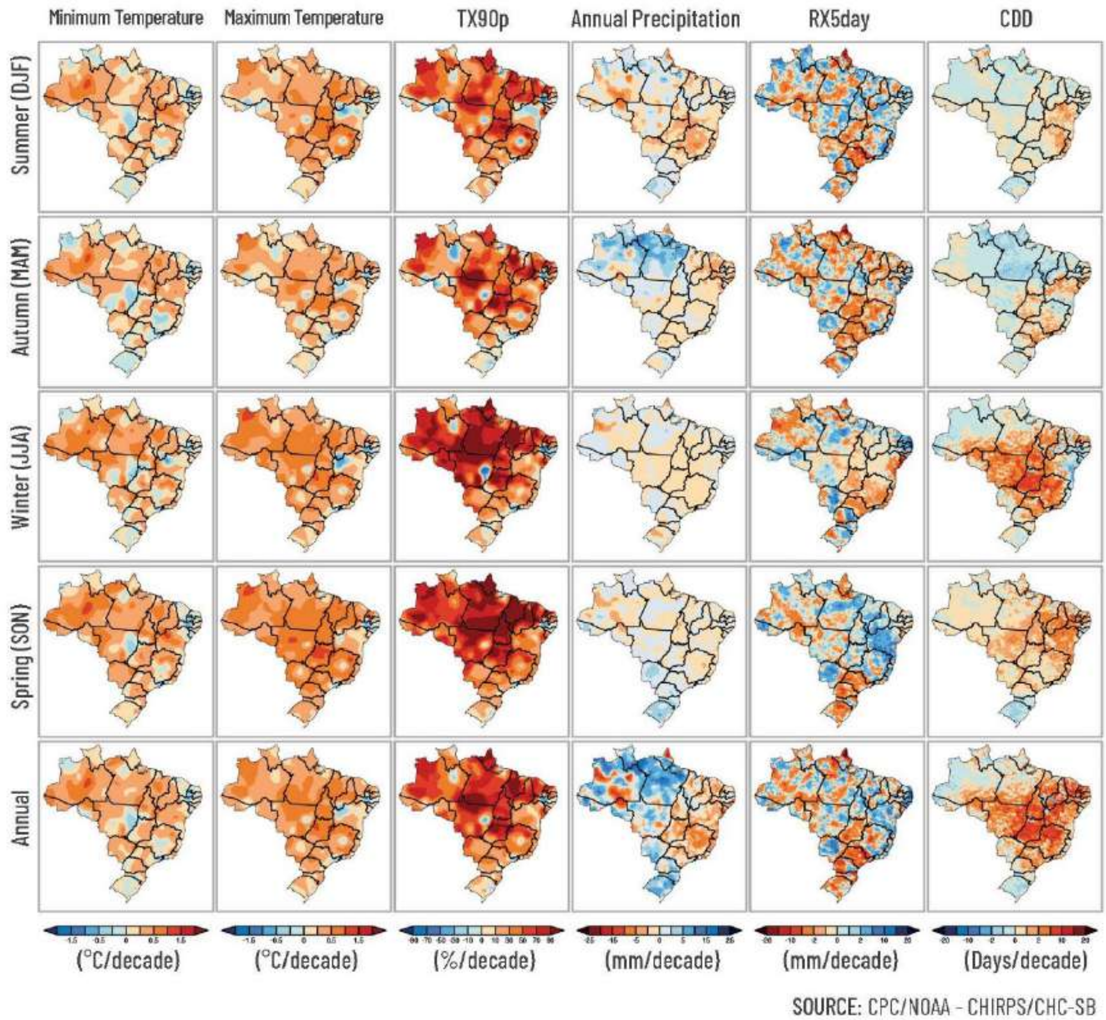



Figure 3.2. Trends noticed from the minimum and maximum temperatures (Celsius/decade); from the annual precipitation (mm/decade); from the number of days with maximum temperature over the percentile 90 – TX90p (%/decade); and maximum rainfall accumulated, between 1980-2018.

In general, the results presented are in line with previous studies that investigated the physical, dynamic, and thermodynamic aspects of atmospheric and oceanic phenomena. These studies have highlighted that Brazil is changing, especially the frequency of extreme precipitation events, that occur with greater intensity (PBMC, 2014), just like the variability of temperatures and precipitation also seem to suffer important changes.

### 3.2.3 Climate Projections

There are climate projections about the Brazilian territory available (viewing and data extraction) at the portal Projeções de Mudanças Climáticas no Brasil: http://4cn.cptec.inpe.br/

As previously described, there may be differences between projections from different climate models. Thus, we present results and analyses from two climate scenarios ensembles, deriving from the simulations of (i) the Eta regional model (Chou et al. 2014a; Chou et al. 2014b), which was adopted as the basis for the IVA studies; and (ii) the HadGEM3-A model (Helix Project), according to the elaboration process shown in Figure 3.3.

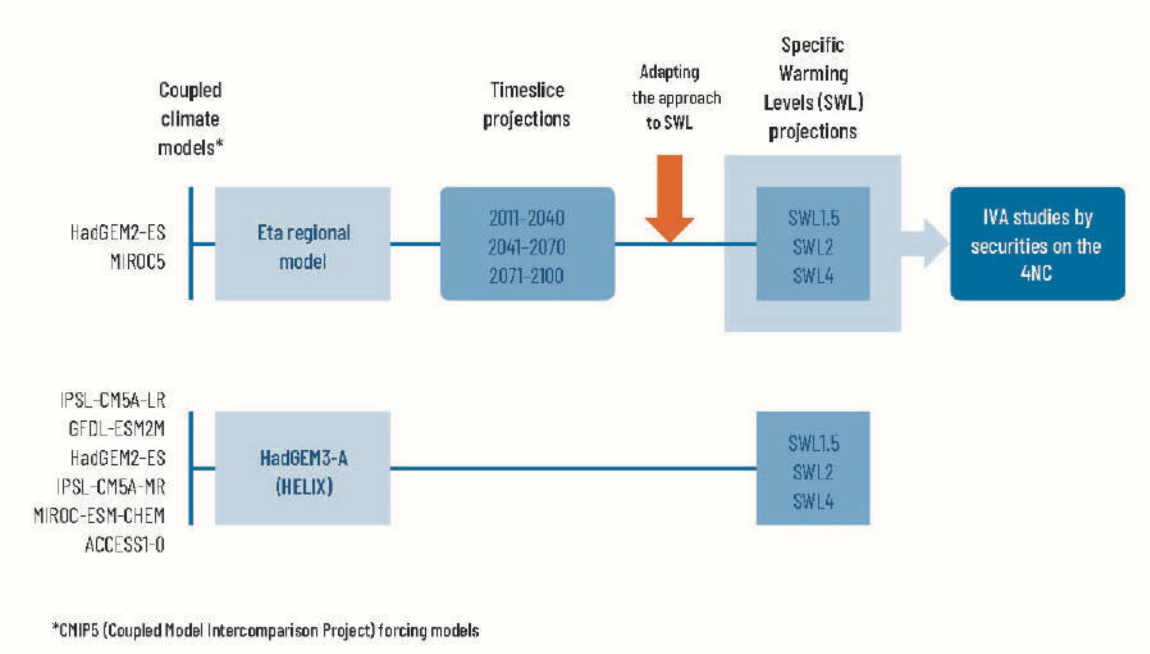



Figure 3.3. Future climate scenarios' elaboration flow to 4NC.

It stands out that the IVA studies per security presented in the following sections were subsidized by the outcomes produced to TNC with the Eta regional model forced by the CMIP5 global models (Eta-HadGEM2-ES and Eta-MIROC5) and fit to SWL1.5, SWL2, and SWL4, from the match indicated in Table 3.1, based on current climate simulations and the projections of the period between 2011 and 2100.

Table 3.1. Regional simulations ensemble (realizations) using Eta regional model and the corresponding CMIP5 forcing models, as well as the corresponding periods where the SWLs are reached.

| Atmospheric Model | Eta realization | CMIP5 forcing model | SWL1.5 | SWL2 | SWL4 |
|---|---|---|---|---|---|
| ETA | r1 | HadGEM2-ES | 2011-2040 | 2041-2070 | 2071-2100 |
| ETA | r2 | MIROC5 | 2011-2040 | 2041-2070 | 2071-2100 |

In addition to Eta's projection results, analyses were carried out for Brazil from future climate projections obtained by the HadGEM3-A model (Global Atmosphere Hadley Centre Model, version 3) (Walters et al., 2016), part of the HELIX Project and CMIP6. Each projection refers to the integration of the HadGEM3-A model with six contour condition variants (corresponding to each entry model), considering RCP8.5, hence providing a set of six projections for a period of 122 years, as it can be seen in Table 3.2.

Table 3.2. High-resolution global simulations ensemble from HELIX Project with HadGEM3 model and the corresponding CMIP5. The periods where SWL is reached are also listed.

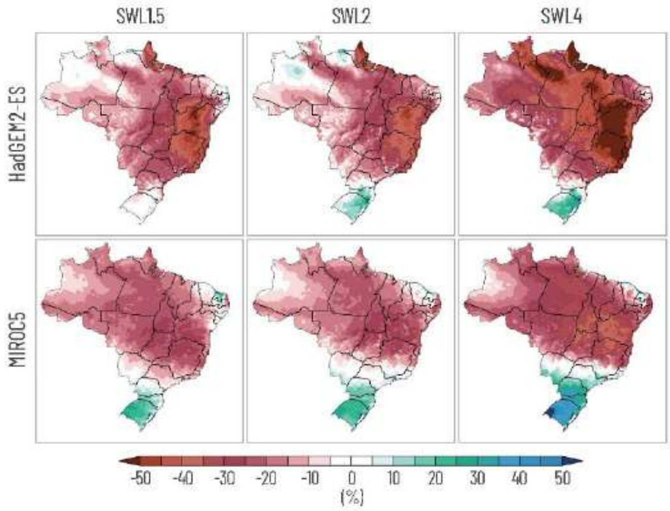
| Atmospheric Model | HELIX Realization | CMIP5 forcing model | SWL1.5 | SWL2 | SWL4 |
|---|---|---|---|---|---|
| HadGEM3 | r1 | IPSL-CM5A-LR | 2006-2036 | 2020-2050 | 2056-2086 |
| HadGEM3 | r2 | GFDL-ESM2M | 2021-2051 | 2037-2067 | * |
| HadGEM3 | r3 | HadGEM2-ES | 1998-2028 | 2018-2048 | 2056-2086 |
| HadGEM3 | r6 | IPSL-CM5A-MR | 2005-2035 | 2020-2050 | 2055-2085 |
| HadGEM3 | r8 | MIROC-ESM-CHEM | 2000-2030 | 2017-2047 | 2053-2083 |

| Atmospheric Model | HELIX Realization | CMIP5 forcing model | SWL1.5 | SWL2 | SWL4 |
|---|---|---|---|---|---|
| HadGEM3 | r9 | ACCESS1-0 | 2012-2042 | 2024-2054 | 2066-2096 |

* the corresponding model has not reached SLW4 until the end of the projection (2100).

### ETA REGIONAL MODEL'S PROJECTIONS

Figure 3.44 shows the annual precipitation change over Brazil, projected to different warming levels (SWL 1.5, SWL2, and SWL4), and the average from 1961-1990 (current climate) from the Eta model's results. It is noted that there is great spatial similarity presented by the two experiments, with rainfall reduction in most of Brazil, except by most of the South region. Furthermore, the scenarios presented by Eta-HadGEM2-ES indicate a greater reduction in rainfall, especially in the states of Minas Gerais and Bahia.




*In red, precipitation reduction, and increase in blue.

Figure 3.44. Precipitation projections: annual precipitation variation (%) compared to the reference period (1961-1990) according to the SWL1.5, the SWL2 and the SWL4 from each experiment carried out with the Eta model.

About minimum temperature annual projection (Figure 3.55), the trend is to increase, which may be higher than 5 °C in nearly all over Brazil, according to results from the Eta-HadGEM2-ES model (SWL4). In turn, the projection results from the Eta-MIROC5 model present a maximum increase in minimum temperature up to 5 °C in the Midwestern region. The results present similar trends to maximum temperature (Figure 3.6). In the same way, Eta's projection models point to an upward trend in hot days (TX90p), especially using the Eta-HadGEM2-ES model (Figure 3.77). Eta-MIROC5 model's version points to a rather lower upward trend on hot days.

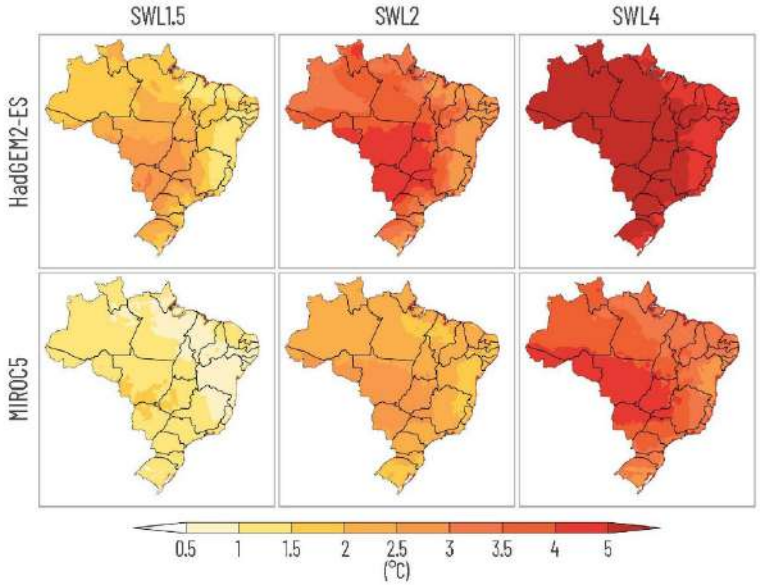



Figure 3.5. Temperature projections: variation of the annual average of minimum temperature (°C) compared to the reference period (1961-1990), according to the SWL1.5, the SWL2, and the SWL4 from each experiment carried out with the Eta model.

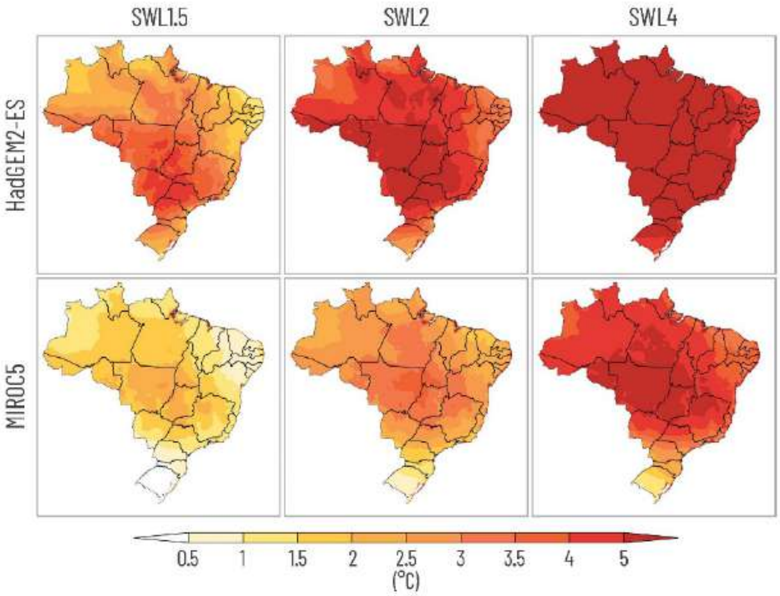



Figure 3.6. Temperature projections: variation of the annual average of maximum temperature (°C) compared to the reference period (1961-1990), according to the SWL1.5, the SWL2 and the SWL4 from each experiment carried out with the Eta model.

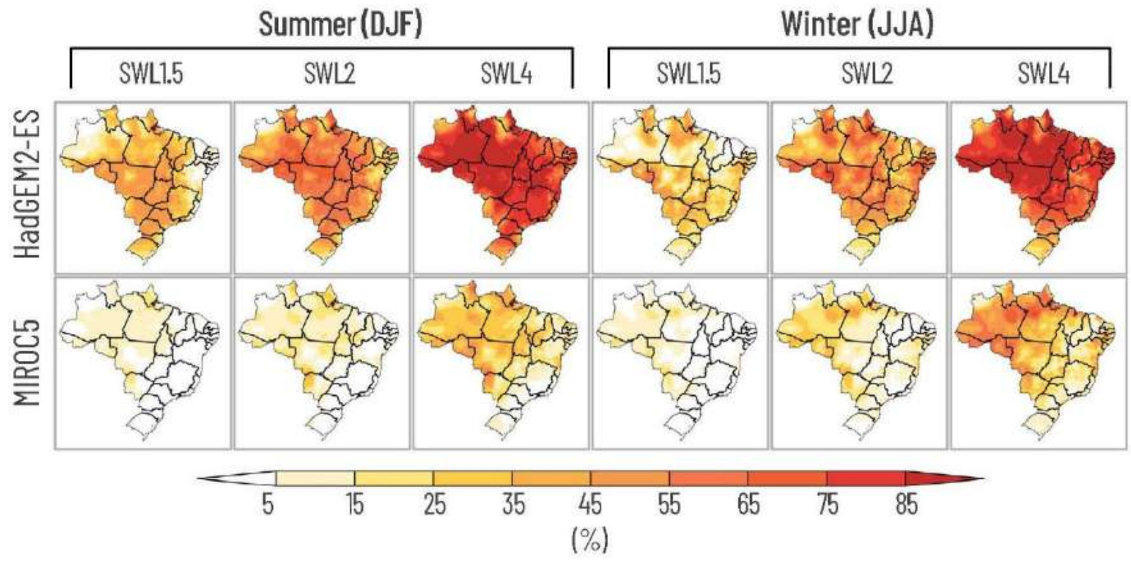
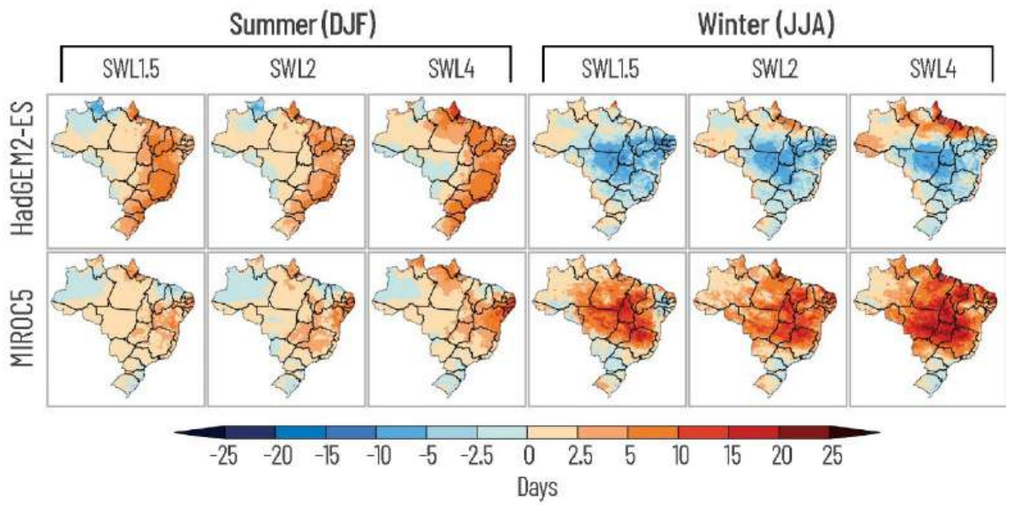


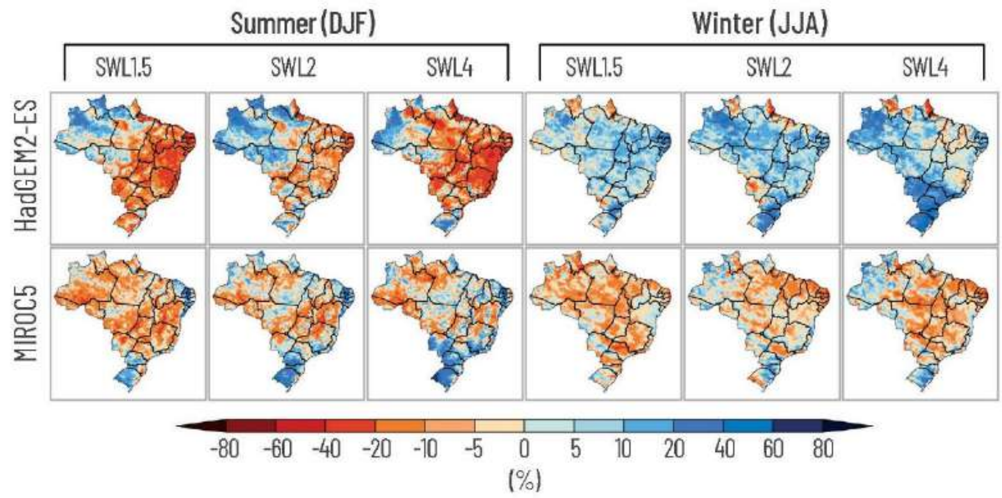

Figure 3.7. Projections of climate extremes: increase of hot days – TX90p (%) compared to the reference period (1961-1990) for the SWL1.5, the SWL2, and the SWL4 in summer and winter from each experiment carried out with the Eta model.

Figure 3.8 presents the projection of consecutive dry days (CDD) for summer (DJF) and winter (JJA), and the results point to an upward trend in consecutive dry days especially in winter, and for the projections of the Eta-MIROC5 model. The projections for summer from both results point to an upward trend in consecutive days in the Northeastern region and the north of the Southeastern region. On the other hand, 5-day maximum accumulated precipitation projections (Figure 3.9) point to an upward trend especially in the South of Brazil. In other regions, the models present different results in both seasons.




* In red, reduction of consecutive dry days, and increase in blue.

Figure 3.8. Climate extreme projections: number of consecutive dry days - CDD compared to the reference period (1961-1990) for the SWL 1.5, the SWL2, and the SWL4 in summer and winter from each experiment carried out with the Eta model.

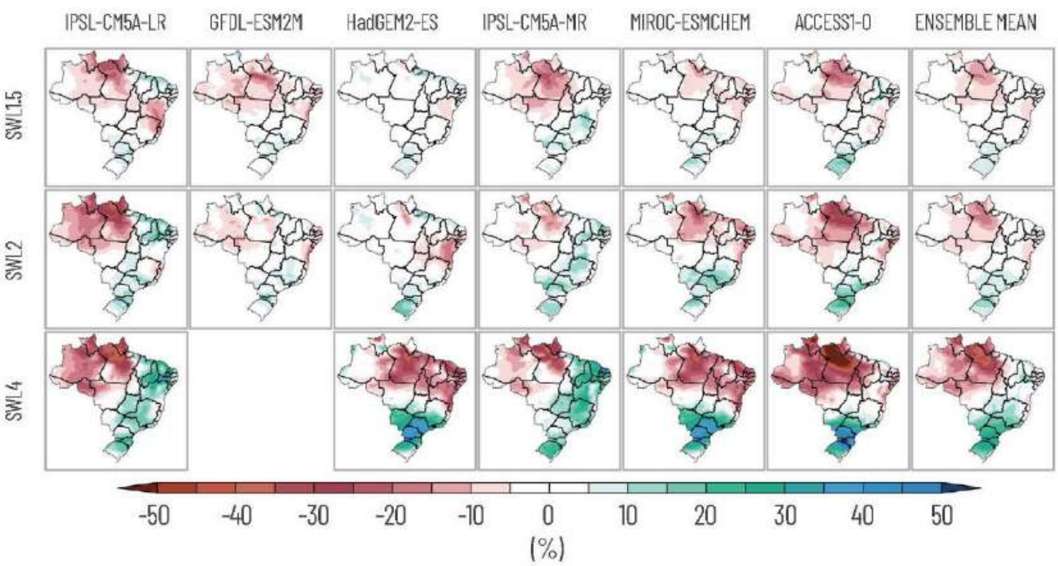



* In red, reduction of maximum precipitation accumulated in 5 days, and increase in blue.

Figure 3.9. Climate extreme projections: number of consecutive dry days - CDD compared to the reference period (1961-1990) for the SWL 1.5, the SWL2, and the SWL4 in summer and winter from each experiment carried out with the Eta model.

### HELIX PROJECT'S PROJECTIONS

Figure 3.10 shows the annual precipitation change over Brazil, projected to different warming levels (SWL 1.5, 2, and 4), and compared to the average of the period 1981-2010 (current climate). Change patterns are nearly similar among the different warming levels, diverging in magnitude only, that is, as the warming level increases, the projected changes become bigger. In general, it is projected a reduction in precipitation upon most of the Amazon (15-30%), whereas in the Southeast and the South it is seen an increase, which is more intense to SWL4, with precipitation gain around 25% a year. It is also noted that the changing areas expand towards the center of the Brazilian territory as the SWL increases. These patterns are consistent within the different forcing models, which provides for less uncertainty in projections.




*In red, precipitation reduction, and increase in blue.

Figure 3.10. Precipitation projections: variation of the annual precipitation (%) in relation to the reference period (1981-2010), according to the SWL1.5, the SWL2, and the SWL4 from each experiment carried out with HadGEM3 model.

The projection results of temperature (minimum and maximum) (Figure 3.11 and Figure 3.12) point an increase in all Brazilian regions, being equal to or above the SWL, that is, what means it may overcome the thresholds of 1.5, 2, and 4 °C. Most of the analyzed models present a major increment on minimum and maximum temperatures to every SWL approached, namely the IPSL-CM5A-LR, the IPSL-CM5A-M, and the ACCESS1-0. On the other hand, the smallest increases are presented by the subset formed by HadGEM2-ES and MIROC-ESMCHEM. The GFDL-ESM2M model, although it also stands out by the increment on the temperatures in SWL1.5 and SWL2 has not reached the temperature of 4 °C on the global average, so the projections associated to that model to SWL4 are not presented.

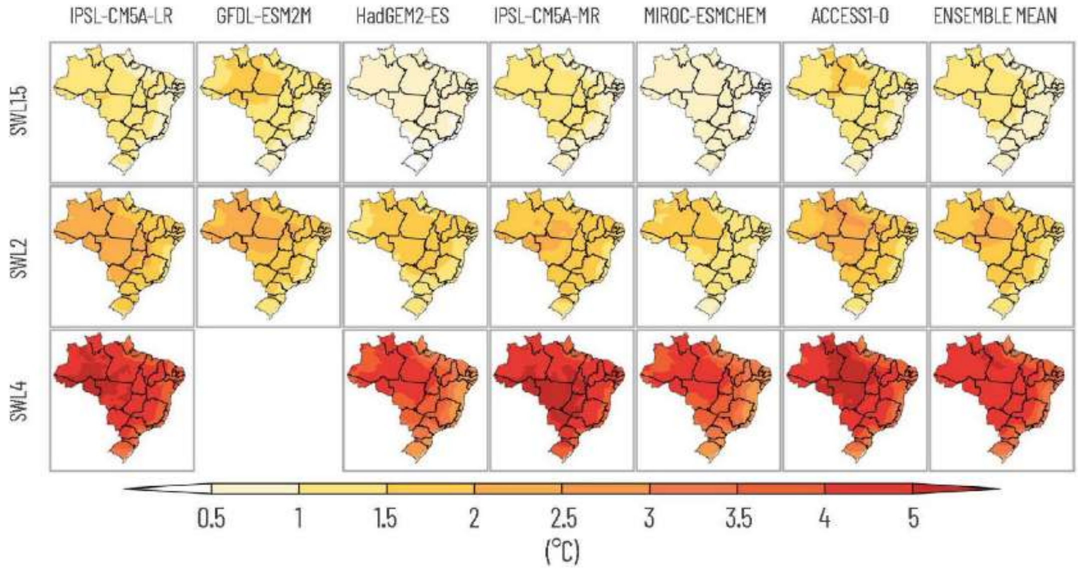



Figure 3.11. Temperature projections: minimum temperature annual average variation (°C) in relation to the reference period (1981-2010), according to the SWL1.5, the SWL2, and the SWL4 from each experiment carried out with HadGEM3 model.

By analyzing Figures 3.11 and 3.12, it is possible to identify that the Brazilian North and Midwest present the highest possibilities of severe changes as to rise in temperature, those being the main regions where minimum and maximum temperature suffer significant increments and in equal proportion, endorsing the projections shown on Figure 3.10, where they show a major reduction in precipitation.

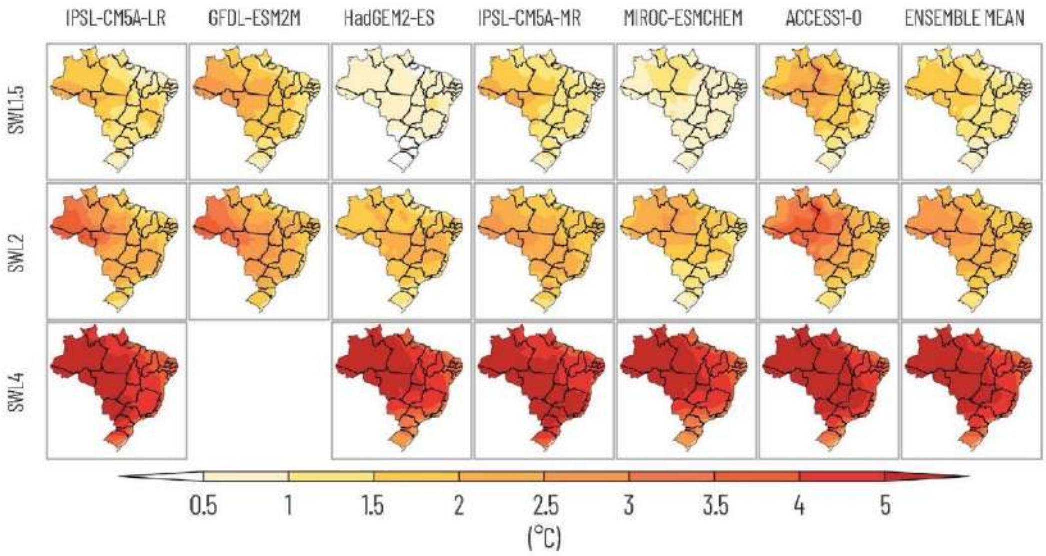
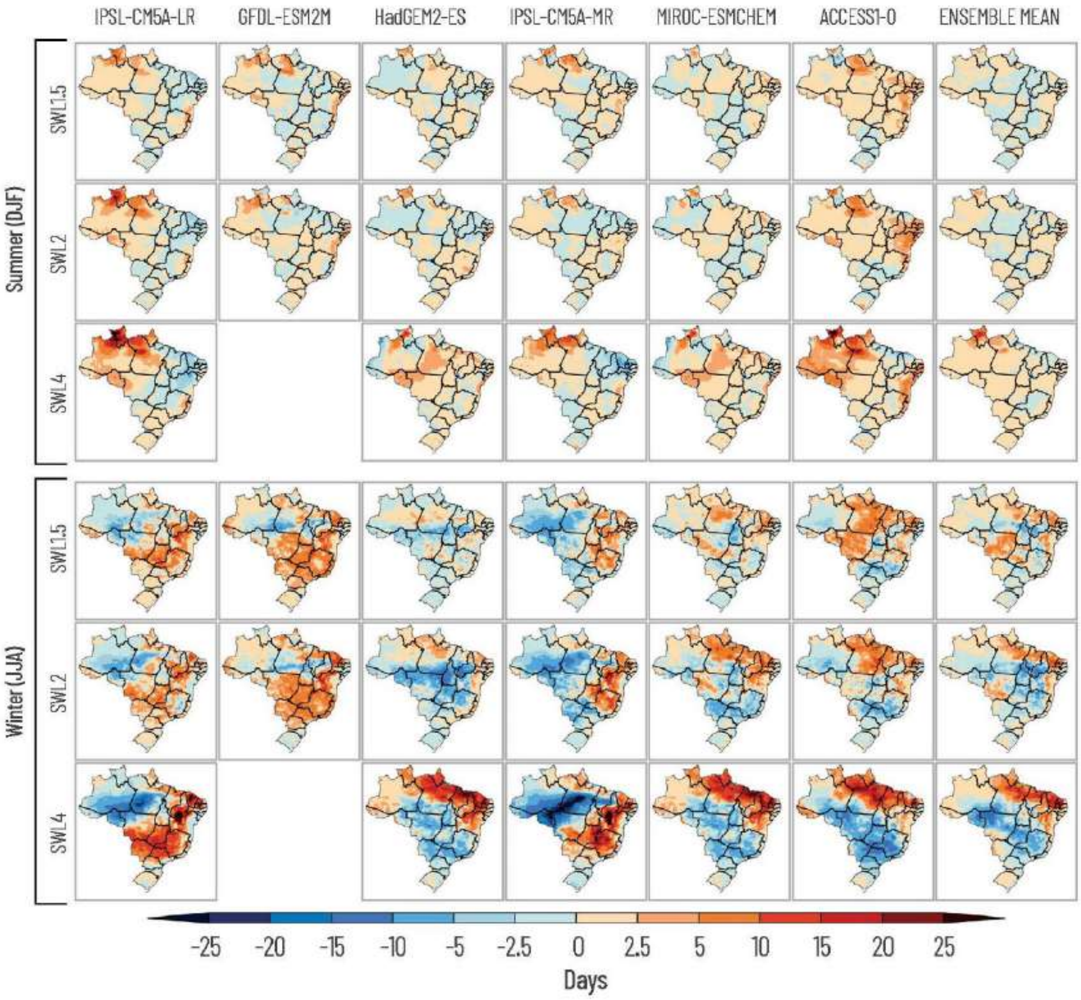



Figure 3.12 Temperature projections: maximum temperature annual average variation (°C) in relation to the reference period (1981-2010), according to the SWL1.5, the SWL2, and the SWL4 from each experiment carried out with HadGEM3 model.

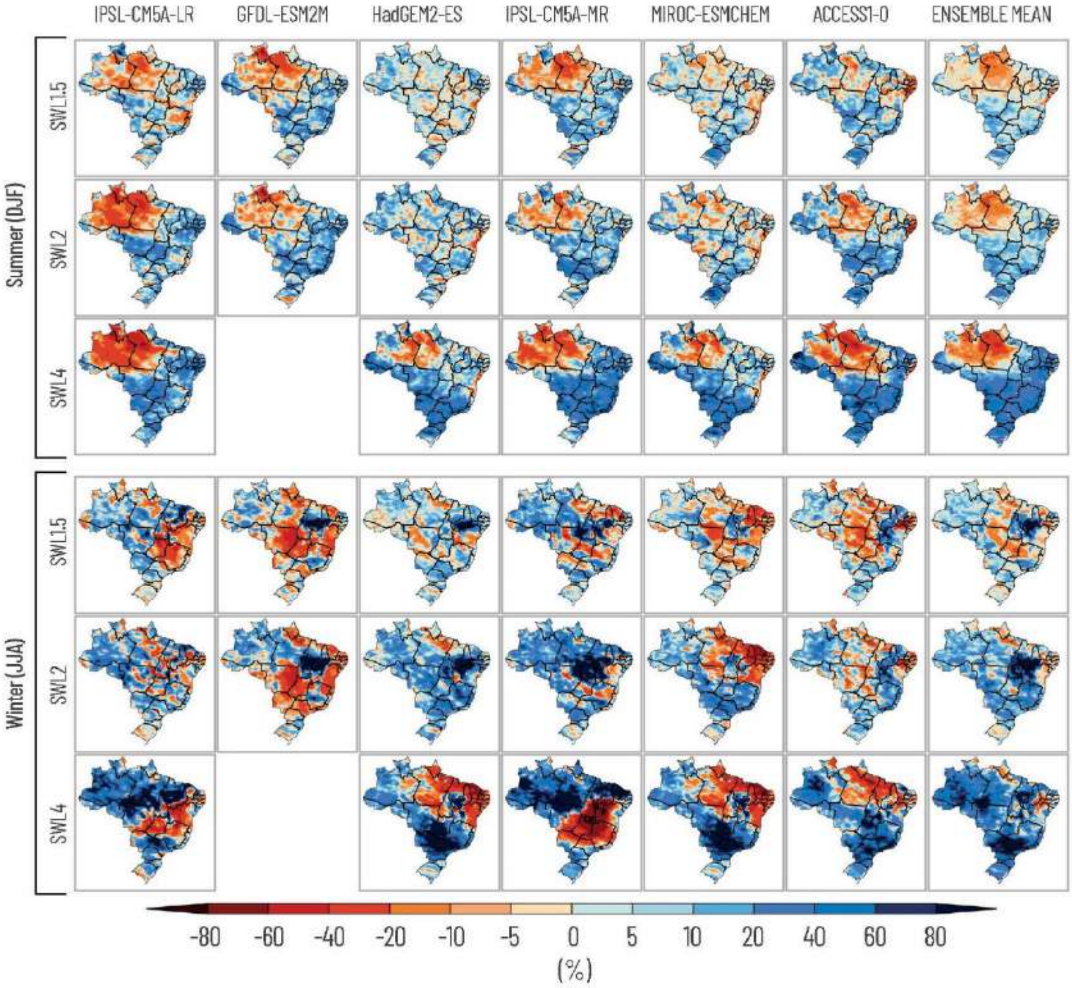
In general, the proportions point to a steady increase of sustained extreme drought events (Figure 3.13), especially in the north from the Northern and Northeastern regions, such changes becoming more prominent on the SWL4, particularly in wintertime, in the states of Amapá, northern Pará, and in practically the whole Northeastern region, presenting a substantial increase on the number of consecutive dry days. Still on the SWL4, there is no consensus between the models in relation to the reduction or the increase on the drought period in the Southeast and the Midwest regions.




*In red, reduction of consecutive dry days, and increase in blue.

Figure 3.13. Climate extreme projections: number of consecutive dry days (CDD) in relation to the reference period (1981-2010), for the SWL 1.5, the SWL2, and the SWL4 in summer and winter to each experiment carried out with HadGEM3 model.

The gauge presented on Figure 3.14 informs how the precipitation maximums will be distributed. During the summer, the states of Amazonas and Pará show relative reduction on the precipitation percentual accumulated during these events. In contrast, in the other country areas, there is an indication of significant increase, whose pattern is observed in all SWLs. The incidence of precipitation extremes extends all over the North and the South during winter. However, there is greater dispersion among the projections of the models, mostly on SWL1.5 and SWL2 over central Brazil. For the South of the Southeastern region and the South of Brazil, the predominance of a percentual increase in intense precipitation is seen in most models, what points that these regions may be susceptible to an increase on the number of floods and waterloggings.




*In red, reduction of the maximum precipitation accumulated in 5 days, and increase in blue.

Figure 3.14. Projections of climate extremes: variation of the maximum precipitation accumulated in 5 days – RX5day (%) in relation to the reference period (1981-2010), for the SWL 1.5, the SWL2, and the SWL4 in summer and winter to each experiment carried out with HadGEM3 model.

The analyses from annual minimum and maximum temperatures respectively shown in Figures 3.11 and 3.12, do not demonstrate whether the number of hot days and/or less cold nights will increase. So, by analyzing the results of the hot days projections (Figure 3.15), a significant increase is seen, with a variation from 15 to 35% in the SWL1.5, especially in the North during summer, and in the North and the Northeast in winter. In the SWL2, the increase pattern is from 25 to 65%, with a major highlight for the North, whereas in the SWL4, the increase on the number of hot days exceeds 75% for the analyzed seasons.

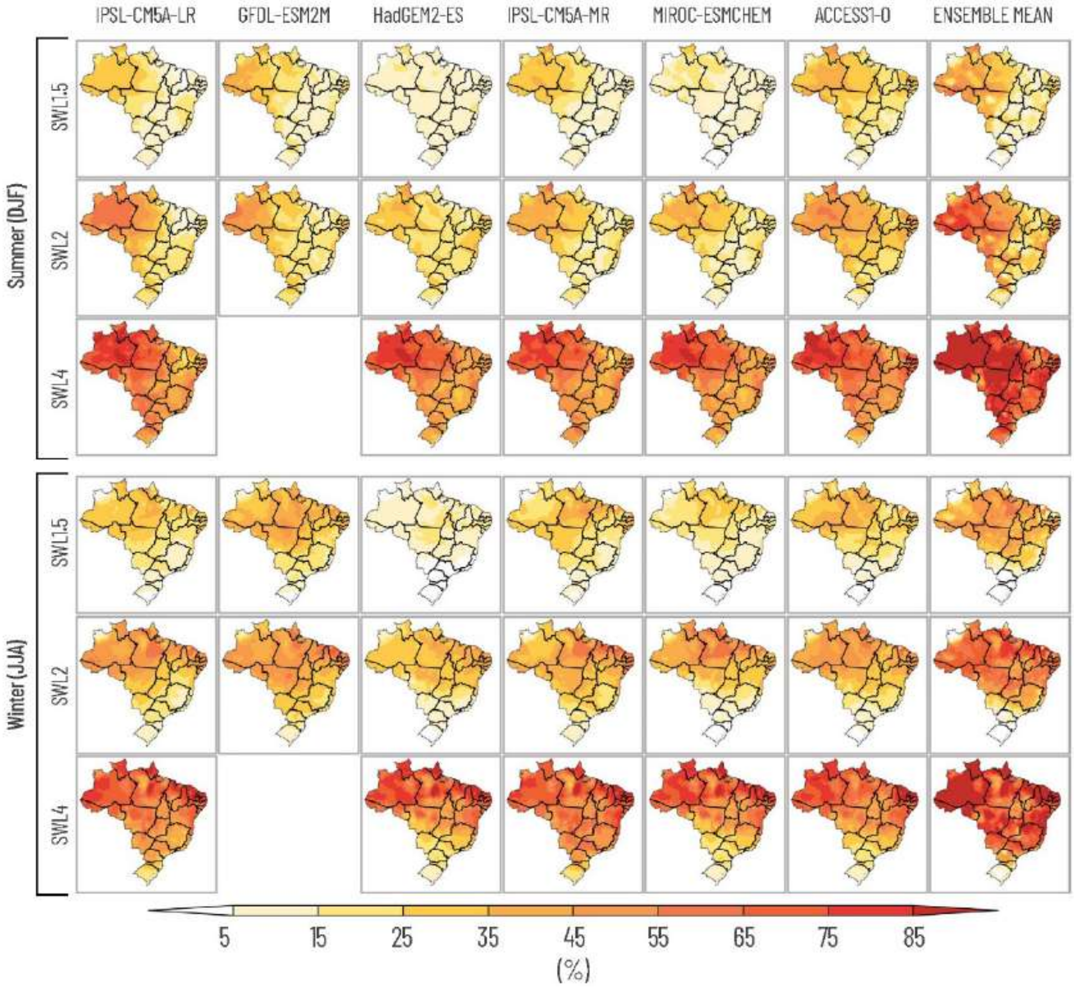



Figure 3.15. Climate extreme projections: increase of hot days – TX90p (%) in relation to the reference model (1981-2010), for the SWL1.5, the SWL2, and the SWL4 in summer and winter for each experiment carried out with HadGEM3 model.

For SWL4, warming level of major impact, from the results derived from HadGEM3 global climate model (Helix project), here are the most relevant observations:

- Increase in minimum and maximum temperatures of approximately 4.5 ° C, throughout the national territory;
- Reduction in the precipitating volume in the North region of up to 35% and an increase of up to 30% for the South region and the southern range of the Southeast;
- Increase in the number of consecutive dry days in the North and East of the Northeast during the summer, and in the North of the Amazon and in practically the entire Northeast during the winter. This situation shows the reduction of precipitation, and the concentration in a few days of accumulated volumes, that is, associated with extreme precipitation events;
- Increase in magnitude in rainfall accumulated in a short time, approximately 5 days, for the Midwest, Southeast and South regions during the summer, and the northwest of the Amazon and the entire southern strip of Brazil during the winter;
- Substantial increase in maximum extreme temperatures in both summer and winter in all regions of the country, but this increase is less pronounced in the South during the winter.

*BOX 3.2:* Sea level on the Brazilian coast: the challenges of a near future.

The global warming arising from the increase in the concentration of carbon dioxide in the atmosphere results in a series of changes in the coupled ocean-atmosphere system. Changes in winds alter the oceanic circulation in the upper layers and the absorption of heat and $CO_2$ produce significant changes in the thermodynamics and biogeochemistry of the entire water column. Among the most worrying aspects are the acidification of the ocean and the rise in the average sea level.

The increase in sea level is a subject that deserves a lot of attention in the Brazilian context, given the high population exposure in coastal cities as well as the location of many of the state capitals. This phenomenon must be understood based on the different contributions that generate it: volumetric expansion by water heating and the volume addition by defrosting the components of the cryosphere in the continental portions of the planet.

From a spatial point of view, the relative rate of sea level rise is not homogeneous in all coastal points around the globe, given that local / regional effects linked to the movement of the earth's crust can influence *on site* measurements made by tide gauges. Throughout ocean basins, the measurements provided by altimetric satellites in the last three decades also show the heterogeneity of change rates in sea level. Gauging between these independent measures ensures reliability in estimating a global average value of +3.37 mm / year in the last three decades. It should be noted that this value is much higher than those estimated with data from tide gauges from the first decades of the 20th century, which means that increase rate is getting higher over time.

In Brazil, although continuous and long-term tide measurements are scarce, existing records indicate similar increase rates in relative sea level from Oiapoque to Chuí, whose values fluctuate around the global average value. Even with the different occupation along the coast, the different tidal regimes and the influence of transient meteorological systems, there are expectations that all of these coastal environments will be affected by the rise in the average sea level, both in terms of the functioning of marine ecosystems and in relation to the infrastructure of coastal facilities.

In general, the most affected locations will be the most extensive coastal plains, in which seawater supply can have effects on the extension of the saline wedge and, therefore, on the use of water for the purposes of crop irrigation, aquaculture / mariculture. or even industrial. It is expected an increase in the frequency of occurrence of flooding events in locations located in lower topographic levels across the border; in particular, in the states of the South and Southeast regions where the influence of frontal systems is more significant and there is a greater amplitude of meteorological tides, it is very likely that the rise in the average sea level will cause an increase in extreme events of coastal floods.

In the different scenarios of global warming listed by the IPCC, the rise expected in average sea level varies considerably, being significantly higher in less optimistic projections. When considering that the sea level rise rate observed along the Brazilian coast is of the same magnitude as the global average, it is possible to rely on large-scale estimates to elaborate concrete perspectives for this increase in our country. In this sense, the estimates presented by Lindsey (2019) in a report on average sea level on a global scale is quite pertinent and very worrying, as he considers that the average sea level may rise between 50 and 250 cm by the end of the century, according to the concentration of greenhouse gases (Figure 3.16). The impacts generated by elevations of the average sea level with this magnitude will be very significant for Brazil, with far-reaching economic and social consequences.

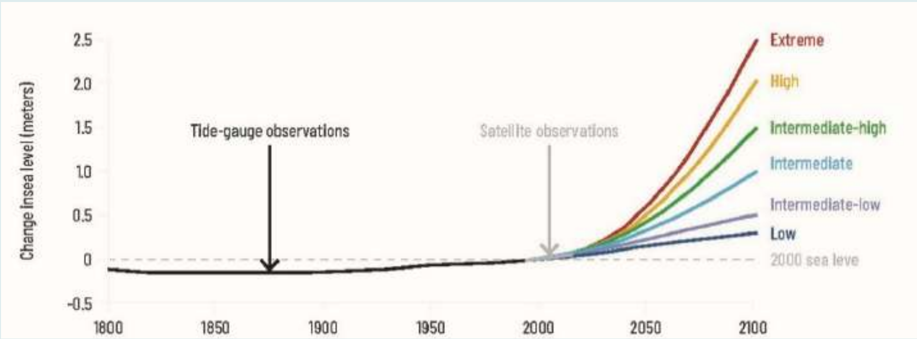



Figure 3.16 Sea level observed from tide gauges (dark gray) and satellites (light gray) from 1800 to 2015, and six possible future scenarios up to 2100 (colored lines). Source: adapted from Figure 3.8 in Sweet et al. (2017) from NOAA Climate.gov.

* Scenarios differ based on potential pathways of greenhouse gas emissions and differences in plausible rates of loss from glaciers and ice sheets.

## 3.3 Impacts and Vulnerabilities

The assessments carried out in the context of water, energy, food and socioenvironmental security considered different types of impacts related to the climate with relevance for the country in present and future scenarios. Although there are several factors that influence vulnerability and exposure to these impacts, given the great socioeconomic and biophysical heterogeneity that exists in the Brazilian territory, it is possible to identify common and / or interrelated aspects.

As mentioned in the previous section, the studies presented in this Chapter adopt Brazilian terrestrial biomes as an analysis territorial selection, with inferences also for cities, coastal areas and oceans. In other words, the reference to a given biome considers the multiple aspects of the territory where it is located, and not just the dimension of the natural ecosystem (unless in sections where this delimitation is specified).

In relation to WATER SECURITY, future scenarios point to an amplification of the current impacts and vulnerabilities related to the climate in Brazil. The reduction in water availability in the Caatinga, Cerrado and Atlantic forest biomes, whose territories are marked by high population concentration and multiple water use, shows the fragility in the relationship between water supply and demand in different warming scenarios. Also worth mentioning are the vulnerabilities that exist in all biomes, especially in the Amazon, Atlantic forest and Caatinga in relation to the occurrence of floods and the low quality of water in metropolitan regions. Likewise, there are vulnerabilities associated with environmental sanitation, such as access to drinking water and sewage. Regarding governance, although Brazilian legislation is advanced and emphasizes the decentralization of water management, Brazil has a huge variation in terms of institutional capacity between the different federation units and municipalities.

As to ENERGY SECURITY, climate change will have an impact on all energy chains in Brazil. The most vulnerable energy sources are water for hydroelectricity generation (mainly in the Amazon and Caatinga biomes), and bioenergetic crops (soy and sugarcane) for the production of biofuels (in the Atlantic forest and Cerrado biomes) or for generation of bioelectricity from sugarcane bagasse. On the other hand, the generation of energy from wind and solar energy sources (for centralized and decentralized generation) could be maintained and / or increased (although, in the case of wind energy, the scenarios indicate a reduction in the potential in areas of the Northeast where much of the installed capacity is currently found).

The reduction in hydroelectric generation, which represents 66.6% of the country's installed capacity, will require its replacement by other generation technologies, which imply an increase in the marginal energy cost of the electrical system and the final price of electricity, as well as local pollutant emissions and atmospheric and GHG emissions, in the case of fossil sources, with impacts on the population and economic sectors. The Brazilian electrical system has a high adaptive potential by allowing the partial compensation of the hydroelectric generation by other renewable sources, in addition to fossil sources. In particular, it appears in future scenarios that there is a good correlation of complementarity between the hydroelectric potential and the national wind power. There is also a tendency to intensify extreme weather events (which may impact the energy infrastructure, such as transmission) and increase of electricity consumption.

About FOOD SECURITY, it is important to consider that the demand for food in the country has been increasing in recent decades, mainly due to population growth and per capita consumption. In parallel, the migration of family farmers to cities leads to greater pressure on production, as the number of producers decreases and the number of consumers in the market increases. In addition, the high volume of food losses and waste in the country leads to an increase in its costs and prices, which affects its availability and access, especially for low-income families per capita or those in extreme poverty.

Climate change has direct effects on agricultural production capacity, influencing, among others, crops' suitability to new local climate conditions. Greater losses and costs in the production chain due to the occurrence of more intense and frequent extreme events may require a greater allocation of financial resources for agricultural insurance, causing an increase in prices and a reduction in producer profits. There are also projections of greater need for irrigation, especially in the Cerrado and Caatinga, with potential conflicts over water use. In fishery, changes in the temperature of the oceans and in water pH may lead to the migration of schools or even their mortality and the reduction in production (capture) in the entire coastal range, rivers and lakes, increasing the role of aquaculture to ensure fish production.

In SOCIOENVIRONMENTAL SECURITY, aspects of vulnerability and exposure are related to sensitivity to increased temperatures, intensification of extreme events and changes in precipitation patterns, which overlap with the structural dimensions of poverty, socioeconomic inequalities, socio-spatial segregation in cities, level of access to basic services (such as health and education), marginalization by gender and ethnicity (such as indigenous peoples, traditional communities, black people) and institutional capacity from government actors to deal with climate change and its consequences.

Future scenarios indicate losses in climate suitability associated with climate change in all biomes, with loss of biodiversity and ecosystem services. In addition, evidence points to the importance of protected areas and spatial planning and management to minimize the exposure and vulnerabilities of ecosystems to the impacts of climate change. The rates and magnitudes associated with habitats loss and ecosystem services resulting from changes in land use and climate change in the 21st century have shown limits on the ability of ecosystems to adapt naturally (Settele, J. et al., 2014).

Projections indicate a significant increase in temperature and an increase in the incidence of extremes of drought and floods, fires and hot spots, as well as diseases (transmitted by vectors, water and thermal transmission) and disasters, affecting all biomes, even if heterogeneous. This context is verified not only in poorer and farthest regions, away from services and information in a timely manner for reaction, and in what affects traditional peoples and communities, but also in large urban centers, where there are marginalized and poor populations.

Further details on impact and vulnerability analyses are presented in the sections corresponding to security.

### 3.3.1 Observed Impacts

In the context of water, energy, food and socioenvironmental security, several climate-impacts can be identified in Brazil, especially in the last decades, which allow to understand the relevance of the adaptation agenda, as well as providing elements for its planning and implementation. Below is a sample of observed impacts in the country, which affect the territory in different ways:

The Caatinga biome, with high poverty incidence, was hit by severe droughts between 2011 and 2017, which affected more than 80% of the municipalities in the region (IBGE, 2017). In 2012, the worst drought in the last 30 years was recorded, with a direct impact on the lives and savings of 30 million people (Novaes, Felix and Souza, 2013). In 2016, 24% of the semi-arid municipalities reported the appearance and / or increase of desertification areas (IBGE, 2017b).

In 2012, where an average reduction of 500 mm in rainfall in the region, the production of beans and corn in the biome suffered losses around 62% and 46%, respectively. For example, the production of beans in Araripina, in the backlands of Pernambuco, decreased by 99.2% in 2012 (compared to the previous year), when the average annual rainfall was 400 mm, 43% less than the average rainfall in region[8].

Among the impacts caused by the drought from 2012 to 2015 in the Northeast there are the diarrhea outbreaks. In 2013, droughts led the reservoirs to depletion or contamination, with the consequent supply water compromise and hospitalizations and deaths of children and elderly people (Rufino et. Al, 2016).

At Cerrado, the low precipitation levels by the end of 2016 impacted the storage of the main supply reservoirs in the Federal District, Descoberto and Santa Maria, which started 2017 with 22% and 42% of useful volume, respectively. The water crisis that occurred was partly related to climate factors and generated impacts on the various water uses (Mesquita et al. 2018).

The Serra da Mesa reservoir (Tocantins River Basin) is the country's largest in terms of storage capacity, and since 2012 it has suffered a decrease in stored volume. In 2017, it reached less than 6% of its useful volume, the lowest value observed since the beginning of its operation in 1998.

[8] climate-data.org

The Três Marias Hydroelectric Power Plant reservoir (HPP), located in the São Francisco River hydrographic basin, in Minas Gerais, regulates part of the affluent flow from other plants located downstream (Sobradinho, Itaparica, Moxotó, Paulo Alfonso, and Xingó). Between 2000 and 2018, the HPP had operational difficulties related to low useful storage volume, and in the most critical period, between 2014 and 2015, the volume was below 10% of its capacity (ANA, 2019). During the droughts in 2014, the HPP reduced its electricity generation from 188 MWmed, in March 2013, to 28 MWmed, in March 2015 (lowest generation in the time span analyzed) (ONS, 2019).

Since 2011, certain food prices showed a relative increase. The soybean was sold by the producer for 60.6 BRL per bag (60 kg) in 2012, 42.3% more expensive than in 2011, due to strong rainfall reduction (around 500 mm), which affected most of the country, including the main producing region, the Cerrado biome (FAO, 2019; Xavier et al., 2016). In 2012, the drought was responsible for the 45.8% reduction in soybean production in the municipality of Tupanciretã, Mato Grosso. The bean was sold by the producer for 158.1 BRL per sack in 2012, 55.9% more expensive than in 2011, also related to the reduction of rainfall in the Cerrado and Caatinga biomes. On the other hand, in Sorriso/MT, in 2014, there was a 24.5% reduction in corn production, due to the higher rainfall volume of 23.8% compared to the previous year.

The AMAZON biome, has been highly affected by droughts and extreme floods in the last two decades (Marengo et al., 2013; Pinho, Marengo and Smith, 2015; Tomasella et al., 2013).

During the 2005 drought, Acre recorded 400,000 people and more than 300,000 hectares of forest affected by the fires (Brown et al., 2006). In the same state, the droughts of 2005 and 2010 increased the number of hot spots and the incidence of respiratory diseases in children under 5 years (Smith et al., 2015). In 2010, 40 out of the 62 municipalities in the state of Amazonas declared state of emergency, and the government released 12 million USD to help the communities affected (Pinho, 2016). Between 2013 and 2017, the state of Roraima had 93% of its municipalities affected by droughts (IBGE, 2017b).

In flood episodes in the Amazon region, the incidence of diarrhea, leptospirosis and dermatitis increased significantly (Hacon, S.; Oliveira, B. F.; Silviera, 2018; Sousa et al., 2018)

In 2014, a historic flood on the Madeira River flooded communities and flooded part of the BR-364 in Rondônia, causing shortagein cities and increase transmitted diseases by water contamination, as leptospirosis (Franca; M endo nça, 2015). A total of 3,758 families went homeless and displaced, and the riverside population was severely affected by the flood (CGU, 2014). In2015, the Acre River level reached maximum quotas of 18 meters and caused major river floods and destruction. The civil defense declared 5,000 homeless families (CEPED, 2015).

In the ATLANTIC FOREST, the impacts caused by the extended drought in 2014 were broad and involved several sectors. The industry production capacity, the agriculture productivity, and even hospitals and schools operations have been compromised (Nobre et al., 2016). Rainfall scarcity in 2014 and 2015 affected activities in the Tietê-Paraná Waterway, one of the most important in the country, in terms of values and volumes transported (ANA, 2019).

The same drought in 2014 affected considerably the sugarcane harvest, especially in the states of São Paulo and Minas Gerais (UNICA,2014a; Nobre et al. 2016). In 2014, a 7.8% reduction was observed in productivity per harvested area in the South Central in relation to the previous year[9], reaching a 12.1% reduction in the state of São Paulo (UNICA, 2014ab). The drop in productivity resulted in a 4% lower harvest than in the previous year.

Sugar production was more sensitive to crop failure, with a 6.7% drop compared to the previous period (UNICA, 2019). The increase in ethanol production, compared to sugar production, generated a *trade-off* of energy security with food security.

*[9] It is noteworthy that the productivity from a sugarcane plantation depends not only on climatic factors, but also on the average age of the cane field, since there is a downward trend on the concentration of total recoverable sugars in sugarcane stems at each annual cutting cycle. Thus, cane fields' renewal is an economic decision for each producer, which ends up affecting aggregated productivity indicators.*

The infrastructure of the electric power distribution and transmission system has also been affected by weather events. The Southern region was hit by an extratropical cyclone (Hurricane Catarina) in 2003 and some tornadoes in recent years.

The deficit of native vegetation in the biome and the high fragmentation of the remnants (Bustamante, Metzger et al., 2019; Scarano and Ceotto, 2015) lead to greater vulnerability in cities. Surface water floods associated with heavy rains reached more than 90% of the municipalities in the region between 2013 and 2017 (IBGE, 2017b). In the mountain region of Rio de Janeiro, in 2011, there were 916 deaths and more than 35,000 homeless, as a result of extreme rains that caused landslides of large land masses, as well as flash floods and surface water floods across the region (Marengo and Alves, 2012).

The storm that occurred in February 2020 in Rio de Janeiro was the most massive in the city's history within one hour. In the same period, the city of São Paulo recorded the highest accumulated rainfall for the month in 37 years.

In PAMPA, soybean cultivation faced unfavorable weather conditions in the 2011/2012 harvest in the Passo Fundo region (RS), with periods of water deficiency and high temperatures (above 30 °C), in addition to irregular rainfall distribution (Embrapa, 2012). This resulted in a 32% reduction in the amount produced in 2012 compared to 2011 (IBGE, 2019). Biodiesel production in the state of Rio Grande do Sul in 2012 was 6.45% lower than in the previous year (ANP, 2018). From 2013 to 2017, 50% of the municipalities in Pampa were affected by floods and river floods (IBGE, 2017b). Like the Atlantic Forest, the Pampa is a very altered biome.

COASTAL ZONES have suffered from climate change through increased surface temperature and ocean acidification, rising sea levels, coastal erosion and coral disappearance. In the coastal city of Cananéia, in the state of São Paulo, observational data from 50 years indicated sea level rise of 4.2 mm per year (Costa, 2007). The caiçara population that occupies the Cardoso Island State Park has already been affected by coastal erosion and river floods (Stonoga, 2017; Tomazela, 2016). Similarly, mangrove changes in recent decades have caused changes in the coastline, the carbon stock, and in the reproduction of marine species (Copertino et al., 2017). Such dynamics have led to significant impacts on the population's ways of life, with reduction in fishing stock, infrastructure loss, and people relocations due to erosive processes and floods (Martins and Gasalla, 2018).

High URBANIZATION and lack of vegetation cover contribute to the formation of heat islands and compromise the provision of ecosystem services of climate regulation for society (Rice et al., 2018). In 2019, large Brazilian capitals showed a significant increase in average temperatures, with occurrences of heat waves, such as Rio de Janeiro city, whose average temperature in summer exceeded 39 ˚C, with high thermal sensation (INMET, 2019). It also stands out the rise in dengue cases related to temperature rise and rainy extremes in Maranhão (Silva et. al, 2016), in the Amazon (Horta et. al, 2014), in Rio de Janeiro (Gomes; Nobre and Cruz, 2012), and in the main Brazilian cities (Barcellos and Lowe,2014).

## 3.4 WATER SECURITY

### 3.4.1 CONTEXT

#### CONCEPTUALIZATION

Water security goes beyond water deficit assessments, it also encompasses economic, social, health and environmental aspects. With a wide range of concepts, depending on the purpose, focus and analysis scale (Cook and Bakker, 2012), the common point is the need to meet the essential demands for human survival, in terms of ensuring water quantity and quality.

Thus, the concepts may include the protection of ecosystems (UN Water, 2013; Wateraid, 2012; WWC, 2013) or the protection of public health, whose focus may be the reduction of water-transmitting diseases (Van Beek; Arriens, 2014; Wateraid, 2012). Water security also involves access to water for basic human needs, livelihoods and local ecosystem services, as well as good management of disaster risks related thereto (WaterAid, 2012).

Thus, in this 4NC, water security indicates appropriate availability of both quantity and quality of water for health, livelihoods, ecosystems, and production, associated to an acceptable level of water-related risks in regard to people, economy, and the environment (Grey & Sadoff, 2007).

## RELEVANCE OF WATER SECURITY FOR THE COUNTRY AND FOR ADAPTATION

### ECONOMIC SECTORS AND WATER

The economy and the maintenance of the lifestyles of the Brazilian population are strongly conditioned by the climate and the hydrological regimes of their hydrographic basins. Economic activities, such as agriculture and industry, depend on climate and water availability in the region in which they are developed. According to projections by the National Water Agency (ANA, 2018), water withdrawals for supply to various users and sectors can reach 2,600 $m^3/s$ in Brazil in 2030, about 24% increase compared to 2017.

In 2012, industry accounted for 20.7% of national GDP and accounted for 8.78 million jobs. The sector accounts for 17% of the total withdrawal outflow and 7% of the outflow consumed, according to the Water Resources Conjuncture report in Brazil (ANA, 2014).

*To learn more about water resources in the country, see* ***item 1.1.3.***

Irrigation, an activity of greater use, accounts for 52% of the outflow from water resources and 68.4% of the outflow actually consumed (ANA, 2018). Based on 2015 estimates, the incorporation of 3.14 million irrigated hectares – an average of just over 200,000 hectares per year – is projected to bring the country closer to the total area of 10.09 million hectares irrigated in 2030 (ANA, 2017). This increase corresponds to a raise of 45% over the current area and the use of 28% of the estimated effective potential.

In Brazil, there is also a high demand for water for energy production, since the country is a major world producer of hydropower, with 66.6% of its electricity, in 2018, based on this type of source (EPE, 2019).

### BRAZILIAN REGIONS UNDER VARIED PRESSURES

The Brazilian regions have quite different climatic and socioenvironmental contexts in relation to water resources. Some regions live with droughts, while others have demand that exceeds water systems' capacity due to population pressures.

The semi-arid region of Northeastern Brazil is marked by the condition of water scarcity, with only 4% of the country's total water resources, although it represents 18% of the national territory and houses 30% of its population (Souza Filho et al., 2018). Some of these areas are classified as high water risk, with annual rainfall of less than 500 mm, water deficit and extended droughts, predominance of crystalline rocks[10] and intermittent rivers, and large use of dams to ensure water supply.

São Francisco, one of the largest rivers in Brazil, is responsible for supplying much of the Northeast (Santos et al., 2012). With 631,133 $km^2$ and an extension of almost 2,900 km, its basin represents about 7.5% of the total Brazilian area and covers an estimated population of 14 million inhabitants. Its water serves multiple uses, such as domestic and industrial supply, irrigation,

*[10] Crystalline rocks are less porous and hinder penetration and accumulation of groundwater. However, in these rocks, due to tectonic efforts, there are faults and fractures allowing water storaging. In crystalline terrains, the productivity of wells depends on the presence, the opening and connectivity of fractures, characteristics that determine the ability to conduct and store water from rocks. In semi-arid regions, where physical weathering prevails, the mantle has little thickness or it is non-existent, further restricting the potentiality of crystalline terrains.*

fishing, hydroelectric power and transportation (Santos et al., 2012), supplying water for 11% of the irrigated agriculture in the country.

Although the Southeast has perennial rivers, it is marked by conflicts for water resources. The Southeast concentrates 40% of the population responsible for 60% of the country's GDP, but its water availability is 6% of the total (Souza Filho et al., 2018).

The Cerrado is one of the 34 *hotspots* of biodiversity in the world. There we find the fountainheads of the three largest hydrographic basins in South America (Amazon/Tocantins, São Francisco and Prata); and the Guarani, Bambuí and Urucaia aquifers, with a strategic role for water reserve and biodiversity protection.

### Groundwater

In relation to groundwater conflicts, studies in the Guarani Aquifer – Bauru System (Southeast) and Alter do Chão (Amazon) – have shown that the current scenario presents intense aquifer exploitation, with considerable reductions in their water levels (Boico; Wendland; Batista, 2018; Saraiva, 2017) and indications of increased pressure in the long term caused by population growth (Boico; Wendland; Batista, 2018).

The municipality of Bauru-SP has 60% of its urban supply system depending on the water from the Guarani Aquifer.

### Beyond Water Availability

The water crises that occurred in several Brazilian regions since 2012 (Cantareira system, São Paulo, 2014; Pardo, Mucuri and São Mateus rivers in the states of Minas Gerais, Espírito Santo, and Bahia, 2015; Brasília, Federal District, 2017; Tocantins-Araguaia, Maranhão, 2017; northern northeast, between 2012 and 2017) (ANA, 2018), show that the vulnerability of a hydrographic basin depends not only on its water availability and natural characteristics, but also on the high demands and quality of its waters.

The efficiency of sanitation service is central for water security. The national average sewage collection network service rate corresponds to 60% of the population on urban areas, and the average treatment generated is 45% (SNIS, 2016).

## Water Security Governance

According to the Federal Constitution of 1988, the Union has the private competence to legislate on waters, and may, by complementary law, authorize federal states to legislate on specific subject-related issues. In addition, the Union has a duty in managing and monitoring the various water uses under its control. Nevertheless, there is a common material competence between Union, states and municipalities to protect the environment, fight pollution, preserve forests, fauna, and flora.

The Water Code (Decree No. 24,643/1934) constitutes the original legislation on water. Law No. 9,433/1997, known as Water Law, was enacted after debates across the 1980s and 1990s, it established the National Policy on Water Resources (PNRH), and created the National Water Resources Management System (SINGREH).

Among its basics, we highlight the integrated management, the hydrographic basin as a territorial management unit, participatory and decentralized management, and water with economic value (Brasil, 1997).

The National Water Agency (Agência Nacional de Águas - ANA), a special authority with administrative, financial autonomy and regulatory agency status, was created by Law No. 9,984/2000 with the task of implementing the PNRH, according to its principles, instruments of action, and institutional arrangements set out, which include National Council of Water Resources (Conselho Nacional de Recursos Hídricos), watershed committees, water agencies, and federal, state and municipal public service agencies and entities.

The National Water Resources Plan was published in 2006, and it is one of the instruments steering water management in Brazil. Built in a broad institutional engagement process, it aims to define a set of guidelines and public policies aimed at "improving water supply in quantity and quality, managing demands and considering that water is a structuring element for the implementation of sectoral policies from a perspective of sustainable development and social inclusion."

The National Water Resources Plan's implementation follow-up is one of ANA's duties, in conjunction with the user sector and the civilian society, with a follow-up by the Technical Plan Chamber (CTPNRH/CNRH).

WATER RESOURCE PLANS. Provided for by the National Policy on Water Resources, they are documents that define the agenda for water resources in one region, including management actions, projects, construction works and prime investments. In addition, they provide up-to-date data that helps enhancing ANA's databases.

The plans are drawn up on three levels: water basin, national and state-based. They also involve governmental agencies, the civilian society, users and various institutions that participate in managing water resources.

The State Water Resources Plans (PERHs) have the role of acting integratedly and in cooperation within the national sphere to enhance efficiency in water supply and use. The PERHs aim to present commitment solutions, mainly with the goal of minimizing conflicts due to water use, in view of the multiple interests of water users, public authorities and organized civilian society, or promoting the prevention and mitigation of critical hydrological events, such as droughts or river floods.

The National Program for Monitoring the Quality of Water for Human Consumption (Vigiágua) is structured based on the principles of the **Universal Health System** (SUS), and consists of a set of actions in public health to ensure access to water in sufficient quantity and quality compatible with the potability standard, established in the current legislation (Federal Decree nº 79,367/1977), in the Ministry of Health assignment, as a component from health promotion actions and prevention of water borne diseases.

The National Water Security Plan (PNSH) was launched in 2019, it is a decision-making instrument in the implementation of strategic water infrastructure for the country, and it establishes an investment program for interventions according to regional priorities, aiming to ensure water supply and reduce risks of extreme flood and drought events (ANA, 2019).

## 3.4.2 IMPACTS AND VULNERABILITIES IN WATER SECURITY

### IMPACT CHAIN

CLIMATE PRESSURES IN THE HYDROLOGICAL CYCLE. Several physical processes that may impact the components of the hydrological cycle are triggered by climate change, especially changes in variability, seasonality and/or intensification of rainfall regime, potential evapotranspiration, outflows, biogeochemistry of water bodies and oceans, and mean sea level (MSL) (Magrin et al., 2014).

CHANGES IN THESE PHYSICAL PROCESSES TRIGGER ENVIRONMENTAL AND SOCIOECONOMIC IMPACTS. Environmental issues are related to changes in water supply, i.e., quantity and quality of surface and groundwater, alteration/destruction of territories, as well as the loss of ecosystem services and biodiversity. Socioeconomic issues triggered by environmental issues are related to the population's ways of life, to health and hygiene conditions, to interferences in productive capacity, to the rise of sectoral conflicts during water crises, and to an increase in eventual disasters.

NON-CLIMATIC FACTORS ALSO CONTRIBUTE TO INCREASED VULNERABILITY OF NATURAL AND HUMAN SYSTEMS. Large urban clusters, disordered land use and occupation, progressive increase in water demands, and deficiency in water infrastructure investments associated with rain scarcity periods result in water crises. The increase in the frequency of droughts can aggravate this scenario, affecting the normalization capability of reservoirs and the productive system, and impact directly the grant policy established for the current climate (ANA, 2018).

It is estimated an increase of 12% of the Brazilian population between 2018 and 2047, from 208 to 233 million inhabitants (IBGE,2018). When demand exceeds supply, it increases the risk of city shortages and treatment costs.

NATURAL ENVIRONMENTS PLAY A KEY ROLE IN WATER SECURITY, as they guarantee and control soil stability, water response, water quality, natural erosion cycle, water inflows and outflows, groundwater recharge, and maintain base flow, which ensures river and reservoir flows during drought. Ripable forests are important in protecting river banks, lakes and springs, and their loss can cause siltation of water bodies and waste load that compromises the water quality and availability (Jacobi and Grandisoli, 2017; Joly, Metzger and Tabarelli, 2014; Scarano and Ceotto, 2015).

The Atlantic Forest, for example, is responsible for providing water to approximately 75% of the Brazilian population (Joly, Metzger and Tabarelli, 2014), and has a fundamental function of maintaining moisture flows in the water and climate balance at regional and global scales (Davidson et al., 2012). Also, the effects of droughts in the Amazon forest had an impact on water security and the conservation of ecosystem services in the Pantanal region (Bergier et al., 2018). Pantanal has a widespread and extended flood season during summer that may be affected by changes and losses in atmospheric humidity transport recycled by the Amazon rainforest (Bergier et al., 2018), knowing that humidity also comes from the tropical Atlantic Ocean.

RIVER FLOODS can occur and produce impacts due to two processes that happen either alone or combined: gradual river floods (floods), which are associated with the occurrence of heavy rainfall across the hydrographic basin, and sudden river floods (flash floods or surface water floods), which are usually associated with the urbanization process.

Natural disasters in cities have greater impacts in the poorest and most exposed areas[11], where there are already vulnerabilities in relation to water resources, lack of sanitation and contact with water borne diseases (Confalonieri, 2003; Debortoli et al., 2017; Espinoza, Ronchail, Marengo, & Segura, 2018; Magrin et al., 2014; Menezes et al., 2018a; Sousa, Amancio, Hacon, & Barcellos, 2018).

The intensification of extreme events, especially those resulting in floods associated with losses and damaged goods, services, infrastructure, health, and socioeconomic activities, directly affects population life quality and social and environmental security.

INCREASES IN AIR AND WATER TEMPERATURE AND RISING SEA LEVELS AFFECT WATER QUALITY. The rising temperatures of the air, and sea and inland waters cause changes in chemical and biological processes that affect water quality. One of the main impacts is the reduction in dissolved oxygen concentrations, which affects the self-purification capacity of water bodies and the maintenance of aquatic communities. The warming of surface waters in lakes and reservoirs also increases the vertical stratification of these water bodies, hence reducing the mix of surface waters with deeper waters, what favors the proliferation of algae. Rising sea levels can intensify coastal erosion, frequency and intensity of floods. Disturbances in the provision of goods and services, reduction of habitable spaces and marine intrusion, which reduces the quality of fresh water and causes biodiversity loss; these are examples of impacts that may be caused (Marengo et al., 2017).

WATER CONTAMINATION SOURCES are numerous, consisting of organic household waste, industrial and agricultural pollution, and thermal pollution via industrial refrigeration effluents that stimulate the development of pathogens, bacteria and viruses. In addition, there is a relationship between diffuse pollution, algal bloom, and the occurrence of cyanobacteria, which reproduce easily in eutrophic environments and, at high concentrations, they are associated with the production of toxic and carcinogenic compounds in water bodies (Calijuri MC; Alves, Alves, Santos, 2006). The high concentration of nutrients in water and the gradual increase in temperature may favor the predominance of toxic compounds over non-toxic compounds (Merel et al., 2013).

REDUCTION IN WATER QUALITY GENERATES SOCIOECONOMIC COSTS. Poor sanitation systems increase the incidence of waterborne diseases (Spilki, 2015). According to the Brazil Sanitation Panel, Brazil registered 258,000 hospitalizations for waterborne diseases in 2017 (TrataBrasil, 2019). Changes in the quality of water resources associated with the release of pollutants and reduction of outflows may increase treatment costs for domestic supply and industrial use, affect use in irrigation, water biodiversity and fishing, increase the incidence of diseases and cause the loss of tourist and landscape values (Tundisi, 2008; Tundisi et al., 2015).

*[11] Vulnerable populations are the ones facing major risks, as they have little capacity to deal with external threats (Jacobi & Grandisoli, 2017; Jacobi, Fracalanza, & Empinotti, 2017).*

MULTI-USE CONFLICTS.

When changes in climate patterns affect water availability, they can turn into water crises, causing uncertainties as to water supply, tensioning the relation of users settled in the region, and enhancing competitive uses, for example, between irrigated agriculture and other user sectors (ANA, 2017). The reduction in water availability projected in future climate scenarios, associated with increasing withdrawal trends for the next 20 years may amplify existing conflicts in water, food, energy and socioenvironmental security.

The Atlantic Forest biome is marked by intense water use in its production and consumption activities, together with mining activities, large urban clusters and the southeasthern system of hydroelectric reservoirs.

The competition for water in production systems yields a raise in food production costs, caused by supply reduction and shrinking in stock capacity. Changes in the water regime and effects of extreme hydrological events may also affect the Brazilian energy grid, strongly dependent on water availability, which may require changes in the mix of energy sources, with possible consequences on generation and investment costs, as well as GHG emissions.

### KEY IMPACTS' ASSESSMENT

According to the chain of impacts and the impacts observed on national water security, this assessment considered "key impacts":

- change in the availability and quality of water resources; and
- variation in the occurrences of extreme events of hydrometeorological origin.

#### METHODOLOGICAL APPROACH

The "key impacts" were approached in a cross-sectional way, based on the Water Security Index model proposed by Gain et al. (2016).

The Water Security index hereby presented has as its main attribute to consider aspects that provide for the risks related to climate change, both in the current context and in future scenarios. To differentiate it from other indexes with the same name, but different purposes and methodological structures, the acronym ISHmc will be adopted here.

The methodological framework adopted for the analysis is presented in a summarized way in the table below.

Panel 3.1: Composition of ISHmc.

| Dimension | Weather perspective | What it seeks to evaluate (to operate Water Security) | Weight on ISHmc composition |
|---|---|---|---|
| Availability | Present and future climate and demand | whether there is sufficient water resources available. | 0.45 |
| Accessibility | Stationary | whether existing water resources, in particular drinking water and basic sanitation services, are accessible to societies and ecosystems. | 0.20 |
| Safety and Quality | Stationary | whether available and accessible resources are of good quality and what are the risk levels of floodings. | 0.20 |
| Management | Stationary | whether governance and management conditions ensure the sustainability of water resources. | 0.15 |

Each dimension is represented by an index composed of a set of indicators.

### DIMENSION - WATER AVAILABILITY

The AVAILABILITY dimension includes two integrated indicators with weighted sum, which represent scarcity and water stress.

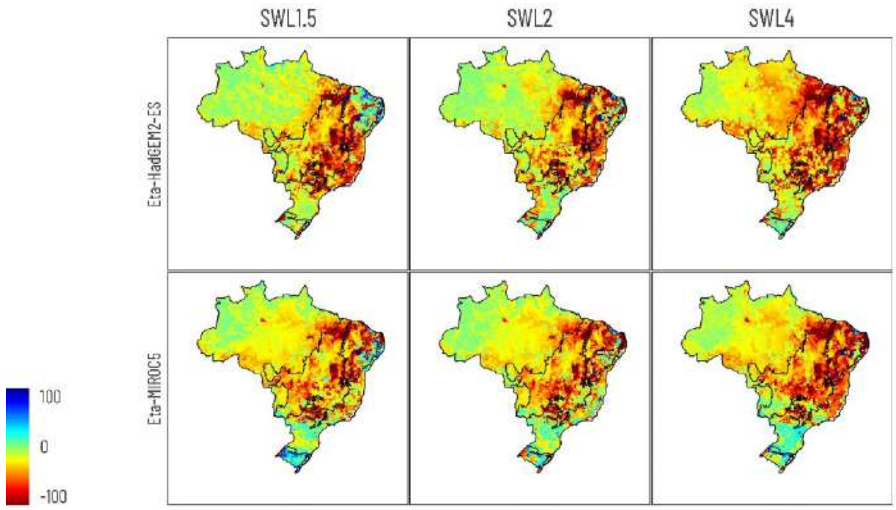
Panel 3.2: Water Availability Index Composition.

| Composition of Availability | Description | Index adopted | Weight in availability index |
|---|---|---|---|
| Water Scarcity | water scarcity when the withdrawal is greater than the supply | **WEI** - *Water Exploitation Index* | 0.70 |
| Water Stress | water stress situation occurs when there are episodes of generalized drought, associated with water crises and in agricultural losses, for example | **SPEI** - *Standardised Precipitation Evapotranspiration Index* | 0.30 |

Although groundwater exploitation is a relevant source of supply in several country regions, it was not considered in this dimension due to the absence of data in the national scale.

Availability was assessed as to the present climate (1961-1990) and three specific levels of global medium warming (SWL1.5, SWL2, and SWL4), with climate projections from two regional models - Eta-HadGEM-2ES and Eta-MIROC5.

EVOLUTION OF AVAILABILITY BETWEEN PRESENT AND FUTURE. The maps with the differences between future climate projections and present climate simulations, in percentage, for the Availability dimension are presented in Figure 3.17.




*Positive values, in cold colors, represent an improvement in availability conditions while negative values, in warm colors, indicate a decrease.

Figure 3.17. Maps on Availability Dimension with the differences between future climate projections and present climate simulations in percentage.

The Caatinga, Cerrado and Atlantic Forest biomes indicated the greatest changes, with reductions in water availability in future scenarios. An upward trend of outflows in the South is pointed out, so as a reduction in the North and Northeast, with the possibility of an increase in the frequency of flood events in the South and drought events in the North and Northeastern regions (BRASIL, 2015; Ribeiro Neto et al., 2016).

#### DIMENSION - ACCESSIBILITY

For the dimension ACCESSIBILITY, it had been used indicators regarding access to DRINKING WATER and SANITATION network, with data from the National Household Sample Survey (PNAD) from 2016, from the Brazilian Institute of Geography and Statistics (IBGE). According to the formula recommended by Gain (2016), the Accessibility index was weighted as follows:

Equation 5: Accessibility = (Drinking Water x 0.60) + (Sanitation x 0.40)

PNAD results (2016) show that more than 72.4 million Brazilians (35% of the total population of Brazil) live in homes that are not connected to sanitation networks. The low accessibility to sanitary sewage in households stands out in the Amazon, Caatinga, Cerrado, and Pantanal. However, the percentage of households with regular water supply in Brazil is high: 97.5%, with the general distribution network being the main source of supply.

#### DIMENSION - SAFETY AND QUALITY

In the SAFETY AND QUALITY dimension, indicators were used for VULNERABILITY TO FLOODS and WATER QUALITY, with spatialization of data on the municipal scale. According to the formula recommended by Gain (2016), the Accessibility index was weighted as follows:

Equation 6: Safety and Quality = (Safety x 0.50) + (Quality x 0.50)

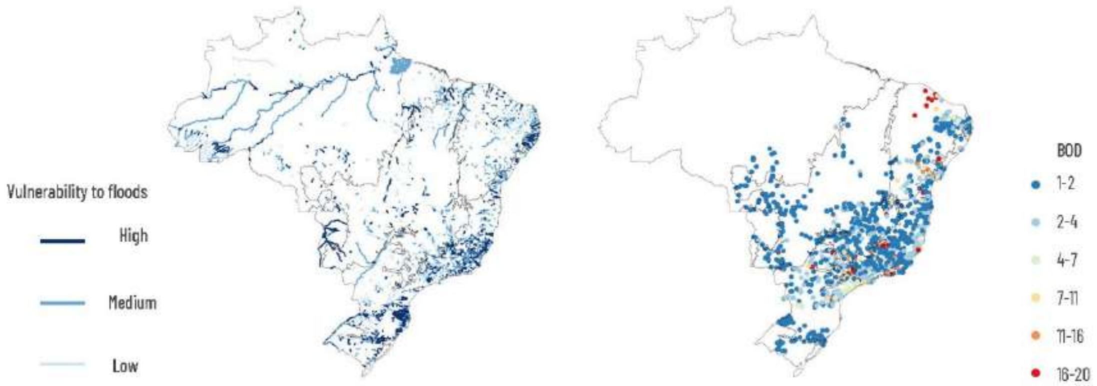



Figure 3.18. Safety and Water Quality Dimension Indicators: Vulnerability to floods and mean concentrations of Biochemical Oxygen Demand (BOD). Source: SNIRH/ANA.

By and large, within the scope of Safety and Quality dimension, the Amazon and Caatinga biomes presented the worst conditions on average. The Amazon is vulnerable to extreme floods, while the Caatinga has low water quality in its dams. The Atlantic Forest presented the best safety conditions, although it presents specific problems of water quality in urban centers.

#### DIMENSION - MANAGEMENT

The Management dimension, translated as the institutional capability to deal with conflicts over water use, was represented by the situation of the state water resources plans (PERH), by the existence of state, interstate, and unified watershed committees (CBHs), and by the water quality monitoring network indicated by the DBO parameter. Although the existence of plans and committees does not guarantee an effective management of water resources, they are its fundamental basis. Similarly, if there is monitoring, it is considered that the region has capability/information to deal with conflicts.

The integration of the Management dimension followed the formula of Equation 7:

Equation 7: Management = (Committees x 0.50) + (PERH x 0.30) + (Monitoring x 0.20)

In relation to PERHs and CBHs, the Caatinga, Pampa and Atlantic Forest biomes, although still presenting their management challenges, have the minimum requirements to move on with their priority agendas. On the other hand, the Amazon, Pantanal and Cerrado biomes are still evolving to develop these instruments, in a situation of greater fragility.

### ISHmc (Availability, Accessibility, Safety and Quality, and Management)

Figure 3.19 presents the results of each ISHmc dimension by biome (median) for the present, considering the availability dimension simulated by data from the Eta-HADGEM2-ES model.

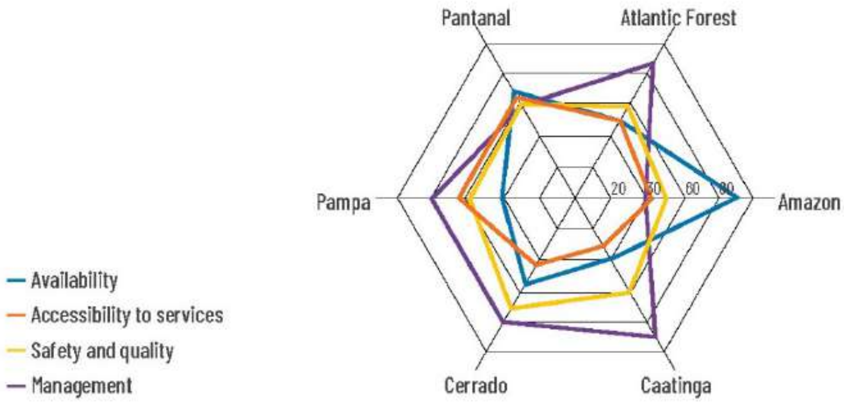
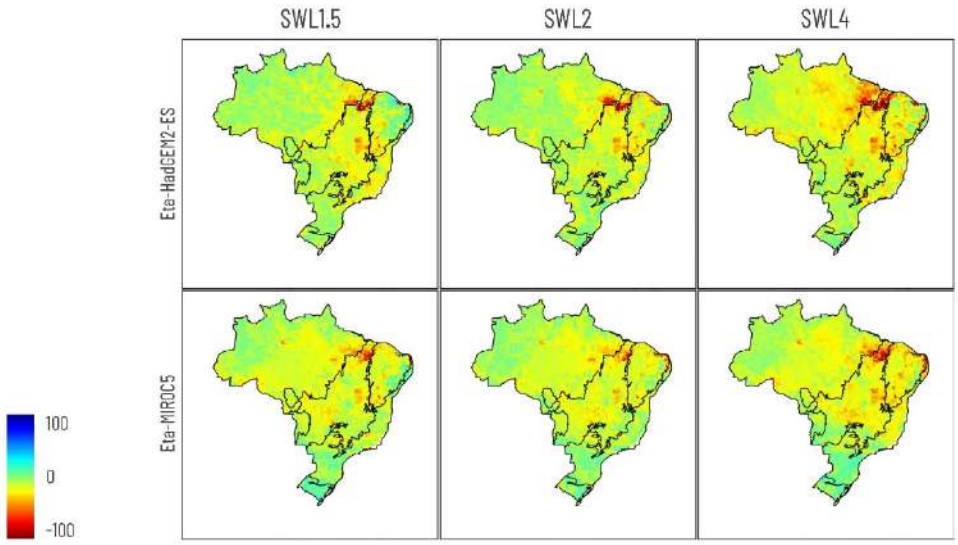



Figure 3.19. Median of each ISHmc dimension for each biome, the availability is simulated by Eta-HADGEM 2-ES model (Eta-MIROC5 model has shown a similar result) for the present climate (1961-1990).

Except Amazon and Pantanal, the results point that the current situation of Availability, if we consider the incidence of droughts and water exploitation levels, is no longer abundant but alert in relation to the use of water resources, with more critical results for Caatinga and Pampa.

Regarding the Accessibility dimension, the Caatinga, the Cerrado, and the Amazon presented the worst scores, with the Atlantic Forest having also a low value. Regarding Safety and Quality, there is no significant difference among biomes, with a value slightly lower than the others in the Amazon, but all with a condition of vulnerability in this dimension. And in relation to Management, the Amazon has proved to be the biome with more weaknesses.

Figure 3.20 shows more accurately the relative variations of ISHmc between each future climate scenario and the present climate.




*Positive values, in cold colors, represent an improvement in water security conditions while the negative values, in warm colors, indicate a decrease.

Figure 3.20. Maps with the differences between ISHmc projections for future climate scenarios and present climate simulations in percentage.

Except Pampa and western Amazonia, for other biomes all scenarios point to a situation of worsened water security. However, the scope of the changes and their intensity vary according to scenarios.

The Caatinga had the lowest water security values for present and future climate scenarios, while the Atlantic Forest and the Amazon had higher mean values for these scenarios, but with a worsening trend. In the Atlantic Forest, there are specific low security areas, but not less relevant, since they are large metropolitan centers. In the Caatinga, Cerrado and eastern Amazon, in general, the worst water security conditions were observed for future climate (Figure 3.20).

It is important to highlight that the Atlantic Forest, the Caatinga and the Cerrado biomes altogether are home to approximately 170 million inhabitants (IBGE, 2010). According to the 2010 Census (IBGE, 2010), Caatinga is home to approximately 8 million rural populations, the Cerrado has 4.2 million and the Amazon has 4.5 million. In total, there are approximately 16.7 million people in rural areas who may have their water security reduced and be directly impacted by climate change in Brazil.

*BOX 3.5:* Brazilian Water Security Index from the National Water Security Plan.

Once again, the ISHmc has a long-term perspective, relating to aspects of vulnerability and exposure in the context of climate change, as brought in the item methodology. Other water safety indexes were elaborated from different methodologies to meet different purposes, so as to the one produced within the scope of the National Water Security Plan (PNSH).

The Water Safety Index (ISH) was conceived under the National Water Security Plan (PNSH), published by National Water Agency (ANA), in 2019, with the objective of establishing water security levels across the national territory. The index was created to portray with simplicity and clarity the different dimensions of water security, and it incorporates the concept of risk to water uses. From an objective metric in space and time, it may be systematically updated and applied across the national territory.

The concepts involved in the ISH composition were structured according to dimensions (Human, Economic, Ecosystem and Resilience), indicators, variables or attributes. The innovative ISH methodology was developed with data from several preexisting studies from ANA and the related bodies, applied on a high degree of detail and scale (ottobacias). The ottobasins are subdivisions of the hydrographic basins in smaller areas (around 5 km²), carried out according to the methodology developed by ANA, based on Otto Pfastetter's method of coding watercourses. The four aggregate dimensions make up the WSI, represented in Figure 3.21

below.

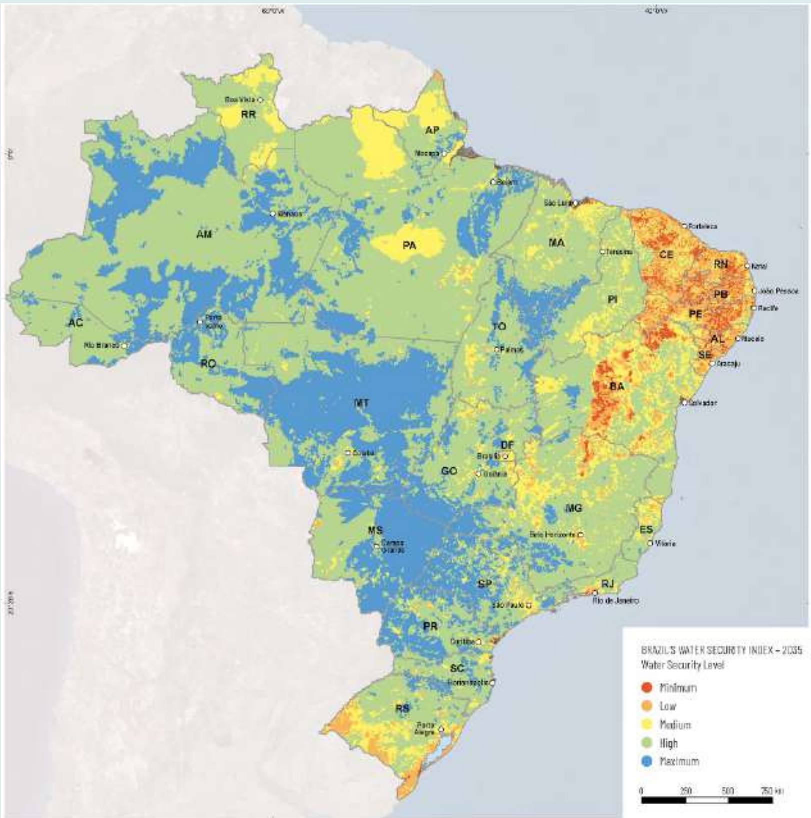



Figure 3.21. Map on Water Security Degree designed for 2035- represented by WSI. Source: ANA (2019).

In 2035, areas with lower water safety in the Northeast are predominant, with an impact of the semi-arid climate, characterized by zero water availability in most of the time (intermittent watercourses) and great inter- and intra-annual rainfall variability, with reflections on the indicators of ecosystem and resilience dimensions. In the southern half of Rio Grande do Sul, the high pressure on available water resources and the low water security index derive from the historical soil occupation by rice crops irrigated using flood method, associated with great rainfall variability. In the case of metropolitan regions, low water security is the result of the significant demands of large urban clusters, in addition to poor water quality, mainly polluted by domestic sewage without the appropriate treatment. In regions with higher water security, WSI result stems from greater natural water availability combined with a small pressure of demands, which reflects in all dimensions. It is also worth mentioning the relative importance of reservoirs, which bring greater resilience to their areas of influence to extreme drought events, increasing water security on these regions.

### 3.4.3 Main Results in Water Security

The results indicate special features on the impacts and vulnerabilities related to water security for each Brazilian biome, from an integrated view of the four ISHmc dimensions.

The Amazon has high water availability, but has low evaluation in the other dimensions of the ISHmc. There are infrastructure deficits and basic sanitation services, with basic instruments for water resource management, state plans and watershed committees still in early development or absent. There is also incipience of water quality monitoring points. This context reveals a fragile situation of regional governance yet to learn and deal with the impacts of extreme drought and flood events that occur frequently. Future climate scenarios indicate reduced outflows and increased extreme drought and flood events. Thus, the region can become even more vulnerable, considering socioeconomic pressures such as the current infrastructure deficit, basic sanitation and monitoring points, as well as deforestation, the presence of a population in poverty and traditional people.

In Cerrado, the relationship between supply and demand is currently alert, since there are regions with intense water withdrawals for irrigation. In the Accessibility dimension, the limited coverage of sewage services, especially rural sanitation, and groundwater contamination were considered as the greatest weaknesses in the current context. Future scenarios point to a reduction in outflows, showing that current risks can be amplified, due to agricultural expansion based on irrigation, associated with the lack of sanitation and control over water quality and sources of diffuse pollution, especially in rural areas, as well as losses in biodiversity.

The Caatinga presented the worst current situation in Availability dimension, with many regions in which water scarcity is critical. This situation occurs, in part, due to its natural condition of water deficit, with seasonality of rainfall regime marked by long and severe droughts that result in rivers with intermittent regimes. The other part is justified by the intense water withdrawal by large urban centers and irrigated agriculture centers. Although it presents the best situation in relation to the Management dimension, with the presence of well-established management instruments, water crises have been recurrent in the region. Future scenarios indicate a reduction in outflows and an increase in extreme drought events and, considering socioeconomic pressures, such as the current infrastructure and basic sanitation deficit, associated with the presence of a population in poverty and family farming, the region may become even more vulnerable in relation to the quality and quantity of water.

The Atlantic Forest has shown better water security conditions compared to other biomes. However, in its large metropolitan centers, water exploration is considered critical. Despite presenting more robust and established management instruments, accessibility, safety and water quality conditions are still limited and well below worldwide averages. Future climate scenarios indicate reduced outflows and increased extreme drought and flood events. Such events place the biome in a situation of vulnerability, when associated with socioeconomic pressures such as social inequality; poor infrastructure, particularly drainage; irregular occupations; high levels of production and consumption.. Situations of undersupply, increases in flood and landslide episodes and waterborne diseases, as well as crop losses, can be aggravated in climate change scenarios.

Pantanal even though it has high water availability nowadays, is currently in state of alert because there are deficits in infrastructure, basic sanitation services, and in water quality monitoring and control. Moreover, the basic instruments for the management of water resources, state plans and watershed committees are still in their early development. This reveals a fragile situation of regional governance to deal with the extreme events of droughts. The limited accessibility condition to sewage services, especially rural sanitation, control of diffuse pollution sources, and the resulting groundwater contamination were considered the greatest vulnerabilities in the current context. Future scenarios indicate increased episodes of exceptional droughts that may cause considerable changes in flood pulses, so that current risks can be amplified and the region could become even more vulnerable to diffuse pollution, groundwater contamination, and biodiversity loss.

The Pampa presented high water availability for the current context, accessibility to basic sanitation services above the average of other biomes and well-established water resource management instruments. However, socioeconomic pressures, such as the increasing demand for water for agricultural production, especially for the production of irrigated rice, indicate weaknesses, also associated with the control of sources of diffuse pollution and groundwater contamination. Future scenarios indicate an increase in extreme events of droughts and floods, and show that impacts related to changes in water quality, such as conflicts due to multiple water use and biodiversity losses can be amplified.

The Coastal Zones were identified as susceptible to sea level rise. According to the Brazilian Panel on Climate Change (PBMC, 2014), this part of the territory has been affected by erosions and coastal floods. Losses of goods, restriction of services, reduction of habitable spaces, marine intrusion and loss of biodiversity and fishing production are some examples of the associated impacts. There may also be changes in water quality due to saturation and salinization of the basins that flow into the coast. The most affected regions are the states of Rio de Janeiro and São Paulo (Alfredini et al., 2013; Harari; France; Camargo, 2007; Marengo et al., 2018c). Major cities can be considered vulnerable to rising sea levels that, along with stronger storms and winds, may cause damages to the population and the economy.

## 3.5 Energy Security

### 3.5.1 Context

#### Conceptualization

Access to modern energy sources allows gains in mobility, productivity, greater access to information and education, poverty reduction and longer leisure time, among other benefits, what contributes to improvements in life quality and sustainable development (IEA and BM, 2015; UN, 2016; UN, 2018; Luo and Zhang, 2012; Reddy, 2015; Reddy et al., 2009).

Energy security can be associated with physical, technical and socioeconomic aspects (Ang et al., 2015; Månsson et al., 2014; Winzer, 2012), as shown below.

- Physical: refer to the energy endowments of a country or region, quantitatively, qualitatively, and in terms of diversification (Pimentel, 2006; Ranjan and Hughes, 2014).
- Technical: refer to system robustness against interruptions in the energy supply associated with infrastructure failures (transmission networks, pipelines, power plants, refineries, etc.) (Anifowose et al., 2012; Sovacool, 2012).
- Socioeconomic: the extent in which the economic structure depends on specific energy services to produce wealth indicates its vulnerability (Jewell et al., 2014; Reddy, 2015).

Some characteristics of energy security do not depend directly on economic conditions, for example, the natural availability of resources, the impacts of accidents or climatic crises and natural disasters, particularly relevant for developing countries (Moreira and Esparta, 2006; Stadelmann and Castro, 2014; Suzuki, 2015). Political and institutional uncertainties can also represent relevant risks to energy security in some regions, which makes it difficult, for example, to transfer and diffuse renewable energy technologies in developing countries (Boldt et al., 2012; Haselip et al., 2011).

Energy security will be addressed in the context of guaranteeing the supply of energy services, with minimization of interruptions, at an affordable price within an energy system and market that operate with efficiency, sustainability, that are sufficiently flexible and prepared to deal with climate change, including sudden and extreme events of any nature or duration.

#### Relevance of Energy Security for the Country and for Adaptation

Strong presence of renewables in the country's electrical grid. Renewable sources represented 83.3% of the country's domestic electricity supply in 2018. The installed capacity of hydraulic energy is 104,139 MW, corresponding to 66.6% of the total supply (EPE, 2019), with 281 hydroelectric power plants (HPPs), 427 small hydroelectric plants (SHPs), and 693 hydroelectric generating plants (HGPs) (ANEEL, 2018a).

The growth of wind, solar and thermoelectric energy to biomass has been contributing so that the electric grid remains renewable for the most part (EPE, 2017). Despite the fact that wind energy represents 8% from the electric generation in 2018, the use of that source has shown significant increase, with 14,390 MW installed capacity, 14.4% more than in the previous year. It is therefore positioned as the third source in the country, behind only hydraulics and biomass (EPE, 2019), and with high potential in the Northeast and South regions.

Solar Energy Potential. It is a renewable source with great potential in Brazil, both for thermal use and for the generation of electric power by means of heliothermic[12] or photovoltaic. Resource availability is greatest in the Northeast, followed by the

[12] *Heliothermic energy is based on the process of using and accumulating heat from the sun's rays using concentrators. The concentrated solar energy is produced with the help of several mirrors to heat the water, which will be transformed into steam that will spin a turbine to generate electricity.*

Midwest and Southeast. Photovoltaic energy can either be connected to the Brazilian Interconnected System (SIN), with an installed capacity of 1,798 MW in 2018, mostly in the Northeast followed by the Southeast; or be a distributed generation source, with installed micro and mini generation capacity of 526.3 MW (EPE, 2019).

THE HIGH RELEVANCE OF BIOENERGY IN BRAZIL. The country is the second largest ethanol and biodiesel producer worldwide, with large-scale production as vehicular fuel and the generation of bioelectricity for SIN, from surplus sugarcane bagasse in distilleries (USDA, 2018; Goldemberg; Coelho; Guardabassi, 2008; Horta Nogueira et al*.,* 2013). The largest sugarcane production is located in the Central-South region[13], which produced 93% of national ethanol in the average of the harvests from 2014 to 2018, 49% in the state of São Paulo (UNICA, 2019). Soybeans, the main raw material for biodiesel manufactured in Brazil, are mainly planted in the states of Mato Grosso, Paraná and Rio Grande do Sul, which accounted for 28%, 18% and 16% of the production amount in Brazil, respectively; on the average of the years 2013 and 2018 (IBGE, 2019). Biodiesel in Brazil is produced exclusively for domestic demand, considering the minimum mandatory blend percentage in diesel for diesel oil B[14].

USER SECTORS FROM PRIMARY AND SECONDARY ENERGY. Total primary energy consumption in Brazil was 255.7 Mtoe in 2018. From these, 32.7% corresponded to the transport sector and 31.7% to industrial use. Energy consumption in the transport sector is mainly due to diesel oil (43.6% of the total consumed) and gasoline (25.8% of the total consumed), due to the road transport of cargo and passengers. Renewable sources reached 23% of the total energy consumed in the sector in 2018 - ethanol with 18.8% and biodiesel with 4.4% (EPE, 2019).

Regarding electricity, the total supply in Brazil in 2018 was 636.4 TWh, with the industrial, residential and commercial sectors being the predominant consumers, corresponding respectively to 37.5%, 25.4%, and 16.9% from the electricity demand that year (EPE, 2019).

THE ENERGY TRANSPORT SECTOR mainly comprises SIN's electricity transmission and distribution networks, which support around 96% of the country's electricity production capacity by connecting, through its four subsystems, the regions South, Southeast, Midwest, Northeast and part of the North region (ANEEL, 2005), in addition to oil and gas pipelines.

THE BRAZILIAN INTERCONNECTED SYSTEM (SIN) BRINGS OPERATIONAL ADVANTAGES AND SECURITY. The interconnection of electrical systems through the transmission grid allows energy transfer between subsystems, allows the achievement of synergistic gains, and explores the diversity between the hydrological regimes of the basins (ONS, 2019). The operation of the SIN is centralized by the National Electric System Operator (ONS).

With the predominance of hydroelectric plants in the SIN, the operational system management is directly dependent on the rainfall regime of the different hydrographic regions. These regions, due to their distinct wet and dry periods, end up complementing each other, since the energy generated in a region with an abundance of water can be redirected to drier regions in a given period.

With generation capacity still reduced in Brazil, the micro and mini-distributed generation have been growing, both in terms of installed power and in the number of consumer units that produce their own energy.

Thermoelectric plants located in the vicinity of the main cargo centers play a strategic role for the safety of the SIN. These plants are activated (or dispatched) depending on the hydrological conditions in force, and allow the management of water stocks in the reservoirs of hydroelectric plants to ensure future service (ONS, 2019), but generate increased costs generation due to the fuels used, in addition to GHG emissions.

CLIMATE CHANGE CAN BE ESPECIALLY CHALLENGING FOR BRAZIL given the high share of renewable sources in its grid (Arroyo, 2018; Jong et al*.,* 2019; Lucena et al*.,*2018; Paredes et al*.,* 2017). Some characteristics of the Brazilian Electric System are directly related to the effects of climate change. The country's continental dimension implies transmission systems on a large scale and between regions, therefore, more susceptible to climate factors. The need for compatibility

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*[13] Geoeconomic regionalization of Brazil, formed by the South, Southeast regions (with the exception of the north of Minas Gerais Gerais) and Midwest (except for northern Mato Grosso)*

*[14] Federal Law nº 13,033 / 2014.*

between different supply capacities and demand profiles can be aggravated in a scenario of more intense climate variability. Likewise, the high participation of hydroelectric sources makes the system dependent on the capacity to regulate the reservoirs, and therefore vulnerable to changes in precipitation patterns. Finally, the high investment and construction time of most of the construction works undertaken by the system place greater weight on the present decisions and provide less flexibility in the face of future conditions.

## Governance in energy security

### Policy and plans

The National Energy Policy, instituted by Law No. 9,478 / 1997, establishes the guidelines for managing and exploiting energy resources (BRASIL, 1997). Among the key institutions of the Brazilian energy system are the Office of the Chief of Staff , the Ministry of Mines and Energy (MME) and the National Energy Policy Council (CNPE). This advises the Presidency of the Republic regarding the guidelines and policies for the energy sector (Schaeffer et al., 2015), while the MME focuses on the implementation of energy policies (BRAZIL, 1997). MME is assisted by the Energy Research Office (EPE), which supports energy planning through studies and research.

Two basic documents guide the sector's decisions: Ten-Year Energy Plan (PDE), which indicates projections of energy expansion in the medium term and serves as the basis for energy auctions and contracting for expansion to the free market; and the National Energy Plan (PNE 2030), which focuses on the long term by exposing trends for the expansion of the energy system, projection of energy demand, among other objectives (EPE, 2007).

### Renewable Energy Programs

Brazil has a long experience in the formulation of public policies related to the energy sector, such as the National Alcohol Program (Proálcool), which promoted ethyl alcohol domestically produced as a vehicle fuel in substitution for imported gasoline (Goldemberg ; Coelho; Guardabassi, 2008), and the National Biodiesel Use and Production Program (PNPB) which forced the entry of biodiesel into the country's energy grid through minimum percentages of mixing with diesel oil - Law No. 11,097 / 2005 (MME, 2018).

Policies for large-scale electricity generation began in the 1960s, a period in which large hydroelectric plants with reservoirs were built, which correspond to a large part of the installed capacity in Brazil and are the basis of the SIN (Schaeffer et al., 2015).

The Program of Incentives for Alternative Electricity Sources (Proinfa), oriented to renewable sources, aimed in the first phase (2004-2008) to implement 3.3 GW of generation capacity from wind, solar sources and biomass. In its second phase, it intends to reach 10% of alternative energies in the national electricity grid by 2026; however, the targets were replaced by the alternative energy auction system after the reform of the electricity sector, which occurred in 2003 (Schaeffer et al., 2015).

> The system for contracting energy through auctions follows the lowest tariff criterion. There have been three exclusive auctions for contracting alternative energy sources (SHPs, biomass and wind), in 2007, 2010, and 2015. In the first two, most of the contracted energy came from wind farms, in 2015 thermoelectric plants existing biomass accounted for most (Schaeffer et al., 2015; CCEE, 2015).

Recently, the RenovaBio program guidelines were launched, which proposes the creation of a national biofuel policy with the aim of promoting its expansion, thus ensuring predictability for the biofuel market, as well as contributing to reductions in the emission of greenhouse gases (BRASIL, 2017).

## 3.5.2 Impacts and Vulnerabilities in energy security

**IMPACT CHAIN**

The energy sector is highly susceptible to impacts arising from climate changes, extreme events and socioeconomic aspects, both on the supply side (in the energy chain, primary energy, production and transformation stages), as well as on the transport and demand (Arnell et al*.,* 2005; Bull et al*.,* 2007; Schaeffer et al*.,* 2008; Lucena et al., 2010; Lucena et al. 2018; Schaeffer et al., 2012).

Climate variations and socioeconomic aspects in the chain. Energy security can be affected by factors that change interactions in energy chains, which can be climate or non-climate based.

- Climate-based: the exposure of an energy system to the impacts of climate changes and variations depends on its setting, that is, the set of resources used and technological options, and the magnitude of climate element variation (Lucena et al*.,* 2008).
- Non-climate-based: socioeconomic and technological pressure factors can affect the energy grid setting, with an effect on the vulnerability and exposure of the energy system. These factors can also affect access to energy sources and the provision of energy services, which puts the development and improvement of the population's quality of life at risk (Luo and Zhang, 2012; Reddy, 2015; Reddy et al., 2009).

Socioeconomic factors also influence the variation in energy demand due to population growth; the variation in GDP and economic activities; and people's consumption and behavioral patterns. In addition, energy demand depends on the energy efficiency of each type of technology used in different economic sectors (industry, agriculture, mining, among others).

Changes in the flow regime or rainfall seasonality generate risks to the hydroelectric system, which largely depend on water storage capacity in the plants' reservoirs (Schaeffer et al., 2012). However, due to environmental factors and other water use needs, there is a tendency that the use of the remaining hydroelectric potential is increasingly based on run-of-river plants, with small reservoirs, which reduces the water system's capacity in compensating climatic variations, making it more vulnerable.

Furthermore, as hydroelectric power plant reservoirs can provide other non-energy services, such as flood control and storage for periods of drought, the decrease in affluent natural outflow and the consequent reduction in the level of the reservoirs affect both hydroelectric generation and multiple uses of this water source. New installations of hydroelectric plants with reservoirs, in turn, can significantly change dams' water downstream availability, in addition to impacting other consumptive water users, and cause changes in land use.

Mix of Sources. The diversity of the electrical grid at SIN makes it possible to compensate for climate impacts on electrical generation between different sources. According to the National Climate Change Adaptation Plan (PNA), this compensation endows the electrical system with an intrinsic adaptation capacity, the so-called Adaptive Capacity (BRAZIL, 2016b). However, the possible variation in generation costs and GHG emissions must be considered.

The wind regime defines the potential of wind generation (Lucena et al., 2009). Wind speed varies significantly with height, soil cover type, and vegetation. Climate change can have an impact on wind potential, as changes in the natural hourly, daily or seasonal wind speed variability have a significant impact on the energy produced from wind turbines (Schaeffer et al., 2012).

The presence of clouds and the variation in temperature have an impact on the amount of solar radiation available for the generation of photovoltaic and heliothermic energy (Bull et al*.,* 2007). An increase in air temperature and humidity and cloudiness reduces the efficiency of solar panels for energy production.

OPPORTUNITIES. The increased availability of solar energy for photovoltaic generation in the Atlantic Forest, Cerrado and Amazon biomes can benefit access to energy in remote areas. In addition, it influences the generation of jobs and income and technological training.

The increase in the frequency of extreme weather events impacts both the production and the harvest of ENERGY CROPS. Climatic factors include heat waves, the intensification of Indian summer (periods with low humidity and high temperatures outside the season), extreme events.

DIRECT IMPACTS ON ENERGY INFRASTRUCTURE. The infrastructure of energy production facilities (thermoelectric plants, oil refining plants, distilleries, etc.), and transportation systems (transmission lines, gas pipelines, among others) and electricity distribution systems may be impacted by landslides, floods, cyclones, forest fires and increased temperatures, with damage to network assets, blackouts and the need for greater investment in maintenance and repair; aside from possible failures in electric power transformers (Schaeffer et al., 2012; IPCC, 2014; ANEEL, 2018d).

IMPACTS ON ENERGY DEMAND. Energy demand can be affected by climate change. Higher air temperatures imply greater demand for cooling (thermal comfort). In addition, temperature variation can influence the transport sector by changing the performance of combustion engines. The variation in temperatures and precipitation can generate water stress and influence other sectors, such as agriculture and livestock due to the greater demand for electricity for pumping in irrigation. And yet, the energy and industrial sector may require greater withdrawal of water and electricity for processes such as cooling (Schaeffer et al., 2012).

The possible variation in air temperature in the coming years may influence the balance of energy demand patterns for heating and cooling in different sectors, such as residential, commercial, service and public buildings, transport and industries (IEA, 2019). These physical effects have direct implications for the reliability of the energy supply, in addition to increasing costs and environmental impacts. According to IEA (2019), the trend in the coming years is that the continued population growth, the development of emerging economies and climate change will lead to a greater demand for heating and cooling in environments

IMPLICATIONS OF THE NEED FOR GREATER SUPPLY. In the Cerrado and Atlantic Forest biomes, the greatest demand for energy due to population density and the industrial sector is concentrated. Thus, these biomes would be the most vulnerable in the event of fluctuations in energy supply. An increase in demand due to climate change (e. g. temperature) and other factors may imply an increase in electricity generation, pollutant emissions and generation costs.

ECONOMIC IMPACTS. Other possible impacts are the increase in electricity generation costs, due to investments to install new electrical plants (from other energy sources) and new transmission and distribution networks, which in turn affect the population and all economic sectors through a raise in the final price of electricity.

### KEY IMPACTS' ASSESSMENT

According to the chain of impacts on the Brazilian energy system, the following "key impacts" were assessed:

- change in the supply of hydroelectric generation and impact on the electric grid;
- changes in the availability of wind and solar energy resources;
- effects on the complementarity of sources for electricity generation with renewable sources (water, solar and wind resources);
- change in biofuels' supply; and
- change in energy demand from the point of view of maintaining thermal comfort in the face of increased temperatures.

Fossil sources were not assessed in detail for three reasons: the vulnerability of these sources to climate impacts is less (Schaeffer et al., 2012); the share of renewable sources in the Brazilian energy mix is very high; the assessment was carried out under the premise of meeting the goals proposed by the Brazilian NDC, in which the participation of renewable sources should be maintained.

CHANGE IN THE SUPPLY OF HYDROELECTRIC GENERATION AND IMPACT ON THE ELECTRIC GRID;

### METHODOLOGICAL APPROACH

PROJECTION OF HPPS AFFLUENT OUTFLOWS. To assess the change in hydroelectric power supply, we used surface runoff variation results, processed by Ribeiro et al. (2016) in Eta-HadGEM2-ES and Eta-MIROC5 climate models, and SWL2 and SWL4 heating scenarios compared to a base scenario.

SIMULATION OF THE VARIATION OF HYDROELECTRIC GENERATION (AFFLUENT NATURAL ENERGY). Affluent outflows already adjusted were used as input data for Computational Investment Decision Model (MDI), with the goal of simulating the supply of energy demand for a given period at a minimum cost of expansion, considering technical and economic restrictions. This modeling is used to predict the variation of hydroelectric generation in the SIN, represented in Affluent Natural Energy (ANE) (MWmed), in climate change scenarios.

The expansion cost consists of the investment cost plus operation and maintenance costs. It is used in the Energy Research Company's Ten-Year Energy Plan and in PDE 2026 and PDE 2027 (EPE, 2017 and 2018).

NEW ELECTRIC GENERATION MIX ASSESSMENT. ANE's variation in MDI leads to a new mix of installed capacity in the expansion of the electric supply. Thus, it is possible to assess how the impacts of climate change on hydroelectric generation - which accounted for 65% of the SIN's electric generation in 2018 (ONS, 2019) - can influence the expansion of the electrical grid, the variation in the cost of the electrical system and GHG emissions in each proposed scenario[15]. The assumptions and restrictions assumed in the modeling follow PDE 2026 (EPE, 2017), considered as Reference Expansion Scenario (REF), with some particular considerations[16] .

### RESULTS FOR AFFLUENT NATURAL ENERGY (ANE)

ANE's results on Reference Expansion Scenario (REF) (taken from PDE 2026) indicate that the Southeast / Midwest (SE / CO) subsystem has the largest amount of energy (43%), followed by South (S) (28%), North (N) (17%) and Northeast (NE) (12%) subsystems. Thus, possible climate impacts, mainly in the SE / CO subsystem, could influence hydroelectric generation transfer to other subsystems, or generate a new distribution of the mix of sources of electrical generation.

CAPACITY DECREASE IN ALL SCENARIOS. SIN analyses show that, starting from ANE, there is a decrease in the hydroelectric generation capacity for all SWL scenarios compared to the REF scenario. According to the Eta-HadGEM2-ES model, the impact is more significant, with a reduction that varies between 27% and 41%. The Eta-MIROC5 model, on the other hand, has a reduction in hydroelectric generation potential between 6% and 10%. Figure 3.22 shows the distribution of impacts on ANE in each interconnected subsystem.

*[15] The ideal expansion plan considers cost, location, seasonal generation, reliability of each energy source, and new plants' projects.*

*[16] (i) The expansion of sugarcane biomass is limited to a maximum of 500 MW / year, from 2021, and forest biomass to 100 MW / year from 2023, due to the limitations imposed by the offer of raw material; (ii) there is no restriction on the expansion of wind and solar plants, as occurs in the PDE; (iii) the power contribution of hydroelectric projects is estimated from the ANEs calculated in this study; (iv) new coal-fired thermoelectric plants can only be installed from 2029, according to MME / EPE (2017); (v) Indication of an uniform expansion (whose amount was optimized by the MDI) of wind supply between the Northeast and South regions from 2021, with 80% allocated in the Northeast and 20% in the South (MME / EPE 2017).*


Figure 3.22. Variation in Affluent Natural Energy for each heating scenario, in relation to the Reference Scenario.

#### RESULTS FOR CHANGES IN THE MIX OF SOURCES OF ELECTRICAL GENERATION

The electrical grid in the REF scenario (based on the PDE 2026 expansion prospects, as mentioned above) has an installed capacity distributed between 46% hydroelectric, 17% wind, 12% natural gas, 9% biomass, 8% mineral coal, 5 % solar, 3% oil products and 1% nuclear. The total additional capacity to be contracted in the REF Scenario is approximately 94 GW, whereby around 30% comes from wind power, 17.7% mineral coal, 17.3% natural gas, 12.6% biomass, 12% represents hydroelectric expansion, and 10.7% solar.

The heating scenarios influence the expansion of hydroelectric generation, and the entire mix of sources of electrical generation therewith. Figure 3.23 shows the total distribution of the electrical grid (in terms of installed capacity) in the REF scenario and in each simulated heating scenario with the support of climate models.

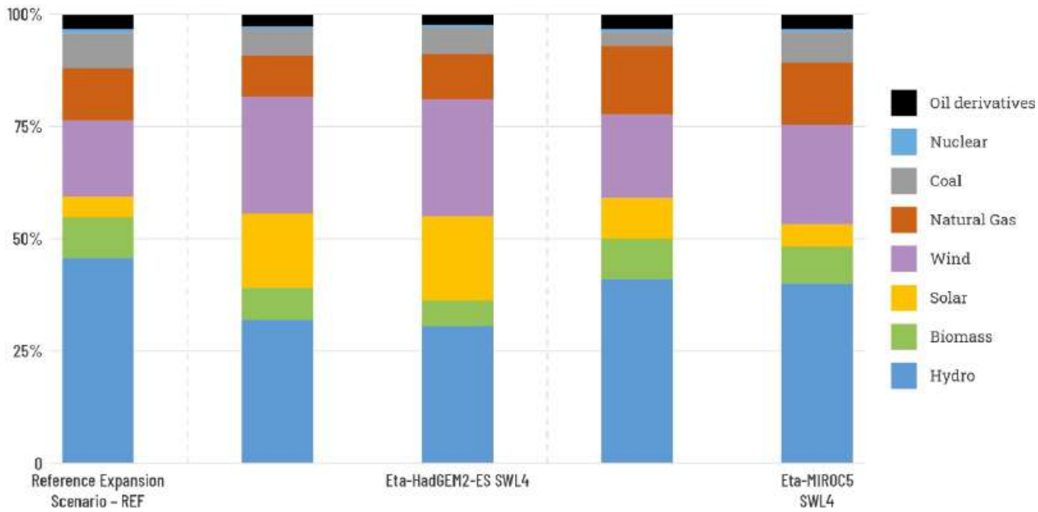



Figure 3.23. Expansion of the Brazilian electrical grid in the reference expansion scenario (REF) and in the SWL2 and SWL4 for the Eta-HadGEM2-ES and Eta-MIROC5 climate models.

#### VARIATION IN GHG COSTS AND EMISSIONS IN THE NEW PROJECTED MIX

The increased installed capacity from different energy sources in heating scenarios generates an increase in marginal expansion cost (Figure 3.24). These costs are directly linked to ANE, as the model opts for more expensive alternatives than hydroelectric to compensate for energy loss. Thus, in SWL4, where ANE has suffered the greatest reduction, costs are higher. In addition, the increase in the share of renewable energy in the scenarios of the Eta-HadGEM2-ES model arises from high marginal energy cost, which now allows the model to choose these sources.

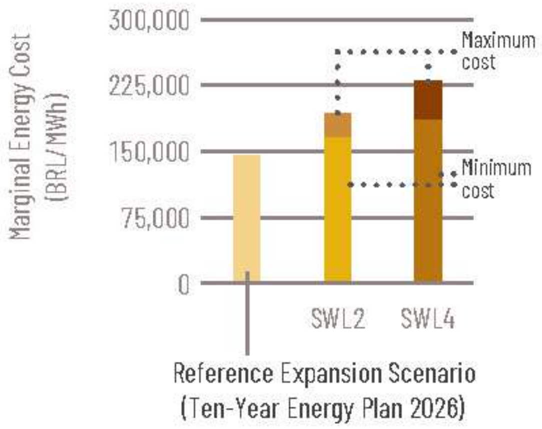



Figure 3.24. Marginal energy cost in the REF scenario and in the SWLs for the Eta-HadGEM2-ES and Eta-MIROC5 climate models.

In SWL2, despite the scenarios have greater participation in terms of installed capacity from other renewable sources in substitution to the water source, the generation of electric energy based on thermoelectric plants that use natural gas increases. In other words, there is a greater dispatch in the generation of thermoelectric plants (considering both pre-existing plants and new infrastructures). On the other hand, in SWL4, the model signals the exhaustion of cheaper generation alternatives, making more investments in wind and solar sources viable.

Regarding GHG emissions in SWL2 scenarios, despite the participation of other renewable sources in substitution to the water source, the estimated emissions are higher than in the REF scenario, due to the higher proportion of TPPs dispatch to natural gas. While in scenarios mostly impacted by climate change (SWL4), the expressive entry of intermittent renewable energy (to compensate for water loss) leads to a reduction in GHG emissions (up to 12%).

### Changes in the availability of wind and solar energy resources

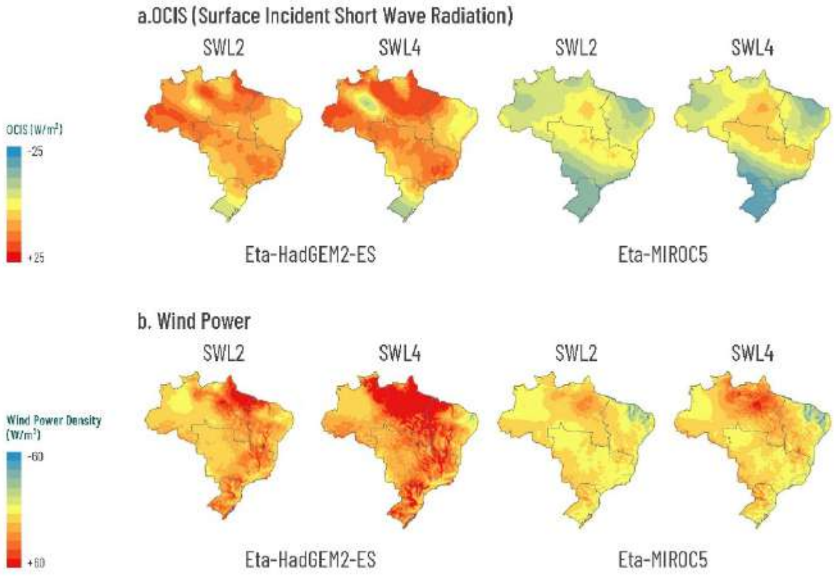
#### Methodological Approach

To analyze the impact on the availability of the solar resource for photovoltaic generation, the radiation variable of Surface Incident Shortwave Radiation (OCIS) was assessed. In the case of wind energy, the analysis was performed by means of the wind power density at a height of 100m, hereby called wind power density (wind speed cube).

These results were processed from Eta-HadGEM2-ES and Eta-MIROC5 models and SWL2 and SWL4 scenarios. The analysis was based on the absolute variation of the availability of energy resources through the annual averages.

#### Results for photovoltaic generation and wind generation

Regarding photovoltaic generation, it is observed that the Eta-MIROC5 model simulates higher OCIS radiation (222 to 329 W/m$^2$) than eta-HADGEM2-Eta-HADGEM2-ES (209 to 325 W/m$^2$). As for the density of wind potential, there is an increase in resource availability for both climate models. Figure 3.25 shows the spatialization of the results obtained.




*The maps have a spatial grid scale and have the delimitation of the SIN subsystems.

Figure 3.25. OCIS annual absolute variation results (a) and wind power density (b) between SWL2 and SWL4 and base scenario.

It is worth indicating that some areas in the states of Rio Grande do Norte and Paraíba (Caatinga biome) present a small decrease in the availability of wind resources in both scenarios of the Eta-MIROC5 model and in the SWL4 scenario of the Eta-HadGEM2-ES model. In these states, installed capacity represents approximately 54% of the country's total installed.

### Effects on the complementarity of sources for electricity generation within renewable sources (water, solar and wind resources)

#### Methodological Approach

Climate changes can change negatively or intensify the complementarity degree[17] between different generation sources in different regions/subsystems. Based on the Eta-HadGEM2-ES and Eta-MIROC5 climate models for the SWL2 and SWL4 scenarios, three complementarity relationships were assessed, including: water sources (hydro-hydro); wind and hydro (hydro-wind); and solar and hydro (hydro-solar).

From the variables: natural affluent flows, surface incidente short wave radiation (OCIS) and wind energy potential density – we verified correlations between a set of *hotspots* - i.e. points of interest - for each energy source, considering a spatial scale of biomes and a monthly time scale. the selection of hydropower hotspots considered their installed capacity and strong correlation results. In the case of the availability of solar and wind resources, a radius of 50 km was applied to define the hotspots.

Correlation between Hotspots. The positive correlation between *hotspots* means that they have availability of energy resources in similar periods and, for this reason, will be identified in this work as *hotspots* that do not complement each other in energy terms. In contrast, negative correlations are identified as *complementary* hotspots.

We identified 19 hydroelectric power *hotspots*, 15 of the solar resource, and 9 of wind energy. The Amazon, although not the biome with the highest hydroelectric use in the country, is the area that concentrates most of the *hotspot*s

[17] *Complementarity is the ability of energy sources to generate electricity in different periods and/or regions, in order to compensate for the moments of low energy production from the other sources present in the system*

(eight) of hydropower, due to the greater number of hydrographic basins and greater distinction between the behavior of natural affluent outflows of hydroelectric plants.

### Results

The Amazon and Cerrado biomes present strong complementarity between water sources in relation to the southern Atlantic Forest region. With increased warming level, the complementarity relationships increase in intensity between the Amazon and the Atlantic Forest biomes, however the opposite occurs in relation to the Cerrado and the Atlantic Forest biomes.

Regarding hydro-wind complementarity, the most significant result refers to the relationship found between the hydroelectric power *hotspot* in the Caatinga, located in the São Francisco river basin, and wind energy *hotspot*s also located in the Caatinga, in the Atlantic Forest, and in the Cerrado. The complementarity relationship between these regions is strong and does not change significantly with increased warming level in the two climate models.

Finally, the intensity of hydro-solar complementarity relationships obtained in climate models diverged. In the Eta-MIROC5 model, the results obtained were stronger in the relationship between hydroelectric plants *hotspot*s found in the Amazon and the solar ones from the same biome and in the Caatinga. On the other hand, the complementarity relationships between these two sources were not significant in the Eta-HADGEM2-ES model.

### Change in Biofuels' Supply

#### Methodological Approach

For the qualitative analysis of the impact of climate change on biodiesel and ethanol production, a review of studies on Agro-Climate Risk Zoning (ZARC) for soybean (Assad et al.,2016) and sugarcane production (Zullo et al.,2018) was carried out, assessing how the variation in the availability of agricultural resources could affect biofuel production.

Soybean and sugarcane ZARCs referring to each study (base scenario and SWLs) were overlapped with the areas of delimitation of biomes, together with the location of existing biodiesel and ethanol plants (EPE, 2019).

Assad et al. (2016) conducted simulations on the possible variation of soybean ZARC considering several factors that affect the productivity, rainfall and temperature data of the Eta-HadGEM2-ES model (RCP 8.5), for the base scenario (1961-1990), and SWL1.5, SWL2, and SWL4.

In the analysis on sugarcane performed by Zullo et al. (2018), we considered a reference scenario (1976-2005) and a projected scenario (2021–2050), based on the results of the HadGEM2-ES and MIROC5 models in RCP8.5. The ZARC modeling considered six levels of climatic risk (grouped into three risk levels: low, medium and high), based on different parameters of average annual temperature and water deficit, which will influence germination process and sugarcane production.

#### Results for Biodiesel Production (Soybean)

Projections show an upward trend of high-risk areas for soybean crops in all biomes, except Pampa, which contains areas at high risk in the base scenario (Figure 3.26).

The Cerrado biome indicates a low-risk area for soybean crops of 92% occupancy in the base scenario, but it is projected a reduction in suitable areas, with the increased heating level: 41% of areas suitable for the SWL scenario1.5; 37% for the SWL2 scenario; and 10% for the SWL4 scenario. The Atlantic Forest biome shows an occupation of 48% of low climate risk areas in the base scenario, with a projection of stronger area reduction as warming levels escalate: 5% for the SWL scenario1.5; 2% for the SWL2 scenario; and no area suitable for the SWL4 scenario. Since approximately 84% of the biodiesel plants in operation are located in the Cerrado and the Atlantic Forest, there is a probability of high impact on the supply of the main raw material currently used in biofuel production. Considering new plants in other biomes (as in Caatinga) is limited due to high climate risk for soybeans in most of this biome.

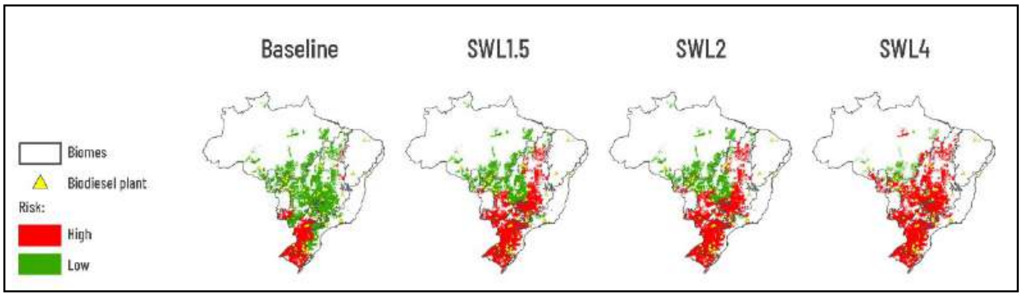



Figure 3.26. Distribution of biodiesel plants by biome and zoning of climate risk for soybean crop. Eta-HadGEM2-ES model and RCP 8.5. Source: Own elaboration based on Assad et al. 2016, IBGE, 2004 and EPE, 2019.

### Results for Ethanol Production (Sugarcane)

In the agroclimatic zoning study area from Zullo et al. (2018) there are 288 plants, distributed between the Cerrado and the Atlantic Forest biomes, representing 76% of the total plants in the country. The results show that for the 2020-2050 landscape, areas of low climate risk can be reduced from 46% (Reference scenario) to 31% and 28% in the MIROC-5 and HadGEM2-ES models, respectively. In addition, we project an increase in area occupancy with a medium risk, which means that the cultivation of sugarcane in this area will depend on irrigation.

Thus, the vulnerability of sugarcane will not only depend on weather conditions, but also on competition for water use with other users. The results show an increase in the occupation of an area with high risk for sugarcane plantation, from 18% of occupation of the study area in the reference scenario to 30% and 27% of occupation projected by HadGEM2-ES and MIROC-5, respectively (Figure 3.27).

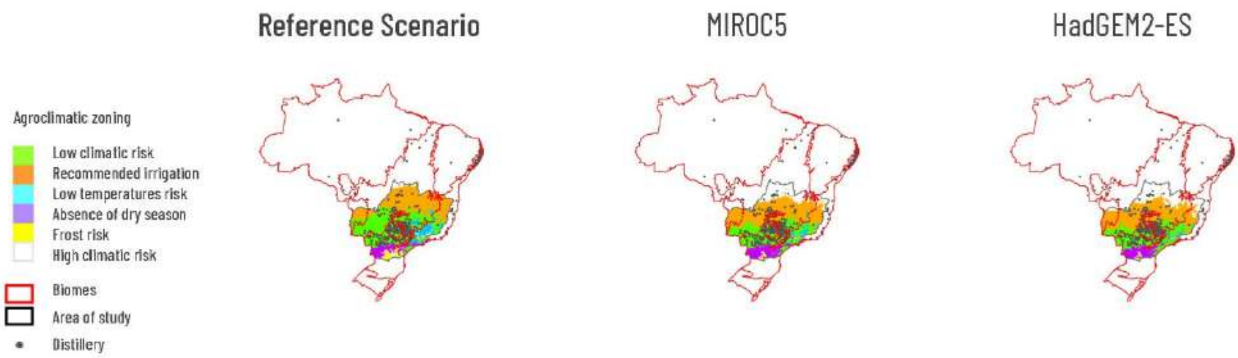



Figure 3.27. Maps with agroclimatic sugarcane zoning variations for the HadGEM2-ES and MIROC-5 and RCP 8.5 models (2020-2050). Source: Zullo et al. (2018), IBGE (2004), EPE (2019).

### Changing Energy Demand for Thermal Comfort

### Methodological Approach

To assess change in energy demand from the point of view of maintaining thermal comfort in the face of temperature increase, awe considered an increase in the use of residential cooling appliances (such as air conditioning). We adopted an indicative assessment methodology on the need for cooling, using the Indicator of Cooling Degrees Days - GDR, understood as the number of days in which the temperature of the outdoor air exceeds the comfort temperature (in which there is no need for cooling), which can be related to the variation of energy demand. For this assessment, 101 Brazilian cities with a population greater than 250,000 inhabitants were selected.

GDR is obtained by means of the annual sum of the number of days in which the average daily temperature exceeds the standard comfort temperature (assumed at 19°C, according to Atalla et al. (2018)).

### RESULTS

The GDR values found in the SWL2 and SWL4 for the cities analyzed are arranged together with their population (Figure 3.28), since the increase in the need for cooling can be translated into a greater or lower energy demand depending on the number of inhabitants of the cities[18].

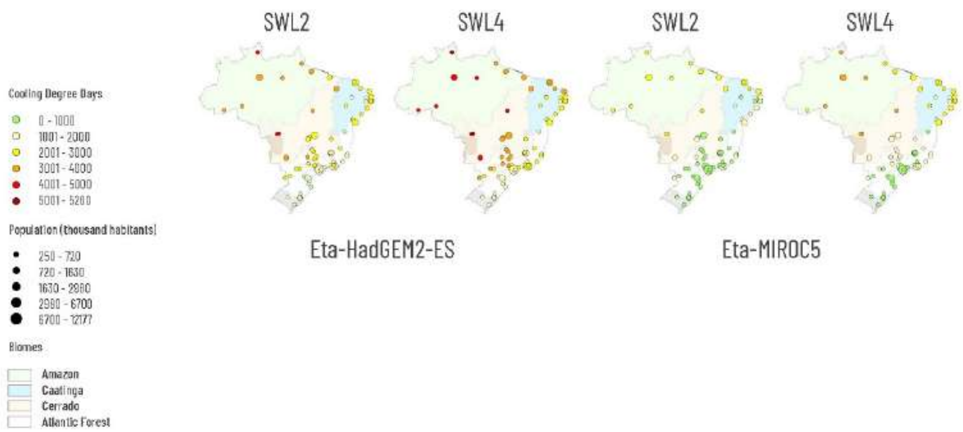



Figure 3.28. GDRs' results for Eta-HadGEM2-ES and Eta-MIROC5 models for SWL2 and SWL4.

The results of the Eta-HadGEM2-ES model showed higher GDR values than those found for Eta-MIROC5, due to its tendency in projecting higher temperatures at all heating levels. However, we observed the upward trend in need for cooling as heating level rises for both models.

The highest GDR values vary between 5,260 and 3,864, and the lowest between 46 and 700. These values are comparable to the research conducted by Sivak (2009), who found a maximum GDR value of 3,954 in the city of Madras (India) and a minimum value of 805 in the city of Madrid (Spain). The Amazon, Pantanal, and part of the Cerrado biomes had shown the highest values for GDR. The Atlantic Forest, although not representing the greatest results, is the biome in which most of the Brazilian population is located, therefore, the energy demand to meet their needs may represent a significant part of the expected increase for cooling.

## 3.5.3 MAIN RESULTS IN ENERGY SECURITY

The VARIATION IN HYDROELECTRIC POTENTIAL occurs due to changes in the affluent natural outflow that change the affluent natural energy (ANE) of hydroelectric plants (HPP)[19]. The results point to a decrease in ANE in the Northeast (Caatinga), North (Amazon biome) and Southeast/Midwest (Atlantic Forest and Cerrado biomes). The ones with the greatest reduction in ANE are the North and Northeast subsystems, which together represent 29% of the ANE in the Reference Expansion Scenario (REF) (PDE 2026).

These regions, especially the North, are responsible for the exchange of electricity to the South and Southeast/Midwest regions at certain times of the year. In addition, the reduction of the natural affluent outflow reduces the level of reservoirs, which directly affects hydroelectric generation, water multiusers, and other services, as well as water storage for dry periods.

[18] *It is worth indicating that the number of inhabitants considered in each city is static, not being considered a projection of demographic growth in time.*

[19] *Both HPP with reservoirs and run-of-the-river plants were considered.*

Changes in the Electric Grid. In the projected scenarios for reduction in hydroelectric generation, the participation mix of energy sources in the electrical system changes with the increased participation of thermoelectric fossil fuels (natural gas) and biomass in energy dispatch, and the entry of installed capacity from renewable sources, which can impact the average energy cost, emissions of air pollutants and GHGs. The same trend occurs for the expansion of the electric grid, for now necessary to ensure compliance with future energy demand, which indicates the need to include new infrastructure and technologies, whether renewable or not, which can increase investment costs and the average expansion cost, hence causing an increase in the final price of electricity.

Simulations indicate that the participation of hydroelectric plants in electric expansion should decrease. One of the factors is the reduction of ANE, what makes HPPs less viable than other sources. Another factor is seasonality, since a plant may not be prioritized in modeling, even though it has a lower cost, due to its inability to meet energy demand in periods of lower supply from other sources. The investment in small decentralized hydroelectric plants as an energy alternative could also be impacted by low affluent natural flow.

Need for Expansion and Entry of Renewables. The expansion results indicate the need for 80% to 90% more installed capacity in relation to base scenario results, in order to meet the projected energy demand. This projection implies the insertion of wind and solar energy sources as an alternative to hydroelectricity drops, which have a low capacity factor in relation to other energy sources.

The Reference expansion scenario already indicates the participation of 31% of non-hydro renewable energy sources in the electric grid. The scenarios of the Eta-HadGEM2-ES and Eta-MIROC5 models consider an approximate participation between 35% and 50% of these sources.

Opportunities with Solar. Regarding solar energy, there may be maintenance or increase of the availability of the resource for photovoltaic generation in the Atlantic Forest, Cerrado and Amazon biomes (North and Southeast/Midwest subsystems), with climate change benefiting penetration of photovoltaic plants, both into the SIN, as well as in a decentralized manner.

Increased Availability for Wind Turbines. The results for onshore wind generation indicate, in general, an increase in resource availability for electricity generation in all biomes, except in some areas in the states of Rio Grande do Norte and Paraíba (Caatinga biome), which present a small decrease in resource availability in the SWL4, and where the installed capacity represents approximately 54% of the total national capacity. Thus, the onshore wind generation could potentially increase its penetration with increased installed capacity in the expansion of the electric grid, despite any negative impacts in areas where there are projects already operational.

Decentralization of the Electrical System. It contributes to energy access in remote areas and reduces the need to build new power transmission lines to connect to the SIN, which also reduces environmental impacts from its implementation. Distributed generation does not require government investments in transmission lines and does not compete for land use occupation. There are many national projects of distributed photovoltaic generation, mainly to supply electricity in rural and/or isolated communities in the Amazon and Caatinga biome, which can be used as a model to compensate for possible losses in the potential to generate electricity with SHPs. In addition, decentralization can be used in cities, thus reducing pressure on the interconnected electrical system and increasing energy supply safety.

Opportunities with complementary sources. In the complementarity analysis, the most prominent correlations are between hydroelectric and wind potential (hydro-wind), and between hydroelectric plants (hydro-hydro). The main results among hydro-wind are in *hotspot*s in the Amazon-Caatinga, Caatinga-Caatinga, and Atlantic Forest-Cerrado biomes. This condition is important, given the relevance for the hydroelectric generation of these biomes, added to a possible reduction of water availability in climate change scenarios. On the other hand, hydro-hydro complementarity is observed in hotspots in the Amazon-Atlantic Forest biomes. These correlations indicate that hydroelectric generation could be maintained, considering the variation of seasonality in these areas, even with the impact of climate change on ANEs. Complementarities with biomass sources (although they have not been modeled) may have the potential to compensate for variations in the hydroelectric source.

Variation in energy demand due to the influence of climate change affects SIN. The thermal comfort indicator for cooling pointed that the populations of cities in the Amazon and Caatinga biomes would be the most affected by the need to increase cooling use. However, the increased demand for cooling in the Atlantic Forest and the Cerrado, yet relatively smaller, results in a more intense impact on the electrical system, due to the higher concentration of consumers. However, the possible increase in energy demand projected by this indicator in the Amazon and Caatinga biomes could be met by decentralized systems of energy sources, such as solar.

Transmission and distribution infrastructure need to be compatible with new challenges. Brazil has an interconnected system that allows the compensation of climate impacts in electrical generation with the operation from other energy sources, such as thermoelectric (adaptive capacity). However, the electric power transmission and distribution system may undergo changes caused by extreme weather events and forest fires.

Bioenergy. Approximately 84% of the biodiesel plants in operation are located in the Cerrado and Atlantic Forest, where there is a possible impact of high magnitude on inputs supply for the production of this biofuel. As for ethanol, the results indicate that the area where 76% of the current producing plants are located could be affected by the reduction of areas suitable for sugarcane plantations. We suggest a reduction of 35% of low-risk areas for sugarcane cultivation (Zullo et al., 2018). This reduced area is redistributed among high-risk (mainly) and medium risk areas, in which irrigation techniques are needed. Crops expansion to new areas could influence plant productivity, increase its irrigation needs and increase its vulnerability, or generate impacts for other sectors.

This scenario for biofuel production can raise the challenge of increasing sustainable bioenergy in the Brazilian energy grid to approximately 18% by 2030 (BRAZIL, 2015a). In addition, considering that the main generation of bioelectricity occurs during the harvest, a period concomitant with drought and reduction of hydroelectric generation, the electric grid would be affected by the reduction of hydroelectric generation and bioelectricity in the same period of the year.

## 3.6 Food security

### 3.6.1 Context

#### Conceptualization

At a meeting of the World Food Summit held by FAO in 1974, food security was defined as the “availability at all times of adequate, nourishing, diverse, balanced and moderate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices" (Universal Declaration on the Eradication of Hunger and Malnutrition, 1975). In 1983, FAO expanded its concept to include securing access by vulnerable people (related to poverty, its determining factors and consequences involved) to available supplies, implying that attention should be balanced between the demand and supply side of the food security equation ensuring that all people at all times have both physical and economic access to the basic food that they need (FAO, 2019), the definition being adopted in this 4NC.

Debates on hunger at the international level started with the *Hot Springs* Food Conference in the United States in 1943, with an agenda aimed at feeding the world population so that each country could have its own independent production. In 1945, the Food and Agriculture Organization of the United Nations (*Food and Agriculture Organization – FAO*) is created and is considered the main initiative of international articulation for the planning of strategies against hunger at the global level (Hirai and Anjos, 2007). The right to food was recognized as a universal right in the Universal Declaration of Human Rights of 1948.

Four points must be considered to ensure food security: physical availability of food; physical and economic access to food; utilization of food through adequate diet; stability and temporal continuity in the availability of food. Thus, food security is conditioned by the availability, quantity, quality, access, and prices of food. Regarding access to food, the population's income is paramount (Bezerra et al., 2017; Bento et al., 2015). Regarding availability in adequate quantity and quality, the food production capacity of the different agricultural systems is key. However, the sustainability of said production capacity depends intrinsically on climate conditions; therefore, it is threatened by the increasing climate uncertainty observed. Thus, in addition to influencing the maintenance of production and lifestyles associated with agriculture, climate change and all its implications are a direct threat to food security, a universal right of humanity.

### THE RELEVANCE OF FOOD SECURITY TO THE COUNTRY AND FOR ADAPTATION

Brazilian agriculture includes a great diversity of production systems representing a prominent sector in the country's economy and the maintenance of lifestyles among their various socioeconomic and environmental functions. In addition to supplying the Brazilian society, national agricultural production contributes to global food security with its important participation in the international market (Amaral and Guimarães, 2017).

In addition to the variety of crops (corn, beans, rice, manioc, coffee, soybean, wheat, among others) and livestock and its derivatives (beef and pork, chicken, milk, eggs, and others), fishing and aquaculture are also important sectors of the food supply in Brazil, although most of these products have low-scale production, and consequently low marketing despite the great diversity of species in the country (Embrapa, 2014).

*To learn more about national agricultural activities, see **item 1.4.2.***

Agriculture is totally influenced by the environmental conditions, and is highly dependent on weather conditions (MOORHEAD, 2009), with most of the variability in agricultural productivity being due to seasonal and interannual climatic variability, overcoming economic, political, infrastructural, and social issues (BRASIL, 2015; NAKAI et al., 2015). Therefore, climate change can directly impact the production capacity of agriculture and livestock, but can also impact it indirectly, with the spread of disease vectors, predatory insects, pests, pollinators, and other factors that influence the activity (GHINI, et al., 2011; HOFFMANN, 2011).

In the agriculture and livestock sector, the damage associated with climate extremes in the period 2005-2015 represented around 67% of the total economic losses in the country, followed by damage to infrastructure representing 16% of the total (Mikosz, 2017). For family farming, the hydrometeorological extremes incurring losses in crops also affect the farmers' lifestyle (Saraiva et al., 2018).

THE INCREASE IN FOOD PRODUCTION IN BRAZIL in the last decades is due to the national technological advances directed to the country's tropical and subtropical reality, to favorable climate conditions, to the great extension of its territory which allows it to comply in a self-sufficient way with the growing domestic demand. Grain production increased 40% between the harvests of 2010/2011 and 2017/2018, going from 163 million to 228.3 million tons with emphasis on the corn and soybean crops (Conab, 2018a). Meat production, on the other hand, grew 27% between 2009 and 2017, going from 19.6 million to 24.9 million tons with emphasis on beef and chicken (Ferreira and Vieira Filho, 2019). Beef exports represent about 3% of Brazilian exports, with an increase of almost 45% in the last 5 years (Gomes et al., 2019).

The Brazilian production of fish was around 1,286 million tons in 2016, with fishing being responsible for 705 thousand tons and aquaculture 581 thousand tons (FAO, 2018b), with the expectation that the production of aquaculture will surpass that of net fishing in the coming years (FAO, 2018b; PEIXEBR, 2019; Siqueira, 2017; Brabo et al., 2016). In 2017, the country imported 383,6 thousand tons of fish (PEIXEBR, 2019).

AGRICULTURE AND LIVESTOCK PRODUCTION SYSTEMS. Brazil has many different production systems varying in terms of scale, type of management, and types of technological management adopted. Among these, we emphasize the no-till system - which in 20 years went from approximately 9 million to 32 million hectares (Febrapdp, 2018) - and the integrated production systems (ICLS, ICLFS, and AFS), which already represent more than 11 million hectares (Embrapa, 2018a). Regarding systems certified as organic production, the production units went from 6,700 in 2013 to approximately 15,700 in 2016, totaling about 750 thousand hectares (MDA, 2016a).

USE OF PESTICIDES[20] . Pesticides are developed to face threats to agriculture and livestock production by agents (pests or disease vectors) that are pathogenic to plants and animals at different levels of toxicity, ranging from bio-based natural ingredients to highly toxic inputs. External inputs are used to give producers increased safety in terms of the final production guarantee. Therefore, it is a basic input to guarantee the availability of food, which is an essential step to ensure food security. However, its use must be well established, as there are risks to the environment and to human and environmental health that must be taken into account (Lopes and Albuquerque, 2018). Pollinators are disappearing on a global scale. Among other factors, it is associated with the use of certain pesticides (Potts et al., 2010; Goulson et al., 2015; Giannini et al., 2015). Therefore, the use of inputs of inadequate toxicity and not following the recommended standards can be a long-term threat to food security, as 68% of the main

*[20] Pesticides are made of chemical substances intended to directly or indirectly control, destroy or prevent pathogens for plants and animals.*

food crops depend on pollinators (Novais et al., 2018). It should be noted that within the scope of the Brazilian Universal Health System (SUS) the General Coordination of Environmental Health Surveillance (CGVAM) also structured the Health Surveillance of Populations Exposed to Pesticides (VSPEA) in 2002 aimed at adopting integrated measures for the prevention of risk factors, health promotion, assistance and surveillance of aggravations and diseases resulting from exogenous pesticide poisoning.

INFRASTRUCTURE DEPENDENCY. Given the high distances in the Brazilian territory and the large volume and diversity of agricultural products distributed throughout all regions, the transport and storage infrastructure plays a major role in the agriculture and livestock chain, relying on land modes (rail and especially road transport), as well as water transportation (both inland waters and the sea), and in some cases air transportation. It is noteworthy that the logistical infrastructure of transport is essential to minimize the rates of food losses[21] impacting its availability and accessibility to the population, aspects that tend to suffer the pressure of climate change (Arruda, 2017). Losses along the production and supply chains are estimated to vary between 10 and 30%, reaching 40% in some cases (Ipea, 2018).

LOSSES AND WASTE IN THE CHAIN. According to the United Nations data, 26.3 million tons of food (10% of the total available) were lost in 2013 in Brazil, with rice and corn being the main products (Fernandes et al., 2016). There is also a high waste of food[22] occurring at the end of the food chain (retail and consumption). It is estimated that 41.6 kg of food per person is wasted in Brazil every year in the following ratios: rice - 22%, beef - 20%, beans - 16%, chicken - 15%, and others (Embrapa, 2018b).

FOOD SECURITY AND POVERTY. In terms of food security, it is important to consider the social inequality and incidence of poverty in Brazil (Barros et al., 2000). In Brazil, the number of malnourished people went from 8.6 million in the period from 2004 to 2006 to 5.2 million in the period from 2015 to 2017 (FAO, 2018). Despite the reduction in malnutrition, 52 million people (in the period from 2013 to 2014) live with some degree of food insecurity, reaching about 22.6% of households in the country (Almeida et al., 2017; IBGE, 2014).

Besides, from the perspective of the food production sector, several policies and normative instruments incorporate climate management and its variability over the agriculture and livestock sector. There is also intense research work in progress looking for technologic and process alternatives and technical arrangements aimed at adaptation and environmental sustainability.

## GOVERNANCE IN FOOD SECURITY

The Ministry of Agriculture, Livestock and Supply (MAPA) formulates and implements policies for the development of Brazilian agriculture and livestock, and integrates market, technological, organizational, and environmental aspects to serve consumers in the country and abroad by promoting food security, generating income and employment, reducing inequalities, and promoting social inclusion (MAPA, 2018c). It coordinates the activities of the Brazilian Agricultural Research Corporation (Embrapa) and the Brazil's National Supply Company (Conab) (MAPA, 2018d). The Secretariat of Family Agriculture and Cooperatives (SAF) was created by Decree No. 9,667/2019 to promote the development policy of rural Brazil, including issues of access to land, agrarian structure, productive inclusion, income from family farming, among others. The Secretariat of Innovation, Rural Development and Irrigation (SDI) is predominantly competent to promote the sustainability of production systems, whose structure coordinates, among others, the National Plan for Low Carbon Emission in Agriculture (Plano ABC) focusing on actions to promote the adaptation to climate change, conservationist production systems, among others.

MAPA has also been responsible for the public policies aimed at fishing and aquaculture since 2015 when the Ministry of Fisheries and Aquaculture was dissolved (Decree-Law No. 11,958/2009), with its duties designated by the Aquaculture and Fisheries Secretariat (SAP/MAPA).

THE BRAZILIAN NATIONAL SCHOOL FEEDING PROGRAM (PNAE) AND THE FOOD PROCUREMENT PROGRAMS (PAA). SAF is also responsible for maintaining programs aimed at accessing basic food, such as PNAE and PAA. The PNAE (Decree No. 37,106/1955) is managed by

[21] *Food losses refer to spilled, scattered, damaged and lost food, or when there is a decrease in the quality and value during its production process.*

[22] *Food is wasted, for example, when the consumer buys products that spoil before being consumed at home, or even due to cultural aspects leading to the disposal of good quality food.*

the National Fund for the Development of Education (FNDE) (FNDE, 2018), and aims to offer school meals, and food and nutrition education actions to students in all stages of public basic education (MEC, 2014). The PAA (Decree No. 10,696/2003) aims to collaborate with the fight against hunger and poverty in Brazil, to strengthen family farming based on the purchase without bidding of food produced by family farming based on the land reform, and to encourage traditional communities to create strategic stocks and distribute them to people in situation of food and nutrition insecurity (MDS, 2018a). Government policies such as PAA and PNAE relate to climate change by purchasing food of agricultural and livestock origin and stimulating the growth of sustainable practices such as agroforestry systems.

The legal and institutional frameworks of the Food and Nutrition Security (SAN) agenda include the creation of the National Plan for Food and Nutrition Security (Law No. 11,346/2006), the re-creation of the National Food and Nutrition Security Council, the creation of the Inter-Ministerial Chamber of Food and Nutrition Security, and the creation of the National Plan for Food and Nutrition Security (2012/2015) (MDS, 2019).

National Food and Nutrition Security National Council (Consea): Brazilian collegiate body providing immediate assistance to the Presidency of the Republic created by Decree No. 807/1993 (Ipea, 2012) and re-created by Law No. 10.683/2003 to coordinate federal programs related to food and nutrition security.

Inter-Ministerial Chamber of Food and Nutrition Security (CAISAN): created by Decree No. 6,273/2007, it is responsible for the coordination and intersectoral monitoring of public policies related to food and nutrition security at the federal level, the fight against hunger, and to guarantee the human right to adequate food. Its competence is to elaborate, coordinate the execution, and monitor the results and impacts of the National Policy on Food and Nutritional Security (PNSAN) instituted by Decree No. 7,272/2010, and the National Plan for Food and Nutrition Security (PLANSAN) (MDSA, 2017; Brasil, 2007).

### Policies related to the sector

*To learn more about the Plano ABC , see **item 4.1.6.***

Various policies and instruments incorporate the climate issue on the agenda of the agriculture and livestock sector and contribute to the promotion of food security in the country. As already mentioned, we can emphasize the **Sectoral Climate Change Mitigation and Adaptation Plan for the Consolidation of a Low Carbon Emission Economy in Agriculture (Plano ABC)** created in 2011 to promote sustainable production systems, contribute to the reduction of greenhouse gas emissions by the agricultural sector, as well as to adapt actions with the support of the mapping of sensitive areas aiming at increasing the resilience of agroecosystems, and developing and transferring technologies. Among other instruments, it also has an exclusive credit line.

The Agro-Climate Risk Zoning **(ZARC)** provides the quantification per crop year of the climate risks that may cause losses to the production by municipality and culture, thus establishing the low or high-risk areas and the respective planting calendars, being an instrument of great relevance in the context of adaptation to climate changes.

The country offers several rural credit and guarantee programs to producers facing crop losses caused by weather events, as well as fluctuations in the prices of products on the market. Mention is made of PROAGRO, PROAGRO Mais, in addition to the Rural Insurance Premium Subsidy Program (PSR), each with specific characteristics seeking to cover different needs of producers and the diversity of production systems, and the regional peculiarities in the country.

Related to theNational Program for Strengthening Family-based Agriculture(Pronaf) to promote the financing of agricultural costs, we can mention the Guarantee-Harvest Program[23] aimed at family farmers living in the Northeast of Brazil and the north of the state of Minas Gerais, and the Insurance for Family Agriculture (SEAF) aimed at family farmers across the country.

To boost the sustainable production of agricultural systems of family farming, the General Law of ATER (Technical Assistance and Rural Extension), Decree No. 12,188/2010, was published to promote the universalization of technical assistance and rural extension services for family farmers. Said law established the National ATER Policy with principles and guidelines aimed at sustainable development, social participation, agro-ecological production, and the qualification of public policies (Castro and Pereira, 2017). The work of the Technical Assistance and Rural Extension

[23] *They aim at guaranteeing minimum conditions for the survival of family farmers in municipalities systematically subject to crop losses due to the phenomenon of dry spell or excess water.*

Companies (Emater) in each state in partnership with the federal and municipal governments and various public and private institutions aims to promote sustainable rural development, and the production of healthy food to ensure food security and income generation (Emater, 2018).

The Program for the Promotion of Rural Productive Activities created by Decree No. 12.512/2011 aims to support the productive structuring of the poorest rural families expanding or diversifying food production and income-generating activities, thus contributing to the improvement of food and nutrition security and overcoming poverty (MDS, 2018a).

In 2012, the National Policy on Agroecology and Organic Production (PNAPO) was created by Decree No. 7,794/2012 to integrate production capacity, use and conservation of biodiversity and other natural resources, ecological balance, economic efficiency, and social justice.

The Native Vegetation Protection Law (Law No. 12,651/2012, known as the Forest Code) contributes to structure sustainable agriculture and livestock production systems, and one of its instruments is the Environmental Regularization Program (PRA) established by Decree No. 8,235/2014 encompassing the Rural Environmental Registry (CAR). The Integrated crop-livestock-forest systems (iLPF - Law No. 12,805/2013) and the Agricultural Policy for Planted Forests (Decree No. 8,375/2014) contribute to these actions.

*To learn more about the Forest Code, see **item 4.1.1.***

Finally, we highlight the National Irrigation Policy (Law No. 12,787/2013) aimed at encouraging the expansion of the irrigated area in the country sustainably, benefiting the agricultural productivity and competitiveness of agribusiness.

## 3.6.2 IMPACTS AND VULNERABILITIES IN FOOD SECURITY

### IMPACT CHAIN

The impacts of climate change on the agricultural sector appear as a risk factor for food security in the country, as they may restrict the production of the main products aimed at feeding the population (Pinto et al., 2019; Assad et al., 2013; Pinto and Assad, 2008). It should also be considered that there will be an increase in the demand for food influenced by the increased population, consumption per capita (internal demand), and exports of agricultural products (external demand).

The potential for losses in the agricultural sector is high, and there may be a reduction in the production capacity of about 11 million hectares of agricultural land by 2030 (Tortelli, 2018).

CLIMATE AND SOCIOECONOMIC PRESSURES. Factors affecting the impacts on food security include climatic aspects (temperature and precipitation anomalies) and the socioeconomic pressure (demand for food, storage, and transportation, technologies, and productivity, land use dynamics, etc.), which can increase or decrease the vulnerability, resilience, and exposure of food production and access systems.

CLIMATE IMPACTS ON FOOD PRODUCTION

THE INCREASED AVERAGE TEMPERATURE, the decreased temperature gradient between day and night, and above all the frequency of days with extreme temperatures - whether high or low - will impact strongly the plant metabolism and animal welfare, with major impacts on the production capacity (HOFFMANN, 2011; BRASIL, 2015). Regarding livestock, it would imply thermal stress for animals, besides influencing the emergence of diseases and pests, among other impacts.

EXTREME EVENTS of more intense and frequent maximum and minimum temperatures are foreseen, which can cause metabolic alterations and affect the development of the crops. One of the main concerns is the increased range of temperatures outside the ideal range for plants, in addition to the alternation between daytime and nighttime temperatures.

In the harvest of 2013-2014, intense heat waves hit the whole country and caused great losses in productivity, harming producers, and affecting the food supply (Silveira et al., 2014).

CHANGE OF PRECIPITATION REGIMES. Both changes in the average and the variability of rainfall affect agriculture and livestock production. Climate projections point to changes in the seasonal distribution of precipitation, with a higher concentration of high-intensity rainfall in a short period of time instead of a spaced distribution of rain during the productive period (HOFFMANN, 2011). An increase in the variability of rainfall occurrences is also projected, mainly during the rainy season in the different Brazilian biomes (Marengo et al., 2011), with reduced averages in the North and Northeast regions, and increased average in the South region (Marengo and Bernasconi, 2014). Said changes may have a negative impact on the production systems since only 5% of agricultural areas in Brazil are irrigated (BRASIL, 2015; NAKAI et al., 2015). In other words, 95% of the area cultivated in the country is subject to natural variations in rainfall, both in quantity and in seasonal distribution. These rainfall patterns potentialize the negative impacts on the system due to the erosive potential of rainfall or their absence in critical periods of the production cycles (Rossato et al., 2017).

REGARDING FISHING AND AQUACULTURE, increased temperatures imply a decreased concentration of dissolved oxygen in the water directly influencing the physiological processes of fish development. The increased surface water temperature directly impacts the survival and reproduction capacity of fish, as well as other biological processes of aquatic ecosystems, for example, changes in water pH affecting the nutrient availability. Specifically, regarding the marine environment, increased ocean temperature, sea level, and frequency and intensity of storms can limit artisanal fishing. Fishing resources become subject to changes in the breeding period, migration of species, increase in diseases, latitudinal distribution patterns and depth, population size, community composition, as well as competition and predation relationships (Faraco, 2012). Thus, climate change presents additional challenges to the management of fish production and potentially impacts living resources, communities, the post-harvest sector, and the consumer market (Gasalla et al., 2017).

Climate change may affect differently each Brazilian region; therefore, it may impact differently the agricultural production systems that characterize each reality. It is estimated that a warming level of 4 degrees in the Amazon could reduce rainfall occurrences by 40 to 45% (FAPESP, 2019). Thus, crops will be affected especially in regions where dry farming[24] and subsistence farming predominates, which depend on the occurrence of rains to meet the water needs of the plant.

Prolonged droughts are occurring in a more frequent and lasting way, reaching areas that are vulnerable to water availability such as the Semi-arid region, affecting not only food production in the region, but also the use of water by the local population (Rossato et al., 2017), and reaching regions with great production potential such as the Cerrado biome responsible for a large part of grain production in the country (Torquato et al., 2010).

GEOGRAPHIC CHANGES IN AGRICULTURAL PRODUCTION IN THE COUNTRY. Climate change may alter the ideal characteristics for the production of various crops traditionally produced that are part of the structuring of the cultural landscape of our regions. From a technological perspective, one of the solutions proposed is the migration of crops to regions with more favorable climate conditions for their development (Saccaro Junior and Vieira Filho, 2018; Embrapa, 2008). The search for harmony between the demands of cultivation and the aptitude of the region associated with rational planning can favor the recovery of degraded areas to the detriment of forest conversion.

Forest areas play an important role in the provision of ecosystem services for various activities of the society, especially agriculture and livestock. Its reduction affects services related to the maintenance of water cycles, soil conservation, pollination, climate regulation, among others (Vasconcellos and Beltrão, 2018).

FOOD LOSS AND WASTE AS FACTORS TO INFLUENCE FOOD SECURITY (Costa et al., 2015; Belik et al., 2012). From the perspective of climate change, food loss, and waste at any stage between cultivation and consumption must be minimized. First, because essential products for the survival and well-being of the population are being discarded. But also because food that is not used also wastes energy for production and soil for cultivation, and generates GHG emissions and economic losses in the different stages of the production chain. In the case of Brazil, the stages of storage and transportation represent high losses of food in the country, especially of that consumed in natura such as vegetables and fruits. In general, intensification of losses in the agricultural production chain is expected, which will reflect on

[24] *Dry farming (predominant in the country) is cultivation without irrigation, that is, only with the use of rain and water stored in the soil.*

the increased production costs and food prices, and consequently on changes in the consumption pattern of families - especially those with less purchasing power -, and on producers' earnings (Blum, 2001).

NUTRITIONAL QUALITY OF FOOD. Climate change will influence not only supply but also the loss of the nutritional quality of food. High levels of carbon dioxide decrease the protein concentrations of wheat, barley, rice, and potato crops by 10 to 15%, and soybean by 1.4% (The Lancet Commissions, 2019b).

WATER SCARCITY AND IRRIGATED AGRICULTURE. To face the potential water scarcity and rainfall instability, irrigated agriculture can be an alternative to minimize losses due to drought and dry spell events, ensuring the maintenance of food production capacity. However, the adoption of irrigation techniques must be followed by effective water management, considering reservation strategies and water reuse, always associated with adequate soil management to enhance both their use and storage. The perspective of increased irrigation in the country, especially in the Cerrado region (ANA, 2017), may be compromised by water crises resulting from the low levels in reservoirs associated with increased water consumption, waste, and decreased water rains.

#### KEY IMPACTS' ASSESSMENT

According to the chain of impacts on food security, two "key impacts" related to climate were evaluated:

3.3 changes in food supply and demand
3.4 losses, costs, and prices in the agriculture and livestock production chain

### FOOD SUPPLY AND DEMAND

#### METHODOLOGICAL APPROACH

Food production (supply) was analyzed based on historical production data, future projections based on macroeconomic indices, and simulations of climate scenarios, considering products from agriculture, livestock, and fishing/aquaculture. Thus, it was possible to assess the risks to internal supply, that is, the supply of the demand projected by the projected offer. Finally, the need for newly planted areas under the projected climate regimes was evaluated.

The historical data of the Brazilian production was obtained from the IBGE's Automatic Recovery System (SIDRA) for the period 2001-2017. The macroeconomic index referring to the Gross Production Value (VBP) produced by Fipe/USP (MCTIC, 2017) was used for the production projection for the period 2018-2050, with projections for the period 2015-2050. Said index considered the aspects that were responsible for the increased production in the historical period, such as the use of new technologies, adequate agricultural management, and an increase in the growing region. Some products such as beans, eggs, and fish do not have information on the VBP, with the growth rates projected by FIESP (2017) until 2050 being used. The projection of domestic supply with the impact of climate change was calculated by discounting the percentage of variation in productivity and/or resulting production from the present period until 2050 (2030 for the production of beef), divided by the domestic supply calculated using the VBP.

### RESULTS AND ANALYSIS

#### IMPACTS OF CLIMATE CHANGE ON AGRICULTURAL PRODUCTIVITY

The supply of food in the country has increased in the last decades. Considering the macroeconomic projections of VBP from Fipe/USP, the production would continue to increase if there was no climate change.

But studies of the climate impacts show that the Brazilian agricultural production will be affected by climate change, with reduced productivity, and consequently reduced production of most agricultural and fishing/aquaculture products in the country (Table 3.3).

Table 3.3. Current and projected productivity (t/ha) and average production (t) based on climate change scenarios.

| Agriculture | | | | |
|---|---|---|---|---|
| Products | Current productivity (t/ha)* | Projected productivity in 2050 (t/ha) | Variation (%) | Source |
| Rice | 4.9 | 4.2 | -15.2 | Fernandes et al., 2012. |
| Coffee | 1.4 | 1.1 | -21.5 | Pinto et al., 2019; Tavares, 2017. |
| Beans | 0.9 | 0.7 | -23.1 | Campos et al., 2010; Oliveira, 2007; Martins e Assad, 2007. |
| Manioc | 14.0 | 14.7 | +4.8 | Araújo et al., 2014. |
| Corn | 4.7 | 2.3 | -51.0 | Bender, 2017. |
| Soybean | 2.9 | 0.60 | -79.6 | Fernandes et al., 2012. |
| Wheat | 2.5 | 1.3 | -46.2 | Fernandes et al., 2012. |
| Livestock | | | | |
| Products | Current production (tons)* | Projected production in 2050 (tons) | Variation (%) | Source |
| Bovine | 9,360,800 | 8,705,544*** | -7.0 | Assad et al., 2013. |
| Milk | 32,292,367,500 | 26,273,381,450 | -18.8 | Klosowski, 2019 |
| Eggs | 3,553,769,000 | 3,433,668,734 | -3.4 | Klosowski, 2019 |
| Fishing/Aquaculture | | | | |
| Products | Current production (tons)** | Production projection to 2050 (tons) | Variation (%) | Source |
| Fish | 95,077 | 84,609 | -11.0 | FAO, 2018b. |

*Average for 2008-2017; **Average for 2006-2011; ***Future value projections to 2030.

### Impacts of climate change on the availability of areas suitable for planting

Likewise, crops will be impacted by the availability of areas suitable for planting. Note that the percentages of productivity reduction (Table 3.3) are similar to those presented by projections of the Agricultural Zoning of Climate Risk[25] (ZARC) (Table 3.4) with compatibility between these results.

[25] *Agricultural policy and risk management instrument in agriculture. Based on the climate risk analyzes, MAPA publishes the list of municipalities suitable for planting with low climate risk and their respective sowing calendars by crop and by Federation Unit, supporting not only the decision-making of the producer, but also the access to Proagro, Proagro Mais, and the federal grant to the rural insurance premium.*

Table 3.4. Planted Area (base year 2012) in millions of hectares for agricultural crops, and impact on the reduction of low-risk areas.

| Crops | The total low-risk area in the base year (2012) (million ha) | Heat level | | | |
|---|---|---|---|---|---|
| | | Low-risk areas in SWL2 | | Low-risk areas in SWL4 | |
| | | Total (million ha) | Variation in relation to the base year (%) | Total (million ha) | Variation in relation to the base year (%) |
| Rice | 2.41 | 2.23 | -7.5 | 2.08 | -13.9 |
| Beans* | 1.96 | 1.06 | -45.6 | 0.84 | -57.1 |
| Beans** | 1.02 | 0.40 | -61.2 | 0.29 | -71.9 |
| Corn* | 7.60 | 6.65 | -12.5 | 5.91 | -22.2 |
| Corn** off-season crop | 7.47 | 1.13 | -84.9 | 0.20 | -97.3 |
| Soybean | 24.98 | 8.56 | -65.7 | 4.69 | -81.2 |
| Wheat | 1.91 | 1.60 | -16.5 | 1.46 | -23.8 |

Source: MCTI, 2016. *First crop; **Second crop.

## ANALYSIS OF IMPACTS BY CROP[26]

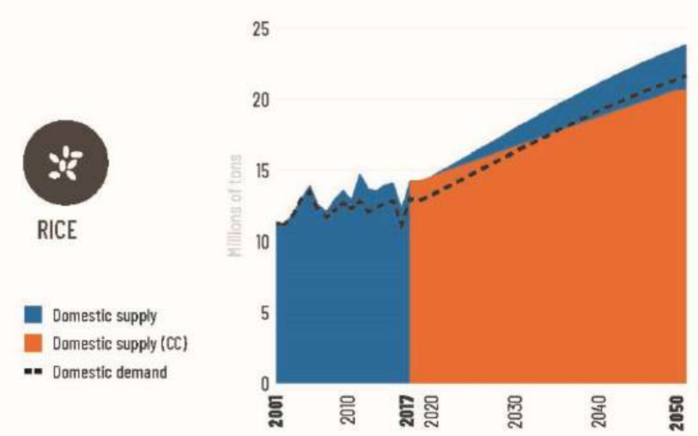



Figure 3.29. Projections of rice domestic supply "without" and "with" climate change (MC) (until 2050).

RICE: there may be a 15.2% reduction in its productivity until 2050 (Table 3.3), with the projected domestic supply decreasing from 23.8 million tons to 20.6 million, slightly below the domestic demand. According to ZARC data, the reduction in suitable areas may be up to 13.9% in SWL4 (Table 3.4). Rice has higher thermal requirements, with its production slightly penalized by photosynthesis when temperatures are below the ideal one. The increased temperature shows an increase in productivity, but in warmer countries such as Brazil where the thermal conditions for photosynthesis are already close to the ideal, there are reductions in the final yield (Fernandes et al., 2012).

[26] *Figures: Relation between domestic supply (VBP), domestic supply under the impacts of climate change (MC), and domestic demand (2001-2050) for the main products of Brazilian food security. Source: Own elaboration based on FAO, 2019; Pinto et al., 2019; Klosowski, 2019; FAO, 2018b; Bender, 2017; Fiesp, 2017; Tavares, 2017; MCTI, 2016; Araújo et al., 2014; Assad et al., 2013; Fernandes et al., 2012; Campos et al., 2010; Martins e Assad, 2007; Oliveira, 2007.*

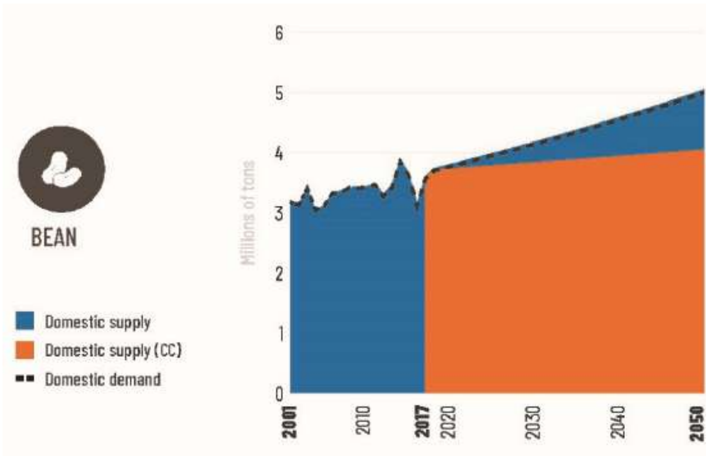



Figure 3.30. Projections of rice domestic supply “without” and “with” climate change (MC) (until 2050).

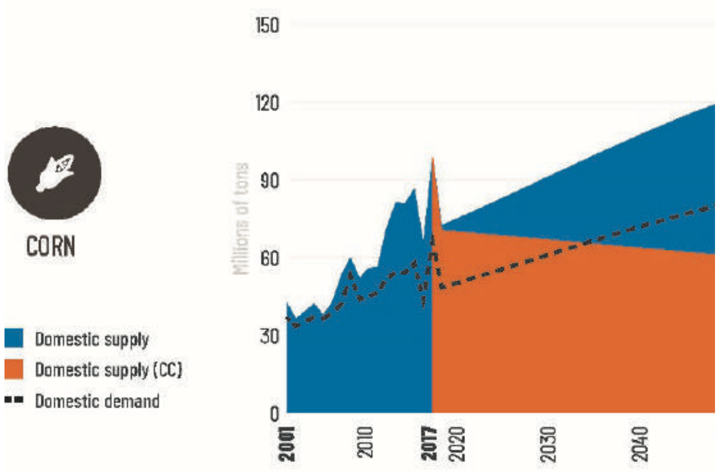



Figure 3.31. Projections of corn domestic supply “without” and “with” climate change (MC) (until 2050).

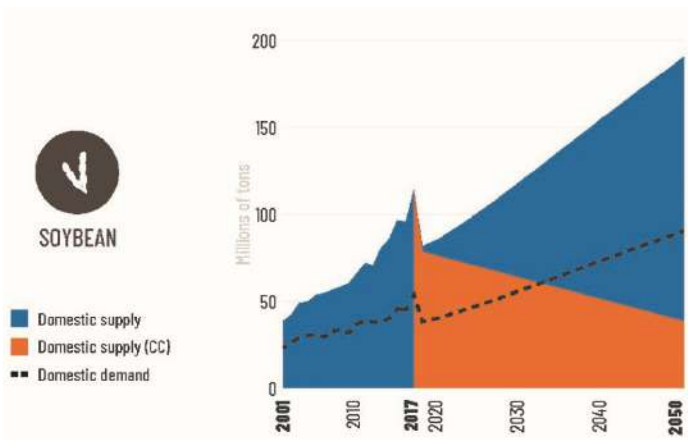



Figure 3.32. Projections of soybean domestic supply “without” and “with” climate change (MC) (until 2050).

BEANS: The projections indicate a potential reduction of up to 23.1% in its productivity (Table 3.3) affecting the domestic supply that can reduce from 5 to 4 million tons when the domestic demand would be 5 million tons. ZARC shows that the reduction of suitable areas may reach a percentage of up to 64.5% (average of the reduction values for the first and second harvests) in SWL4 (Table 3.4). Projections of increased temperature and reduced precipitation are the causes for the reduction of bean productivity mainly associated with the shortening of the phenological phase (Campos et al., 2010; Costa et al., 2009; Oliveira, 2007; Martins e Assad, 2007).

CORN: A 51% reduction in productivity is foreseen (Table 3.3) so that the projected domestic supply would decrease from 121.8 million tons to 60.4 million below the internal demand of 81.6 million tons. This estimate is similar to the ZARC projection in which the reduction in suitable areas could be up to 59.8% (average of the reduction values for corn and corn off-season crop) in SWL4 (Table 3.4). Besides, Martins et al. (2019) showed that losses of corn productivity in the Northeast region of Brazil under dry farming conditions can vary from 30% to 60% for SWL2 and SWL4, respectively. Climate change negatively affects corn productivity both in the 1st and 2nd crop (especially the latter) due to the shortening of the crop cycle and the greater water deficit in future scenarios (Bender, 2017).

SOYBEAN: There may be a reduction in productivity of up to 79.6% in 2050 according to the climate scenarios (Table 3.3), which would imply changes in the domestic supply from 190.2 to 38.5 million tons, whereas domestic demand would be 90,4 million tons. The reduction in suitable areas projected by ZARC is up to 81.2% in SWL4 (Table 3.4). Reductions in soybean productivity occur due to water limitations during production, mainly during the grain filling period, thus reducing the crop cycle (Fernandes et al., 2012).

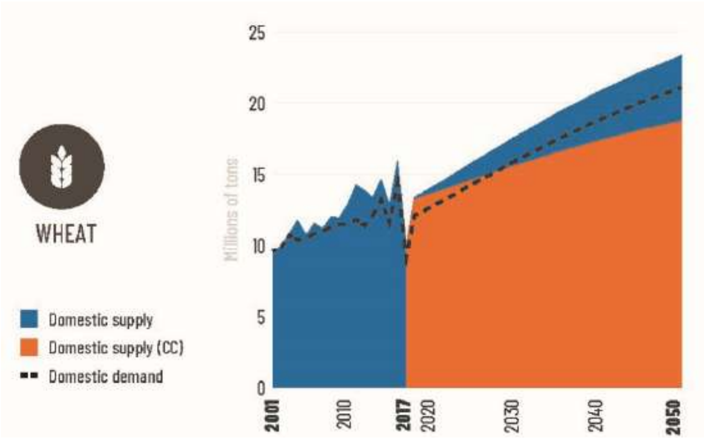



Figure 3.33. Projections of wheat domestic supply “without” and “with” climate change (MC) (until 2050).

WHEAT: The climate scenarios indicate that wheat may have a 46.2% reduction in its productivity by 2050 (Table 3.3) representing a reduction in the future domestic supply from 23.3 million tons to 18.7 million, whereas the domestic demand would be 21.1 million. ZARC points out to a reduction of suitable areas up to 23.8% in SWL4 (Table 3.4). The reductions in wheat productivity are due to the shortening of the harvest cycle given the greater accumulation of thermal time leaving fewer days available for grain filling. Insufficient water availability may affect wheat productivity more than other factors suggesting the development of varieties with characteristics that are more resistant to water scarcity, such as the greater capacity to deepen the portion of the soil explored by the roots, and more favorable distribution of the leaf angle (Fernandes et al., 2012).

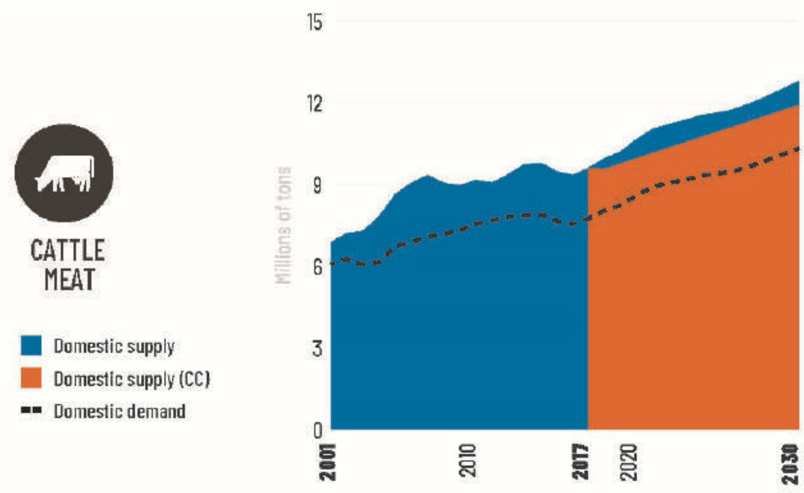



Figure 3.34. Projections of beef domestic supply “without” and “with” climate change (MC) (until 2050).

LIVESTOCK PRODUCTS: There was also a projected reduction in the production of the main livestock products in the coming years due to the impacts of climate change. The reduction in beef domestic supply will be 7.0% (Assad et al., 2013), reaching a total of 11.9 million tons in 2030 instead of 12.8 million tons without the influence of climate change, and above the domestic demand of 10.3 million.

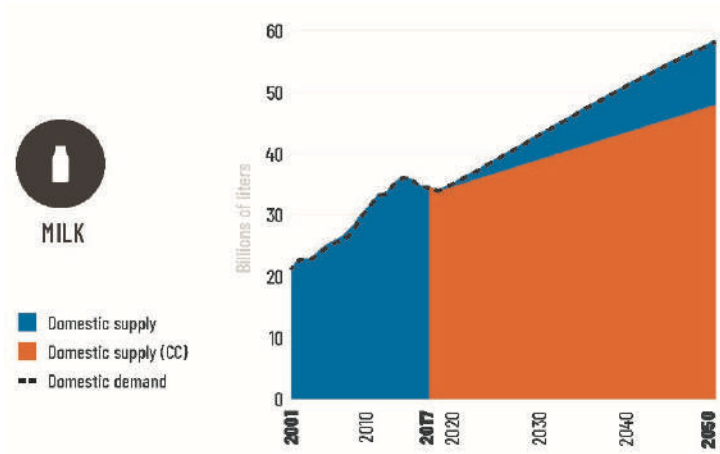



Figure 3.35. Projections of milk domestic supply “without” and “with” climate change (MC) (until 2050).

MILK AND EGGS: The domestic supply of milk and eggs will be reduced by 18.8% and 3.4%, respectively, reaching a total of 47.7 billion liters and 11.8 billion dozens in 2050, figures that are below the domestic demand that will correspond to 58.1 billion liters and 12.1 billion dozens, respectively.

FISH. the supply will be 11.0% lower, reaching a total of 5 millions of tons considering the increase in the domestic demand which will be 5.2 million of tons making the country more dependent on imports.

### NEED FOR PLANTED AREAS UNDER THE NEW CLIMATE REGIME

Due to the potential reduction in productivity due to climate change, and if there is no technical intervention for the adoption of more resilient systems with better ability to adapt to climate change associated with effective risk management, the need for planted areas for certain crops to meet domestic demand in the future is projected (Figure 3.36). Currently, beans require 3.6 million hectares to meet their domestic demand, but in 2050 this number is expected to increase to 7.2 million hectares. In the case of corn, the growing region to meet domestic demand is expected to increase 201.7% by 2050 (reaching a total of 35.6 million hectares) due to the reduction projection in productivity of 51% with the climate change (Table 3.4), and the increase in the domestic demand. If it is considered that there will be no reduction in productivity, the demand per area will be 17.3 million hectares in 2050. Currently, 11.8 million hectares are planted (corn crop and off-season crop) in the country. Note that said results do not necessarily mean that there will be demand for new areas in the same ratio as a large part of the corn and beans production is grown in the second crop in rotation with other crops, such as soybeans, thus minimizing the increase shown in Figure 3.36.

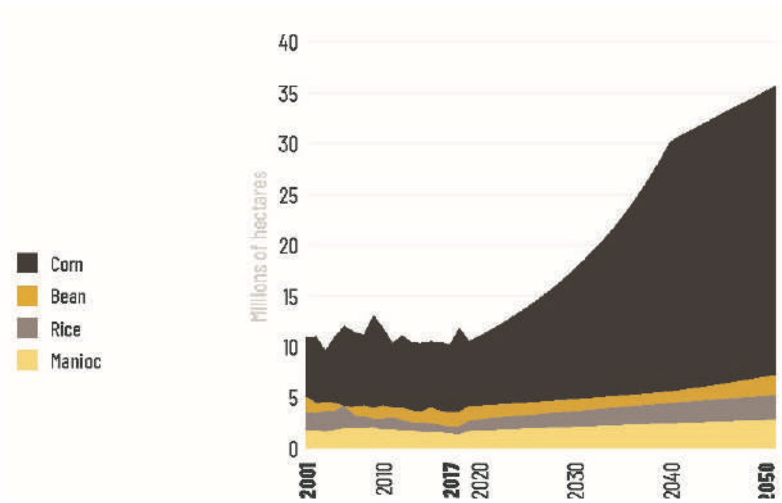



Figure 3.36. Planted area to meet the domestic demand for the main Brazilian food security products (2001-2050) in a scenario of climate change. Source: FAO, 2019; Bender, 2017; FIESP, 2017; MCTI, 2016; Araújo et al., 2014; Fernandes et al., 2012; Campos et al., 2010; Martins e Assad, 2007; Oliveira, 2007.

### INCREASED IRRIGATION AND POSSIBLE TRADE-OFFS

Another potential effect resulting from climate change is the increased use of irrigation (projected in 10 million hectares by 2030), which has already shown significant growth in the last decades going from 1.5 million hectares in 1980 to 7 million hectares in 2015 (ANA, 2017). Grain production in the Cerrado region is the main responsible for the increase in the irrigated area in the country. Martins et al. (2019) demonstrated that the reduction in corn productivity in the Northeast of Brazil with the use of irrigation was less severe than the productivity drops found for corn in dry farming. The projected reductions were limited to 20% for all simulations, except for the end of the century in the most pessimistic scenario (SWL4). Although this activity can contribute to minimizing the impacts of climate change on agricultural production, it must be planned and implemented in an integrated manner with other uses of water.

## LOSSES, COSTS, AND PRICES IN THE AGRICULTURE AND LIVESTOCK PRODUCTION CHAIN

### METHODOLOGICAL APPROACH

In this section, we analyze the profile of the country's agricultural production losses, the development of agricultural production costs and food prices. Then, we analyze the main government agricultural financing and credit programs and their impact in recent years. Finally, we discuss the production losses associated with the change in the availability of areas suitable for cultivation.

Production losses (up to pre-harvest) were calculated using the agricultural loss index according to the methodology applied by IBGE (2004).

Changes in suitable areas in the present and future period were considered according to the ZARC projections developed within the scope of the Third National Communication (TCN) (MCTI, 2016) simulated using the Eta-HadGEM2-ES model.

Historical climate data (precipitation and maximum and minimum temperatures) was obtained from the database of Xavier et al. (2016 a,b)[27] for the period 1980-2017. The annual average of precipitation and temperature for the present period (1980-2009) and anomalies for the following years were calculated with said data.

Finally, we compared the agricultural production in Brazil and data on losses, costs, and prices with historical data on climate - temperature and precipitation (made available by IBGE), and extreme climate events (drought, heavy rain, dry spell, frost, and hail) - based on information provided by Mikosz (2017) for several Brazilian municipalities in recent years.

## Results and analysis

### Profile of agricultural losses

Climate anomalies affecting agriculture and livestock activities include, above all, changes in precipitation regimes and increases in the temperature and their effects at different time scales. Precipitation reductions were more evident in the years 2012 and 2015 with negative anomalies of up to 500 mm in most of the country, reaching mainly regions comprising the Caatinga, Cerrado, and Atlantic Forest biomes. On the other hand, the southern region of the country (Pampa and Atlantic Forest) showed an increase in the rainfall in 2015, with positive anomalies of up to 1,000 mm. Temperature increases were observed practically across the country, where positive anomalies were up to 3°C, mainly in the Caatinga and Cerrado biomes (Xavier et al., 2016).

The Caatinga biome has been showing high losses in the production of several crops due to the droughts that have hit the region in recent years. Losses in corn and beans production were over 40% in 2012 and 2016. Formanioc, losses were 34.3% in 2012. Production losses for corn in the Cerrado biome were also observed - 8.7% in 2016 -, which is significant given the high production in that region. In the case of rice in the Pampa and Cerrado biomes, there was a reduction of 7% and 10.1% in 2016 due to the occurrence of dry spells. Losses in coffee production were also significant in Zona Costeira in 2016, with a reduction of 16.7%. Soybean showed more significant losses in 2012 in the Atlantic Forest and Pampa biomes (18.6% and 38.1%, respectively). Wheat, on the other hand, lost production in all biomes in which it is grown, with a reduction of 18.5% in Cerrado (2013), and 15.6%, 28.2%, and 60.9 % in 2015 at Atlantic Forest, Pampa, and the Coastal Zone, respectively, mainly due to the occurrence of dry spells (Mikosz, 2017).

### Costs in national agricultural production

Agriculture and livestock production involves costs (fixed and variable) related to factors such as land lease, inputs, seeds, fertilizers, among others. In the last decades, the cost of production increased in the main products across the country.

The average production cost of corn and corn off-season crop between 2010 and 2012 increased 19% in the Atlantic Forest, and 30% in Cerrado, with the national inflation rate in this period being approximately 18.3% (Conab, 2018) based on the Broad National Consumer Price Index (IPCA). The cost of pig farming has also increased in recent years in the main producing regions, with an increase of 31%, between 2014 and 2016 in Atlantic Forest, 41% in Cerrado, and 20% in Caatinga, with the inflation rate in this period being approximately 23.4% (IBGE, 2019a) based on the IPCA.

[27] *Available at https://utexas.app.box.com/v/Xavier-etal-IJOC-DATA (Accessed on 12/18/2018).*

### FOOD PRICE

The price of food in Brazil varies according to several factors, such as production losses. In general, the prices paid to producers have increased in recent years. For example, the price of corn raised more than 45% between 2013 and 2016, with inflation in the period being 33.8%, showing that there was a net increase in the price of the product. In livestock, beef prices raised 51.9% between 2013 and 2016, with inflation for the period being approximately 43%. The severe drought that the semiarid region has been experiencing since 2011 has substantially influenced the wholesale prices. The Caatinga biome presented high prices between the years 2010 and 2016 compared to the other biomes in most of the products sold.

PUBLIC SPENDING THROUGH AGRICULTURAL CREDIT AND FINANCING PROGRAMS. The reporting of losses at Proagro has been variable over the years due to the frequency of events covered by the program, and in greater numbers at Proagro Mais which specifically serves family farmers. In the 2012-2013 crop, the number of adherence due to loss reporting was almost three times higher when compared to the previous crop. This increase coincides with the period of severe drought that has been affecting the Caatinga biome (semi-arid) since 2011. In the 2017-2018 crop, the number of adherence due to loss reporting increased again, and was 1.5 times higher than the previous crop, with the value in this crop being one of the highest ever applied (about R$13.5 million). In the crops of 2012-2013 and 2017-2018, the percentage of adherence by loss communications from family farmers COMPARED to the total number of adherence was 66.5% and 69.2%, respectively (Banco Central do Brasil, 2015, 2019).

Actions of the Guarantee-Harvest Program aimed at family farmers in the semi-arid region of the country can minimize the effects of systematic crop loss due to drought events or excessive rain. Among the states served by the Guarantee-Harvest Program, Ceará and Bahia are the ones who make the most use of the resources made available, receiving 32.4% and 18.8% of the amount paid in recent years. The number of payments made increased from the crop of 2011-2012 due to the drought in this period, reaching 769 thousand payments, about R$1.4 billion (MDA, 2016c). During this period, the semiarid region experienced a reduction in rainfall, with a deviation of -300 to -500 mm. The climate change will expose the semi-arid region of the country to greater occurrences of drought events (Araújo et al., 2014) potentially demanding a greater performance of the Guarantee-Harvest Program.

### AVAILABILITY OF AREAS SUITABLE FOR CULTIVATION

The Agro-Climate Risk Zoning (ZARC) indicates areas of low and high agroclimatic risk. The risk is determined by the AET/MET (actual evapotranspiration and maximum evapotranspiration) ratio, which depends on the temperature and water supply, that is, it is related to water deficiency during the crop cycle (Figure 3.37).

Losses in agricultural production may be intensified with climate change, since the trend will be a reduction in the areas suitable for cultivation of most crops, according to the following analysis:

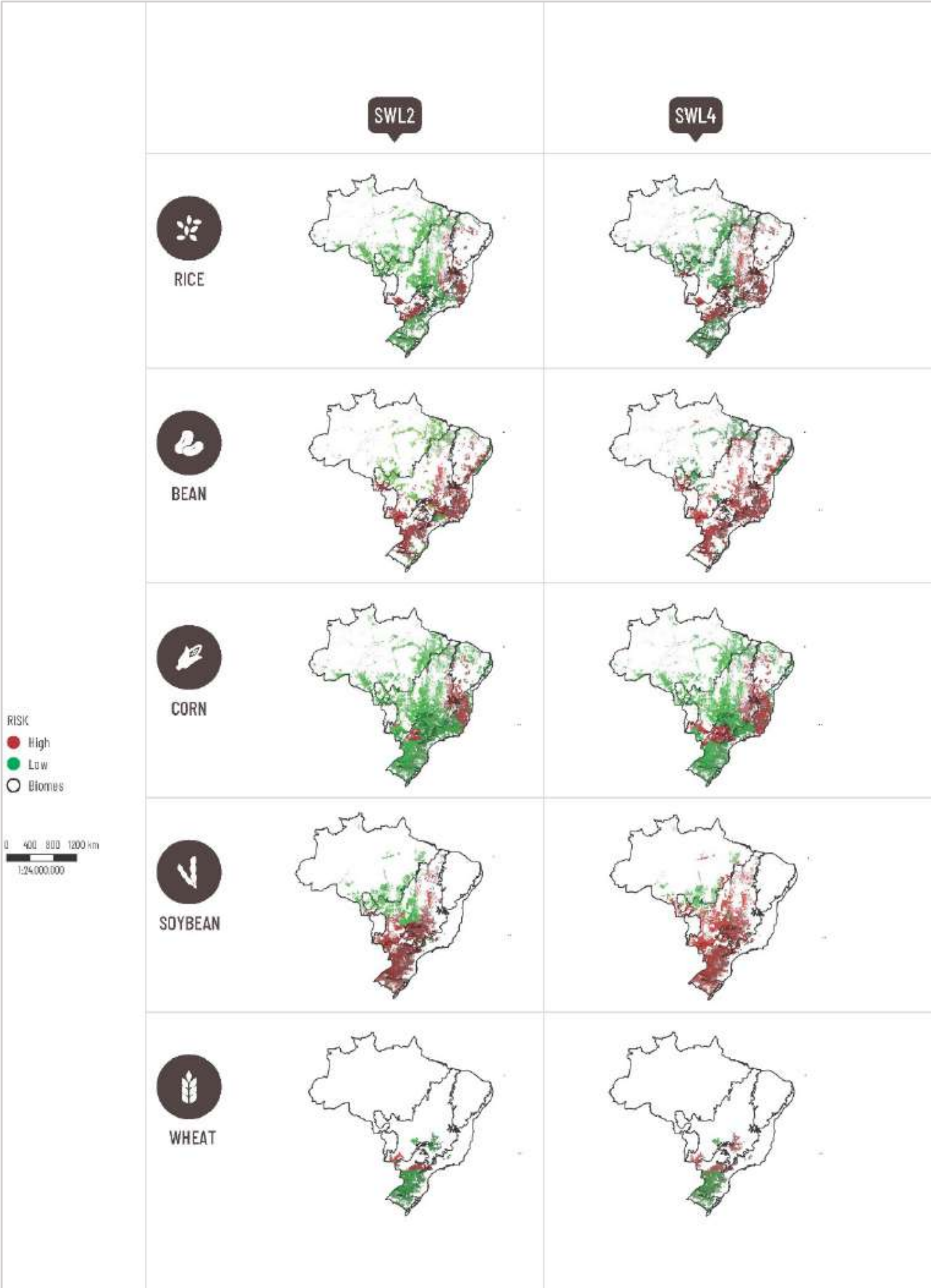



Figure 3.37. Agro-Climate Risk Zoning (ZARC) for the main crops comprising food security in Brazil considering SWL2 and SWL4 (future period). Source: MCTI (2016).

**RICE**: The highest rate of loss of areas suitable for warming scenarios is observed for dry farming rice crops in the Cerrado biome. In SWL4, areas of high climatic risk may increase by 335.4 thousand hectares, reducing the low-risk areas from 2.41 million hectares in 2012 to 2.08 million hectares (-13.9%). This context limits rice production to only irrigable areas with good rain supply in part of the Cerrado and Amazon biomes.

**CORN OFF-SEASON CROP:** It is a crop of high climatic vulnerability, the risk of which tends to increase with the increase in temperature and water deficiency, thus limiting production in almost the entire national territory. In SWL4, areas of high climatic risk may increase by 7.3 million hectares, reducing the low-risk areas from 7.47 million hectares in 2012 to 204.3 million hectares (-97.3%). Losses of low-risk areas will also be seen in the summer crop of corn (crop 1). In SWL4, areas of high climatic risk may increase by 1.7 million hectares, reducing the low-risk areas from 7.6 million hectares in 2012 to 5.91 million hectares (-22.2%). In the south of the country, the Pampa and Atlantic Forest biomes will have favorable conditions for the production of certain crops due to the reduction in the occurrence of frosts.

**BEANS (FIRST CROP)**: In SWL4, areas of high climatic risk may increase by 1.1 million hectares, reducing the low-risk areas from 1.96 million hectares to 838.9 million hectares (-57.1%). The tendency is to confine planting in the southern part of the Atlantic Forest biome where temperatures are milder and the water deficit is reduced. The southern part of the Cerrado biome may also remain a productive area.

In SWL4, in the bean culture for the second crop, areas of high risk may increase by 733.4 thousand hectares, reducing the low-risk areas from 1.02 million hectares to 286.9 million hectares (-71.9%). The perspective is that the production will be confined to the southern part of the Atlantic Forest biome in the Cerrado and Amazon, where the water deficit is reduced during the production period of the second crop.

**SOYBEAN AND WHEAT:** In SWL4, in the case of soybeans, areas of high risk may increase by 20.3 million hectares, reducing the low-risk areas from 24.98 million hectares to 4.69 million hectares (-81.2%). In SWL4 for wheat, areas of high climatic risk may increase by 23.8% (455.2 thousand hectares), reducing the low-risk areas from 1.91 million hectares to 1.46 million hectares. Among the factors, we can mention the warmest winters and the increase in nighttime temperatures.

### 3.6.3 MAIN RESULTS IN FOOD SECURITY

AGRICULTURE AND LIVESTOCK PRODUCTION HAS ALREADY SUFFERED LOSSES. Food production in Brazil has grown in recent decades and continues to grow gradually more due to the increased productivity than the expansion of new areas of cultivation. However, agriculture and livestock activity are very vulnerable to the adversities imposed by the climate. Climate extremes have affected the production capacity of all systems across the national territory with strong impacts on the economy and rural life. The agriculture and livestock sector has already shown losses due to extreme events. In 2012, there were production losses of more than 40% in the beans and corn crops and 34.3% in manioc in the Caatinga. The Pampa biome had production losses of 38.1% in the soybean crop that year, and in 2015, the Coastal Zone had losses of 60.9% for the wheat crop.

A PRODUCTIVITY REDUCTION OF SEVERAL AGRICULTURAL CROPS IS PROJECTED in the 2050 horizon, such as: 15.2% (rice), 21.5% (coffee), 23.1% (beans), 46.2% (wheat), 51.0% (corn), and 79.5% (soybeans), affecting the food supply. In livestock, the projected production reduction is 3.4% (eggs) and 18.8% (milk) by 2050, and 7.0% (beef) by 2030. In fishing and aquaculture, the reduction in fish production will be 11.0% by 2050. Besides, crops will suffer losses of areas of low climate risk in SWL4 corresponding to 13.9% (rice), 22.2% (1st corn crop), 23.8% (wheat), 57.1% (1st beans crop), and 81.2% (soybeans).

Said reduction in productivity may lead to more cultivated areas to meet the internal and external demands if adaptation measures are not adopted.

REGIONAL VULNERABILITIES ARE HETEROGENEOUS. It should be noted, however, those different vulnerabilities are present in each region depending on the models and production scales, availability of technical assistance services, and access to information especially for family production units and traditional communities, as well as levels of environmental degradation and ecosystem fragmentation.

**CERRADO AND CAATINGA -** Droughts and dry spells will be regionally differentiated causing reductions in productivity and production losses, affecting the major food-producing centers in the country. The increasingly frequent and intense drought and dry spell events have been reducing water availability and affecting agricultural activities, especially dry farming. To minimize losses, there is potential to increase the demand to use irrigation in agriculture, with this increase being already estimated at around 45% by 2030 (10 million hectares - ANA, 2017), without considering the effects of climate change. Currently, the Cerrado biome has the largest irrigated area in the country (2.9 million hectares), mainly focused on the production of corn, soybeans, and wheat. However, the use of water for irrigation must be compatible with other uses of water, such as energy supply and production.

In the Caatinga biome, family farming may be the most affected one, with a productivity reduction of corn and beans. The drought was responsible, for example, for the crop failure in 2012 in the Northeast region, reducing corn production by 99.2% in Araripina/PE.

**Atlantic Forest, Amazon, and Pantanal -** Likewise, the reduction in precipitation, the increase in temperature, and the greater occurrence of extreme events (dry spells and heavy rains) should impact the production systems.

**Pampa** - In addition to the increase in temperature, it is projected an increase in average precipitation and the occurrence of extreme events (frosts, hail, and heavy rains), including periods of drought, with consequences for food production, especially for the cultivation of soybean and rice. For example, the South region showed a reduction in the volume of rain in 2012, thus reducing soybean production by 45.8% in Tupanciretã/RS, and a reduction of 25.5% in the rice crop in 2005 in Rio Grande do Sul.

**Coastal areas -** with extreme events (heavy rains) and increased temperatures of the oceans, there may be a reduction in fish stocks.

Agriculture and livestock production costs are affected by climate change, with an increase in the cost of corn production of up to 30% in the Atlantic Forest and Cerrado biomes (2010-2012); in the Caatinga biome, the increase was 41% in pork production (2014-2016). Increases in food prices were also observed, with corn (60 kg bag) getting 45% more expensive between 2013-2016. Soybeans and beans (60 kg bag) were 40% and 50% more expensive, respectively, between 2011-2012, when there were droughts and dry spells in the Caatinga and Cerrado biomes. In livestock, increases in prices were also observed, with beef (15 kg) getting 51% more expensive between 2013-2016.

Implications for producer protection policies. In this context, both Proagro and Guarantee-Harvest Programs - instruments of agricultural insurance - are affected by periods of climate extremes. Excessive droughts and rains are the events bringing the most damage to producers and occurring more frequently. In recent years, there has been a gradual increase in public spending due to the greater demand for adherence and payments made, especially in the Northeast region where there were more intense and frequent droughts. In the 2011-2012 period, Proagro accounted for a significant volume of deferred coverage throughout the country, much of it for family farmers (Banco Central do Brasil, 2015). In the same period, Guarantee-Harvest Program actions also reached significant payments due to drought events in the semiarid region. Therefore, agricultural insurance spending could be affected by climate change.

## 3.7 SOCIOENVIRONMENTAL SECURITY

### 3.7.1 Context

#### Conceptualization

Explicit reference to Socioenvironmental security in climate change is still recent in the literature, although the issue is present in several studies under other names. These, in general, start from the definitions of human security (*human security*, in English) and lifestyle and livelihoods (*livelihoods*, in English) to arrive at a comprehensive concept of Socio and environmental security (Biggs et al., 2014; Adger et al., 2014; Olsson et al., 2014; Hoegh-Guldberg et al., 2018; Roy et al., 2018).

Globally, changes in ecosystems and habitats have advanced intensely since the Industrial Revolution, characterizing the so-called Anthropocene[28] (Crutzen, 2006). Assessing impacts, vulnerabilities, and risks on Socioenvironmental security in the face of climate change mean considering the dynamics between social systems (individuals, governance, institutions, and the market) and natural ones, translated into ecosystem services of provision, support,

[28] *The Anthropocene perspective involves forcing dynamic, complex and intertwined structures, between climate, ecosystems, society, the market economy and governance, which result in emergent phenomena and unintended consequences, manifesting a warmer world with an incidence of climate extremes at multiple spatial scales (Bai et al., 2016; O'Neill, BC et al., 2017; Brondizio et al., 2016).*

and regulation for human well-being (Millenium Ecosystem Assessment, 2005; Ostrom 2009). Such interactions can be referred to by socio-ecological dynamics[29] or Socioenvironmental as they will be addressed in this document.

Ecosystem services come directly or indirectly from ecosystems, which provide benefits to human needs (Millennium Ecosystem Assessment, 2005; Costanza et al., 2017; Daily, 1997; Duraiappah et al., 2005). In this sense, a utility value is attributed to biodiversity and ecosystems based on their economic importance and use (Haines-Young and Marion Potschin, 2010). At the same time, it also considers the intrinsic value of nature, beyond the monetary aspect, expressed, among other spaces of awareness, in the knowledge and lifestyles and culture of indigenous peoples and traditional communities (Diaz et al., 2018). Services are classified as: provision (water, food, fiber, fish, energy, among others); regulation (climate, water purification, pollination, vector, and pathogen control, among others); cultural (tourism, spiritual enhancement, landscape aesthetics, and human well-being); and support (productivity or maintenance of biodiversity and soils, for example) (Agard and Schipper, 2014; Millenium Ecosystem Assessment, 2005).

Given this perspective, in this 4NC, the condition by which human existence, in all its aspects, interact with ecosystems, favoring its services, has ensured a dignified and satisfactory life without damage to other living beings and ecosystems integrity and intrinsic value must be recognized. Analysis of Socioenvironmental dynamics can highlight production and reproduction forces of the vulnerabilities of ecosystems, social actors, and sectors at different scales of space and time (Araujo et al*.,* 2019).

## The relevance of Socioenvironmental security for the country and adaptation

Brazil is a country of medium to high Socioenvironmental vulnerability to climate change (Viola and Franchini, 2014); (i) for having a long coastline with high population density (Leal Filho et al., 2018); (ii) because it is a food-based country (*food-based*, in English), both for food production and for the production of *agricultural products* for the international market (Lapola et al., 2014; Martinelli and Filoso, 2008); (iii) for containing an enormous extension of tropical forest in the world, rich in biodiversity and cultural diversity (Maffi, 2005; Mittermeier, Robles-Gil and Mittermeier, 1997); and also, (iv) for presenting high rates of poverty and socio-economic inequality, mainly in precarious urban settlements, which hinder access to health, education and income (Cedeplar / MMA / UNDP, 2017; Darela et al., 2016; Pinho et al ., 2014).

### Biodiversity and ecosystems

Even though Brazil has large extensions of natural and semi-natural ecosystems maintained under protection, mainly in the Amazon biome, climate and land-use projections indicate a significant risk of biodiversity loss (Faleiro et al. 2013; 2018; Lemes et al. 2013; Loyola et al. 2014; Ribeiro et al. 2016; 2018; Sales et al. 2017a; Silva et al. 2018; Vieira et al. 2018 apud Ometto et al., 2018) and ecosystem services in the future ( Costa et al. 2018; Diniz-Filho et al. 2012; Faleiro et al. 2018; Gianinni et al. 2017; Vieira et al. 2018 apud Ometto et al., 2018).

Currently, at the federal level, without considering Private Natural Heritage Reserves (RPPNs, for its acronym in Portuguese, there are a total of 296 Conservation Units - (UCs, for its acronym in Portuguese), of which 185 are in the category of Sustainable Use and 149 of Integral Protection, which represent about 20% national territory (CNUC/MMA, 2019). An increase in the number of Conservation Units (UCs) per biome occurred in the country in the late 1980s, mainly in *hotspots* in the Atlantic Forest, Amazon, and Cerrado, but less significant in the Caatinga (semi-arid), Pampa and Pantanal (wetlands) biomes (Saraiva et al., 2018). Efforts to conserve marine ecosystems advanced until 2018[30], surpassing the 10% predicted by the Aichi Targets until 2020. However, the numbers are still incipient compared to terrestrial biomes (Bustamante, Metzger *et al.,* 2019).

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*[29] In this document, we will use the word Socio and environmental to describe and refer to socio-ecological systems (Ostrom, 2009).*

*[30] In 2018, two APAs were created each 40 million hectares (ha), in addition to the Natural Monument of Trindade and Martim Vaz, with 6 million hectares, and that of São Pedro and São Paulo, with 4 million hectares. Brazil goes from 1.5% of marine protected areas to 25%, which allows the fulfillment of Aichi Target 11, which provides for the protection of 17% of the marine and coastal areas of each country by 2020 (Decrees No. 9313/2018 and No. 9312/2018).*

Brazilian biodiversity represents 10 to 20% of the global diversity of species (Motta, 2015) and comprises about 30% of the world's tropical forests (Myers et al., 2000). In an estimate, the number of endemic species of flora and fauna in the Amazon biome is 1314 and 2600, respectively; in the Caatinga it is 232 and 2579, respectively; in the Cerrado (savanna), it is 631 and 7347; in the Atlantic Forest it is 2731 and 10349; in the Pampa there are 60 and 260; in the Pantanal, it is 63 and 167; and in marine, it is composed of 334 species of fauna (Brazil, 2019).

BRAZILIAN SOCIO-CULTURAL DIVERSITY is an essential element that adds to the biodiversity present in this country of continental dimensions to understand the different lifestyles, cultural and historical values, and the interaction with the environment in which they are inserted. To exemplify this issue, Brazil brings together 305 indigenous ethnic groups, 900 thousand Indian persons who speak at least 274 languages (IBGE, 2016), who are vulnerable to the impacts and risks of land-use changes and climate incidence extremes (Saraiva et al., 2018). In the Amazon biome, approximately 561 Indigenous Territories (TI), for its acronym in Portuguese, spread over 116.8 million hectares and represent about 20% of the area.

URBANIZATION AND CLIMATE PRESSURES. Urbanization is a vector for modifying habitats, mainly when it occurs in an accelerated and disordered manner, which compromises human health and well-being, and increases its susceptibility to climate extremes. The impacts on the incidence of diseases and disasters related to climate extremes, such as thermal discomfort and cardiovascular diseases in the elderly (Lapola et al., 2019), respiratory and waterborne (Hacon, Oliveira and Silveira, 2018), in addition to flooding and landslides (Perez, 2016), mainly affect poor populations living in dense areas with precarious infrastructure (Mikosz, 2017).

Above all, urbanization along the extensive Brazilian coastline (8500 km), occupied by about 25% of the Brazilian population (Brazil, 2011), distributed in approximately 400 municipalities in the country, has been a significant vector of the loss of native vegetation and ecosystem services.

Also, within a complex set of vectors, the loss of agricultural productivity coupled with the advance of desertification areas influences migration processes in the semi-arid (Lindoso et al., 2018), the increase in housing density in precarious urban settlements, and pressures on ecosystems (Bustamante, Metzger et al., 2019).

## GOVERNANCE IN SOCIOENVIRONMENTAL SECURITY

The main national public policies aimed at environmental conservation, traditional peoples and communities, family farming, cities, and risk management and social protection are described below.

### ENVIRONMENTAL CONSERVATION, TRADITIONAL PEOPLES AND COMMUNITIES

The country's main environmental governance instrument is the National Environmental Policy (PNMA, for its acronym in Portuguese), (Law No. 6,938/1981), whose main objective is "preservation, improvement, and recovery of environmental quality provide to life, aiming to ensure in the country the conditions for socio-economic development, the interests of national security and the protection of the dignity of human life."

*To learn more about the country's environmental characteristics, see **item 1.1.***

The **Native Vegetation Protection Law** (LPVN, for its acronym in Portuguese) - (Law No. 12,651/2012), or New Forest Code, establishes general norms for the protection of vegetation, Permanent Preservation Areas (APPs), for its acronym in Portuguese, Legal Reserve (RL), for its acronym in Portuguese, forest exploration and forest fire control and prevention (Brasil, 2012). The National Policy for the Recovery of Native Vegetation (Proveg, for its acronym in Portuguese) and the National Plan for the Recovery of Native Vegetation (Planaveg, for its acronym in Portuguese), both of 2017, aim at recovering RLs, APPs, and degraded areas with low agricultural productivity.

The **Brazilian System of Conservation Units** (SNUC, for its acronym in Portuguese) - (Law No. 9,985/2000), implemented by the Ministry of the Environment (MMA, for its acronym in Portuguese) and other national and subnational entities, operates in territorial ordering to prioritize biodiversity conservation, the sustainable use of natural resources, encourage productive chains of biodiversity, and extractivism by indigenous peoples and traditional communities, to guarantee the maintenance of the lifestyle, subsistence, and economy (MMA, 2011).

Also noteworthy is the National Policy for the Sustainable Development of Traditional Peoples and Communities (PNPCT, for its acronym in Portuguese) - (Decree No. 6,040/2007), which provides for the recognition and visibility of Traditional Peoples and Communities (PCT, for its acronym n Portuguese), and the regularization of their territories, whose implementation is the responsibility of the Ministry of Social Development. The National Policy on Territorial and Environmental Management in Indigenous Lands (PNGATI, for its acronym in Portuguese), (Decree No. 7,747/2012) aims at the protection, recovery, and sustainable use of natural resources in indigenous lands as a way of guaranteeing the conditions of life and culture of these peoples. Its coordination and execution are carried out by the National Indian Foundation (FUNAI, for its acronym in Portuguese) (Law No. 5,371/1967), linked to the Ministry of Justice and the National Council for Indigenous Policy. The Quilombolas Reserves (Decree No. 4,887/2003) guarantee the right to use the land and are given to descendants of black slaves and residents of rural areas.

Some socioenvironmental protection programs aim to financially reward forest conservation and ecosystems to indigenous peoples and traditional populations, such as the Bolsa Verde Program[31] and the Bolsa Floresta Program[32] .

Within the scope of strategies on biodiversity, sustainable, productive chain, and food security, especially for indigenous peoples and traditional communities, the National Plan for the Promotion of Socio-Biodiversity Product Chains (PNPSB, for its acronym in Portuguese), the National Plan on Agroecology and Organic Production (PLANAPO, for its acronym in Portuguese) and Minimum Price Guarantee Policy for Sociobiodiversity Products (PGPM-Bio, for its acronym in Portuguese) (MMA, 2016).

Brazil also has the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm, for its acronym in Portuguese) created in 2004, which was also established for other biomes, such as Cerrado (PPCerrado). Also noteworthy is the program for monitoring hot spots and fires carried out by INPE.

The National Commission to Combat Desertification (CNCD, for its acronym in Portuguese) is responsible for implementing the National Policy to Combat Desertification and Mitigate the Effects of Drought, transversal to other sectoral policies, programs, projects, and related government activities in the country.

For aquatic ecosystems, Brazil has been a signatory since 1971 of the Ramsar Convention (RC), which includes conservation actions in Wetlands, with its guidelines in different modalities of UCs (Bustamante, Metzger and et al., 2019).

#### CITIES AND DISASTER RISK MANAGEMENT

Policies and instruments for territorial planning at the local level, together with the regional Ecological-Economic Zoning, are essential to ensure and increase urban areas' resilience with a high environmental value. The Statute of the City (Law No. 10,257/2001) defines the subdivision guidelines in small parcels and use of urban land. It establishes the Master Plan, the main urban instrument, mandatory for municipalities with more than 20 thousand inhabitants (among other criteria).

It is important to point out the federal programs My House, My Life (Minha Casa, Minha Vida), which seeks to facilitate access to homeownership for low-income families, and National Basic Sanitation Plan(PlanSab, for its acronym in Portuguese) which aims to universalize environmental sanitation, reduce the proliferation of waterborne diseases and the impacts of natural disasters in urban areas.

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*[31] It is an income aid for the rural and extractivist population to develop activities of production and income generation.*

*[32] Financial compensation for forest conservation services provided by the traditional and indigenous populations of the Amazon.*

The Ministry of Regional Development is responsible for disaster management in urban areas, with urban planning and fighting disasters. In this context, stands out the National Policy on Protection and Civil Defense (PNPDEC, for its acronym in Portuguese) (Law No. 12,608/2012), which provides support to municipalities for the elaboration of Risk Reduction Plans and institutional arrangements between federal, state and municipal Civil Defense. The National Plan for Risk Management and Response to Natural Disasters of 2011 also created the National Center for Monitoring and Early Warnings of Natural Disasters (Cemaden, for its acronym in Portuguese), under the management of the Ministry of Science, Technology and Innovations (MCTI, for its acronym in Portuguese), which monitors natural threats in risk areas in municipalities and issues risk alerts for hydro-geo-meteorological disasters to state and municipal civil defenses. Finally, the Geological Service of Brazil (CPRM, for its acronym in Portuguese) is responsible, at the federal level, for preparing vulnerability maps for floods and landslides (Mikosz, 2017).

As a way of strengthening the response capacity of the Universal Health System (SUS) in the face of emergencies in public health as in the case of disasters, the Ministry of Health has the Environmental Health Surveillance of Risk Associated with Disaster (Vigidesastres) within the scope of the General Coordination of Environmental Health Surveillance (CGEMSP ) of the Department of Environmental Health, Workers and Surveillance of Public Health Emergencies (CGVAM / DSASTE). The program promotes the development of actions to be continuously adopted by public health authorities to reduce the risk of exposure of the population, infrastructure, and health professionals to the impacts caused by natural disasters. CGEMSP also manages the Center for Strategic Information in Health Surveillance (CIEVS), whose main objective is the identification of public health emergencies continuously and systematically, and the expansion of the technical capacity to respond to events comprising public health emergencies, including training of human resources to develop research, control and prevention actions.

### Social Protection

Certain programs and services are essential in maintaining human health and well-being, such as the Family Allowance Program (Bolsa Família) (Law No. 10,836/2004), a world reference in the fight against poverty and social inequality, whose objective is to relieve poverty and promote social inclusion to provide education, health, and employment, through intersectoral coordination between the three spheres of the federation.

*To learn more about social policies in the country, see **item 1.4.***

In the semi-arid region of the Brazilian Northeast, which comprises the Caatinga biome, for decades, intersectoral policies have been in place to reduce the impacts of recurrent drought extremes. Superintendence for the Development of the Northeast (Sudene, for its acronym in Portuguese), (Law No. 3,962/1959) acts on the Northeast socio-economic development, intending to minimize the impacts of drought on regional emigration and the production of family farming.

The Universal Health System (SUS, for its acronym in Portuguese) is formed by a wide social protection network, such as the Family Health Program (PSF, for its acronym in Portuguese) to serve the poorest communities in the country, working mainly in preventive health. Related to climate change, in 2011, the Health Sectoral Plan for Mitigation and Adaptation to Climate Change (PSMC, for its acronym in Portuguese) was created; It establishes SUS adaptation measures to minimize the vulnerabilities of needy populations and strengthen the response of health services in the face of climate change, in addition to forming a National Force for the contingency of emergencies in cases of floods, landslides, prolonged droughts, and epidemics.

Given the important relationship between air quality and health, the Universal Health System (SUS) has, within the scope of the General Coordination of Environmental Health Surveillance (CGVAM) of the Ministry of Health, with the Surveillance of Populations Exposed to Air Pollution (VIGIAR) aimed at promoting the health of the population exposed to environmental factors related to natural and/or anthropogenic air pollutants (from fixed sources, mobile sources, activities related to mineral extraction, burning of biomass, or forest fires). VIGIAR's actions are developed jointly with the Municipal, State, and Federal District Health Departments.

### 3.7.2 Impacts and vulnerabilities in Socioenvironmental security: ecosystems and ecosystem services

Due to the wide thematic scope of Socioenvironmental security, the analysis was structured in two ways: the first dealing with ecosystems and ecosystem services, and the second of disasters, migrations, and health.

#### Impact chain: Ecosystems and ecosystem services

Climate change and the processes it changes are fed back by changes in land-use, generating a chain of impacts.

Climate pressures include rising temperatures, changes in precipitation patterns (including increased incidence and magnitude of extreme events), heat waves, rising sea levels, and ocean temperatures and ocean acidification.

Non-climate factors also contribute to the increased vulnerability of natural and human systems. Climate change, along with other vectors of degradation, has led to an increase in ecosystems and biodiversity's susceptibility and vulnerabilities, undermining its condition to provide essential ecosystem services for human and economic well-being and development. The pressure factors for land-use change, population growth, changes in consumption and technological patterns, and socio-economic activities are cited as an example.

> Biodiversity has the role of mediator of all ecosystem services of provision, regulation, support and cultural (Díaz et al., 2018)

From another perspective, poverty, marginalization (by gender, ethnicity, race, and social class) and socio-economic inequality, including lack of access to technologies and infrastructure, overlap with degradation and loss of ecosystems and are conditioning factors of vulnerabilities to different climate-related impacts (Adger et al., 2014; Olsson et al., 2014). Also noteworthy are the traditional populations, indigenous peoples, and family farmers who directly depend on the forest's integrity and the ecosystem services it provides, making these groups highly vulnerable to the impacts of environmental degradation and climate change.

> Climate change is an obstacle to the eradication of poverty and socio-economic inequalities, and can put more people in this situation (Hallegatte and Rozenberg, 2017).

The tipping points and their uncertainties. The climate impacts, superimposed on the processes arising from changes in land use, affect ecosystems in a non-linear way, heterogeneous in time and space, and are still poorly elucidated, such as the debate on "*tipping points*" [33] (Lenton et al., 2008). The "*tipping points*" are associated with thresholds of change (including climate factors), which, if exceeded, can compromise the stability of ecosystems and generate negative impacts for the economy and society. These thresholds are difficult to predict and even more to reverse. However, they must be recognized to anticipate and manage emerging risks (Oppenheimer et al., 2014), which challenge governance for sustainability and the fight against climate change (Rocha, Peterson and Biggs, 2015; Scheffer et al., 2001).

> Tipping point of the Amazon Forest. The loss of part of the forest can compromise the ecosystem's integrity (Lovejoy and Nobre, 2018; Nobre, et al., 2016). This tipping point would happen with 40% deforestation over the original forest distribution. It would affect the region's hydrological cycle, which would cause a reduction in moisture availability and a prolongation of the dry season. And consequently, the transition to a new level of ecological stability (Malhi et al., 2008; Lovejoy and Nobre 2018; Lapola et al., 2018). As the Amazon Forest regulates the hydrological cycle in the Amazon and transports moisture to the Midwest, Southeast, and South regions, favoring the occurrence of rains (Marengo et al., 2004 and Arraut et al., 2012), the anthropic pressure on this ecosystem it can jeopardize the continental climate (Nobre, Sellers, and Shukla, 1991; Marengo et al., 2018; Watts et al., 2019).

The growing role of climate change in ecosystem degradation. For Brazil, modeling analysis of the cumulative effects of climate and non-climate vectors on the variation in the average abundance of species reveals that land-use change has always played a predominant historical role in altering terrestrial ecosystems [34] and marine environments (1658) Joly et al., 2019). The reduction in the average abundance of species until 1970 was estimated at 22.6%, with a small

[33] *tipping points or points of non-return to the original state and functionality.*

[34] *In these MUT analysis, the Pantanal biome was not considered.*

climate change share. From that decade on, there is an increasing influence of climate change on biodiversity loss processes. In 2050, the loss would reach 45%, that is, an increase of 23.4% compared to 1970, with climate change alone being responsible for up to 10%, according to the analyzed trajectory (Ometto et al., 2018).

Occupation of coastal areas and consequences for ecosystem services. In coastal areas, urban occupation impacts the provision of water and food (overfishing, for example), generates pollution and loss of ecosystem support services for coastal and cultural stability, such as recreation and tourism (Bustamante, Metzger et al., 2019). The vulnerability of coastal cities, with precarious settlements and lack of native vegetation, is mainly associated with floods and erosive processes arising (and aggravated) by rising sea levels and an increase in the frequency and magnitude of extreme events (Copertino et al., 2017). Provision of ecosystem services at risk. Pressures on ecosystems, habitats, and biodiversity caused by changes in climate and land use have direct impacts on the ability to provide services to these natural systems, as well as on the human systems dependent on them.

> The loss of coral reefs, associated with oceans warming, will further reduce fishing stocks (Donner and Potere, 2007), which together with overfishing will compromise the lifestyle and income of around 1 million fishermen, mainly from the North. and Northeast of the country (Saraiva et al., 2018).

> The impacts of climate change on altered ecosystems can also compromise tourism (Bustamante, Metzger et al., 2019; Mikosz, 2017).

water availability. Well-structured soils, such as forest soils, capture and store water and play an important role in providing drinking water for human supply, agriculture, livestock, and power generation. The loss of ecosystem resilience expected from the SWL2 for the Amazon, Atlantic Forest, and the Cerrado may compromise water availability in different regions and increase competition between different sectors such as urban supply and agricultural production.

food production. It is directly dependent on soil quality and water availability and is associated with native vegetation and ecosystem pollination services. Ecosystem changes caused by climate change have made food production vulnerable to climate extremes (Gomes et al., 2019).

Alteration of the livelihoods, mainly among indigenous peoples and traditional populations and family farmers, associated with the impacts of climate extremes on agricultural, fishing, commercial, and subsistence practices are directly related to environmental degradation and poverty levels, and socio-economic inequality (Lapola et al., 2018; Pinho, Marengo, and Smith, 2015; Tomasella et al., 2013). Erosion of coastal and continental areas and silting of rivers generate "forced" migrations, both for the Caiçara population that occupies the coastal zones and for the riverside population that occupies the margins of large rivers (Cedeplar / MMA / UNDP, 2017; Lapola et al., 2018; Pinho, 2016).

human health Altered ecosystems imply greater vulnerability to climate change in the health of the population. Less presence of native vegetation and/or greater degraded areas is reflected in the increased incidence of waterborne diseases and/or dispersion by vectors (e.g., dengue, malaria, and yellow fever) (Barcellos and Lowe, 2014; Sena et al., 2017). Similarly, balanced ecosystems and the preservation of natural systems in urban areas contribute to heatwaves' control, mainly affecting more vulnerable populations such as the elderly, children, and pregnant women (Lapola et al., 2019).

> fragmentation in the Atlantic Forest. Changes in rainfall and prolonged droughts indicate loss of primary productivity in the Atlantic Forest (Pires et al., 2017). The high fragmentation of the biome leads to the creation of borders that negatively affect the structure of vegetation, biodiversity, biomass, and, consequently, the carbon storage service (Bustamante, Metzger, et al., 2019; Robinson et al., 2015). Without or with little border effect, forests retain up to three times more carbon than small fragments (Magnago et al., 2017). Compared to other biomes, the Atlantic Forest is undoubtedly the one with the least adaptive capacity in the face of climate change impacts, precisely because it has only 14% of its original vegetation cover (Lapola et al., 2014).

## KEY IMPACTS' ASSESSMENT: ECOSYSTEMS AND ECOSYSTEM SERVICES

### METHODOLOGICAL APPROACH

According to the chain of impacts related to climate in Socio and environmental security, the "key impacts" evaluated are:

- alteration of ecosystems, habitats, and biodiversity;
- the occurrence of fire episodes;
- loss of ecosystem services.

ANALYSIS OF IMPACTS BY BIOMES. The "key impacts" were analyzed from an integrated perspective for each Brazilian biome, considering results from the modeling of the resilience of biomes to climate change carried out based on the distribution of climate niche, based on variables of temperature and precipitation for the current period (1960-1990) and future scenarios (SWL1.5, SWL2, and SWL4).

Climate niche is understood here as the set of favorable climate conditions for the occurrence of each of the biomes in Brazil.

THE RESILIENCE OF BIOMES refers to the "ability of the forest to absorb disturbances and reorganize itself to maintain its functions and functioning structures, considering that ecosystems rarely return to their state and conditions before the disturbance" (Scheffer, 2009, p. 357). Resilience is considered the recovery rate after the disturbance and the maximum disturbance that the forest can absorb before transforming into another type of ecosystem (Gunderson, 2000; Scheffer et al., 2009).

Also, other factors that act in synergy with the loss of resilience of biomes were considered, such as changes in land use, socio-economic activities, urbanization, among others, in addition to climate change.

Several uncertainties hinder the accurate projection of land-use scenarios and the future impact of climate change on Brazilian biomes' ecosystems (Ometto et al., 2018). However, observed data offer good indicators of Brazilian biomes' impacts and vulnerabilities in the current scenario (Lapola et al., 2014; Soares-Filho et al., 2006; Strassburg et al., 2017).

As for the Coastal Areas, in addition to the resilience factors of the modeled biomes, there are specific aspects related to the climate, such as sea-level rise, rising ocean temperatures, coastal erosion, and acidification, with consequences and negative impacts on the aquatic ecosystem services and biodiversity, described in BOX 3.5. Oceans and Socio and environmental resilience in Coastal Zones to Climate Change.

MODELING RESILIENCE OF BIOMES TO CLIMATE CHANGE. To estimate the resilience (or potential eco-climate response) of biomes, it was assumed that each type of vegetation is adapted to certain climate conditions. Suppose in the future a biome is exposed to different conditions, to which it is not adapted. In that case, its resilience will decrease to a point where it would transform, resulting in vegetation characteristics of another biome. Thus, each biome represents a stable state within a multistable system (Scheffer et al., 2012). It presents a phenotypic response peculiar to a region's prevailing climate conditions, consolidated throughout evolutionary history (Donoghue and Edwards, 2014).

Four climate predictors (Lehmann et al., 2014; Oliveras and Malhi, 2016) were selected from two eco-climate axes, according to Anjos and Toledo (2018): moisture availability - (1) annual accumulated precipitation and (2) precipitation seasonality - and energy availability - (3) average annual temperature and (4) annual temperature range. Such variables were obtained from the Eta-HadGEM2-ES climate model (Chou et al., 2014), with a spatial resolution of 0.20 ° (~ 20km). More than 21,000 points distributed equally across the country were selected, containing, in addition to information on the presence or absence of terrestrial biomes, rain and temperature patterns for the present and the future.

"Resilience" represents the degree of dominance of a certain biome within certain biogeographic limits. High values of this variable indicate that a biome has a strong predominance compared to others. On the other hand, low values point to a greater susceptibility to transition events to other stable states of ecosystems. To better interpret the results, it is understood that the biome is not observed where the resilience value is 0. In contrast, positive non-zero values approximate the probability of finding the biome in that location, both in the historical and future scenarios. The highest resilience value found in biomes in Brazil was 996 (in their original conditions). The range of colors adopted in the maps is from 0 to 1000, to contemplate this maximum value.

The results obtained show that, in the current climate, each biome occupies a certain range of the environmental climate gradient. Within this context, they all have high relative resilience in their domains and low or intermediate resilience in the transition ranges of biomes, with little overlap in the climate niche occupation (temperature and precipitation)[35].

### Analysis of Impacts by Biomes.

For each biome, an analysis (quali-quantitative) of the exposure of ecosystems and habitats in the face of the respective resilience projections, given the evidence and trends associated with other non-climate pressure factors.

### Amazon

The Amazon is a *hotspot* of biodiversity and constitutes the largest tropical forest in the world, providing ecosystem services for regional and global climate regulation (Byers et al., 2018; Mittermeier, Robles-Gil, and Mittermeier, 1997). Likewise, it is a *hotspot* of climate change given the sensitivity of the forest to increased temperatures, reduced and increased rainfall and moisture (Cox et al., 2004, Nobre et al., 2016), and because it is located in the tropics, the average increase in global temperatures is much more expressive (Hoegh-Guldberg et al., 2018; IPCC, 2014). In the socio-economic context, Amazonian cities have been treated as a *hotspot* of socio-climate vulnerability due to **a significant increase in** temperature, loss of forest cover and ecosystem services, high poverty rates, and lack of infrastructure (Darela et al., 2016; Torres and Marengo, 2014).

### Amazon Loss of Habitats, Ecosystems, and Biodiversity

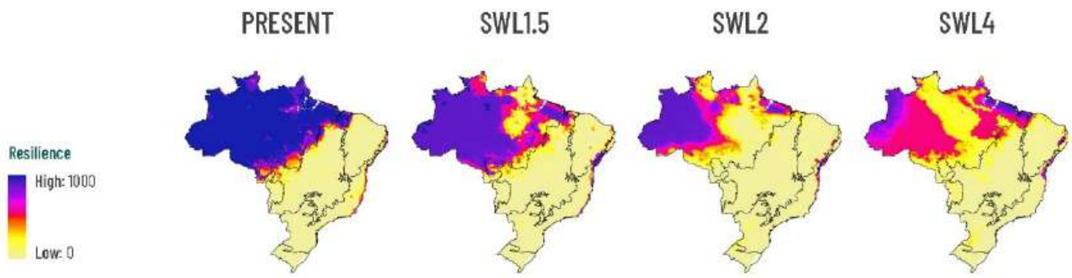


Figure 3.38. Projections of the Amazon biome's resilience, in the present and the scenarios SWL1.5, SWL2, and SWL4.

The amplitude of resilience in the eco-climate space of the reference period occupied by the Amazon (high levels of precipitation and temperature) denotes a high adaptive capacity of the forest. Trends in decreasing rainfall and moisture would affect its resilience, with the threshold of its change being sensitive to a decrease in annual rainfall below 1,500 mm/year. The projections show a significant change in resilience and show a loss in the most biome, starting from SWL1.5. It is concentrated in high resilience only in the biome's western part, but with significant retraction at higher heating levels (Figure 3.38). Such a scenario increases tree mortality, a reduction in forest biomass, and an increase in fire episodes incidence until the loss of biodiversity and ecosystem services (Anjos and Toledo, 2018; Ometto et al., 2014; Silva et al., 2018).

The Amazon rainforest has been subjected to forced land-use change, which increases its susceptibility to the impacts of climate change and compromises its regeneration capacity (Davidson et al., 2012; Hoegh-Guldberg et al., 2018; Marengo et .al, 2018). Over the past decade, deforestation rates in the Amazon have dropped significantly compared to 2004 levels, but from 2016-2018 they have grown again (Aguiar et al., 2016; Aragão et al., 2018).

[35] *The results of this modeling have also been described by Zanin, Machado and Albernaz (2016), showing compatibility with the results.*

### AMAZON: INCIDENCE OF FIRES

In the Amazon region, fire is a widespread technique, especially for land clearing and agricultural management and hunting and religious rituals by indigenous peoples and traditional communities (Hecht, 2006). Over the past 20 years, in conjunction with the increase in forest conversion to other uses, severe droughts have amplified fire occurrences (Campanharo et al., 2019). For the Legal Amazon, in the states of Acre, Amazonas and Pará, during the droughts of 2005, 2010, 2016, and 2017 there was a significant increase in the number of active hotspots due to the burning of biomass (Figure 3.39).

The increase in forest fire episodes affects the structure of the forest, leads to the loss of biodiversity, compromises ecosystem services, in addition to increasing greenhouse gas emissions (Aragão et al., 2014).

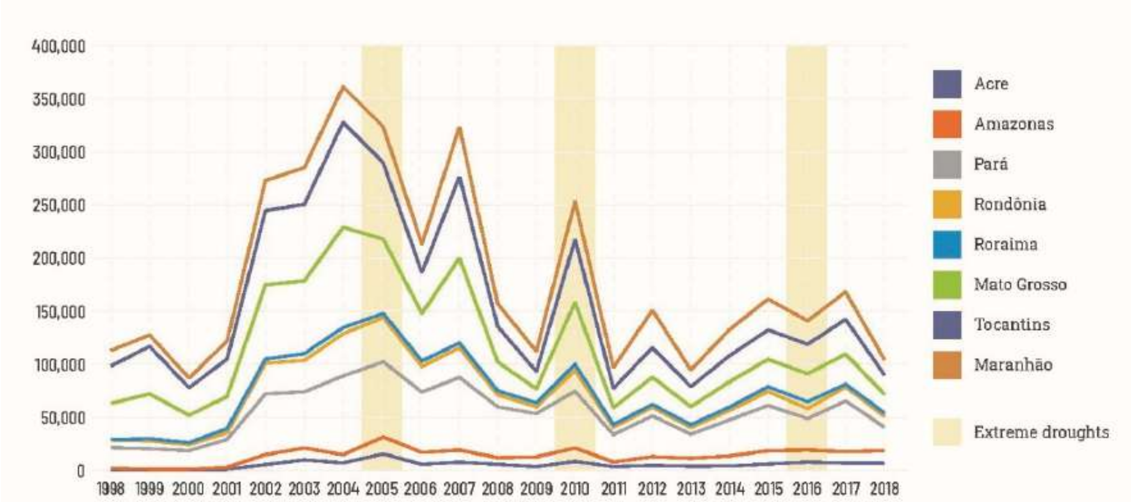


Figure 3.39. Total active hotspots detected by the reference satellite, from 1998 to 2018, for the states of the Legal Amazon and extreme drought peaks in 2005, 2010, and 2016. Own preparation based on data provided by INPE[36].

In the state of Acre, during the extremely dry year of 2010, fires spread to remote regions, which impacted private and public protected areas, with a total affected area approximately 16 times greater than in normal weather years (Campanharo et al., 2019).

A recent assessment showed that, although the rate of deforestation decreased by 76% between 2003 and 2015, in 2015, the incidence of fires during drought increased by 36% compared to the previous 12 years. In 2015/2016, it was estimated that about 46% of the biome in the Brazilian part was affected by severe and extreme drought, compared with 16% and 8% for the droughts in 2009/2010 and 2004/2005, respectively (Anderson et al. 2018).

There is evidence about the association between emissions from burning biomass in the forest and respiratory diseases, especially in children under 5 years of age (Carmo, do, Alves and Hacon, 2013). In the Amazon, during the drought in 2005 and 2010, there was an increase of 1.2 to 27% in hospitalizations of children (under 5 years of age) due to respiratory diseases (Smith et al., 2014). In 2018, cities in the states of Amapá, Pará, Maranhão, and Mato Grosso registered significant increases in hospitalizations of children (under 10 years of age) due to respiratory problems (total of 5,091 hospitalizations per month, when the expected value would be 2,589). In Pará, in 2018, 86 deaths of children (under 5 years of age) due to respiratory problems were recorded. Only in 2018, it is estimated that hospitalizations of children due to respiratory problems would have generated a surplus cost of R$ 1.5 million in public hospitals and SUS-affiliated hospitals (Barcellos et al., 2019).

[36] http://www.inpe.br/queimadas/portal/estatistica_estados.

### Amazon Ecosystem Services

Another resulting impact is the loss of primary productivity of the forest as a CO sinkhole$_2$ (Aragão et al., 2018). The ability of forests to retain carbon has been compromised, possibly due to the reduction of moisture or saturation of the fertilization effect by $CO_2$ (Lapola et al., 2018). The net sinkhole of carbon (net productivity) in the Brazilian Amazon can be neutralized or reversed during the drought years (Aragão et al., 2014).

Besides, recent evidence shows that forests affected by fires have biomass levels 24.8 ± 6.9% below the biomass value of the unburned control parcels after 31 years, which indicates that forest fires, especially in the Amazon, can significantly reduce forest biomass for decades, and increase tree mortality rates (Silva et al., 2018).

In the Amazon, studies show the relationship between deforestation, urbanization, and the incidence of fire episodes, which provide conditions for the spread of the malaria-transmitting mosquito (*Anopheles darlingi*) and the increase in the incidence of the disease in the region (Hahn et al., 2014), in addition to dengue and cardiorespiratory diseases (Brondízio et al., 2016b; Jacobson et al., 2014; Lapola et al., 2019; Oliveira Alves, de et al., 2017).

In the Biome region, both the low and the high volume of rivers impact transportation, the lifestyles and the productive activities of the population, which systemically compromises the infrastructure, the food supply, the supply of energy, health and education services (Lapola et al., 2017; Pinho, Marengo and Smith, 2015). In the Amazon biome, if global warming reaches 2ºC, it could reduce the main rivers' flows by up to 25%, significantly impacting the population's food and water security (Betts et al., 2018).

The loss of moisture from the Amazon biome, which together with the moisture of the tropical Atlantic Ocean brought by the trade winds, generates rain patterns (flying rivers) in the South-Southeast of the country (Arraut et al., 2012; Marengo et al., 2004, 2020; Nobre, 2014), may compromise crop production in that region. Such a chain of impacts, linked to environmental and climate changes, reveals the importance of the ecosystem service of climate regulation of the Amazon, which crosses the dimension of the local scale to the regional and global scale.

The large urban centers in the Amazon are highly vulnerable to the impacts of drought and flood events due to the high population density and poverty rate (Pinho et al., 2014). Analysis of Brazil's socio-climatic vulnerability shows that Amazon biome's major centers are hotspots, such as Manaus and Belém (Darela Filho et al., 2016; Torres et al., 2012). Poor access to urban areas places these areas and their population in a high vulnerability to Socio and environmental risks in the face of extreme events (Parry et al., 2017).

For the urbanized ecosystems of the deltas and estuaries in the Amazon, an index of urban vulnerability to floods based on the dimensions of exposure, socio-economic sensitivity, and infrastructure, indicated that 60-90% of the urban population is highly vulnerable. Most urban sectors have exposed the risks of flooding, and health problems, associated with poverty and basic structural deficiencies, such as insufficient access to drinking water or inadequate waste collection (Mansur et al., 2016).

### Cerrado

Like the Amazon, the Brazilian Cerrado is recognized as a *hotspot* for biodiversity and is considered the richest savanna in the world, as it houses 11,627 species of native plants already cataloged, in addition to about 4,800 types of endemic plants and vertebrates (Strassburg et al., 2017). The biome occupies 2 million km$^2$ of the national territory. It is present in 15 Brazilian states and is home to three large basins, contributing 43% to the national water supply (Lahsen, Bustamante and Dalla-Nora, 2016; Strassburg et al., 2017). The biome has less than 19% of native vegetation, and only 7.5% of its area is protected with UCs and TIs.

### Cerrado: Loss of Habitats, Ecosystems, and Biodiversity

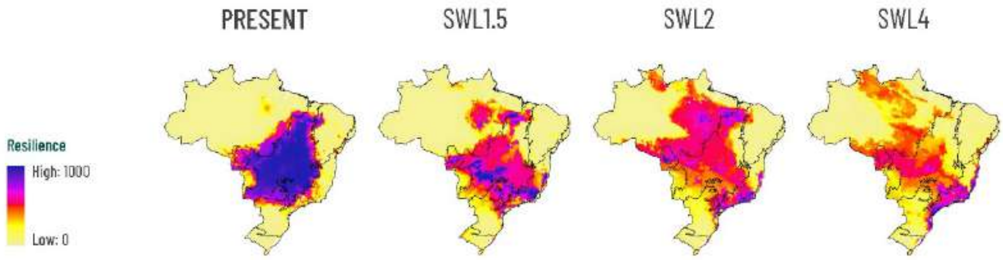


Figure 3.40. Projections of the Cerrado biome's resilience in the present and the scenarios SWL1.5, SWL2, and SWL4.

For the Cerrado, the range of resilience amplitude is high, greater than for the Amazon. The biome has relatively low resilience concerning increased rainfall (~ 2,500 mm/year) and greater tolerance to the high-temperature gradient in the current period. It also has an intermediate level of biomass. Projections show that starting from SWL1.5, areas more favorable to the Cerrado expand over areas previously occupied by the Amazon and Atlantic Forest biomes and the coastal region. For SWL2 it advances significantly over much of the Amazon and the Atlantic Forest. For SWL4, the models indicate a decrease in resilience in the region currently occupied by the Amazon biome. In this same scenario, the coastal region (Atlantic Forest) is occupied by the Cerrado, with intermediate resilience (Figure 3.40).

Results from resilience modeling corroborate the IPCC evidence, which shows that a temperature rise of 3 °C in the Cerrado, starting in 2070, will incur ecosystem impoverishment (Hoegh-Guldberg et al., 2018; IPCC, 2014).

The Cerrado, in the last 15 years, suffered a loss of intense vegetation, around 236 thousand km$^2$ between 2000 and 2015, corresponding to more than half of the recorded in the Amazon forest for the same period. Some of the effects of deforestation are fragmentation and habitat loss, which, together with climate change, are major factors in the loss of biodiversity and endemic species (Ometto et al., 2018). Likewise, habitat loss projections indicate high risks of extinction of mammals and endemic plants, in addition to expected losses of 50% of areas with climate suitability for the distribution of *Dipteryx alata* (baru), native plant species, for example (Diniz-Filho et al., 2012).

Even though the savanna has less sensitivity to climate stress and greater adaptation capacity than forest biomes, such as the Amazon and the Atlantic Forest, the Cerrado is vulnerable to climate impacts.

### Cerrado: Incidence of Fires

Fire episodes are natural agents of Cerrado ecology. However, the increase in the frequency and intensity of events (outside the biome's historical standards) compromises the ability to recover its flora and fauna, alters the soil's quality and elements of the hydrological cycle (Bustamante et al., 2012). The Cerrado biome has been the most impacted by fire in recent decades so that in ten years (2000 to 2010), the detected fires affected the equivalent of 203 million ha (Bustamante, Metzger, et al., 2019).

The coupled effects of climate change with changes in the rainfall regime, increased temperature and prolonged droughts imply an increase in the potential for fires (occurrence and spread), as well as longer fire seasons for the next decades in the country (Liu, Stanturf and Goodrick, 2010). The substitution of native vegetation for exotic species, with different flammability and adaptations to fire, associated with a hotter and drier climate, significantly altered the fire regime and severity, which affected the resilience of native species with significant impacts on the biodiversity (Enright et al., 2015; Kelly and Brotons, 2017). Projections suggest a systematic increase in critical fire hazard days, from about 20% at present to 28% in 2021-2050 and 32% in 2071-2100 (Joly et al., 2019).

### CERRADO: ECOSYSTEM SERVICES

The Cerrado is a critical ecosystem for climate stabilization, preservation of biodiversity, and provision of fundamental ecosystem services, such as water cycle regulation (Dickie et al., 2016; Lapola et al., 2014; Scarano and Santos, 2018; Strassburg et al., 2014).

In the last decades, the biome has been impacted by extreme temperature events, drought, and precipitation, with economic losses mainly associated with the agriculture-livestock and urban supply sector (Mesquita, Lindoso and Rodrigues Filho, 2018; Sawyer, 2009). Degradation and loss of resilience in the biome until the end of the century (Figure 3.40) will compromise grain production due to the loss of ecosystem services, whose impacts permeate all economic and political aspects (Ayeb-Karlsson et al., 2016). Also, observational data indicate a correlation between reduced rainfall and increased droughts in the Cerrado with compromised water availability in the main basins of the Biome (Bustamante, Metzger, et al., 2019; Sawyer, 2009).

### CAATINGA

The Caatinga is currently one of the most altered biomes in Brazil, with about 57% deforested (Bustamante and Metzger 2018; Ometto et al. 2018), it has only 1% of its protected area and few studies on conservation actions (Koch, Almeida-Cortez, and Kleinschmit, 2017). Livestock expansion and other activities such as urbanization led to the conversion of 45% of the original cover, which impacted terrestrial and aquatic biodiversity directly, through the conversion of land use, and indirectly through the use of inputs in agriculture (Ometto et al., 2018; Schulz et al., 2016).

### CAATINGA: LOSS OF HABITATS, ECOSYSTEMS, AND BIODIVERSITY

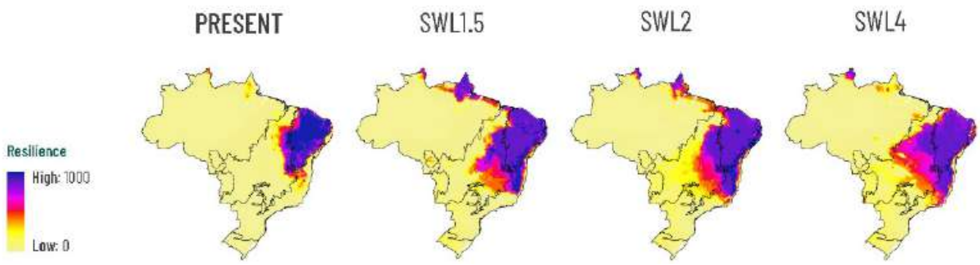


Figure 3.41. Projections of the Caatinga biome's resilience in the present and the scenarios SWL1.5, SWL2, and SWL4.

The range of amplitude of the eco-climate variables (temperature and precipitation) where the Caatinga shows high resilience is very narrow in the current period. Future projections show another stable state, more characteristic of deserts, without biomass, high temperatures, and critical precipitation levels. Such factors indicate a greater tendency towards the aridization process, which, together with environmental degradation, can lead to an expansion of desertification areas with the dilution of the amplitude of resilience. In the scenarios SWL1.5, SWL2, and SWL4, an expansion of the Caatinga biome can occur to coastal areas, Southeast and Midwest regions of the country, over the Atlantic Forest and Cerrado biomes (Figure 3.41).

For the Caatinga, climate change has led to seasons with more severe and prolonged drought extremes, which already affects 18% of the areas suitable for specialist tree species from seasonally dry tropical forests (Rodrigues et al., 2015).

Recent evidence shows the importance of protected areas in protecting ecosystem processes and native vegetation from the negative effects of climate change and deforestation and in reducing the process of desertification. Strictly protected areas show greater productivity and considerable resistance to low precipitation levels in the Caatinga than sustainable use or unprotected areas (Acosta Salvatierra et al., 2017).

### Caatinga: Ecosystem Services

The Caatinga biome concentrates 35% of the area of family farming in the country, responsible for a significant part of the production and diversification of food to supply the national market (Embrapa, 2014).

Only in Pernambuco, Paraíba, and Sergipe, 25-32% of the total area is occupied by family farming. The aridization processes and the consequent loss of resilience expected in the biome at the different heating levels above SWL2 will increase family farming vulnerabilities, resulting in productivity and lifestyle. The poverty rates in this biome are also expressive, with a low and intermediate human development index (HDI income, health, and education) compared to other regions of the country (IBGE, 2017a), which shows aspects of social vulnerability in the face of the impacts of the change of the climate.

### Atlantic Forest

In the face of an old and well-established occupation, the Atlantic Forest is the biome that has undergone the greatest change in habitats and ecosystems, left only 14% of native vegetation (Lapola et al., 2014; Rezende et al., 2018). Most of the Atlantic Forest remnants are less than 50 ha (0.5 $km^2$). Almost half of the forest is less than 100 meters from a border area, which leads to the impracticability of many ecological processes and associated biodiversity (Ribeiro et al., 2009). Ometto et al. (2018) point out that in the interior, seasonal forests, and the São Francisco River region, there is only 5% to 7% of the original cover, while more than 30% of the Atlantic Forest cover is maintained in the moist forests of Serra do Mar.

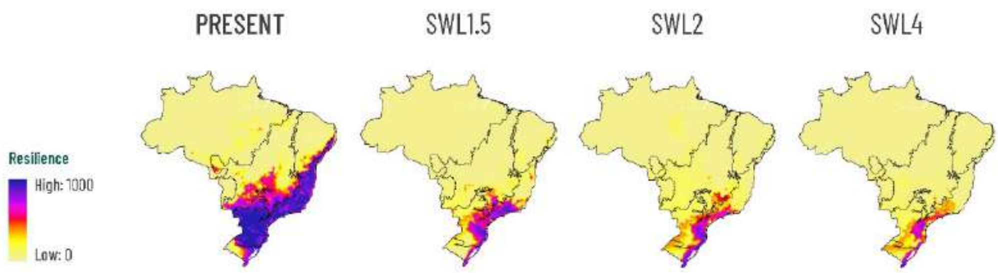


Figure 3.42. Projections of the resilience of the Atlantic Forest biome, in the present and the scenarios SWL1.5, SWL2 and SWL4.

### Atlantic Forest: Loss of Habitats, Ecosystems, and Biodiversity

For the Atlantic Forest, the division pattern of resilience ranges is very strong, with a high-temperature range (12 °C to 26 °C) but with a range more restricted to annual precipitation averages (~ 1,200 and 2.000mm/year), which suggests a critical threshold for the Atlantic Forest to transition to another biome, such as the Cerrado. For SWL1.5, a retraction in the biome's occupation is projected with significant loss of resilience, low resilience mostly occupied by the biome, and intermediate and high resilience concentrated on the coast. With SWL2, high resilience occurs only in small patches of the coastal region, and, for SWL4, most of the biome becomes resilient low (Figure 3.42).

The main losses of habitat and changes in the Atlantic Forest ecosystem services were mainly due to urbanization. The biome is home to a significant portion of the country's population and economic activity (Bustamante, Metzger, et al., 2019; Cedeplar/MMA/UNDP, 2017). The biome includes seven of the nine main basins in Brazil, which are currently compromised and/or threatened due to the high level of expansion of the urban area, consumption, and pollution in these areas (Bustamante, Metzger, et al., 2019; SOS Mata Atlântica, 2018). Due to the high loss and transformation of the Atlantic Forest habitat, the biome has the least adaptive capacity in the face of climate change impacts (Lapola et al., 2014). However, recent evidence shows that for the first time in a historical series, in 2018, the Atlantic Forest did not register deforestation (net) and showed an increase in forest recovery in the state of São Paulo (SOS Mata Atlântica, 2018).

### ATLANTIC FOREST: ECOSYSTEM SERVICES

The loss of ecosystem services in the Atlantic Forest biome due to high rates of urbanization and climate change has impacted the health of the population, with a significant increase in episodes of **dengue** in the region, which are directly associated with the sensitivity of the transmitting mosquito the increase in temperatures and changes in the pattern of precipitation (Barcellos and Lowe, 2014). From 2013 to 2017, most dengue cases (outbreaks and deaths) were recorded during the drought of 2015 and 2016 and in urbanized and peri-urban areas, especially in the Southeast, followed by the Northeast and Midwest. Such evidence of health impacts is directly linked to the deficit of native vegetation and a greater Socio and environmental susceptibility due to the absence of biodiversity in regulating the occurrence of pests, parasites and providing health conditions for the population.

Likewise, the deficit of native vegetation indicates a loss of **primary productivity** associated with changes in precipitation and prolonged drought regimes, compromising the capacity of this ecosystem and the primary forest to absorb carbon (Pires et al., 2017).

The biome's ecosystem service is related to **water supply**, whose demand is expressive in the regions covered. The projections for 2030 point to a greater withdrawal and consumption of water in the cultivation of sugar cane, especially in São Paulo and the Zona da Mata in Northeast Brazil (Alagoas, Bahia, Paraíba, Pernambuco, and Sergipe) (ANA, 2017). These results, associated with scenarios of increased drought extremes, show greater competitiveness between different sectors for the use of water, including industrial and urban supply.

Recent evidence also indicates that in the global warming scenarios in the Atlantic Forest, the **pollination services** will be compromised due to the high fragmentation in the biome, resulting in a reduction in the diversity of pollinators and losses between 8 and 100% of the persimmon, tomato, mandarin and sunflower crops until 2050 (Giannini et al., 2017). Given the relevance of these services for agricultural food production and nutritional diversity for the population, a case study is presented (Box 3.4).

URBAN AREAS AND ECOSYSTEM SERVICES. The Atlantic Forest biome is home to 145 million people (72% of Brazil's population), the vast majority in the **coastal zone**, and 38 of the country's 50 largest cities (IBGE, 2017a; SOS Mata Atlântica, 2018 IBGE, 2017a). The pressure of urban areas on ecosystem services is great, and projections indicate that they will increase until 2030 (Cedeplar / MMA / UNDP, 2017; Saraiva et al., 2018). In São Paulo's megacity, the urban ecological footprint[37] per capita is 25% greater than that of the rest of the state and 49% greater than Brazil's average (WWF, 2012, p. 61).

The tendency for population growth and concentration in cities and megacities may demand more natural resources, which may cause changes in ecosystems, loss of services, increased incidence of diseases, and impacts on food production and supply to cities (Buckeridge, 2015; Marengo and Scarano, 2016; Roy et al., 2018).

### PAMPA

The main economic activity in the Pampa biome is agriculture and livestock, and climate variability has already incurred significant agricultural and livestock losses, which favors the migration of producers to the Midwest and North regions of the country (Bustamante, Metzger, et al., 2019; Ometto et al., 2018). The vulnerability to climate extremes in the biome is relatively high; as an example, from 2013 to 2017, ~ 50% of the biome's municipalities in the South of the country were affected by floods (IBGE, 2017b). With only 26% of native vegetation, high fragmentation of habitats, and less than 3% of its protected areas (0.6% of the country's total UCs), the biome has a low capacity to adapt to climate change (Bustamante, Metzger, et al., 2019; Jenkins et al., 2015).

[37] *Environmental accounting methodology that assesses the consumption pressure of human populations on natural resources, expressed in global hectares (gha).*

### PAMPA: LOSS OF HABITATS, ECOSYSTEMS, AND BIODIVERSITY

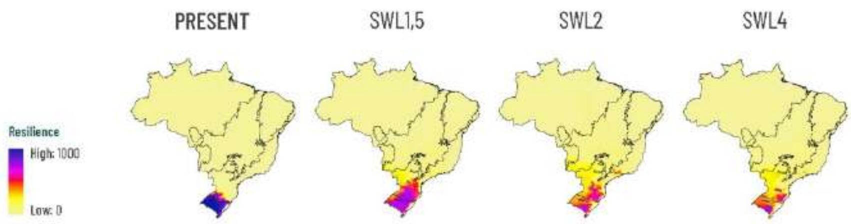


Figure 3.43. Projections of the Pampa Biome's resilience in the present and the scenarios SWL1.5, SWL2, and SWL4.

For the Pampa biome, the temperature variation thresholds are the lowest (~ 18 - 22 ºC), with a relatively narrow range of precipitation (1100 to 2000 mm) for high resilience (Figure 3.43). The biome loses its high resilience at all levels of warming, concentrating on only one strip in the country's extreme South at the end of the century. There is also an expansion of this biome to other areas occupied by the Cerrado at all heating levels, but with low resilience. In the same way as for other biomes, the loss of biodiversity is expected, compromising the functionality of ecosystems, as well as the provision of ecosystem services to society.

#### PAMPA: ECOSYSTEM SERVICES

Invasive species can lead to the loss of native species, changes in ecological processes, and ecosystem services provision. The invasion of herbaceous species in the Pampa, besides altering the balance between endemic plant species to the native field, dominate the herbaceous strata, and alter the natural cycle of fire. The spread of the mosquito *Aedes aegypti*, another invasive species, contributes to increased dengue cases, yellow fever, zika, and chikungunya. The lack of vegetation cover (such as riparian forests, around hillsides and others) and biodiversity fail to provide the ecosystem protection service against floods and river floods, acting as "buffer zones," minimizing flash floods, erosions, and landslides (Bustamante, Metzger, et al., 2019). In 2019, several large Brazilian capitals, such as Porto Alegre, had a significant increase in average temperatures, with heatwaves (INMET, 2019).

*BOX 3.4.* Impact of climate change on pollinators

One of the most important ecosystem services provided by biodiversity is pollination, which is critical for several crops of economic importance. The climate delimits the geographical distribution of pollinating species on a global and continental scale, and climate change should change the limits of the distribution of terrestrial species (Bustamante et al., 2019). In Brazil, important products, such as Brazilian nut, cashew, apple, passion fruit, melon, watermelon, avocado, plum, onion and guava, and even soybean, depend on external pollination, some to a lesser extent.

The future geographic distribution of 53 species of bees essential for the productivity of urucum, acerola, and passion fruit in Brazil was projected (Giannini et al. 2017) through ecological niche modeling. According to the simulations, the areas that currently concentrate the highest values of pollinator species richness in Brazil are in the Southeast and South regions and throughout the Brazilian coastline. In this way, the Atlantic Forest stands out as the biome that contains the greatest potential wealth (up to 41 species out of the 53 analyzed) among the six Brazilian biomes. Most climate change scenarios indicate vast areas of species loss, especially in the Cerrado and the Atlantic Forest. The greater warming scenario (SWL4) predicts that some of the Atlantic Forest and the Cerrado regions may lose climate suitability for up to 100% of the pollinators evaluated.

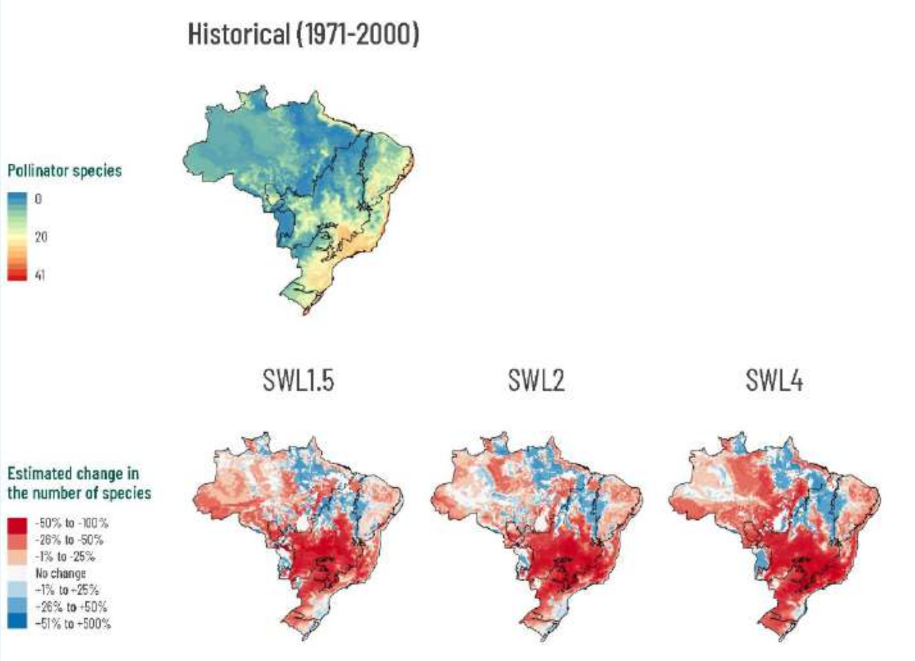


Figure 3.44. The potential richness of pollinator species in the historical scenarios (1971-2000) and the SWL1.5, 2, and 4. Source of data: list of species by Gianinni et al. (2017); records of occurrence of species Link[38] and GBIF[39]; climate variables of the Eta-HadGEM2-ES model (Chou et al. 2014).

* The SWL scenarios represent the loss (-1% to -100%), maintenance, or gain (+2% to +500%) of the number of species in relation to the historical scenario. Variables used in the modeling: diurnal temperature variation, temperature seasonality, the hottest month's maximum temperature, precipitation in the wettest month, and precipitation seasonality. Ecological niche modeling method: MaxEnt (Phillips et al. 2006), through the Dismo library (Hijmans et al. 2017) of the R software (R Core Team, 2017).

*BOX 3.5*. Oceans and Socioenvironmental resilience in Coastal Zones to Climate Change.

Brazil has one of the largest coastlines in the world (~ 9,000 km$^2$); its Exclusive Economic Zone (EEZ), up to 200 miles from the coast, is equivalent in surface to the area of the Legal Amazon, with about 3.5 million square kilometers (Gerhardinger et al., 2018; Kerr et al., 2016; Prado, Seixas and Berkes, 2015a). The wide coastal extension is home to remnants of the Atlantic Forest, parts of the Amazon and Caatinga biomes (Marroni and Asmus, 2013), and around 25% of the country's population (equivalent

[38] splink.cria.org.br/

[39] https://www.gbif.org/

to more than 50 million people) in an area of only 4 % of the total area of the national territory (Brazil, 2011, p. 124) (Figure 3.45).

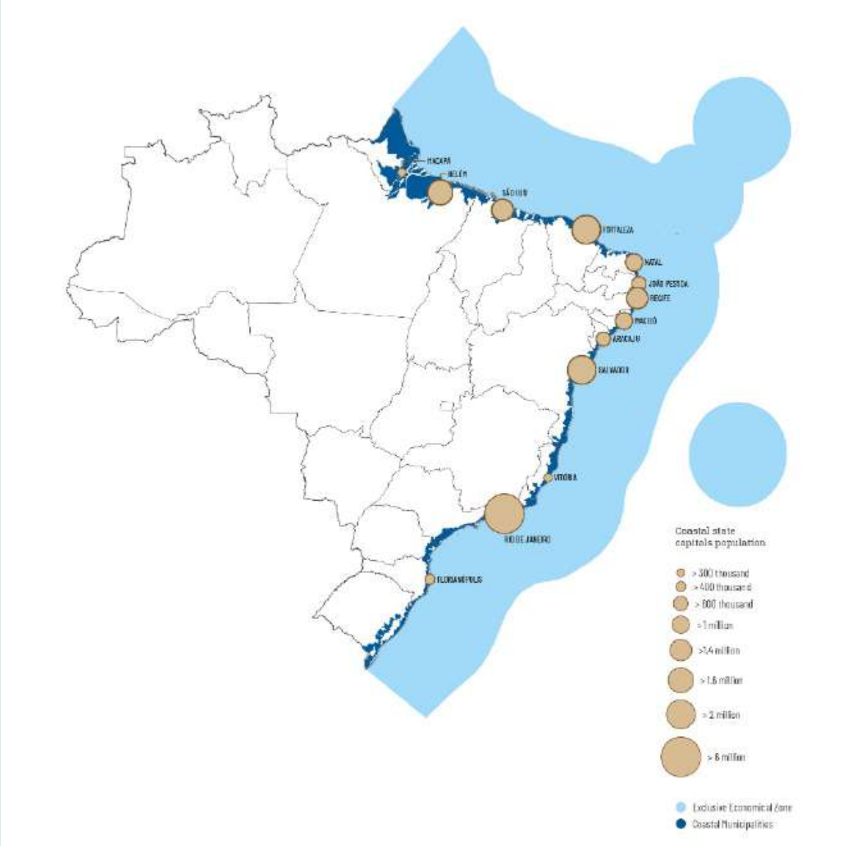


Figure 3.45. The Exclusive Economic Zone and coastal municipalities and capitals (IBGE, 2010).

The oceans play a central role in capturing $CO_2$ and offer a climate regulation service, beneficial to the population and the economy at multiple spatial scales (Bergstrom et al., 2019; Copertino et al., 2017; Weatherdon et al., 2016). Likewise, with vegetation of mangroves or marshes, coastal environments accumulate $CO_2$ in organic material in sediments.

Oceans and coastal zones are fundamental for adaptation processes to climate change, especially considering the wide range of ecosystem services provided (Horta et al., 2012). Coastal vegetation, coral reefs, or algae act as physical and chemical buffers for global stressors (Bustamante, Metzger, et al., 2019; Copertino et al., 2017). Extreme events such as storms and or heavy rains have their impact absorbed in part by algae reefs, which reduce damage from events in the coastal region (Weatherdon et al., 2016). Coral reefs represent a type of submerged forest and function as a nursery, refuge, and feeding area for many socio-economic relevance species (Tedesco et al., 2017).

However, warming oceans, rising sea levels, the incidence of climate extremes (storms, droughts, floods), and acidification have led to the loss of coral reefs, mangroves, seaweed banks, and seagrass (Cramer et al., 2014; Oppenheimer et al., 2014), which weakens coastal defenses and exposes mangroves to storms and ocean waves, among other impacts.

Besides, the warming of the Atlantic Ocean has led to significant variations in rainfall patterns in the Amazon and Northeast Brazil (and throughout the national territory), highlighting the regional scale of importance of climate regulation and the interdependence between ecosystems. Terrestrial and oceanic (Marengo et al., 2019). It is noteworthy that the lack or excessive rainfall alters the functioning of coastal environments. In Santa Catarina, a reduction in coastal salinity has been documented, which may be associated with the disappearance of submerged forests and their ecosystem services, such as those related to carbon stocks and primary production (Horta et al., 2012).

The vulnerabilities of the oceans and the coastal zone have been increasing due to dynamics associated with territorial planning and governance, representing sources of alteration of these ecosystems, pollution, and overfishing (Copertino et al., 2017; Gerhardinger et al., 2018; Horta et al ., 2012). There is an intersection of risks related to climate change with ecologically and socially vulnerable areas in coastal areas in the country, given the poverty and socio-economic inequality of the urban population, caiçaras, indigenous and quilombola peoples who depend on coastal areas and oceans for their lifestyle and economy (Saraiva et al., 2018). 82% of Brazilian coastal municipalities have less than half of their households connected to the sewage network, which implies the irregular dumping of waste in watercourses that flow into the sea (IBGE, 2010). Also, fishery production and other aquatic resources essential for subsistence and economics are compromised by over-exploitation and inadequate management and being threatened by climate change.

Losses of the limestone algae skeleton, organisms that structure gigantic banks and cement reef formations, can reach 80% when exposed to acidification and different temperatures (Muñoz et al., 2018), when combined heating (already observed during heat waves) and the advance of coastal pollution, the loss of 50% of the calcification capacity reduces the primary production of limestone algae by 90 to 100% (Schubert et al., 2019). Projections of global warming until 2100 show a reduction in the adequacy of the niche of species such as algae*Sargassum vulgare*, one of the main structures of Brazilian submerged forests, from 10-50% in some areas, moving from environments with tropical affinities to more South.

The warming process will impact products and services from coastal ecosystems, especially fisheries. Limiting global warming to 1.5 ºC above pre-industrial levels is essential for the survival of reef systems and limestone algae, as from 2 ºC these will disappear completely (Roy et al., 2018 ).

#### ROLE OF CONSERVATION UNITS (UCS) AND INDIGENOUS TERRITORIES (TI) FOR THE RESILIENCE OF BIOMES

Brazil has about 2,475,000 $Km^2$ of protected areas (29.7% of Marine Areas, 27.7% in the Amazon, 8.9% in the Atlantic Forest, 8.8% in the Caatinga, 8.1 % in the Cerrado, 4.6% in the Pantanal and 3.1% in the Pampa).

Projections of ecosystem resilience in the face of climate change indicate a decrease in all biomes in future scenarios. It is important to understand the role of protected areas as ecosystems in these areas are important to various sectors and human well-being.

The risk on the protected areas tends to increase with the increase in the global average temperature. With the loss of resilience of biomes in most protected areas in the country, except for the extreme west of the Amazon, the effectiveness of these areas in maintaining ecological processes' viability in the face of climate change impacts will be reduced.

Recent evidence shows the importance of different categories of UCs and TIs in containing deforestation processes, forest degradation, and incidence of fires (Rochedo et al., 2018; Adeney, Christensen and Pimm, 2009; Uriarte et al., 2012), also to provide ecosystem services at multiple scales (local, and regional) for the population, including large urban centers (Medeiros and Young, 2011).

Extractivists communities residing in federal Conservation Units for Sustainable Use, in particular Extractive Reserves (Resex), National Forests (Flona), and Sustainable Development Reserves (RDS), registered by the end of 2016, represent 56,903 families and around 300 thousand people. According to 2016 data from the Union Patrimony Secretariat - (SPU, for its acronym in Portuguese), 58,417 riverside dwellers live in territories benefiting from the Term of Authorization for Sustainable Use - (TAU, for its acronym in Portuguese) in the Union area. The indigenous population is 896 thousand people, representing approximately 0.42% of the country's total population, of which 36.2% lived in urban areas and 63.8% in rural areas until 2010 (Brazil, 2017). In the Amazon biome alone, indigenous peoples and the riverside population total about 1 million people, an underestimated number because many live remotely or in a situation of invisibility before the State and society (Pinho et al., 2014; Pinho, Marengo and Smith, 2015).

For indigenous peoples, the ecosystem services provided by "nature" are perceived as intrinsically interconnected (Viveiros de Castro, 1996). In this context, the protection of indigenous territories and traditional peoples and ensuring numerous ecosystem services are relevant to maintaining cultural values and lifestyles. Indigenous and traditional peoples' practices are sustainable but live with pressure factors in their areas, such as overfishing and commercial fishing, logging activities, mining, and others (Nogueira et al., 2018; Pinho, Orlove and Lubell, 2012).

It is important to prioritize the protection of connectivity stretches between the Western Amazon, Pantanal and the restoration of Caatinga stretches, Cerrado, Atlantic Forest, and Pampa to avoid greater impacts on Brazilian biomes in future scenarios, resulting from the interaction between habitat loss and fragmentation with climate change, (Segan, Murray, and Watson, 2016). Likewise, securing and demarcating indigenous lands plays an important role in protecting biodiversity and ecosystem services of global importance (Rochedo et al., 2018).

### 3.7.3 IMPACTS AND VULNERABILITIES IN SOCIOENVIRONMENTAL SECURITY: DISASTERS, MIGRATION, AND HEALTH

#### IMPACT CHAIN: DISASTERS, MIGRATION, AND HEALTH

Among the expected effects of climate change in Brazil include increased temperature, changes in the rainfall regime, and an increase in extreme climate events, emphasizing rainy extremes, droughts, elevations, and over-rises sea level.

### DISASTERS

Extreme climate events, such as intense rains, droughts, or heat waves, are characterized by intensity, duration, or temporality abnormal to the average climate state (Marengo, 2009). What classifies them as disasters are the effects these phenomena have on society (Tominaga et al., 2009). High-intensity, short-term rains cause flooding, flash floods, and river floods; medium-intensity and long-term rains soak the soil and the subsequent occurrence of short-term and high-intensity rains, with the soil already soaked, cause landslides, particularly in areas at high risk of disasters (Tominaga, 2009).

Extreme rain events can intensify disasters such as floods, flash floods, river floods, and landslides that cause deaths, leave people homeless, and alter communities' social relationships. They also affect the health of the population and increase the risk of contamination by waterborne and other diseases.

SOCIAL VULNERABILITY AND DISASTERS. The lack of urban infrastructures, such as rainwater drainage systems and environmental sanitation, and the occupation of marshlands and slopes, intensify the impact of rainy extremes in urban areas (Tucci, 2008); This happens mainly, but not exclusively, in precarious and informal settlements, where the poorest and most vulnerable population also resides - these are families that do not have the financial capacity to build their homes inappropriate conditions and places and to rebuild their post-disaster lives.

### HEALTH EFFECTS

OUTBREAKS AND EPIDEMICS CHARACTERIZE WATERBORNE DISEASEs; are associated with extreme events such as heatwaves, floods, river floods, and social factors such as low-income population, inadequate sanitation conditions, and infestation of transmitters of diseases. In gastroenteritis, outbreaks of the disease have been associated, in post-flood periods (Heller et al., 2003; Ahern et al., 2005), and prolonged droughts, with food contamination and dehydration resulting from the increase in temperature (Fleury et al., 2006; Naumova et al., 2007; Xu et al., 2014).

The HEATWAVES are associated with increased stress and heatstroke, exacerbations of cardiovascular diseases, kidney failure, and acute kidney damage due to dehydration (Hacon, Oliveira, and Silveira, 2018).

Several studies have quantified the effect of temperature by assuming a linear response below and above a threshold defined as mortality temperature or minimum hospitalization (McMichael et al., 2011; Baccini et al., 2011; Hajat and Kosatky, 2009). Recently, in addition to temperature, other variables, such as relative humidity, wind speed, and solar radiation, have also been incorporated into indicators that reflect the body's physiological response in certain climate conditions.

Regarding VECTOR-BORNE DISEASES, temperature and precipitation are the main climate factors. However, environmental degradation and contributing directly to vector reproduction's climate conditions increase the risk of transmission of these diseases and their geographical expansion. The influence of climate factors in vector diseases varies according to the particular characteristics of each disease.

### MIGRATORY PROCESSES

The lack of water for desedentation and cultivation can induce migratory processes. Even if subtle in climate, Variations affect family farmers with crop losses, livelihoods, and rising food prices, which can exacerbate migration to urban areas and increase poverty (Olsson et al., 2014). Migration and densification of the poorest urban settlements put pressure on environmental preservation areas, such as water sources, which interfere with a water supply and other activities dependent on ecosystem services, increasing disasters' risks (Winsemius et al., 2018). No less important are the aspects of social segregation, increased demand for urban infrastructure and services, and impacts on food security because of the increase in food-consuming populations at the expense of producers, among other migration issues.

HISTORICAL MIGRATION AND PRESSURES ON FOOD, ENERGY, AND WATER SECURITY. Rural-urban migration, which has grown since the 1950s, has only recently reduced due to the already emptied rural environment. The population concentration in urban centers has been increasing the demand (IBGE, 2010) for food, energy, water, and infrastructure in general, especially far from the area where these elements are produced (IBGE, 2018).

SOCIAL AND CLIMATE VULNERABILITY. The socioeconomically most vulnerable populations are also the most vulnerable to climate change impacts (Olsson et al., 2014). The impacts of climate change on human life are complex and can be enhanced or minimized depending on the individual and collective determinants. Such factors are inherent to a given social organization and its interrelationships and include age, the health system's capacity, and social conditions. The situation of housing, food, personal hygiene, sanitation, and access to health services are also social factors that influence populations' vulnerability to climate stress factors. Adding to other environmental exposures, these may act synergically and generate even more risk for populations (Hacon, Oliveira, and Silveira, 2018).

It must be considered that 85% of the Brazilian population lives in cities, almost 25% in metropolitan regions of the country, and a large part does not have adequate environmental sanitation and urban drainage (IBGE, 2010). They are cities of great socio-economic inequality, with enclaves of poverty and slum-growth (Caldeira, 2000).

### KEY IMPACTS' ASSESSMENT: DISASTERS, MIGRATION, AND HEALTH

According to the chain of impacts on Socio and environmental security presented, the "key impacts" to be studied in greater detail are:

- disasters of hydrometeorological origin, especially flash floods, floods, river floods, and landslides;
- population migrations with climate forcing factors, focusing on Northeast Brazil;
- effects of climate change on the spread of diseases: cardiorespiratory, vector-borne, and waterborne.

### DISASTERS

#### METHODOLOGICAL APPROACH

What characterizes the impacts of rain extremes as natural disasters are their effects on society. As described in the chain of impacts, the consequences of these impacts are enhanced by the urbanization process. Thus, we focused on Brazilian urban areas, where there has been a significant increase in disasters.

To analyze the impact of climate change on river floods, flash floods, and landslides, socio-economic and urban infrastructure data were treated, observed disasters and climate scenario data (*baseline* and future), based on qualitative and quantitative information.

The following concepts were adopted in disasters:

Flash floods: high-energy transport flash floods, associated with the extrapolation of rainwater in watercourses or the urban rainwater drainage system (Tucci, 2008), caused by heavy rains in small and rugged relief basins.

River floods: processes in which areas outside the normal limits of a watercourse are submerged, in areas that are not normally submerged, gradually in lowland areas, usually caused by distributed rain and high accumulated volume in the basin contribution (Cemaden, 2019).

Surface water floods: characterized by the extrapolation of the drainage capacity of urban drainage systems, accumulation of water on streets and sidewalks (Cemaden, 2019).

Landslides: Also called mass movements, they are movements of descending soils and rocks under the effect of gravity, usually enhanced by the action of rainwater (Cemaden, 2019).

URBAN VULNERABILITY AND EXPOSURE (SOCIO-ECONOMIC DATA). Based on factors considered important by the literature on the topic (Tucci, 2008; Hardoy and Pandiella, 2009; Tominaga et al., 2009), an urban vulnerability index (IVU, for its acronym in Portuguese) was established for the spatialization of vulnerability. Its objective is to characterize urban infrastructure's precariousness and the social conditions that interfere in urban communities' vulnerability.

According to the IPCC/AR5 (IPCC, 2014), exposure[40] is a key factor in understanding the risks related to climate change. The IVU applied here considers the degree of exposure as a function of population density, generating the IVUexp [41] (IVUexp = IVU * population density).

IVU AND IVU exp. Data and calculations for the IVU, the following alphanumeric data were spatialized by municipality: number of people per household (IBGE, 2010); percentage of households connected to the water, sewage network and with garbage collection (IBGE, 2010); average income (IBGE, 2010); number of inadequate or semi-inadequate households[42] (IBGE, 2010); Basic Education Development Index (IDEB, 2011); Performance Index of the Unified Health System (IDSUS, 2010).

Population density and the other indicators of sanitation, income, health, and education were calculated for the entire municipality, from its area and total population, regardless of whether the census sector is urban or rural.

A HISTORICAL RECORD OF DISASTERS. THE spatialization of disaster events, based on the systematization of those reported by municipalities, was carried out by the National Center for Risk and Disaster Management (Cenad, for its acronym in Portuguese), of the National Secretariat for Civil Protection and Defense. The 2005-2015 historical series of gross occurrence records were treated[43] by Mikosz (2017), and disasters were grouped into two types: (i) landslides and mass movements and (ii) floods, river floods, and flash floods.

CLIMATE SCENARIO DATA (SIMULATIONS OF EXTREME CLIMATE EVENTS). Debortoli et al. (2017) created two[44] indexes of climate extremes: i) floods (flash floods, river floods and surface water floods); ii) landslides. They consider that each extreme precipitation event's intensity and duration have a greater correlation with a certain type of disaster in tropical countries. Both indicators were generated from the weighting of four climate extremes indicators, using data from climate models.

INDICATORS OF CLIMATE EXTREMES ADOPTED. RX1day - maximum precipitation in one day; Rx5day - maximum accumulated precipitation in five days; R95p - accumulated precipitation on very rainy days (95% percentile); CWD - maximum consecutive days with rain (with precipitation greater than 1mm). The outputs of the regional model Eta-MIROC5[45] were used for the 1961-1990 baseline period and SWL1.5, SWL2, and SWL4.

### RESULTS AND ANALYSIS

Between 2005 and 2015, approximately 10,554 river floods, flash floods and surface water floods, and 17,013 landslides were recorded, totaling 28,000 records. The density of disasters recorded by Cenad (2018) compared to *hotspots*[46] of urban vulnerability shows the spatial relationship between them (Figure 3.46). From the perspective of urban infrastructure and their populations' social conditions (largest IVUexp), the densest and most precarious municipalities recorded the most occurrences of disasters in the period.

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*[40] Defined as "the presence of people, means of subsistence, species or ecosystems; environmental functions, services and resources; infrastructure, or economic, social or cultural assets, in areas or locations that may be adversely affected by climate-related impacts".*

*[41] The use of the logarithmic function to calculate the exposure was necessary for the spatialization of data to demonstrate the heterogeneities between population densities in Brazil, knowing that 90.5% of Brazilian municipalities have less than 50 thousand inhabitants, 6% between 50 and 100 thousand inhabitants, and the remaining 3.5% more than 250 thousand inhabitants.*

*[42] Adequate households are those with environmental sanitation and up to two residents per bedroom, semi-inadequate those that have at least one adequacy characteristic and inadequate those that do not have any adequacy characteristics.*

*[43] As an example, flash floods in the North Region are grouped with floods and river floods, in the rest of the country they are grouped in landslides, since in the North Region such records are floods of running water (Tucci, 2008) and in the rest of the country they are flows of mud and debris, which Cenad considers landslides or mass movements.*

*[44] For a detailed description of each composite indicator: Debortoli et al. (2017)*

*[45] The comparison of the results of the Composite Indexes of Rainy Extremes of the two regional Eta models, for the baseline period 1961-1990, showed that the results of Eta-HadGEM2-ES showed an underestimation for all regions of the country, being the results of Eta-MIROC5 more consistent with the reality of observed meteorological data, mainly in the Amazon, presenting an underestimation only for the Northeast region (Chou et al, 2014). Therefore, for this study, only the results of Eta-MIROC5 were used.*

*[46] The vector data IVUexp was exported to points, which contained the vulnerability of each municipality and later converted into a raster, whose pixel value was related to the vulnerability class, determining the spots with the highest concentration of occurrences, which are the hotspots.*

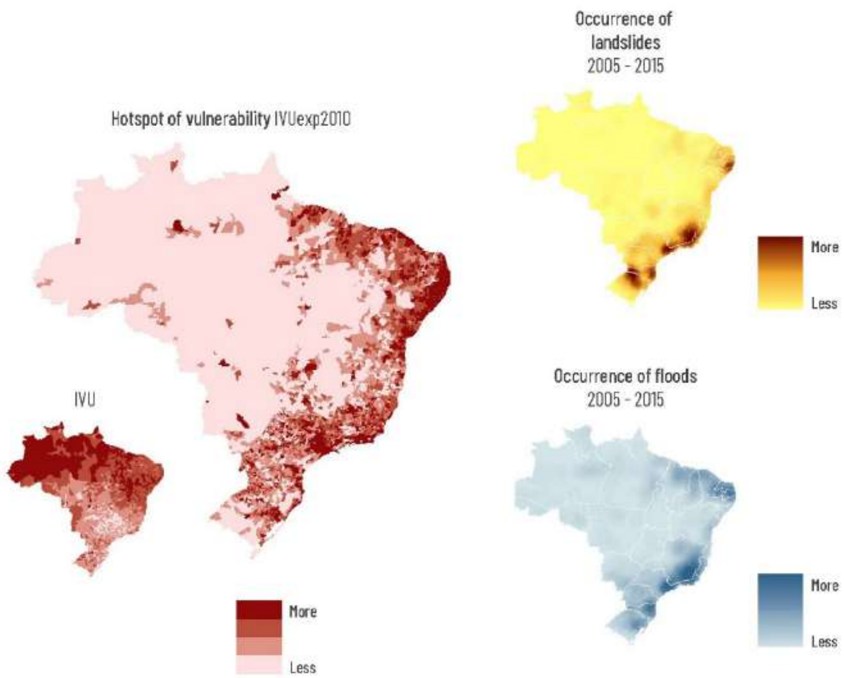



Figure 3.46. *Hotspots* for urban vulnerability and disasters. Own elaboration based on Cenad (2018) data and IBGE (2010).

In the strip close to the Atlantic, there are spots of high urban vulnerability, as well as a high concentration of occurrences - 10% of the total, which affects 50 million people (IBGE, 2010). Concerning the South and Southeast regions, which concentrate 27 and 80 million inhabitants, it is possible to observe that exposure is an important factor when analyzing the impact of disasters in the country. In both maps of *hotspot*s of disasters, the concentration of occurrences happens around the metropolitan regions, with a high population concentration.

The occurrences of floods are concentrated in the Southeast region, especially Minas Gerais, São Paulo, and Rio de Janeiro; in the Northeast region, mainly in the states of Rio Grande do Norte and Paraíba; and in the South, in Santa Catarina and Rio Grande do Sul.

Landslides depend on geomorphology (such as rugged reliefs), while flash floods, river floods and floods are correlated with precarious urbanization, in addition to physical aspects, such as local hydrology.

For the occurrences of landslides, the *hotspots* are located in the South, on the border of Santa Catarina, and Rio Grande do Sul, in the region of the Serra Espigão, Mariri and Taquara Verde and around Blumenau; in the Northeast, on the border of Pernambuco and Alagoas, in the Serra da Roncadeira region; and in the Southeast, in Serra da Mantiqueira.

High vulnerability is observed in the North's municipalities and the interior of the Northeast, Midwest, Southeast, and South regions. There are municipalities with a large territorial area and small urban concentrations in the North, with very low environmental sanitation infrastructure levels. In other regions, municipalities in the states' interior have great territoriality and population concentration in small urban centers, precarious in environmental sanitation. Raw data from the number of records show that 78% of the occurrences of flooding, flash flood, or floods and 80.5% of the occurrences of landslides occurred in municipalities with less than 50,000 inhabitants.

The municipalities in the north of the country and west of the northeast have the more precarious urban infrastructure, lower average income, and lower education levels and access to health services (Figure 3.46). However, 45% of the municipalities with more than 250 thousand inhabitants are in the coastal zone, with 13 capitals bordering the Atlantic Ocean. In the four states of the Southeast region, 40% of the Brazilian population lives. On the other hand, there are fewer inhabitants in the entire North region than in the Metropolitan Region of São Paulo (IBGE, 2010).

The results of flood records (by biome), based on Cenad's raw data (2018) - between 2005 and 2015, show higher percentages of dead, injured or missing, as well as homeless and displaced people in the Amazon (Figure 3.47). The high rates in Amazon are mainly due to the historical floods of 2015 when approximately 50 thousand people were left displaced or homeless in the state of Acre and the city of Manaus. Although there were not so many occurrences in the region, many were affected. Suppose the IVU is observed (without the exposure factor), associated with the 2015 floods. In that case, it is possible to infer that the lack of sanitation in the North of the country (Figure 3.46) is related to the high number of people affected by floods and river floods (Figure 3.47).

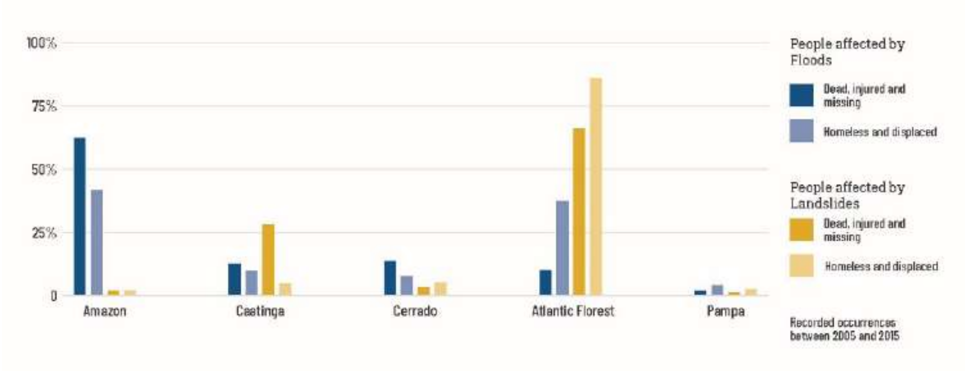
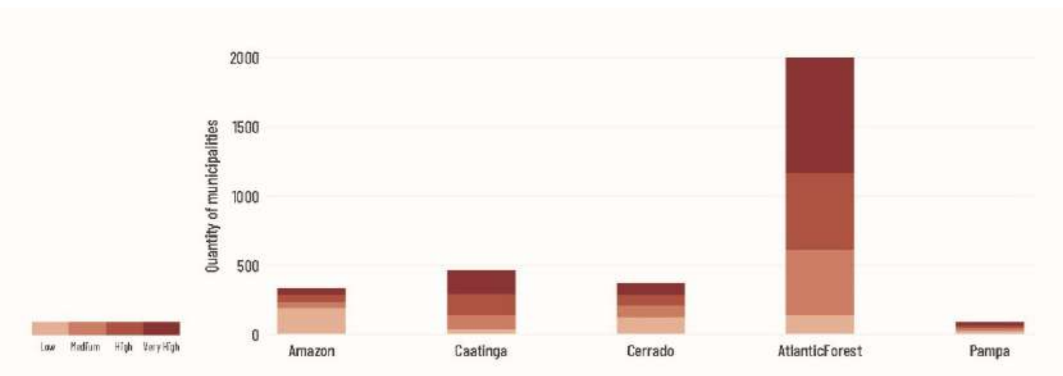



Figure 3.47. Percentage of people affected by "floods, flash floods, and river floods" and "landslides" by biome (2005-2015). Own elaboration based on data from *Cenad (2018).*

In the Caatinga, the disasters of March 2009 stand out, in which more than 110 thousand people were affected by the floods in 54 municipalities in Ceará and in other northeastern states; as well as the intense rains of 2013, which hit the Metropolitan Regions of João Pessoa and Recife, leaving thousands of families homeless due to landslides (Figure 3.47).

The high number of people affected in Atlantic Forest stands out, largely due to the disaster in the mountainous region of Rio de Janeiro (in 2011) for floods, flash floods and river floods, and landslides (Figure 3.47) (Cenad, 2018).

When an urban vulnerability is observed, from the IVUexp (Figure 3.46), for the municipalities in which disasters occurred, the results show that those located in the Atlantic Forest are the most vulnerable and are in greater number, followed by the municipalities located in Caatinga, Cerrado, Amazon, and Pampa.




* Darker, greater vulnerability.

Figure 3.48. IVUexp in municipalities with disasters. Own elaboration based on IBGE (2010).

The municipalities located in the Amazon and the Cerrado are very vulnerable from the point of view of environmental sanitation, income, and quality of education and health services (IVU), but they have low population density. Only a small part of the Amazonian municipalities presented high IVUexp (Figure 3.46). In the Caatinga, the capitals and other centralities, with high population density, also have high IVU and high IVUexp. In the Atlantic Forest and Pampa, despite the differences in the absolute number of people affected by disasters, the municipalities have, in general, medium IVU and high density, thus denoting a high number of municipalities with high IVUexp.

When associated with the occurrence records of floods with current and future climate simulations, it is possible to observe that future projections indicate increased risk in the Atlantic Forest, the most populated biome (Figure 3.49).

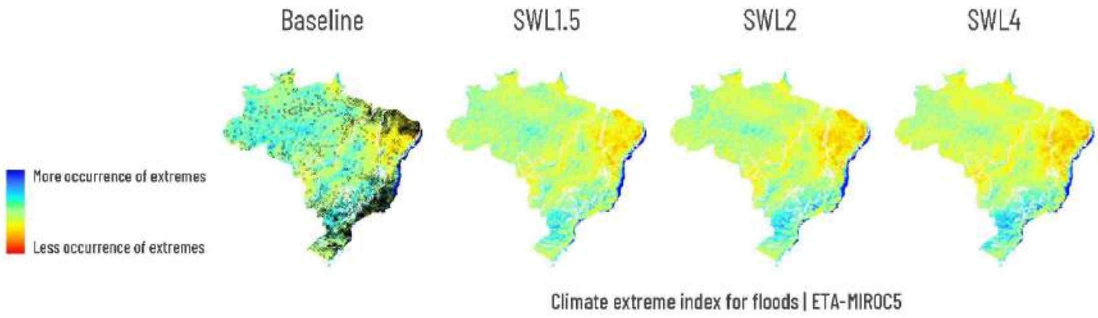



Figure 3.49. The composite index of climate extremes for floods (river floods, flash floods and surface water floods). Source: Debortoli, 2017.

The same association for landslides shows that, especially for the SWL2 scenario, the extreme rains that cause the landslides are expected to increase further in the south and southeast of the country and coastal areas (Figure 3.50).

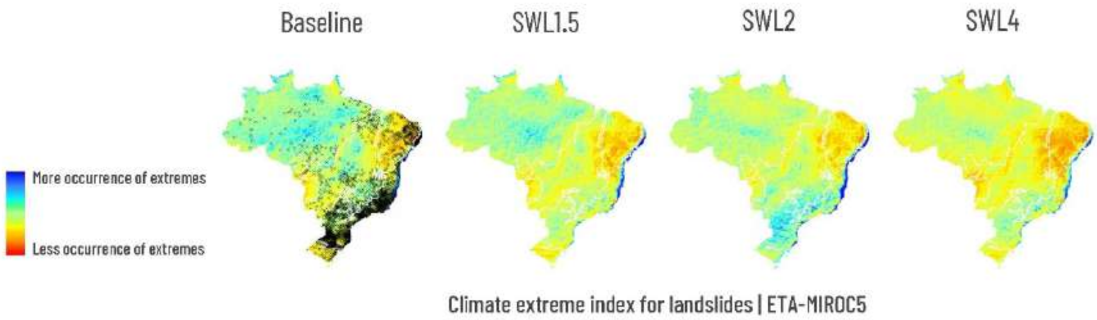



Figure 3.50. The composite index of climate extremes for landslides. Source: Debortoli, 2017.

Both results corroborate with the results of the Third National Communication - TCN (Brazil, 2016) and WGII AR5 (IPCC, 2014) that the extreme events of rain that cause disasters should increase in the South and Southeast regions of Brazil, but mainly in Coastal Zone, where most of the Brazilian state capitals and a large part of the country's population are concentrated. It should be noted that, on the coastline, the risks of disasters can be heightened by events associated with sea-level rises, such as storm tides (phenomena that can be similarly influenced by climate change). Added to this process are the impacts on port regions, especially on maritime and river transport. In addition to being an alternative to other modes, such as road and rail, this mode is an important commercial vector. Therefore, sea-level rise can directly affect infrastructure and indirectly important productive sectors.

SEA LEVEL RISE. Considering the different geomorphological compartments of the Brazilian coast, Muher (2010) indicated that the areas most vulnerable to sea-level rise are concentrated in cities, with flood risks having the greatest impact on the population. The same study points out that the lack of long-term observed data makes it difficult to construct future vulnerability and risk scenarios in cities on the Brazilian coast with greater accuracy. The data provided by ECLAC (2019) also point out the vulnerability in the capitals in an imprecise way, corroborating the statement of Muher (2010).

### MIGRATION

Barbieri et al. (2010) point out that research on climate change impacts the population's spatial distribution is difficult because it involves many variables. The researchers propose to assess how populations tend to adapt to climate change, with migration as one of the potential forms of adjustment.

NE has 51% of the municipalities in the Caatinga and 28% in the Cerrado. There are more than 23 million inhabitants living in the semiarid, 18 million in the Caatinga and 4 million in the Cerrado (IBGE, 2010).

NORTHEAST BRAZIL IN FOCUS. In Brazil, it is inevitable to relate climate and migration to the Brazilian Northeast, the semiarid region with the highest population concentration globally, which is home to approximately 4 million small rural producers (Lindoso et al., 2018). Extreme droughts occur recurrently in the Northeast and have been recorded since the 16th century, responsible for major regional emigration processes (Magalhães et al., 1988). In the late 1950s, approximately 10 million people emigrated from the region, fleeing the drought (Namias 1972; Hastenrath and Heller, 1977), the same decade in which the Federal Government started to implement policies to reduce[47] the impacts of these events. Even so, emigration processes persist even to a lesser extent (Barbieri et al., 2010).

According to Tacoli (2009), the current migration trends in the country are more likely to persist, even if with a certain reduction in flow, since today less than 20% of the Brazilian population lives in rural areas (IBGE, 2010) and that Income transfer programs influence the reduction of migratory flows, including return migration, as in the case of Northeast Brazil (Ojima and Fusco, 2015 and 2017). Climate change will not necessarily affect the migration pattern or trend, mainly determined by economic issues, territorial development differentials, and policy impacts - but will affect migration.

Drought events in the Northeast region may be more frequent with climate change (Marengo et al., 2016; Cunha et al., 2019), with increased dryness, episodes of deficit in rainfall and aridification in the region, bringing the desertification risk (Marengo and Bernasconi, 2015; Vieira et al. 2015), which could encourage new migratory flows to other regions of the country.

According to Barbieri et al. (2008), in the specific case of the Northeast, migration constitutes an effective element of survival to climate change because of the availability of relatively efficient transport and communications networks, the relatively low population density in the interior of the states, compared to others developing countries, and the strong regional variability of the climate (factors that are related to the history of migration in Brazil)

In this sense, the author mapped migratory flows in the country in (i) two historical time frames and (ii) future climate scenarios, focusing on the Northeast. The methodology used was established in the project "Climate change, migration, and health: scenarios for the NE, 2000-2050", financed by the *Global Opportunities Fund* and prepared by Cedeplar/UFMG.

CLIMATE MODELING. Migration balances[48] based on census data between 1986-1991 and 1995-2000 were considered, as well as current climate data and future scenarios based on trajectories A2 and B2[49] (2025 - 2030 | 2035 - 2040 | 2045 - 2050), derived

[47] *Adaptation measures based on public policies such as straw hats and ProAgro Mais, for small rural producers, in addition to social benefits such as family stipend and the benefit of continued provision (BPC), for its acronym in Portuguese, can not only reduce migration but also encourage return migration (Ojima and Fusco, 2015 and 2017).*

[48] *The choice for the migratory balance indicator was made because it makes it possible to assess the net result of demographic exchanges between historical sections, and to analyze the spatial configuration of the areas of origin and destination.*

[49] *Scenarios that consider different projections of greenhouse gas emissions, Socio and environmental aspects and regional differences. Scenario A2 is more pessimistic about carbon emissions and represents greater global warming, while B2 is more optimistic and less warming.*

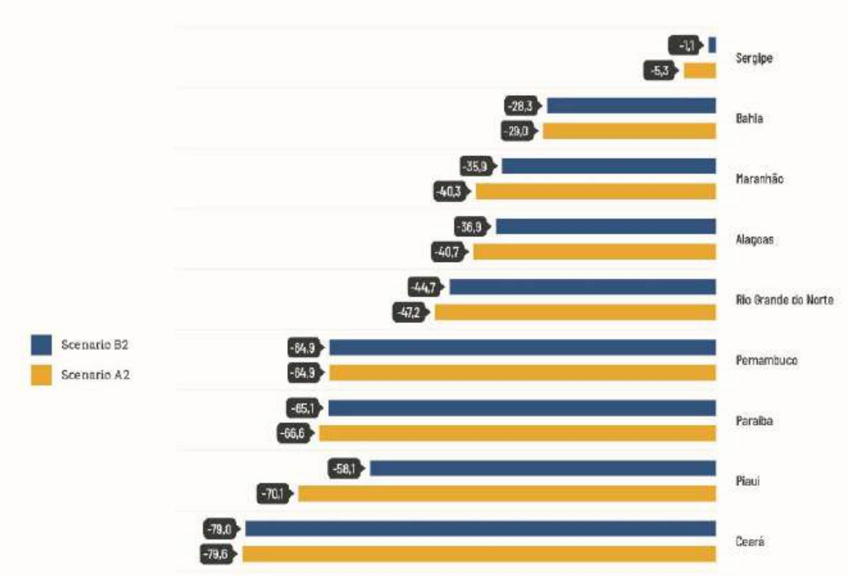
from the downscaling of the English global model HadAM3P with the regional model Eta (MetOffice[50], 1999). The analysis of the impacts of climate change on migration is concentrated on the increase in average temperature, which causes a reduction in water availability, an increase in evapotranspiration, and a consequent loss of agricultural productivity. Socially and economically, more vulnerable structures, such as small-scale family production units, with reduced access to services and technological options, suffer more intense impacts, thus causing the region's emigration processes (Barbieri et al., 2008).

Several factors were modeled from these results that influenced the migratory processes, including the climate ones and the loss of agricultural productivity. Conceptual models of immigration scenarios were also built, where the Northeastern population would go in the future (Barbieri et al., 2008).

### MAIN RESULTS OF "CLIMATE CHANGE, MIGRATION AND HEALTH: SCENARIOS FOR THE NE, 2000-2050." [51]

An analysis of the impact of climate change on job security, using scenarios A2 and B2[52], shows that in some municipalities in Piauí, Ceará, Pernambuco, and Paraíba, in both scenarios, climate change can affect 20 to 30% of the adult population. Also, Ceará, Pernambuco, and Paraíba, states with the highest percentage of the area used for family farming, will have the greatest percentage loss of employment, in scenario B2 (Barbieri et al., 2008).

Among the several results by Barbieri et al. (2008), land availability, with water security for planting, was also obtained in the NE (Figure 3.51).




* The loss of land availability by state represents a loss of agriculture and livestock production. The Northeast economy is negatively affected, generating migratory and capital displacement effects.

Figure 3.51. Shocks in the supply of the land factor for agriculture and livestock, for each climate scenario (variation % total between 2010 and 2050) – Source: Barbieri et al. (2008).

In scenarios A2 and B2, practically all northeastern states will suffer from loss of land for agriculture and livestock, which may imply the migratory process due to the loss of jobs and subsistence and an impact on Brazilians' food security in general.

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[50] *MetOffice (1999): https://www.metoffice.gov.uk/weather/learn-about/how-forecasts-are-made/computer-models/history-of-numerical-weather-prediction*

[51] *Extracted from Barbieri et al. – Main results of "Climate change, migration and health: scenarios for the NE, 2000-2050". CEDEPLAR - UFMG, 2008*

[52] *Scenario A2 is more pessimistic about carbon emissions and represents greater global warming, while B2 is more optimistic and less warming.*

VULNERABILITY REDUCTION POLICIES. Income transfer programs are an important tool to mitigate the effects of climate change on migration. For Ojima and Fusco (2015 and 2017), this type of program's performance to reduce these populations' vulnerability and increase their capacity to adapt caused effects of return migration, from the generation of jobs and income in the region. However, Barbieri et al. (2008) also point out that the low degree of development in the northeastern municipalities may increase the demand for federal government policies.

Although it is not a simple task to deal with migration and climate change, mapping flows in the country is of paramount importance as an adaptive measure; This is a scientific gap, given the scarcity of studies on the subject. Migration processes can occur at different scales and regions of the country, and even between countries and different factors, including the impacts of climate change directly or indirectly.

## HEALTH

Variations and climate change can have direct or indirect impacts on human health.

The direct impacts are those associated primarily with the occurrence of extreme events, such as heatwaves, droughts, and intensification of extreme rains (IPCC, 2014). They include an increase in total morbidity and mortality from circulatory, respiratory, and genitourinary diseases. The increase in temperature and extreme heat events, especially those characterized by hot and humid days, can trigger and exacerbate signs and symptoms associated with various diseases, such as asthma, acute myocardial infarction, heart failure cerebrovascular diseases. The increase in the number of deaths and hospitalizations for cardiopulmonary diseases was also associated with exposure to *black carbon*, tropospheric ozone, and particulate matter, which are pollutants particularly related to climate change (Hacon, Oliveira, and Silveira, 2018).

The indirect impacts correspond to those mediated by changes in ecosystems and biogeochemical cycles that can modify the distribution of vector and waterborne diseases and increase the emission of air pollutants. Expected impacts include those associated with vector diseases, as climatic variables can influence their respective transmission cycles. Both the increase in temperature and extreme events such as prolonged droughts and rains, together with the lack of basic sanitation, can contribute to the geographical expansion and seasonal abundance of these diseases, including introducing new arboviruses (IPCC, 2014).

This section will deal with cardiorespiratory diseases transmitted by vectors and waterborne (especially infantile diarrhea).

### CARDIORESPIRATORY DISEASES

The impact of climate change on the occurrence of cardiorespiratory diseases is related to meteorological and climate conditions, resulting from the combination of temperature, air humidity, wind speed, and radiation. Most diseases are also considered multi–causal with different mechanisms, vulnerabilities, and exposures in a changing climate.

#### METHODOLOGICAL APPROACH

For this section, for Brazilian capitals, we analyze data related to:

- mortality (deaths) and morbidity (hospitalizations) for respiratory diseases and cardiovascular diseases related to an increase in temperature;
- mortality (deaths) for respiratory and cardiovascular diseasesrelated to thermal stress.

Both analysis used similar methodologies in the treatment of data, with two distinct stages:

- an estimate of associations between exposures (temperature and thermal stress) and health outcomes, from 2000 to 2010;
- projection of the impacts of increased exposures and health effects, assessed according to the scenarios SWL1.5, SWL2, and SWL4.

ASSUMPTIONS AND STATISTICAL METHODS ADOPTED

Health outcomes: The daily number of hospitalizations or deaths for the baseline period from 2000 to 2010, made available by DATASUS[53], was used to analyze: general mortality; mortality and hospitalization due to cardiovascular diseases (over 45 years); and mortality and hospitalization for respiratory diseases (over 60 years).

Climate conditions: The following were used: average daily temperature and thermal stress using the “wet–bulb temperature” indicator (*Wet–Bulb Globe Temperature* –WBGT), which represents exposure to climatic conditions that influence the body’s ability to maintain thermoregulation, that is, exposure to heat that implies thermal stress (WBGT ≥28 ° C). For the projections, data from the regional Eta–HadGEM2–ES model (RCP8.5) were used, calibrated according to the method presented by Hempel et al. (2013) in the scenarios *baseline* (1965 to 2005) and SWL1.5; SWL2; SWL4.

For the analysis, the statistical method was proposed by Gasparrini et al. (2017). Evaluation and adjustment of heterogeneity between the capitals were carried out through meta–regression, having variables the temperature amplitude and the Social Vulnerability Index (urban infrastructure, human capital, income and work – provided by Ipea).

## RESULTS AND ANALYSIS

### TEMPERATURE EFFECTS

It was found that the association between temperature and cardiovascular diseases in those over 45 years, in the period from 2000 to 2010, was stronger for death than for hospitalization, both in cold and in heat in all capitals. For the number of deaths, the Relative Risks (RR) were greater than 1.5 for most capitals; exposure to temperatures above or below the optimum temperature is associated with an increase of 50% of deaths than exposure to the optimum temperature.

For respiratory diseases in the older adults 60 years of age or more, the results point to more significant associations when exposed to higher temperatures, both for hospitalization and death. Regarding death, Relative Risks (RR) greater than 2 (mainly associated with heat) were observed, which means that exposure to heat is associated with an increase of at least 100% of deaths than exposure to optimum temperature.

It is noteworthy that each capital has its optimal temperature (or minimum risk) associated with climate impacts on health, as shown in Table 3.5.

Table 3.5. Medians of Temperatures in °C of Minimum Risk, according to health outcomes and regions of Brazil (2000 to 2010).

| Region | Respiratory system diseases | | Circulatory system diseases | |
|---|---|---|---|---|
| | Hospitalization | Death | Hospitalization | Death |
| North | 26.6 | 24.2 | 26.8 | 26.4 |
| Northeast | 24 | 24.6 | 25.8 | 28.2 |
| MIdwest | 27.3 | 25 | 28.2 | 26.7 |
| Southeast | 25.8 | 23.4 | 27 | 26.2 |
| South | 26.3 | 23.6 | 13.8 | 25.8 |
| **Brazil** | **26.4** | **24.4** | **26.4** | **26.8** |

Observation: The minimum risk temperature is estimated by the statistical models used in the association study's present analysis.

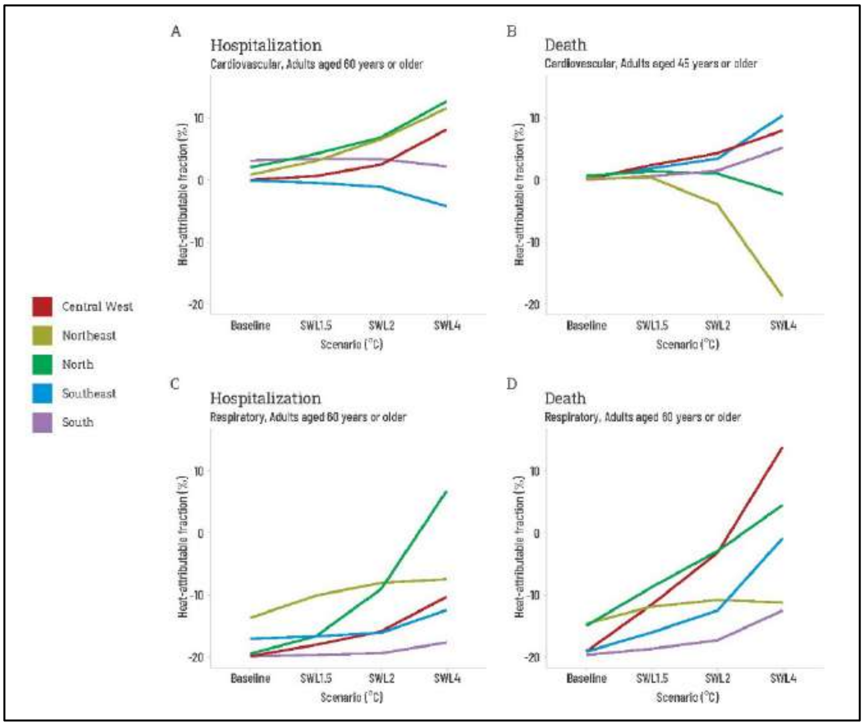
### TEMPERATURE EFFECTS: ASSESSMENT OF FUTURE IMPACTS ON HUMAN HEALTH

In general, for all health outcomes, the more global warming increases, the greater the number of deaths and hospitalizations attributable to temperature, especially to heat.

[53] www.datasus.gov.br

Considering only the capitals, it is observed that for cardiovascular diseases in people 45 years of age and older, the number of deaths and hospitalizations in the Midwest region may increase, with the percentage of deaths being approximately 8% and hospitalizations attributable to heat in SWL4 (Figure 3.52). There was a possible increase in hospitalizations in the North and Northeast regions and reduced deaths, with approximately 12% of hospitalizations attributed to SWL4. A possible increase in deaths was observed in the South and Southeast regions, attributed to the heat and hospitalizations reduction. In the Southeast region, 10% of deaths may be attributable to SWL4, while it may be 5% in the South region.

As for respiratory diseases in the elderly, there was an increase in the fraction of hospitalizations and deaths attributable to heat in all regions as the level of heating increases. It is noteworthy that approximately 30% of hospitalizations and 30% of deaths in capitals in the North region will be attributable to SWL4. Considering the same scenario, in the Midwest, it will be approximately 40%, in the Southeast, it was estimated at 23%, and in the South, 9% increase in hospitalizations and deaths. The Northeast region was the only one that had an attributable fraction of hospitalizations greater than that of deaths in the capitals, with approximately 15% of hospitalizations attributable to SWL4.




*FA - Attributable fraction of deaths and hospitalizations due to temperature rise.

Figure 3.52. Attributable fraction of deaths and hospitalizations in the regions of Brazil, according to the scenarios SWL1.5, SWL2, and SWL4. Own elaboration according to the statistical method proposed by Vicedo-Cabrera et al. (2019).

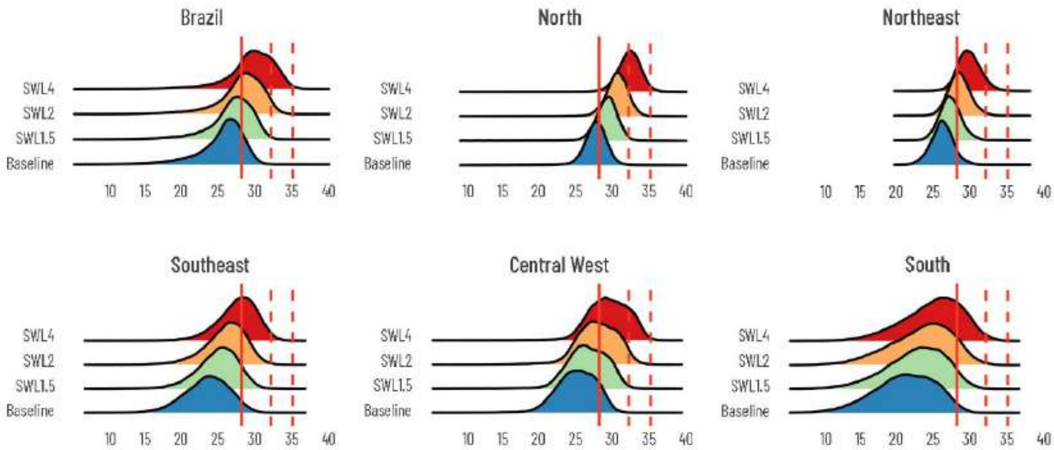
### EFFECTS OF THERMAL STRESS

Figure 3.53 shows the WBGT thermal stress indicator distribution for the baseline period (1961-2005) and the SWLs in the Eta-HadGEM2-ES climate model (RCP 8.5). The vertical red line indicates the limit value (WBGT 28 ° C) (ACGIH, 2013; ISO7243, 1989).

According to the heating scenarios, there is a shift in the distribution of these values, emphasizing the North and Northeast capitals, which will have more than 90% of the days above this threshold in the SWL4 scenario. Also noteworthy is the capital of Mato Grosso, Cuiabá, and in the Southeast, Rio de Janeiro and Vitória.

For the evaluated health outcomes (deaths and hospitalizations due to cardiovascular and respiratory diseases due to thermal stress), as global warming increases, the greater the number of deaths, the impacts differ according to the assessed outcomes' location and characteristics.

The impact of thermal stress conditions was more pronounced for respiratory diseases than general mortality and cardiovascular diseases. Among the capitals, the most impacted cardiovascular deaths were Vitória, Rio de Janeiro, Palmas, Cuiabá, and Porto Velho. The last two mentioned with attributed fraction estimated above 30% in SWL4. Concerning deaths from respiratory diseases, Rio Branco, Fortaleza, Vitória, Rio de Janeiro, Campo Grande, Goiânia, Boa Vista, Cuiabá, and Palmas stand out, and in particular, João Pessoa, Porto Velho, and Belém, with attributable fraction greater than 30% in SWL4.




* The curves represent the distribution of the days of the year concerning the occurrence of temperature. Regarding the colors of the curves, blue for the baseline period (2000-2010), green for SWL1.5, orange for SWL2, and red for SWL4.

Figure 3.53. Thermal stress exposure risk scenarios (WBGT), by region of the country.

## Vector-borne diseases

Vector-borne diseases contribute significantly to the global disease burden, especially in developing countries. These diseases' transmission dynamics are associated with several factors that include population growth, migration, inadequate urbanization, poor functioning health systems, and the unavailability of environmental sanitation services in adequate quantity and quality.

In the context of climate change, vector-borne diseases are among the best-studied, not only because of their epidemiological importance but also because of their high sensitivity to climatic factors. The simplest connections are observed for temperature that affects the sanguine meal rates (bite), survival and reproduction of vectors, and the survival rates and development of the pathogens they carry. In addition to temperature, precipitation also exerts a very strong influence, especially in vector-borne diseases with stages of aquatic development (such as mosquitoes), or via humidity for vector-borne diseases without these steps, such as those transmitted by sandflies.

### Methodological Approach

The results presented relate the occurrence of dengue, visceral leishmaniosis, yellow fever, and malaria, having as a *baseline* the years and 2000 years scenarios and 2000 years SWL1.5, SWL2, and SWL4 in the Eta-HadGEM2-ES model (RCP 8.5).

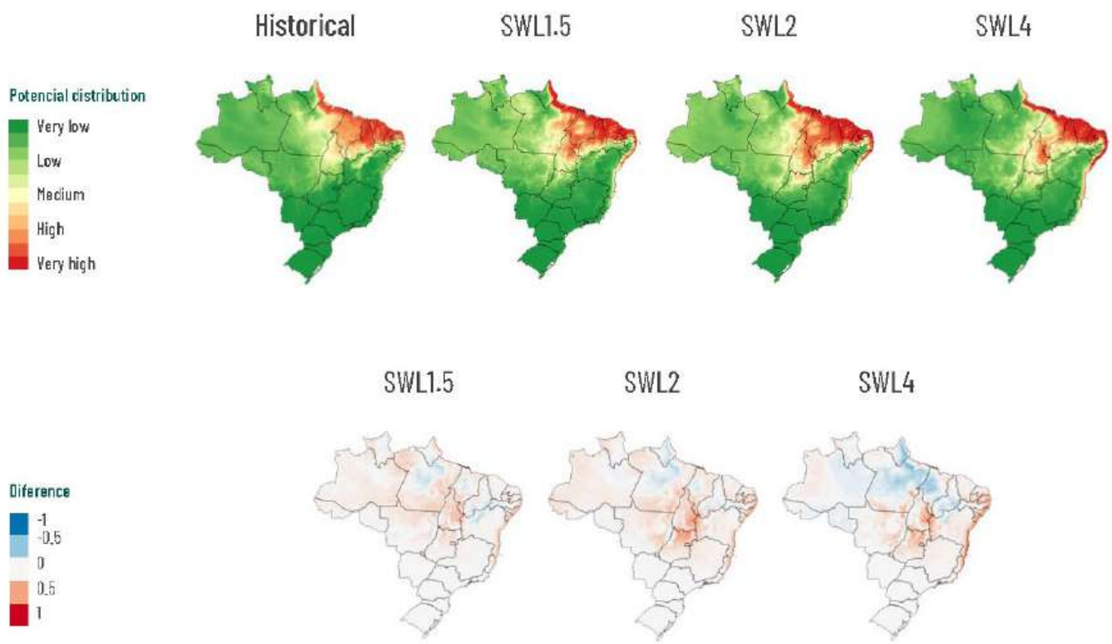
DATA AND PROJECTIONS. For the construction of future scenario projection models, the Maxent software (Phillips et al., 2019) was used, which is based on the maximum entropy model (med), which is a way of predicting probability distributions based on the number of individuals of a species or the occurrence of a certain event (Phillips et al., 2006).

Several covariables were used, including temperature, precipitation, and bioclimatic variables established by Worldclim[54]: thermal amplitude (ampterm), minimum temperature (mntp), maximum temperature (mxtp), precipitation (prec), temperature seasonality (bio4), and seasonality of precipitation (bio15).

The figures brought in are dark in color to indicate high probability and lighter shades of yellow to indicate a low probability of adequate conditions for an epidemic.

### RESULTS AND ANALYSIS

DENGUE: High climate suitability areas are prevalent in most states in the Northeast of Brazil, following the same pattern in future scenarios. There is an increase in the potential distribution in the Atlantic strip's extension, running along the coast and heading towards Bahia and Espírito Santo. For SWL4, there is a reduction in the probability of adequate climate conditions for an epidemic in the Brazilian Amazon (Figure 3.54).




* Dependent variable was defined as all municipalities in Brazil with an annual cumulative incidence above 300 cases per 100 thousand inhabitants.

Figure 3.54. Climate suitability for dengue in Brazil, according to SWLs scenarios, based on climate data from the Eta-HadGEM2-ES model.

VISCERAL LEISHMANIOSIS: the areas of high climate suitability for visceral leishmaniosis, according to the model, represent the well-known distribution of the disease, mainly in the Northeast, Midwest, and Southeast regions. Considering the SWL4, there was a reduction in favorable climate conditions for the North, Northeast, Midwest, and expansion conditions in the Southeast and South. A strip on the north coast of Pará Amapá and Maranhão (Figure 3.55).

[54] *Worldclim is a global climate database that provides layers in different resolutions for the current climate, and for past and future climate scenarios. For more information see: www.worldclim.org.*

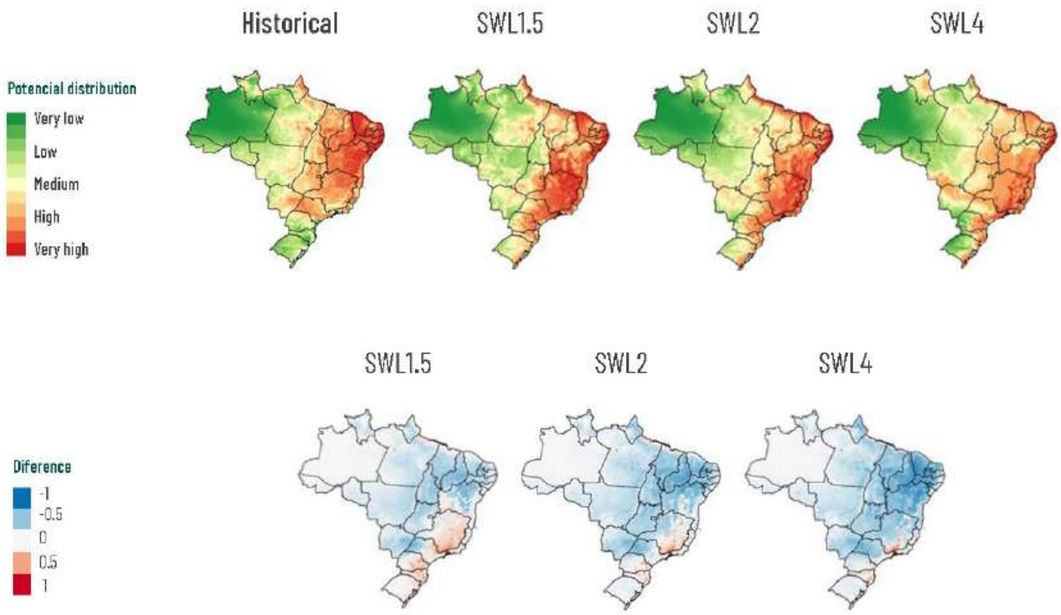



Figure 3.55. Climate suitability for visceral leishmaniosis in Brazil, according to SWLs scenarios, based on climate data from the Eta-HadGEM2-ES model.

YELLOW FEVER: The areas with favorable climate conditions for yellow fever, according to the model, are mainly distributed in the Southeast, South, Midwest, and North regions. This adequate area will increase significantly in the warming scenarios, especially in the Midwest and North regions (Figure 3.56).

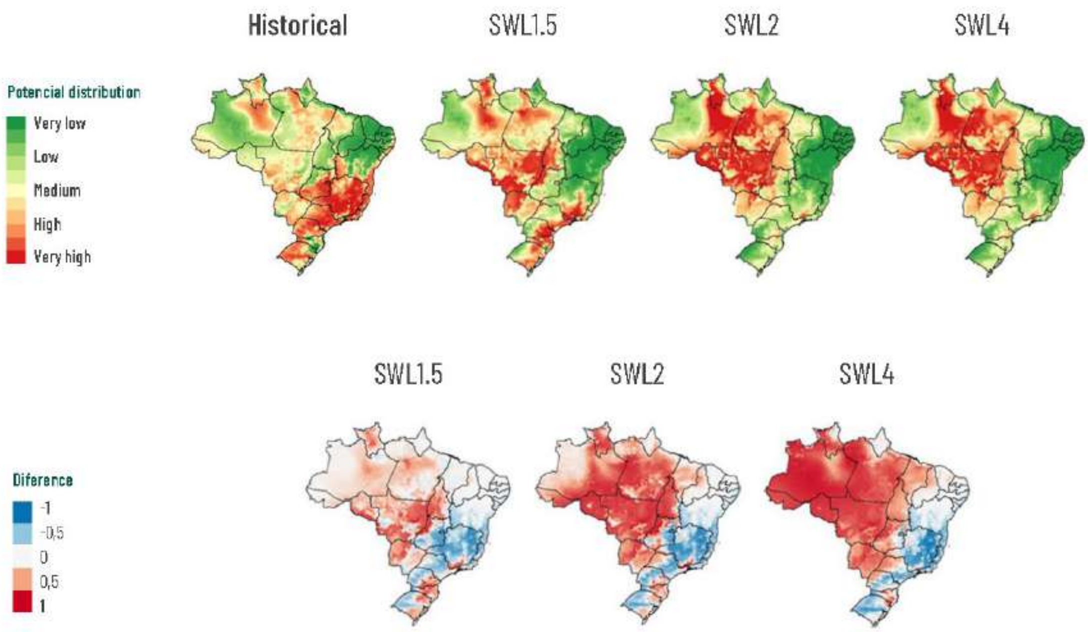



Figure 3.56. Climate suitability for yellow fever in Brazil, according to SWLs scenarios, based on climate data from the Eta-HadGEM2-ES model.

MALARIA: From the application of the cutoff point to select the municipalities with the highest incidence in the studied period, it was evident the aggregation of these in areas with favorable climate conditions, mainly in the North region. The warming scenarios indicate an increase in favorable climate conditions in the Northeast, Southeast, and part of the Midwest (Goiás and Mato Grosso), with a reduction in this area in Tocantins. The SWL1.5 and SWL2 scenarios reinforce increases in favorable climate conditions for locations in the north of Pará. In contrast, the SWL4 scenario points to a concentration of greater climate suitability in the western Amazon (Figure 3.57).

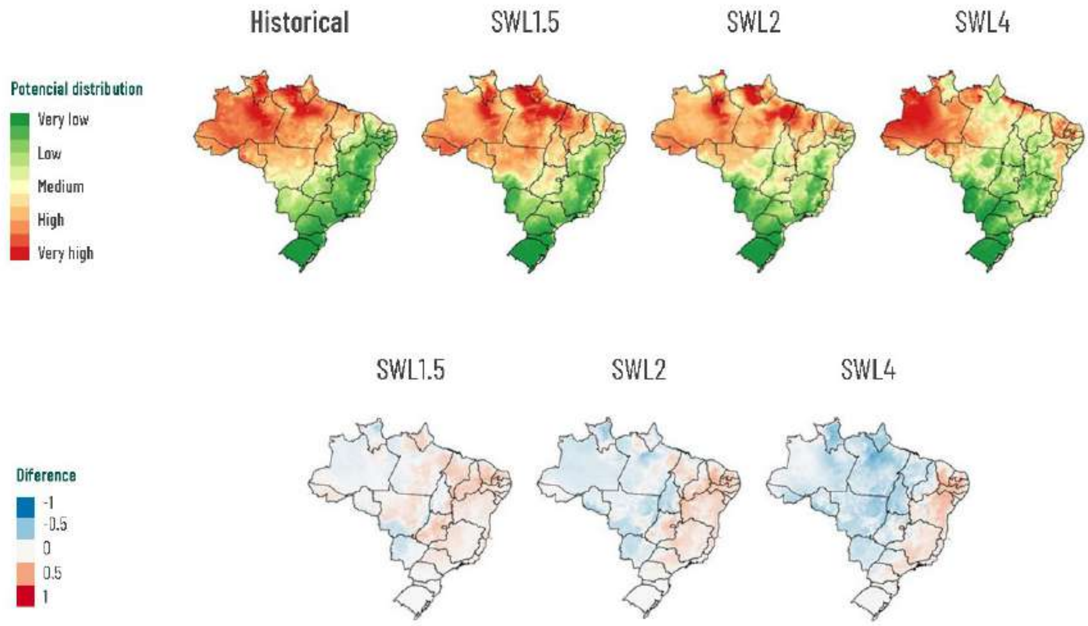



Figure 3.57. Climate suitability for malaria in Brazil, according to SWLs scenarios, based on climate data from the Eta-HadGEM2-ES model.

### WATERBORNE DISEASES: CHILDREN'S DIARRHEA

Among gastroenteritis, infectious acute diarrheal diseases (ADD) are of great importance for Public Health due to the greater frequency in the population, especially in children under 5 years of age. ADD can lead the patient to death, especially when associated with malnutrition or immunosuppression[55].

ADDs are caused by the consumption of contaminated water and food or other means of contamination, such as contact with people and/or animals. They take place in contexts of recognized poverty, low schooling, under precarious home and home hygiene conditions, limited access to health services, deficient food and nutritional situation, and other related and synergistic factors, that is, in a situation of high social and environmental vulnerability. In this context, climate change can further aggravate a situation already configured as being highly vulnerable.

Temperature increase, heat waves and precipitation events, such as floods, and other extreme events (Campbell-Lendrumand; Woodruff, 2007), can cause changes in the environment such as changes in ecosystems and biological cycles, hydrological and geographical that can increase the incidence of infectious diseases, with an emphasis on waterborne diseases (such as leptospirosis).

The literature points out that not only is the increase in temperature associated with an increase in the number of cases of acute diarrhea, but also a reduction in temperature can create favorable environments for the proliferation of viral diarrhea, although these conditions may also be associated with the rainfall regime and variations in humidity (Ghazani et al., 2018; Carlton et al., 2016).

[55] http://www.saude.gov.br/saude-de-a-z/doencas-diarreicas-agudas

DATA PROCESSING. Concerning data on infantile diarrhea, children under 5 years of age and average temperature data (generated by the Eta-HadGEM2-ES model) were considered for *baseline* (1965-2005) and SWL1 scenarios, 5, SWL2 and SWL4. The impact of increasing temperature on the relative risk (RR) for infantile diarrhea was evaluated.

Hospitalization data for infantile diarrhea - children under 5 years old - were obtained for each Brazilian municipality in the period 2000-2018, in the database of MS-Datasus (2019).

To select the municipalities with the greatest socioeconomic and health vulnerability, a cutoff point was applied based on the third quartile of the IVUexp values (described in the topic “Disasters” in item 3.3.5.5.1 of this Chapter), that is, the 25 % higher vulnerability values.

RESULTS AND ANALYSIS

The warming scenarios indicate a significant increase in the average temperature, especially in the Midwest and North regions. In the SWL1.5 scenario, average temperatures in Brazil will increase by up to 3.6 °C (Corguinho, MS), with the highest values found in the states Mato Grosso do Sul (3.3 °C), Goiás (3.2 °C), and São Paulo (3.0 °C).

In the SWL2 scenario, average temperatures in Brazil can increase up to 5.3 °C (Britânia, GO), with the highest values found in the states of Goiás (4.9 °C), Mato Grosso do Sul (4.8 °C) ) and Mato Grosso (4.6 °C). In the SWL4 scenario, average temperatures in Brazil can increase up to 5.3 °C (Urucurituba, AM), with the highest values found in the states of Mato Grosso do Sul (7.6 °C), Mato Grosso (7.5 °C), and Goiás (7.4 °C).

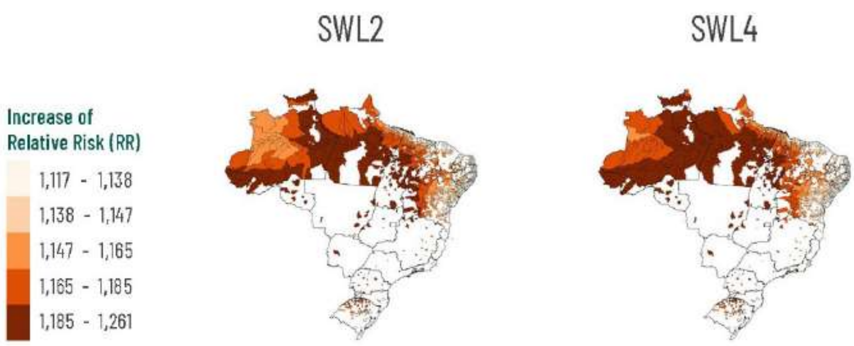



Figure 3.58. Rate of increase in the relative risk (RR) for infantile diarrhea in SWL scenarios for the municipalities with the greatest urban vulnerability in Brazil.

The maps point (Figure 3.58) to the North of the Northeast's municipalities, more precisely in the semi-arid region, as the regions at greatest risk of increasing infantile diarrhea's occurrence for all warming scenarios, mainly in SWL4.

### 3.7.4 MAIN RESULTS IN SOCIOENVIRONMENTAL SECURITY

The following summarizes the main aspects of impacts and vulnerabilities on social and environmental security from Brazilian biomes' territorial perspective.

In general, it is noteworthy that all biomes lose resilience. They suffer the loss of stable states in the warming scenarios above SWL2 until the end of the 21st century. Consequently, biodiversity losses are expected, with potential changes in the biomes' types, among other impacts. The loss of ecosystem services overlaps with the population's socioeconomic conditions, social inequality, socio-spatial segregation present in cities, and other factors.

The biome Amazon is highly vulnerable to climate change. The loss of resilience associated with different levels of warming can be aggravated by the dynamics of land-use changes, causing the loss of ecosystem services. This context, together with the increase in fires and accelerated and precarious urbanization (with a lack of urban infrastructure and environmental sanitation), exposes the population to various impacts related to the climate. Also, distances between population agglomerations make access to health and education services difficult, and even the organization of civil defenses and health teams for emergency assistance disasters and epidemics.

The intensification of rainy extremes points to an increase in diseases such as infantile diarrhea. While vector-borne diseases, such as yellow fever and malaria, tend to remain significant or increase in the region with increasing temperatures, which should also cause an increase in deaths and hospitalizations due to heat stress and heatwaves.

Currently, the sensibilities and the low capacity for adaptation of indigenous peoples and traditional populations in the Amazon are already evident in the face of climate extremes in the region (Brondízio et al., 2016; Pinho, 2016; Pinho, Marengo, and Smith, 2015), in addition to factors of poverty, marginalization, and lack of governance (Maru et al., 2014). The projected loss of resilience is a threat to Conservation Units and Indigenous Territories.

The biomes Cerrado and Atlantic Forest, which present a high degree of endemism and configure *hotspots* worldwide of biodiversity (Myers et al., 2000), show a high reduction in the original vegetation cover, aggravated by the high demand for land-use conversion, together with the relatively low coverage of protected areas. This tendency to reduce natural vegetation leads to the loss of essential ecosystem services for the population, with social and environmental impacts at different scales (Bustamante, Metzger, et al., 2019; Agard and Schipper, 2014; Millenium Ecosystem Assessment, 2005).

Given that **Atlantic Forest** will suffer a loss of resilience in the different levels of heating until the end of the century, the only areas that would potentially remain resilient, today are anthropic environments.

At Cerrado, a biome that is likely to be most affected by the increase in temperature in future scenarios, heatwaves, and thermal stress, in addition to the increase in malaria, are the greatest health impacts. Some municipalities have difficulty accessing health services for the region's population, even in better conditions than Amazon. The impacts of extreme rain events, which have already displaced or dislodged thousands of families in the region, should also focus on attention.

In Atlantic Forest, mainly in the Southeast region - the one with the highest population density in the country - there are municipalities with a high incidence of precarious and informal settlements, which present a high concentration of urban vulnerability and a long history of disasters, of great magnitude, or the constant floods that affect metropolises and several cities (medium and small) during the summer rains. The increase in temperatures in this region should imply an increase in deaths and hospitalizations due to heatwaves and thermal stress, in addition to the possible increase in the occurrence of visceral leishmaniosis.

In **Coastal Zones**, disaster risks can be heightened by events associated with sea level rise, such as storm tides, phenomena that can be similarly influenced by climate change.

For Caatinga, the loss of resilience in the Biome and increased incidence of desertification will lead to a profound impact on food production, especially by rural family farmers, which can compromise the supply of the local and regional market, knowing that 35% of the entire area of food production by family farming is located in the Caatinga (Embrapa, 2014). The desertification process could lead to food and water insecurity, in addition to possible 'poverty traps[56]. '

The increase in temperature and drought extremes are expected in future scenarios, which should cause a higher occurrence of deaths and hospitalizations due to heatwaves and thermal stress, in addition to causing an increase in the occurrence of malaria, visceral leishmaniosis, dengue, and infantile diarrhea (the latter, also a result of low sanitation infrastructure). There may be new migration flows from the Caatinga, mainly due to future scenarios of increased aridity. On the other hand, rainy extremes are also intensifying, so the Northeast capitals are already suffering recurrent impacts from river floods and surface water floods.

The Pampa loses resilience at all levels of warming and is concentrated with high resilience in only one strip in the extreme south of the country at the end of the century. There is also an expansion of this biome to other areas originally occupied by the Atlantic Forest at all levels of warming, but with low resilience and overlapping with

[56] *A poverty trap occurs when families, or a community, who are already poor are affected by extreme events and short-term situations, forcing them to continue in the cycle of poverty without being able to get out of this situation.*

potential Cerrado conditions. In the same way as for other biomes, the loss of biodiversity is expected, compromising the functionality of ecosystems, as well as the provision of ecosystem services to society.

The high number of occurrences of disasters already recorded (as in the border between the Pampa and the Atlantic Forest) warns of the risk of increasing these episodes in the region, both due to the intensification of rainy extremes and droughts and to the increase in temperature, superimposed on urban vulnerability. from southern cities to natural disasters.

Concerning health, the area suitable for malaria growth in the South region, especially in Paraná and Santa Catarina, is noteworthy and the favorable scenario for the increase of infantile diarrhea in Rio's interior Grande do Sul. In general, the three states that make up the region must suffer from the increase in temperature for deaths and hospitalizations caused by heatwaves and thermal stress.

## 3.8 Adaptation in the Securities Context

### 3.8.1 Adaptation Options

Considering the described impacts and vulnerabilities scenarios, a SET OF ADAPTATION OPTIONS emerges to minimize climate change's negative effects while providing sustainable development opportunities and improving the country's population's well-being. Adaptation actions can be synergistic with each other or represent *trade-offs,* which should be considered when formulating public policies in the context of a changing climate.

The adaptation options presented here refer to the possibilities identified in the context of security, where three aspects of urgency were considered : i. options that take into account the current climate variability and/or that arise from non-regret (that bring co-benefits and are justified in a wide range of future climate scenarios); ii. that lead to decisions with long-term repercussions or have lasting consequences; or iii. that are linked to a long time of implementation (structural and slow measures).

Water resources management has a transversal role in adaptation to climate change. Water is a vital resource for society's consumption and economic activities, including food production, biofuels, energy generation, industry, and others. The strengthening and political-institutional articulation to manage multiple uses and efficient water use are of great importance to minimize water crises and measures such as the implementation of reservoirs and related infrastructures.

Besides, the diversification of generation sources (including solar photovoltaic and wind power) presents itself as an important adaptation option, given the predominance of water sources in the electrical matrix (vulnerable to variations in flows and water balance). Likewise, considering climate scenarios in energy planning can strengthen the energy system's resilience and adaptability, knowing that its assets have high cost and useful life. Complementarities between different sources, such as hydro-wind and hydro-solar, offer additional opportunities in the Brazilian context, despite promoting the user sectors' energy efficiency.

Adaptation strategies in the agricultural sector are necessary to guarantee food supply, reduce losses, and yield drop in production, maintain the producer's income and the landscape in which he finds himself. The adoption of sustainable farming practices involving the appropriate use of resources, in particular soil and water, the maintenance of ecosystems, and the development of varieties more resistant to water and thermal stresses, are measures that can benefit not only food security and energy but contribute to aspects of water quality and quantity, health and others.

Besides, changes in agro-climate risk and productivity conditions have generated, from a strictly technical assessment, proposals for the migration of crops to more favorable areas, as a potential response from the productive sector. Considering the productive sector's conservative spirit and a connection with the landscape, perhaps the producer seeks less extreme alternatives. However, as a guide to this proposal, it will be necessary to consider strengthening territorial planning policies to make productive activities compatible with the conservation of natural environments and ecosystem services.

Ecosystem services are fundamental to society, including food, disease control, soil conservation, climate regulation, and the hydrological cycle. Thus, adaptation solutions based on the integrated management of natural resources contribute significantly to the strengthening of transversal and effective resilience through the maintenance and recovery of natural environments and the integration of green (natural) infrastructure with the gray (built). Adaptation measures of this nature can, for example, act as natural barriers in extreme precipitation events, minimize the occurrence of disasters (flash floods, river floods, and landslides), and improve the quality of urban environments.

In this sense, integrated urban planning represents an instrument capable of enhancing the use of green infrastructure, of promoting solutions that make cities more efficient in the use of resources, such as water and energy; and more equitable, with better access to infrastructure, urban services and quality of life, with special attention to precarious settlements. The control of urban expansion over areas of risk or environmental sensitivity is also urgent, in the sense of not generating new social vulnerabilities and pressures on ecosystems.

Finally, it is emphasized that adaptation can minimize impacts and risks, but it cannot eliminate them. Thus, systems for monitoring and communicating risks to the population and public managers are becoming increasingly essential.

An analysis of the main issues to be considered in the planning and implementing adaptation measures is presented below, considering the territorial specificities, conjunctural and conditioning factors for each security (water, energy, food, and Socio and environmental). Although some options are transversal, they are eventually considered in security with greater thematic adherence.

### WATER SECURITY

STRENGTHENING WATER RESOURCES GOVERNANCE. Brazil has robust legislation and instruments on the topic of water resources, which point to Integrated Water Resources Management (IWRM) in a decentralized manner by the National Water Resources Management System (SINGREH, for its acronym in Portuguese), and impose the integration of water resources policies with other policies, such as municipal master plans, agro-ecological zoning, and land use and occupation legislation. However, the institutional capacity for implementation is heterogeneous and follows regional peculiarities (Empinotti et al., 2014; Jacobi; Fracalanza; Empinotti, 2017).

In the Amazon, for example, where extreme events of floods and droughts are occurring, state and river basin plans are needed, among other mechanisms to deal with the impacts on the affected populations. In the Caatinga, Cerrado, and Atlantic Forest biomes, although most of the territory already has plans and programs in place, impacts and conflicts from the recent water crises indicate the need for complementary actions.

Also, water sector planning will be more effective when considering climate-related impacts and risks to generate and provide information that incorporates uncertainties.

In this context, one of the priority issues for directing adaptation actions is the political-institutional articulation for transversal approaches to water resources policies with other policies and at different levels (federal, state, regional), to evolve in management and more efficient use of water, to avoid crises and the impacts of low water availability for consumptive and non-consumptive uses[57]. For example, we highlight the integrated planning of land use, more flexible management systems capable of dealing with climate uncertainties, and preventive compensation and regulation instruments, such as Payment for Environmental Services (PES) based on the concept of provider-receiver[58].

*[57] Consumption uses are those that remove water from wellsprings/fountainheads for its destination, such as irrigation, use in industry and human supply. Non-consumptive uses do not involve the direct consumption of water - leisure, fishing and navigation are some examples, as they take advantage of the water course without consuming it.*

*[58] The preventive provider-receiver concept complements the current punitive environmental policy, based on the polluter-pays.*

INCREASE IN WATER INFRASTRUCTURE TO INCREASE SUPPLY. In more critical climate scenarios, investments in water storage infrastructure are relevant to guarantee supply in semiarid regions and high population concentrations. The implementation of reservoirs and dams and cisterns is included to ensure water supply in the face of the rain regime's seasonality in an unfavorable and drier climate scenario.

INTEGRATION OF GREEN AND GRAY INFRASTRUCTURE refers to integrating strategies that start from better managing natural resources to conventional engineering works to provide water services. As an example, the implantation of reservoirs and water treatment plants, in synergy with reforestation in hydrographic basins and floodplains, generates benefits for water quality and reduction of treatment costs (Sousa Júnior, 2013; Kroeger et al., 2017), at the same time can serve as an efficient containment/control mechanism for floods and droughts and increase the water storage capacity in the soil, reducing the demand for irrigation. Green infrastructure can increase water resources' resilience (Filoso et al., 2017) and postpone the need for new infrastructure.

PROMOTING THE EFFICIENT USE OF WATER. The water losses of the user sectors, which eventually operate under the premise of abundant resources, are considered a pressure factor for water security (in the present and future scenarios).

Brazil lost US$ 3.04 billion in 2016, due to water waste, which corresponds to 92% of the total amount invested by the basic sanitation sector in the same year in the country (US$ 3.30 billion) (It deals with Brazil, 2018), with leadership in the North and Northeast regions.

Optimizing the use of water resources brings benefits without regrets to different segments. Expanding the efficient use of water in Brazil takes place in a broad context, which includes, since the need to reduce losses in supply systems, especially in large cities, adjust the meter systems of the urban network to legal requirements, promote reuse techniques[59] in the various sustainable sectors (including industrial) and irrigation technologies and practices (representing the largest water use in the country).

Legal requirements and management instruments, such as granting the right to use water resources (authorization for water use) and charging for use, can help the sector's sustainability, increase efficiency, and reduce waste (ANA, 2017).

UNIVERSALIZATION OF BASIC SANITATION. Limited access to basic sanitation services puts populations at risk, with negative effects amplified in climate uncertainty situations. Therefore, the universalization of sanitation services and improving the control of industrial and agricultural activities are actions considered relevant for adaptation.

OTHER ADAPTATION ACTIONS. The elaboration of contingency plans for droughts and floods, with long-term planning and periodic reviews; soil conservation strategies with an impact on water production; improvements in water availability forecasts; as well as the replacement of certain technologies by more efficient methods in the use of water and energy are examples of actions that strengthen the adaptive capacity of institutions and society.

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[59] *Reuse is defined as the use of water previously used (one or more times) in some human activity, to supply the need for other beneficial uses, including the original that can be direct or indirect, as well as arising from planned actions or not.*

## Energy security

The inclusion of impacts and vulnerabilities in the energy planning process; This involves conducting studies of future climate scenarios and using the results in the energy sector's planning instruments (such as PDE[60] and PNE[61]), especially concerning expanding supply-demand, transport, and future energy auctions.

Relevant information includes analysis of changes in the potential of energy resources in future scenarios, which can subsidize the location and use of future facilities for energy production at all levels, in addition to investments in the repowering of hydroelectric plants.

In energy demand projections and GDP growth, and other socioeconomic aspects, the behavior in energy use motivated by climate change and its impact on the population and economic sectors should be evaluated.

In scenarios of reduced hydroelectric potential and increased demand, it is opportune to take advantage of alternative energy sources to diversify the energy matrix, especially with renewable resources, given maintenance indications or a small increase in solar availability and wind energy resources in the country.

Critical infrastructure. Part of critical infrastructures in the country (such as those related to water supply, generation, and transmission of electricity, road, and port) already have vulnerabilities to the current climate due to low efficiency and/or poor maintenance (IIS, 2019). The increase in extreme climate events can impact different systems' infrastructures, such as energy, representing a greater risk of interruption in its supply.

Thus, conservation and damage prevention to energy production and transport infrastructure are relevant actions for adaptation. It is highlighted the importance of carrying out specific studies on the occurrence of interruptions due to climatic factors and future scenarios to support the corresponding actions.

For example, the oil refining sector should consider the incremental climate risk element associated with climate change and natural disasters in defining refineries' location. As for existing refineries, studies on the intensification of extreme climate events should be taken into account so that locally appropriate measures can be taken, seeking to increase the robustness of production plants (such as the construction of flood walls and containment dikes, level of buildings and structural reinforcement).

Incentives for decentralized energy generation can minimize possible electric power generation, distribution, and/or transmission failures caused by extreme climate events. They can apply to both isolated systems and large urban centers, transportation systems, and industrial hubs. This measure can increase the energy supply and thus reduce the pressure on the energy system. Particularly for isolated systems in the Amazon biome, one can take advantage of the increased solar incidence for photovoltaic generation; invest in small hydroelectric power plants or hydro-kinetic turbines[62]; promote the use of biodiesel from vegetable oils found locally, such as palm oil, and the use of biomass generated by forest residues, waste from the production of açaí, and cupuaçú (Teixeira, 2013).

*[60] PDE – Ten-Year Energy Plan (Plano Decenal de Energia)*

*[61] PNE- National Energy Plan (Plano Nacional de Energia)*

*[62] These hydroelectric plants have reduced environmental and social impact and still guarantee energy security. (Miller et. al., 2011; Goldemberg, 2004).*

The vulnerability of power transmission increases in large infrastructures, such as the SIN, a condition applicable in its expansion to serve more distant uses, such as isolated communities located in the Amazon biome, with high investment costs in distribution and transmission.

COMPLEMENTARITY OF SOURCES OF ELECTRICAL GENERATION. There are opportunities for adaptation in the complementary relationships between water, water-wind, water-solar, and possibly wind-solar sources, especially in the Amazon, Cerrado, Atlantic Forest, and Caatinga biomes. It is also worth mentioning the complementarities between wind and solar sources, specifically for regions with greater wind potential at night, when there is no solar energy generation, as in the country's Northeast region (Caatinga biome).

Brazil has a National Interconnected System and a diversity of the electrical matrix that endows it with adaptive capacity in relation to the climate impacts on generation (BRASIL, 2016b).

Generation through hybrid wind-photovoltaic plants has a lower average generation cost than a purely solar or wind power plant because it optimizes operating and investment costs, generating scope savings, in addition to reducing socio and environmental impacts, minimizing the impacts on the electricity grid resulting from fluctuations in power generation and reducing the cost of system interruptions. However, the initial investment cost makes its implementation dependent on specific government policies and actions to become economically attractive (EPE, 2017).

GENETIC IMPROVEMENT OF BIOENERGETIC SPECIES is a measure that can contribute to increasing the resilience of the biofuel system in the face of climate change. The increase in areas of high agro-climate risk in soybean and sugar cane production in the Atlantic Forest and Cerrado biomes (Southeast, Midwest, and Northeast regions) directly impact the main inputs for Brazilian bioenergetic ethanol chains and biodiesel.

There are excellent breeding improvement programs in Brazil for sugarcane and soybean (Carvalho and Furtado, 2013; Freitas, 2011). Concerning soybeans, national grain improvement programs were of fundamental importance to enable adaptation of cultivation in low-latitude regions, expanding the agricultural frontier of soybeans to the Cerrado biome, where currently there is the largest share of national production (Freitas, 2011).

GREATER EFFICIENCY IN THE CONVERSION AND USE OF ENERGY. Included are the promotion of efficiency both in energy transformation processes and in its different uses, such as buildings (for example, Procel Edifications), industrial and transport, which requires instruments of public policy, technology, and users behavioral change. These measures are enhanced if integrated with urban planning, such as natural cooling systems (passive cooling), for example, green spaces on roofs.

BIOMASS AS AN ALTERNATIVE SOURCE OF ENERGY. The adaptation in the advanced biomass chain is related to the energy use of residual biomass[63], such as agro-industrial waste, generated in a concentrated way where its energy use will take place; agricultural waste, generated in the field in a dispersed manner, dependent on equipment for its collection; and solid urban waste and biogas.

## FOOD SECURITY

The impact of climate change on the country's food supply may be intense in all production sectors due to the great dependence on local climate conditions (PBMC, 2013). The fact will require the adoption of measures that increase resilience and reduce the vulnerability of agriculture and livestock production systems, considering how much can be produced in a given sector and how the food will be produced and distributed so that availability and access to food are guaranteed.

DEVELOPMENT OF VARIETIES AND AGRICULTURAL MANAGEMENT SYSTEMS ADAPTED TO CLIMATE CHANGE. Reduced productivity of rice, beans, corn, soybeans, wheat, and coffee (Cavero, 2016; Assad et al., 2013), due to the lower availability of water and an increase in average temperature, may compromise the supply of these products for the consumption of the Brazilian population (Assad

[63] *materials of biological origin with energy potential that are generated as co-products or by-products of human activities, such as agriculture, industry or consumption.*

et al., 2013). The production and the suitability of grain planting areas may suffer great reductions, especially in the Midwest region (Assad et al., 2013; Embrapa, 2008).

The improvement of management systems and production technologies can contribute to greater productivity. When adopted within an integrated landscape approach, conservationist agriculture principles allow the establishment of highly productive, profitable, and resilient production systems, with the capacity to face climate uncertainties. Strategies such as the No-till farmingstand out, systems integrated with their different forms (iLPF, iLP, SAFs), which, among others, allow production elements, such as soil and water, to ensure the maintenance of a balance of temperatures and water availability within a range of climate uncertainty.

The integration of agricultural, livestock and forestry production systems (iLPF and SAFs) allows the sustainable intensification of land use for gains in productivity of food, fibers, and energy (Cordeiro et al., 2015), and the provision of ecosystem services (Vasconcellos and Beltrão, 2018). Additionally, integrated systems allow, among others, an improvement in the animal production environment, with a reduction in thermal stress, and consequently, an improvement in productive performance (Barba, 2011)

Likewise, cultivars' genetic improvement with greater tolerance to water deficit and thermal stress can develop agricultural production systems that are more resistant to climate change.

In the Brazilian semiarid, the adoption of more rational irrigation management systems has increased (Castro, 2017) to minimize the drought impact on agriculture. Used sustainably, it becomes an adaptation strategy (Cunha et al., 2013).

Technical assistance and income transfer and financing and risk transfer mechanisms (credit and agricultural insurance) are relevant for reducing agricultural and livestock production systems' vulnerability, especially family farming, to minimize impacts production losses (Miranda and Gomes, 2016).

Examples of these are the Technical Assistance and Rural Extension (ATER, for its acronym in Portuguese) services[64]; the National Program for Strengthening Family Agriculture (Pronaf, for its acronym in Portuguese), and its actions such as Garantia-Safra[65] and Family Agriculture Insurance (SEAF, for its acronym in Portuguese); the Agricultural Activity Guarantee Program (Proagro, for its acronym in Portuguese); the Family Agriculture and Livestock Activity Program (Proagro Mais); the Rural Insurance Premium (PSR, for its acronym in Portuguese) Subsidy Program and the Plano ABC credit line.

Monitoring of agro-climate risks is relevant to subsidize government and farmers in decision-making. Various public policy instruments can rely on this information, such as the Agro-Climate Risk Zoning (ZARC, for its acronym in Portuguese)[66] , which is consulted for contracting and mitigating risk in taking credit and financing from Proagro, Proagro Mais, and PSR.

Maintenance and recovery of natural environments. In general, adaptation actions focused on the conservation and/or restoration of ecosystems and reducing deforestation is important for maintaining ecosystem services and, consequently, for the maintenance and/or increase of agriculture and livestock production (PBMC, 2019). The strengthening of the actions of Registration and recovery of Permanent Preservation Areas (APP, for its acronym in Portuguese) and legal reserves in agricultural properties, as provided for in the Forest Code, strengthen the fronts of fostering sustainable agriculture and livestock production systems. The real balance between the sustainable management of production systems, with intensified production, integrated with the local landscape, and the protection of natural resources and ecosystems strengthens

[64] *Focused exclusively on small and medium rural farmers and, being based on informal basic education, it promotes management, production and trade related to agriculture and livestock activity, including also forest management, collection and handicrafts (Castro and Pereira, 2017).*

[65] *Subsidized to farmers in the semi-arid region due to the systematic losses that occur in agriculture and livestock production, mainly due to the occurrence of extreme events (droughts and excessive rains).*

[66] *It is a tool that guides the rural producer about the best time for planting and sowing crops, in order to reduce agricultural losses caused by adverse weather conditions (Comunello, 2016).*

agriculture and livestock production systems' resilience. It is evident in improving the producer's income and the ecosystem services made available to the community.

IMPROVEMENT OF FOOD DISTRIBUTION AND STORAGE INFRASTRUCTURE. Food losses occur during the production, storage, and transport phases (Creus, 2018), and waste, which represents the amount of food discarded without being consumed, reduces food availability, with consequences negative consequences for producers and consumers. In this sense, there are measures to improve the food distribution and storage infrastructure in the country, mainly in the supply centers (Martins and Farias, 2003), in the transport, packaging, and marketing structures, among others that can minimize also waste, which also depends on promoting consumer education.

IMPLEMENTATION OF FISH STOCKS MANAGEMENT SYSTEMS. Fish production may be affected by lowering the water's pH and increasing the temperature, causing acidification of the oceans and, consequently, an environmental imbalance of marine life (Campos, 2019). Measures aimed at implementing and/or improving the management systems of fisheries stocks may result in the greater economic exploitation of ocean fishing and Brazilian continental waters (MMA, 2019; Viana, 2013), together with the promotion of aquaculture.

### SOCIOENVIRONMENTAL SECURITY

PROTECTION OF FORESTS. Changes in land use and the impacts of climate change require adaptation strategies and policies for protected areas (Conservation Units and Indigenous Territories), in addition to reforestation and restoration of degraded areas in all biomes, intending to strengthen resilience ecosystems (Paul Leslie and J. Terrence McCabe 2013; Acosta Salvatierra et al. 2017). Such actions must be promoted in an articulated manner between the national and subnational spheres, aiming at efficiency and effectiveness in their implementation.

The maintenance and connectivity between protected areas provide ecological processes' viability by maintaining redundancy and functional diversity of species, especially in biomes *hotspots* (high biodiversity and endemism), such as the Amazon, Caatinga, Cerrado, and Mata Atlantic, including coastal areas and oceans. They also aim to preserve culture, religiosity, and lifestyle, insofar as they enable the effective and continuous participation of traditional peoples.

Among the options for adapting through economic incentives, the Payment for Environmental Services (PES) stands out, aiming to financially reward communities and or rural producers for environmental protection, inside and outside legal reserves. Specifically for traditional and indigenous peoples, the Reduction of Emissions from Deforestation and Forest Degradation (REDD+) acts as PES, contributing to forest adaptation strategies in several biomes, mainly in the Amazon.

The sustainable use of protected areas, based on traditional local knowledge, can reduce their vulnerabilities; This includes developing business models for sustainable forest products, important for subsistence and the regional economy.

TERRITORIAL PLANNING In addition to protecting forests, it is important to discipline socioeconomic activities. In the Amazon biome, the Ecological-Economic Macrozoning (MacroZEE) of the Legal Amazon can be used as a guiding instrument for planning land use and infrastructure in the region to reduce environmental and social impacts, contributing to the adaptation to climate risks.

PREVENTION AND COMBAT OF FOREST FIRES. Forest fires increase the exposure of ecosystems due to loss of forest and moisture and soil depletion, in addition to causing damage to agriculture and health impacts. The integrated management of impacts and risks of forest fires contributes to adaptation, such as the monitoring system for hot spots and fires and fire risks of INPE, which can be integrated with the civil defense of municipalities and states, and with information collected by farmers and the civil society.

> It is important to incorporate fire management in environmental policies, in the Amazon and Cerrado biomes, especially in agriculture and livestock activities, knowing that the practice has been used by traditional and indigenous communities for centuries (Bustamante et al., 2018; Saraiva et al., 2018).

PROMOTION OF INTEGRATED URBAN PLANNING. In cities and their surroundings, it is necessary to apply instruments that ensure the protection of ecosystem services and biodiversity due to the expansion of urban areas (the rational densification of cities can be considered an option). In a context of intensification of extreme events, in the same way, integrated urban planning is an instrument that allows trees and urban permeability to be encouraged (which promote thermal comfort, lower energy expenditure, reducing the effect of heat islands, and contribute to reducing the impacts of floods), and the integration of land use planning with urban infrastructure and services, such as basic sanitation and rain drainage, mobility, among others.

> It is essential to train city halls' technical bodies, especially small municipalities, to expand the implementation of a local urban policy or even form institutional rearrangements (Santos et al., 2017).

SOCIAL PROTECTION PROGRAMS. Greater resilience and adaptability of ecosystems and the population demand social protection mechanisms and measures to reduce vulnerabilities (Heltberg et al., 2009; Rezende et al., 2018) since social inequalities aggravate climate change risks. Programs to support poorer communities and populations at risk, such as Family Allowance Program, are relevants for social assistance and income transfer (Lindoso et al., 2014; Lemos 2015; IPCC, 2014).

HEALTH SERVICES. Climate change has affected or aggravated the spatial distribution, frequency, and the number of occurrences of vector-borne diseases, waterborne diseases, or heat waves (such as cardiorespiratory diseases), together with the intensification of natural and migratory flows. Therefore, prior planning of health services will be necessary to serve populations exposed to climate change impacts, knowing that ecosystems' conservation is also essential for minimizing various types of diseases and the universalization of environmental sanitation.

Adaptation in health includes investments in research on the proliferation and treatment of diseases and the structuring of health services and professionals' training to deal with epidemics and disasters. It is also worth mentioning the expansion of vector control, monitoring and communication systems for disaster alerts, and protocols for the various categories of morbidities.

RISK AND DISASTER MANAGEMENT AND COMMUNICATION SYSTEMS. In the face of disaster intensification scenarios, especially those related to intense rains and droughts, there is a need for continuous improvement and modernization of risk and disaster management and communication systems, strengthening competent bodies such as Cemaden, Cenad, INMET, among others. Also, training for emergencies of state and municipal civil defenses, primary health care teams, among others, is recommended.

> Natural disasters of a hydrometeorological nature, such as landslides, floods, and flash floods, are strongly conditioned by cities' disorderly growth, the occupation of marshlands or areas of a high declivity, lack of rain drainage infrastructure and environmental

sanitation, including garbage collection and diffuse pollution control. Thus, disaster risk management's effectiveness depends on implementing complementary actions that deal with these aspects.

MAPPING OF POPULATION MOBILITY SCENARIOS[67]. Migration in response to climate change tends to be associated with loss of rural and urban productivity, difficulty accessing water, food, and, to a lesser extent, energy. Thus, it is important to know the migration processes to anticipate planning in health, housing, economics, and the provision of water, energy, and food.

PROTECTION OF AQUATIC ECOSYSTEMS (FRESHWATER AND MARINE). Changes resulting from climate change lead to eutrophication, loss of coral reefs and nurseries for breeding species, loss of biodiversity, productivity (including fishing), the ability to absorb $CO_2$, coastal erosion and displacement, and loss of traditional and coastal populations lifestyles, as well as impacts on tourism. Additionally, non-climatic pressure factors work together on aquatic ecosystems, such as urbanization, dams, overfishing, organic, chemical, and solid waste pollution.

The disappearance of coral reefs associated with increasing temperatures and acidification of the oceans are seen as 'hard' limits for adaptation. Once this limit is crossed, it is impossible to re-establish the ecosystem without incurring economic and non-economic losses.

Adaptation in this context includes implementing specific marine and freshwater coastal habitats and ecosystems, increasing legally protected areas, integrating coastal management with the terrestrial environment, and encouraging participatory management instruments in these locations. It is also worth mentioning the restoration of coral reefs and seagrass banks and the expansion of algae cultivation (ensuring controlled BOD).

### 3.8.2 SYNERGIES AND TRADE-OFFS BETWEEN ADAPTATION OPTIONS

Potential relationships and complementarities between energy, water, food, and socio-environmental security for the adaptation's formulation and implementation should be considered having in mind integrated policies between sectors to maximize synergies, optimize trade-offs, and to avoid negative impacts.

Synergies can be understood as adaptation actions that enhance others or bring co-benefits with other objectives. On the other hand, there are adaptation actions that minimize certain risks while aggravating others, generating choice conflicts or trade-offs.

From the adaptation options presented, synergies and trade-offs from each the security (water, socio-environmental, energy, and food) are described.

#### WATER SECURITY WITH OTHER SECURITIES

When it comes to synergies between adaptation options, water occupies a central position among securities, highlighting its complex governance per se and challenged to integrate energy and food security in the face of climate change impacts, requiring more complex and several governance arrangements mentioned as "multilevel coordination challenges" (Pahl-Wostl, 2009).

Thus, strengthening capacities and political-institutional articulation for cross-cutting approaches with other policies at different levels can amplify management and optimal efficient water use, avoiding crises and impacts of low water availability as broad adaptation options that also favor water availability for food and energy production.

[67] *The proposal is that the National Household Sample Survey - PNAD/IBGE will generate systematic and periodic migration data that can, spatially, be analyzed with climate data.*

Promoting actions for efficient water use, as well as the prioritization of reuse water on industrial, agricultural, and urban sectors, are adaptation measures that offer synergy with other securities, given the multiple water uses.

Increasing infrastructure interventions can ensure water supply for human supply and its use in productive activities, and reduce risks associated with critical events (such as droughts and floods), benefiting energy and food production sectors. However, purely structural/physical interventions (such as water reservoirs) have a high environmental cost, which may influence negatively fishing management, result in vegetation removal to implement construction works, losses of connectivity of protected areas, and change in aquatic ecosystems, generating trade-offs for social and environmental security.

The options that strengthen the integration of green infrastructure and the integrated management of natural resources with gray infrastructure for water production and protection of water resources have synergy with integrated urban planning, minimizing eventual disasters and bringing health benefits.

Besides, they bear the potential for multiple environmental and social benefits, such as the integration of local communities and the maintenance and the restoration of ecosystem services (necessary for long-term water security and effective water use techniques), such as reuse and implementing wetlands.

#### Energy Security with Other Securities

Renewable power sources (hydroelectric, solar, wind, and biomass) in Brazil already present vulnerabilities in the face of climate change. The actions that strengthen resilience and power system adaptability can be beneficial for all the other securities, as well as power efficiency and conservation measures in all user sectors, by contributing to the reduction of power demand.

Improving physical power infrastructure can contribute to stability and/or increase power supply. However, there could be trade-offs for other securities, especially when it comes to implementing hydroelectric plants and their interconnections, either by the impact of construction works on the environment and ecosystem services or in reducing water availability for other uses or areas for the production of food and fishing resources. Concerning thermoelectric plants, the increase in emissions of local air pollutants and GHG (compared to renewable power sources) stands out as a trade-off.

The use of complementarities between power sources can benefit water security in the availability of resources to other users, including agricultural use, as well as power access to isolated communities, for example, the implementation of hybrid wind-photovoltaic plants in the Caatinga biome (Northeast region), as well as the incentive to generate decentralized power and non-hydroelectric renewable sources.

The genetic improvement of plant species most relevant to the Brazilian bioenergy system (sugarcane and soybean) may enable these crops in future climate scenarios and magnify the confidence in biomass supply to ethanol and biodiesel plants (whose participation in the Brazilian power grid tend to increase). This measure can contribute to water security since the use of bioenergy in a complementary way with hydroelectricity promotes greater availability of water resources to other users. However, the demand for irrigation may increase (with the expansion of sugarcane and soybean cultivation areas), which would represent a trade-off with other water uses.

According to Embrapa (2015), the goal of the genetic improvement program (as in the case of sugarcane) is to develop clones with high productivity, high sucrose content, drought tolerance, high ethanol, and biomass production, developing efficient plants that require low use of nitrogen fertilizers, among others, which may reduce environmental impacts. However, for food security and socio-environmental security, trade-offs can be generated, as it may increase the demand for use conversion and land competition, especially impacting family farmers and traditional populations. Also, there may still be unforeseeable impacts of new genetic varieties on ecosystem services.

The use of residual biomass as an alternative power source may generate synergies with other securities, since it is based on the use of agricultural, agro-industrial, and municipal solid waste, giving destination to waste that would otherwise be sent for disposal.

### Food Security with Other Securities

Actions to promote food security may generate synergies with other security factors especially when adaptation options include the maintenance and recovery of natural environments and/or through sustainable agriculture, with the development of varieties and agricultural management systems adapted to climate change.

The proper management of the agricultural production process, the adoption of good practices, the solid principles of conservation agriculture of soil and water management, which we obtain with such success with the no-tillage system, the implementation of integrated systems, among several other known practices, allow the sustainable intensification of agricultural production, improving its productivity. These are some technical adaptation options among many others (Cohen-Shacham et al., 2016), which coupled with a guarantee of food availability and income generation of agricultural producers also present synergies with water security (optimal water management, including sometimes water table replenishment), socio-environmental security (by proper land use, reducing pressure on preservation areas of natural ecosystems), among others.

Some strategies to face climate uncertainty and ensure food security should be assessed in their context, so as not to generate impacts on other securities. The threat of new diseases and pests due to climate change, so far unbeknownst to the sector, for example, may require the use of non-specific, consequent-based, generic, and of greater impact pesticides, with possible consequences for the biodiversity in the surroundings. Another example involves the adoption of irrigation strategies to face the scenarios of water scarcity, which threatens food production capacity. It should be implemented within a broader water management context, with reuse and preservation strategies, among others, to avoid impacts on water security in the region.

Strengthening monitoring, information, and management systems for agroclimatic risks and risk transfer mechanisms (credit and agricultural insurance) can assist producers in managing rural risk by providing information promptly regarding climate risks. The appropriate information associated with contingency plans guides producers in their decision-making about planting and handling their agricultural and animal production system, reducing their vulnerability to climate events.

On the other hand, technical assistance actions and technology transfer to traditional populations and for family farming can enable them to use more appropriate technologies, with the adoption of sustainable practices, better management, and use of natural resources, allowing better productivity, sustainability, and resilience of production units. Consequently, we have an income increase and guarantee, which are key to social development. Essential aspects to enable these communities to seek appropriate answers to face climate uncertainties, ensuring their productive capacity and reproduction of their way of life. Additionally, these actions may contribute to the maintenance of protected areas and the subsistence of these communities, just like the implementation and improvement in the management of fishing stocks, with emphasis on the protection of aquatic ecosystems.

Besides, improving food distribution and storage infrastructure enables more effective dynamics in food distribution, reducing losses, creating also better opportunities for small-scale production, such as family farming, and connecting agricultural production to market demands by improving processes along the local agriculture value chain, with synergies for other securities, contributing to the population's welfare and reducing pressure on production systems, among other socioeconomic and environmental benefits.

The reduction of energy consumption with better efficiency in the distribution stages is a direct contribution to energy security. A more efficient system in the stages of storage and transportation results in a reduction of product losses, which among others directly reduces the environmental footprint caused by waste and discard now avoided, and indirectly the environmental footprint using the area for production.

### Socioenvironmental Security with Other Securities

Ecosystem services provide benefits to human needs, including supply services (food, fiber, wood, fuels); regulation (climate regulation, regulation of diseases, water purification); cultural (aesthetic, recreational, spiritual); and support (primary production, nutrient cycling, soil formation). Therefore, keeping them is essential for all securities.

As Brazil is a rich country in natural resources and biodiversity, adaptation actions based on integrated management of natural resources such as the maintenance of wetlands and green spaces contribute significantly to building resilience and adaptability in socio-environmental security, in synergy with the management of watersheds and other measures aimed at maintaining biodiversity.

Economic, social, environmental, and cultural benefits can be achieved by using an integrated analysis of landscape elements, as healthy environments play an important role in protecting infrastructure and expanding human security, acting as natural barriers and reducing the impacts of extreme events. In the management of flood risks, the preservation of floodplains and their reconnection to rivers can also favor the conservation of ecosystem services (Ozment et al., 2015; Opperman et al., 2009).

Additionally, the maintenance and recovery of areas with natural vegetation (including forests, wetlands, and floodplains) favor pollination, benefiting both ecological balance and agricultural production (MEA, 2005). Also contributing to reducing the risk of a water crisis, particularly in the face of future climate stresses (Ozment et al., 2015), improving water quality, increasing water table recharge, and reducing surface water runoff during storms (Colls, Ash and Ikkala, 2009).

The preservation of the Amazon and recomposition of native forests in the Southeast may improve water conditions for water jets to continue operating and feeding reservoirs (Fundação Boticário/Iclei. 2015), which favors the generation of hydroelectric power. This occurs because there is a relationship between hydrological cycles at different scales in the country with the ecosystem functions of the Amazon biome the same way as the Atlantic Forest biome minimizes the formation of heat zones (which can prevent the formation of rains) in southeastern Brazil.

Integrated urban planning is also highlighted as a way to coordinate and enhance the implementation of actions in different sectors. Among these, there are afforestation, soil permeabilzation, urban agriculture, the intelligent density of regularized and consolidated areas of cities, the urbanization of precarious settlements, and the maintenance of social relations of low-income populations (controlling the expansion of anthropized areas, especially in risk or environmental sensitivity areas).

Such measures contribute to minimizing heat islands and energy expenditure with air conditioning, allowing rainwater capture and reducing pollution in water bodies by urban sewage. These actions have synergies with risk monitoring and communication systems, with underground and surface water availability, and with the population health.

However, the reduction of areas available for agriculture and infrastructure due to the increase in protected areas can be considered a trade-off. In this sense, solutions such as agroforestry, for example, can increase fertility and reduce soil erosion, increasing fruit, wood, and forage productivity.

Nitrogen-fixing plants with deep roots can naturally re-enter soil nutrients in agricultural systems, assist in the filtration of sediments and nutrients, keeping waters clean and available for human consumption, and reinforcing carbon sinkholes. Well-managed and conserved pastures provide forage for livestock while storing carbon in biomass above and below ground.

Fostering and improving risk and disaster management and communication systems, heat waves and forest fires have synergy with all securities.

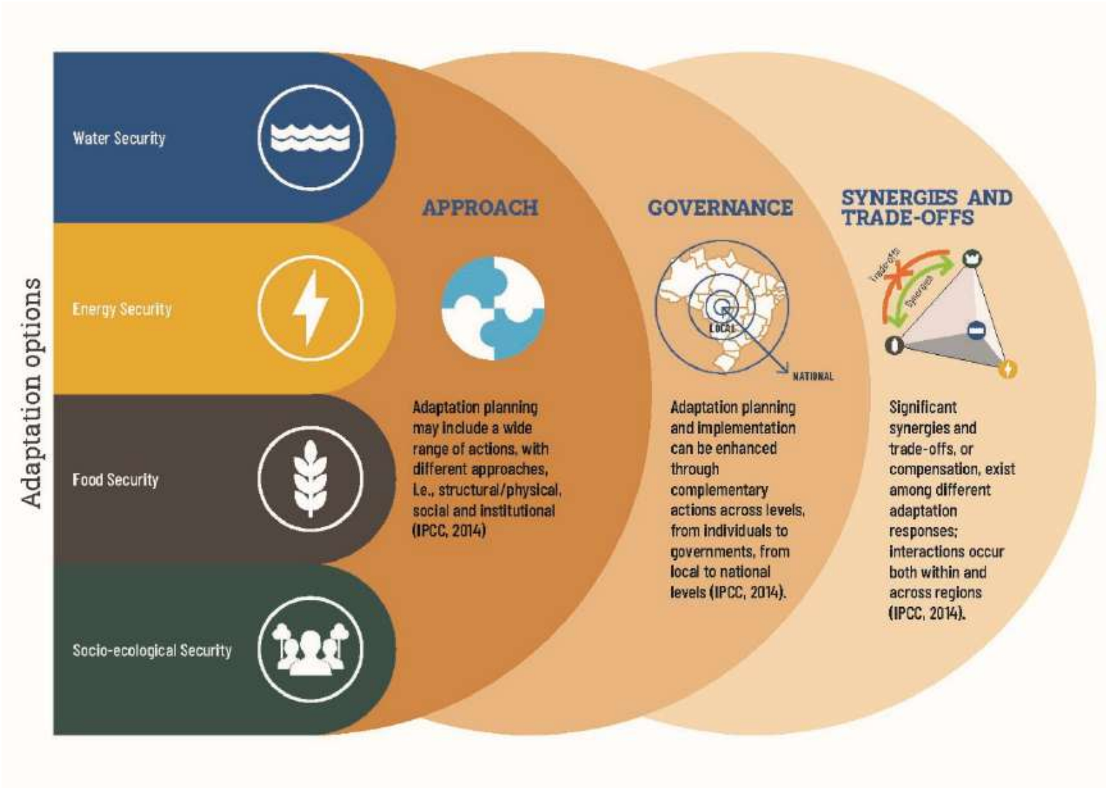



Figure 3.59. Integrated adaptation planning.

Finally, it is noteworthy that implementing adaptation (given its transversality with other public policies and socioeconomic development agendas) will be more effective when combining measures with complementary approaches at different levels of governance and considering synergies and trade-offs among them (Figure 3.59).

# CHAPTER 4

# SUMMARY

## *4. CLIMATE CHANGE MITIGATION AND ADAPTATION MEASURES*

# 4. CLIMATE CHANGE MITIGATION AND ADAPTATION MEASURES

## 4.1. PUBLIC POLICIES, PROGRAMS, PROJECTS AND OTHER INITIATIVES TO MITIGATE AND ADAPT TO CLIMATE CHANGE

The Brazilian government incorporated principles, objectives, guidelines, and instruments into the National Policy on Climate Change (PNMC) that inform the development and implementation of public policies and government programs, as reflected in Decree No. 9,578/2018, which overrides Decrees No. 7,343/2010 and No. 7,390/2010, which are primarily aimed at fulfilling their voluntary national commitment pertaining to Nationally Appropriate Mitigation Actions (NAMAs). These actions were supported by the implementation of sectoral mitigation and adaptation plans under the PNMC, such as PPCerrado, PPCDAm, the ABC Plan, and the Sectoral Plan to Reduce Emissions in the Steel Industry, which are described throughout this chapter.

*See **item 1.6** for more information on the PNMC.*

It is of note that over the past 10 years other relevant actions have also been developed at the national and subnational levels with a view to mitigating national emissions and adapting the country to climate change. Some of these actions culminated in the development of other related initiatives and projects, such as Brazil's strategy for the GCF, PNA, PoMuC, TNA_Brazil, CITInova, GIDES, and Brazil PMR Project, which are discussed below as an illustration of this array of supporting measures that have been adopted. It is also worth mentioning the existence of cross-cutting national policies, which focus on a different issue to climate change, but which strongly contribute to the achievement of the results of the PNMC, such as the Forest Code, RenovaBio and Proveg.

In addition to the national efforts discussed in this chapter, countless public policy instruments and initiatives that contribute to adaptation under the jurisdiction of subnational entities are recognized, as well as initiatives by the business sector and the civil society.

With regard to the subnational levels, it should be pointed out that 16 of the 27 Brazilian states have an approved state climate change policy in place, 17 states have set up climate change forums, and 10 states have adaptation plans in place. In addition, several municipalities have climate policies and/or strategies in place, such as: Belo Horizonte (MG), Salvador (BA), Palmas (TO), Recife (PE), Rio de Janeiro (RJ), São Paulo (SP), Santos (SP), and Fortaleza (CE); in addition to the 110 municipalities participating in the Global Covenant of Mayors for Climate and Energy, including 26 capital cities.

Similarly, there is great potential for private sector actions in the country, which often has the support of the academic community and civil society organizations in implementing adaptation, including the following: Thematic Chamber on Energy and Climate Change (CEBDS); Adapta Sertão (Coalition of family farming cooperatives and Redeh); Xingu Program (ISA); Agroclimatic Intelligence Project (IAC) (businesses, farmers, Embrapa and others); Observation and Monitoring System for the Indigenous Amazon (SOMAI Platform) (IPAM, Funai, COIAB and APIB); Corporate Platform for the Climate (EPC) (FGVces); Adaptation Project based on Ecosystems in Marine, Terrestrial and Coastal Regions (CI; Municipality of Porto Seguro; SOS Mata Atlântica; Porto Seguro Advocacy Movement; UFSC and USP); Brazil Network in the Global Compact - Energy & Climate WG (Ethos Institute, CBPG and associated businesses).

### 4.1.1. Forest Code

The Native Vegetation Protection Act No. 12,651/2012, known as the new "Forest Code", establishes general rules for the protection of native vegetation, including Permanent Preservation Areas (APP), Legal Reserve (RL) and Restricted Use; forest development, the supply of forest raw materials, controlled origin of forest products, control and prevention of forest fires, and the provision of economic and financial instruments to achieve its objectives.

One of the innovations in this Law is the creation of the CAR and the envisaged implementation of the Environmental Regularization Program (PRA) in the various States and the Federal District.

### *Rural Environmental Registry (CAR)*

The CAR constitutes a strategic database for controlling, monitoring and combating deforestation of forests and all other forms of native vegetation in Brazil, as well as the environmental and economic planning of rural properties (Panel 4.1). It requires all rural properties to register electronically based on information such as the demarcation of APPs, RLs, remnants of native vegetation, consolidated areas, areas of social interest and of public utility. The CAR allows the Federal Government and state environmental agencies to keep track of not only the location of each rural property, but also the status of their environmental compliance.

The CAR also provides inputs for the management of agricultural credit and insurance, tax exemption for the main agricultural inputs and equipment, among other economic benefits. For the implementation of actions under the Land and Territorial Planning pillar of the PPCDAm, the creation of the CAR and the Rural Environmental Registry System (Sicar) assists in the environmental regularization of rural properties and possessions, directly supporting[1] some priority municipalities, in addition to strengthening and improving the implementation of the Environmental Regularization Program (PRA). Figure 4.1 summarizes key results of the CAR for October 2018.

*Panel 4.1. Main Characteristics of the Rural Environmental Registry System (CAR)*

| Rural Environmental Registry (CAR) | Information |
|---|---|
| Joining the CAR | The following details must be provided: (i) Identification of the rural owner or occupier; (ii) proof of rural land ownership or occupation; (iii) Identification of the rural property; (iv) definition of the property's perimeter; areas of remnants of native vegetation; the Permanent Preservation Areas (APP) and Legal Reserve (RL); restricted use areas and consolidated areas. |
| Benefits of the CAR | • Potential instrument for planning rural properties • Access to the Environmental Regularization Program (PRA) • Trading of Environmental Reserve Quotas (CRA) • Access to agricultural credit. |

Source: Based on BRASIL, 2012; EMBRAPA, 2012.

### *Environmental Regularization Program (PRA)*

The PRA includes a set of actions to be developed by rural landowners and occupiers, with the objective of promoting the environmental regularization of their properties or possessions. Thus, it helps states provide guidance and monitor rural producers in the preparation and implementation of the actions required to restore areas with environmental liabilities on their rural properties or possessions, whether in APPs, RLs or Restricted Use Areas.

[1] *The Amazon Fund has supported projects that enable rural landowners to join the CAR.*

*Panel 4.2. Main Characteristics of the Environmental Regularization Program (PRA)*

| Environmental Regularization Program (PRA) | Information |
|---|---|
| Joining the PRA | PRAs must be put in place in the States and the Federal District, and in order to join them one must enter their rural property in the CAR. Formal inclusion in the PRA involves signing a Term of Commitment that contains at least the commitments to maintain, recover or restore the degraded areas or areas altered in APP, RL and Restricted Use Areas in the rural property, or to offset Legal Reserve Areas. |
| Benefits of the PRA | Once the obligations in the PRA Term of Commitment and its timing and conditions have been fulfilled, the fines referred herein will be deemed as services for preservation, improvement and recovery of the quality of the environment, with the regularization of the use of consolidated rural areas as defined in the PRA[2]. |

Source: Based on BRASIL, 2012; EMBRAPA, 2012.

### 4.1.2. Brazil's Strategy for the Green Climate Fund (GCF)

The Green Climate Fund (GCF) is a global initiative that is intended to promote low carbon development and climate resilience. It was established by 194 countries with a view to limiting or reducing greenhouse gas emissions in developing countries and to helping vulnerable societies to adapt to the impacts of climate change.

A key principle of the GCF is that projects are aligned with the needs and priorities of the proposing countries, thus promoting ownership by the beneficiary country of the results of the projects to be funded. Thus, it is essential that countries submit their priorities and their strategy for engaging with the Fund.

As such, under the coordination of the Ministry of Economy's Secretariat for International Affairs (SAIN), as the National Designated Authority to the GCF in collaboration with the relevant Ministries, the base document for the discussion of the "Brazil Strategy for the Green Climate Fund - GCF" was prepared[3]. Panel 4.3 summarizes the strategic pillars and investment areas described in the document.

*Panel 4.3. Strategic pillars in Brazil's Strategy for the Green Climate Fund (GCF)*

| Strategic pillars and investment areas for GCF's activities in Brazil | |
|---|---|
| Pillar I: Agriculture and Forestry | Sustainable management of forest assets, forest-based economy and access to markets. |
| | Recovery, reforestation, protection, and payments for REDD+ results. |
| | Low-carbon agriculture and adaptation in the production sector. |

[2] *As of the signing of the Term of Commitment, the sanctions resulting from violations related to the illegal suppression of vegetation in Areas of Permanent Preservation, Legal Reserve and Restricted Use Areas committed prior to 07/22/2008 will be suspended.*
[3] *Main international organizations accredited: IDB, World Bank, CAF, IFAD, GIZ, KfW, AFD, Avina Foundation, UNDP, UN Environment, FAO; national accredited Direct Access entities: CAIXA, Funbio and BNDES.*

| Strategic pillars and investment areas for GCF's activities in Brazil | |
|---|---|
| Pillar II: Sustainable Infrastructure | Low emission modes of transport. |
| | Renewable energy, distributed generation and energy storage. |
| | Energy efficiency for public lighting, vehicles, industrial facilities, and buildings. |
| | Advanced biofuels and bioenergy technologies. |
| Pillar III: Resilient Cities, Communities and Territories | Urban planning for climate risk management. |
| | Efficient buildings and housing resilience. |
| | Ecosystem-based adaptation (EbA) and water security. |
| | Resilience and sustainability of indigenous peoples and traditional communities. |

Source: Based on ME, 2017a; 2017b.

### 4.1.3. Action Plan for the Prevention and Control of Deforestation and Forest Fires in the Cerrado biome (PPCerrado)

Launched in 2010, PPCerrado is one of the main instruments of the National Policy on Climate Change (Law No. 12,187). The Plan is in its 3rd implementation stage (from 2016 to 2020). PPCerrado encompasses several policies and actions from the Federal Government and is structured in nine specific objectives distributed into four thematic pillars. Panel 4.4 summarizes the main elements in the Plan.

*Panel 4.4. Main Elements about PPCerrado*

| PPCerrado | Information |
|---|---|
| Goals | Implement an estimated reduction of 104 million $tCO_2e$ by 2020, with the reduction of deforestation and the degradation of native vegetation by promoting the maintenance of ecosystem services through the sustainable use of forest resources and the promotion of sustainable agricultural systems. |
| Characteristics | PPCerrado involves the implementation of commitments in sectoral plan related to national voluntary commitments as stipulated under Law No. 12,187/2009. For each action or macro-objective, results expected by 2020 are established, which will be used as guiding principles for future planning reviews to be carried out by the federal government. PPCerrado covers the voluntary national commitment to reduce emissions from deforestation in the Cerrado as well as other actions |

| PPCerrado | Information |
|---|---|
| | described in the PPCerrado Operational Plan, whose emissions will be calculated under the agriculture and steel sector plans, thus avoiding double counting in emission reductions. |
| Thematic Pillars | i) environmental monitoring and control; ii) land tenure regularization and territorial management, iii) fostering sustainable productive activities, and iv) normative and economic instruments. |
| Instruments | The other sectoral plans under the PNMC umbrella, such as the Sectoral Climate Change Mitigation and Adaptation Plan for the Consolidation of a Low Carbon Emission Economy in Agriculture (ABC Plan) and the Plan to Reduce Emissions in the Steel Industry (charcoal), have broad complementarity and integration with PPCerrado, since it is on this biome that some economic activities in these sectors can be found; (i) activities related to monitoring of rural properties through the Rural Environmental Registry (CAR); (ii) activities related to the promotion of actions to encourage the sustainable development of the Cerrado and the identification of municipalities with the highest deforestation rates; (iii), PPA budgetary actions; and, (iv) financial actions. |

Source: Based on MCTIC, 2016; MMA, 2016-2020; 2016-2020b.

With regard to public policies for the conservation and sustainable use of this Biome, in addition to the PPCerrado, special mention should be made of the National Program for Conservation and Sustainable Use of the Cerrado Biome – Sustainable Cerrado Program (PCS), established through Decree No. 5,577/2005[4]. Its purpose is to promote the conservation, restoration, recovery, and sustainable management of natural ecosystems, as well as to elevate the value and recognition of its traditional populations, seeking conditions to counter the negative socio-environmental impacts from the traditional occupation process.

### 4.1.4. Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm)

***Sustainable Amazon Plan***

*Launched in May 2008, the PAS was prepared under the coordination of the Chief of Staff Office of the Presidency of the Republic and the Ministries of the Environment and National Integration. It is currently led by the Strategic Affairs Secretariat of the Presidency of the Republic.*

The Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm) was established in 2004, and works in complementation with the Sustainable Amazon Plan (PAS), which provides a set of guidelines to guide the sustainable development of the Amazon by appreciating socio-cultural diversity and reducing regional inequalities (Panel 4.5).

*4 This Decree established the National Commission for the Sustainable Cerrado Program (CONACER), with members from the federal government, states, academic community, NGOs, social movements, and the business sector. CONACER's main duties are to monitor the implementation of the Sustainable Cerrado Program, facilitate the establishment of partnerships and propose adjustments to policies related to this biome.*

*Panel 4.5. Main Elements in PPCerrado*

| PPCDAm | Information |
|---|---|
| Goals | Reduce deforestation and the degradation of native vegetation by promoting the maintenance of its ecosystem services through the sustainable use of forest resources and the promotion of sustainable agricultural practices. |
| Characteristics | Government action arrangement launched in 2004 in response to rising deforestation rates in the Amazon. The results achieved contributed significantly to the fall in deforestation rates, thus achieving, for example, an estimated reduction of 564 million $tCO_2e$ by 2020. |
| Thematic Pillars | i) environmental monitoring and control; ii) land tenure regularization and territorial management, iii) fostering sustainable productive activities, and iv) normative and economic instruments. |
| Stages | PPCDAM - Phase 1 (2004-2008). |
| | PPCDAM - Phase 2 (2009-2011). |
| | PPCDAM - Phase 3 (2012-2015). |
| | PPCDAM - Phase 4 (2016) – Operational Plan 2016-2020. |

Source: Based on IPEA/GIZ/CEPAL, 2007; BNDES/MPDG/MMA, 2018; MMA, 2016.

In 2009, Decree No. 7,008/2009 was signed, which established the Arco Verde Operation under the PPCDAm. This operation continues to work on a permanent basis and it's purpose is to promote sustainable production models in the municipalities assigned priority level for the control and reduction of deforestation in the Legal Amazon.

The active involvement of state governments became more evident after Phase 2 of the PPCDAm, with the development of plans to combat deforestation in the Amazonian states with a view to ensuring fulfillment of the goals planned at the state level in the PPCDAm. This process was guided by the federal government, which initially established three main lines of action: (i) land use planning; (ii) environmental control; and, (iii) fostering sustainable production activities.

In Phase 3[5] in the implementation plan (2012-2015), efforts were made to implement actions consistent with the new dynamics of deforestation and to give scale and emphasis on the pillar related to Promotion of Sustainable Production Activities by incorporating observations and recommendations aimed at reviewing the governance structure of the Plan; restructuring of the pillar to promote sustainable activities; and, arrangements for actions under the land use planning pillar. In addition, the Brazilian Government has developed its National REDD+ Strategy.

*5 For Phase 3 of the PPCDAm, funds of around BRL 1.4 billion were allocated from the 2012-2015 Pluriannual Plan.*

In Phase 4 of the PPCDAm (2016-2020), in addition to maintaining the three pillars from the previous phases[6], a new pillar is proposed to develop standards and economic, fiscal and tax instruments to help combat all levels of deforestation (in terms of both prevention and control): (iv) regulatory and economic instruments.

### 4.1.5. National Adaptation Plan (PNA)

Enacted on May 11, 2016 through MMA Directive No. 150, the National Adaptation Plan to Climate Change (PNA, for its acronym in Portuguese) is an instrument developed by the federal government in collaboration with the civil society, the private sector and subnational governments, and has as its general goal:

> "To promote management and reduction of climate risk in the face of adverse effects associated with climate change in order to take advantage of emerging opportunities, avoid losses and damages, and build instruments for the adaptation of natural, human, production, and infrastructure systems (MMA, 2016)."

The NAP advocates for the inclusion of climate change risk management in existing sectoral and thematic plans and public policies, as well as in national development strategies, based on the following principles: (i) intergovernmental coordination; (ii) intragovernmental coordination; (iii) a sectoral, thematic and territorial approach; (iv) social, cultural, economic, and regional coverage; (v) co-benefits between adaptation and mitigation; (vi) mainstreaming of adaptation to climate change in government planning; (vii) use of scientific, technical and traditional knowledge as the basis for adaptation actions; (viii) fostering Ecosystem-based Adaptation – EbA in public policies; and (ix) promotion of regional cooperation.

In order to develop institutional, methodological and scientific bases for the reduction and management of the risk associated with climate change, 24 goals were established, as well as thematic and sectoral strategies[7], namely: Agriculture, Water Resources, Food and Nutrition Security, Biodiversity, Cities, Disaster Risk Management, Industry and Mining, Infrastructure, Vulnerable Peoples and Populations, Health Care; and Coastal Zones.

The NAP includes four-year implementation cycles and a review of the current cycle in year four. This means that a new NAP monitoring and evaluation stage is underway. Its findings will support its review, along with additional feedback, lessons learned and, above all, the impact of climate change on the country, with serious effects on its economy and society.

The First NAP Monitoring and Evaluation Report[8] (2016-2017) informed trends in national adaptation goals and guidelines and helped to measure the challenges that persist to achieving the planned goals, thereby showing that the Plan also contributed to make the National Policy on Climate Change (PNMC) effective and to strengthening other public policies and international frameworks.

### 4.1.6. Sectoral Climate Change Mitigation and Adaptation Plan for the Consolidation of a Low Carbon Emission Economy in Agriculture (ABC Plan)

The overall objective of the Sectoral Climate Change Mitigation and Adaptation Plan for the Consolidation of a Low Carbon Emission Economy in Agriculture (ABC Plan) is to ensure the continuous and sustainable improvement of

*6 In the previous phases of the PPCDAm, initiatives of an economic or regulatory nature already were already in place, though they could fall under the three thematic pillars (planning, monitoring, promotion).*

*7 These are based on a broad discussion process within the GEx-CIM. In addition to the legal requirements for sectoral issues, criteria were established for the allocation of jurisdiciton within the Federal Government, priorities and urgencies in relation to vulnerabilities.*

*8 Prepared by the Ministry of the Environment with the participation of several Ministries and Federal agencies, in addition to the collaboration of the private sector and the support of partner institutions.*

management practices that enhance the production efficiency of agricultural systems resulting in greater economic gains, increased resilience to climate uncertainties and control of greenhouse gas (GHG) emissions.

Coordinated by the Ministry of Agriculture, Livestock and Food Supply (MAPA), the ABC Plan has national coverage, but its vertical political structure allowed for the development of state and municipal plans.

The ABC Plan is a key instrument for promoting sustainable agriculture in Brazil; and it is one of the sectoral plans prepared in accordance with Article 3 of Decree No. 7,390/2010, which regulates articles in the National Policy on Climate Change (PNMC), which has recently been amended by Decree No. 9,578/2018.

The ABC Plan was created in 2010, and its aim is to promote and adopt sustainable production technologies selected to respond to the commitments undertaken by Brazil regarding the reduction of GHG emissions in the agricultural sector. The emission reductions achieved through this Plan is monitored through the ABC Platform, one of the pillars of action of the SIN-ABC (ABC Plan's Integrated Information System). Results recently released through the Platform have shown that the Plan has been successful in achieving goals and in enhancing the control of emissions.

*See **item 5.1.1**. for more information on the SIN-ABC.*

Successful achievement of the planned goals is the culmination of a strategically designed policy, which integrates a robust scientific and technological base designed with Brazil's tropical and subtropical reality in mind, with the concern of maintaining productivity and profitability of rural lifestyles. This ensures effective involvement of the production sector, and as a result it ensures that ongoing results are provided and that the sustainability of the national agricultural sector is strengthened. Hence, stepping up efforts to collect technical and scientific information and adopting appropriate technologies at the national level are fundamental steps to achieve progress and for the continuation of the ABC Plan. These are also to be achieved through ongoing review, improvement and conduction of studies at the regional level in order to ensure this public policy is improved.

### 4.1.7. Sectoral Plan to Reduce Emissions in the Steel Industry

The purpose of the Sectoral Plan to Reduce Emissions in the Steel Industry is to drive the sector's transition to a low emissions future in Brazil. The plan has two fundamental pillars: (i) expansion of the planted forest stock, and (ii) improvement of the efficiency and environmental quality of the carbonization process. Implementation of the emission reduction goal should engage private entrepreneurs in public-private partnerships to take advantage of the sector's experience with Clean Development Mechanism (CDM) projects. The collection of approved CDM project methodologies – ranging from the planting of energy forests for the steel industry to the elimination of methane in the carbonization process – will allow for emission reductions so as to comply with the measurement, reporting and verification (MRV) criteria.

Implementation of the sector plan is decentralized and involves a diverse cast of public and private actors, while its performance is monitored within the Steel Industry Competitiveness Forum (which brings together representatives from all links in the sector's supply chain, which has been expanded with the participation of representatives from the FBMC and other relevant institutions), in order to ensure transparency and broader participation by civil society.

### 4.1.8. National Biofuels Policy (RenovaBio)

The National Biofuels Policy (RenovaBio) aims at promoting the adequate expansion of biofuels in the energy mix, thus promoting the regularity of fuel supply in the market and inducing gains in energy efficiency and reduction of GHG emissions. (Panel 4.6).

This encouragement is reflected in the granting of Decarbonization Credits (CBIO) to fuel dealers based on the Energy environmental Efficiency Ratings associated with the biofuels they trade. Calculation of the Energy-Environmental

Efficiency Rating of a biofuel is based on the difference between its carbon intensity and the carbon intensity of its substitute fossil fuel, which is established through a certification process based on RenovaCalc, a supporting tool that is used to calculate the intensity of a biofuel (in g $CO_2$eq/MJ). Adoption of a certification process is intended to make the environmental performance evaluation credible and transparent through the RenovaBio Program.

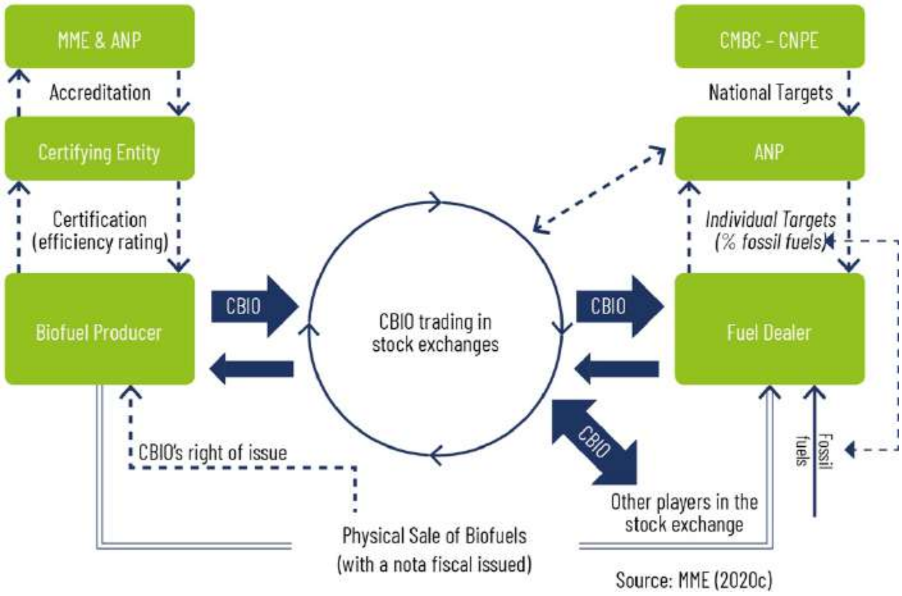
*Panel 4.6. Key Elements in the National Biofuels Policy (RenovaBio)*

| RenovaBio | Information |
|---|---|
| Legal Framework | *Decree No. 9,308, of March 15, 2018, revoked by Decree No. 9,888, of June 27, 2019. |
| Goals | I – To contribute to meeting the country's commitments included in the Paris Agreement under the UNFCCC; II – To contribute to an adequate ratio of energy efficiency and reduction of greenhouse gas emissions in the production, trade and use of biofuels, including life cycle assessment mechanisms; III – To promote the adequate expansion of production and use of biofuels in the national energy mix, with an emphasis on regular fuel supply; and IV – To contribute to predictability to the competitive participation of the various biofuels in the national fuel market.[9] |
| Instruments | The instruments in the program include, but are not limited to, i) definition of GHG emissions targets in the fuel mix; ii) establishment of Decarbonization Credits (CBIO) and Biofuels Certification; iii) mandatory addition of biofuels to fossil fuels; and iv) use of tax, financial and credit incentives. |
| Institutional Arrangements | The RenovaBio Committee includes representatives from the following institutions: I – Ministry of Mines and Energy, as the coordinating body; II – Chief of Staff of the Presidency of the Republic; III – Ministry of Economy; IV – Ministry of Infrastructure; V – Ministry of Agriculture, Livestock and Food Supply; VI – Ministry of Science, Technology and Innovations; and VII – Ministry of the Environment. |

Source: Based on BRASIL, 2020a; 2020b; 2020c; 2020d.

The following diagram provides a summary of RenovaBio's operating model (MME, 2020c; 2020d).

9 Law No. 13,576, of December 26, 2017.




Source: MME (2020c).

*Figure 4.2. Operational flow for RenovaBio*

### 4.1.9. National Policy for the Recovery of Native Vegetation (Proveg)

The National Plan for the Recovery of Native Vegetation (Planaveg) is the primary implementation instrument in the National Policy for the Recovery of Native Vegetation (Proveg). Panel 4.7 summarizes the main information about Proveg.

*Panel 4.7. Key Elements in the National Policy for the Recovery of Native Vegetation (Proveg)*

| Proveg | Information |
|---|---|
| Legal Framework | Decree No. 8,972, of January 23, 2017. |
| Goals | To develop, integrate and promote policies, programs, financial incentives, markets, best agricultural practices and other actions necessary for the recovery of native vegetation covering at least 12 million hectares by 2030, mainly in permanent preservation areas (APP) and legal reserve areas (RL), but also in degraded areas with poor yields.[10] |
| Instrument | National Plan for the Recovery of Native Vegetation (Planaveg); Interministerial Directive No. 230, of November 14, 2017. |
| Governance and institutional arrangements[11] | Establishes the National Commission for Native Recovery (Conaveg), which includes the following institutions: (i) Ministry of Mines and Energy, as the chair; (ii) Chief of Staff of the Presidency of the Republic through the Special Secretariat for Family Agriculture and Agrarian Development; (iii) Ministry of Economy; (iv) Ministry of Agriculture, Livestock and Food Supply; (v) Ministry of Science, |

*10 Law No. 12,651, of May 25, 2012.*

*Conaveg members were appointed through MMA Directives No. 138, of March 28, 2017, and No. 246, of July 14, 2017.*

| Proveg | Information |
|---|---|
| | Technology and Innovations. Conaveg has: (i) two sitting representatives and two alternates from the States, appointed by the Brazilian Association of State Environmental Entities (Abema); (ii) a sitting representative and an alternate from the Municipalities, appointed by the National Association of Municipal Environmental Bodies (Anamma); and (iii) two representatives (sitting and alternates) from civil society organizations, to be selected through a formal procedure based on a Directive from the Ministry of the Environment. |

Source: Based on BRASIL, 2012; MMA/MAPA/MEC, 2012; 2017.

Preparation of Planaveg was coordinated by the MMA with the help of a network of experts, and received inputs from the public, research institutions and government agencies in a public consultation process.

In order to fulfill its objective, the plan is based on eight strategies as summarized below:

- Education of farmers, agribusiness, urban citizens, opinion leaders and decision makers;
- Promotion of the supply chain for the recovery of native vegetation with policies to improve the quantity, quality and accessibility of seeds and seedlings of native species;
- Promotion of trade in timber and non-timber products, protection of springs and areas for aquifer replenishment, among other services and products generated from the recovery of native vegetation;
- Allocation of roles and responsibilities between government agencies, businesses and civil society, and integration of public policies for the recovery of native vegetation;
- Development of financial mechanisms to encourage the recovery of native vegetation;
- Expansion of the rural extension service (at the public and private sectors) to train landowners, with an emphasis on low-cost recovery methods;
- Implementation of a national land use planning and monitoring system to support the decision-making process for the recovery of native vegetation;
- Investments in research, development and innovation with a view to reducing costs, improving quality and enhancing the efficiency of the recovery of native vegetation.

Panel 4.8 shows three existing programs and policies that complement the eight strategic initiatives and create adequate conditions to encourage, facilitate and implement the recovery of native vegetation.

*Panel 4.8. Complementary Policies and Programs to Planaveg*

| Policies and Programs | Information |
|---|---|
| Sustainable intensification of agriculture | Increased productivity of pastures and crop areas outside areas to be recovered through programs for the sustainable intensification of agriculture. |
| Native vegetation protection law | Implementation of orders and instruments under Law No. 12,651/2012, including the Rural Environmental Registry (CAR), and the Environmental Regularization Programs (PRAs). |
| Land regularization | Increased number of rural landowners holding title to the land and the right to use recovered forest resources. |

Source: Based on MMA/MAPA/MEC, 2012; 2017.

## 4.1.10. Climate Change Policy Programme (PoMuC)

The Climate Change Policy Programme (PoMuC) is the culmination of a bilateral collaboration between the governments of Brazil and Germany in the context of the International Initiative on Climate Change (IKI) of the Ministry of Environment, Nature Conservation, Construction and Nuclear Safety of Germany (BMUB). Implementation of the PoMuc is a joint effort between GIZ (German technical cooperation implementing agency), the MMA and ME in partnership with other ministries and institutions. Panel 4.9 summarizes the main information about the Program.

*Panel 4.9. Key Information on Climate Change Policy Programme (PoMuC)*

| Climate Change Policy Programme (PoMuC) | Information |
|---|---|
| Goal | To support selected sections of the National Policy on Climate Change to ensure that they are successfully implemented with the participation of states and municipalities in the implementation of the program and the country's environmental assets, notably renewable energies, forests and biofuels. |
| Thematic Pillars | (i) Transparency System[12]; (ii) REDD+[13]; (iii) Adaptation[14]; (iv) Climate Fund[15]; (v) Climate Change Financing[16]; (vi) Emissions Reporting[17]; and (vii) Knowledge Management[18]. |
| Expected Impacts | (i) effective, transparent and participatory implementation of the National Strategy for REDD+; (ii) reduced vulnerability of people and ecosystems by supporting the implementation of actions under the National Adaptation Plan; (iii) strengthened Brazilian institutional arrangements; and (iv) improved coordination, cooperation and exchange of experiences among the climate change community, as well as the multiplier effect at national and international levels by disseminating and sharing experiences, lessons learned and work done. |

Source: Based on MMA, 2017b; GIZ, 2018.

Implementation of the PoMuC should strengthen Brazil's position in actions to tackle climate change through the dissemination of mitigation and adaptation actions, based on a transparency and support tool.

*12 A policy monitoring platform will be deployed in several ministries and institutions. The purpose of this platform is to disseminate the impacts and achievements of measures and strategies for the implementation of Brazil's NDC.*

*13 International funding instrument for Reducing Emissions from Deforestation and Forest Degradation (REDD+): the basic conditions for implementing the National REDD+ Strategy will be optimized, for example, through greater involvement and better qualification of representatives of indigenous peoples and traditional peoples and communities (PIPCT).*

*14 National Adaptation Plan: vulnerability maps will be created under the National Adaptation Plan for all 5,570 Brazilian municipalities. These maps will indicate how weak the municipalities are in the following risk categories: droughts, landslides and floods.*

*15 Strengthening institutional capacities of the National Fund on Climate Change.*

*16 Public sector and private sector actors will be involved in strengthening actions, policies and instruments related to climate change funding.*

*17 The regulatory impacts of several concepts for a National GHG Emissions Reporting Program at the level of economic agents for Brazil will be assessed by the consultancy consortium GFA, Way Carbon and by the Austrian Federal Environment Agency in collaboration with the ME.*

*18 Cooperation and the exchange of knowledge between the key actors involved in the implementation of the national climate change policy will be strengthened on an ongoing basis.*

## 4.1.11. Project: "Technological Needs Assessment for the Implementation of Climate Action Plans in Brazil (TNA_BRAZIL)"

The purpose of the "Technological Needs Assessment for the Implementation of Climate Action Plans in Brazil (TNA_BRAZIL)" project is to strengthen the technical capacity of the Brazilian government by developing a comprehensive assessment of technological needs for the implementation of climate action plans in Brazil with a view to providing inputs for decision making processes regarding the fulfillment of GHG mitigation goals, taking into account Brazil's Nationally Determined Contribution and strategy for the Green Climate Fund.

The project preparation process includes three phases: i) identification and prioritization of technologies for the selected sectors; ii) identification and analysis of value chains, co-benefits and main barriers to the development and dissemination of priority technologies, with measures to address them; and iii) proposition, based on previous findings, of the Technology Action Plan (PAT) to encourage the development and dissemination of the priority technologies for each sector covered.

***PAT***

This consists of an action plan that could be of a technological nature, that could involve training, promotion, among others, and which translates into concrete actions to be implemented with a view to developing and/or disseminating technologies in the priority sectors.

The findings are endorsed by different actors belonging to the sectoral Chambers (CS) and Technical Advisory Committee (CTC) of the TNA_BRAZIL project, respectively comprised of specialists from the private sector and the academic community, and government members (Figure 4.3).

The engagement of key stakeholders, including decision makers throughout the TNA process, is critical to ensuring that prioritized technologies are included in government programs, strategies and plans. In addition, this arrangement helps to substantiate access to funding from national and international mechanisms.

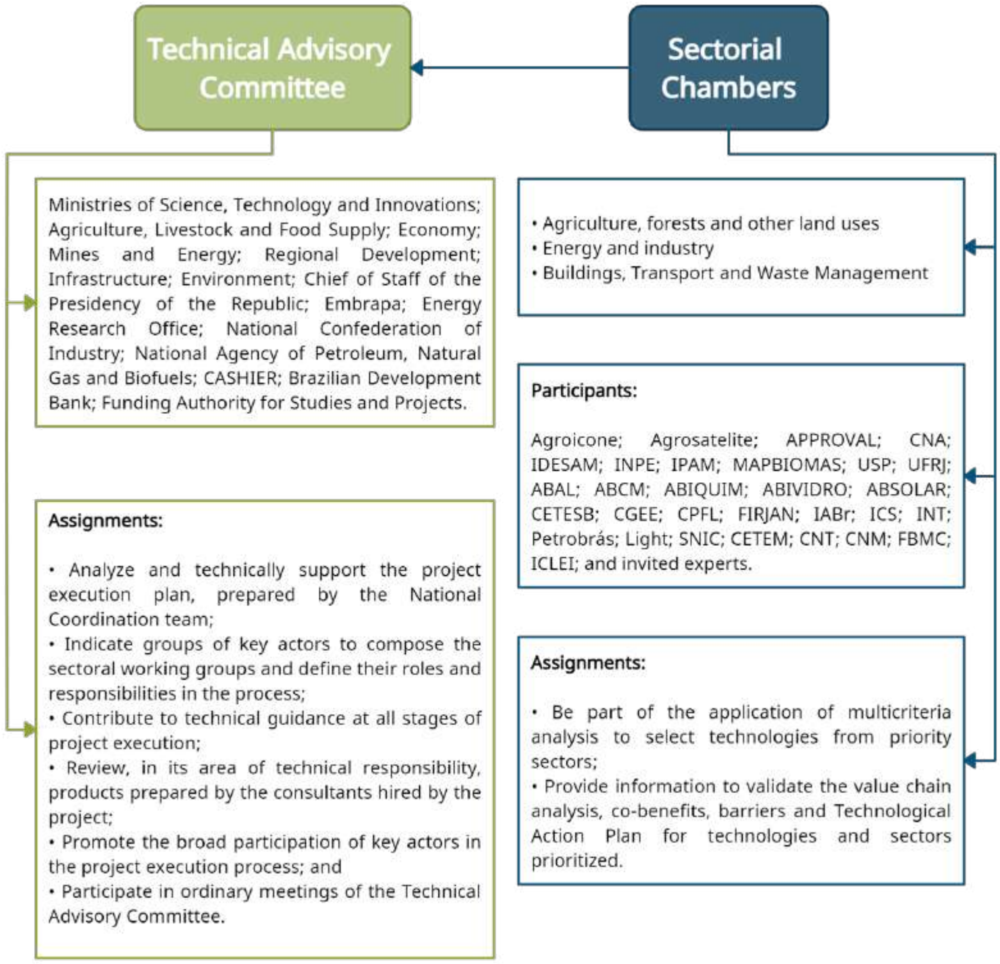



*Figure 4.3. TNA institutional arrangement for results validation.*

Brazil's action plans from such sectors as agriculture, forestry, other land uses and the energy system include: precision agriculture; genetic breeding for beef cattle; forestry and genetic improvement of native species; forestry with mixed plantations for restoration; satellite monitoring; hybrid flex vehicles; ethanol fuel cell electric vehicles; industry 4.0; innovative materials for cement; floating photovoltaic solar energy; utilization of agricultural and agro-industrial waste; electric induction-based photovoltaic solar cookers.

### 4.1.12. CITinova Project

With national coverage and specific activities in Recife (PE) and Brasília (DF), CITinova is a multilateral project carried out by the Ministry of Science, Technology and Innovations (MCTI), with support from the Global Environment Facility (GEF), implementation of the United Nations Environment Programme (UNEP) and carried out in collaboration with the Recife Agency for Innovation and Strategy (ARIES) and Porto Digital, the Center for Management and Strategic Studies (CGEE), the Sustainable Cities Program (PCS), and the Federal District Environment Secretariat (SEMA/GDF). The following panel summarizes relevant information about the Project.

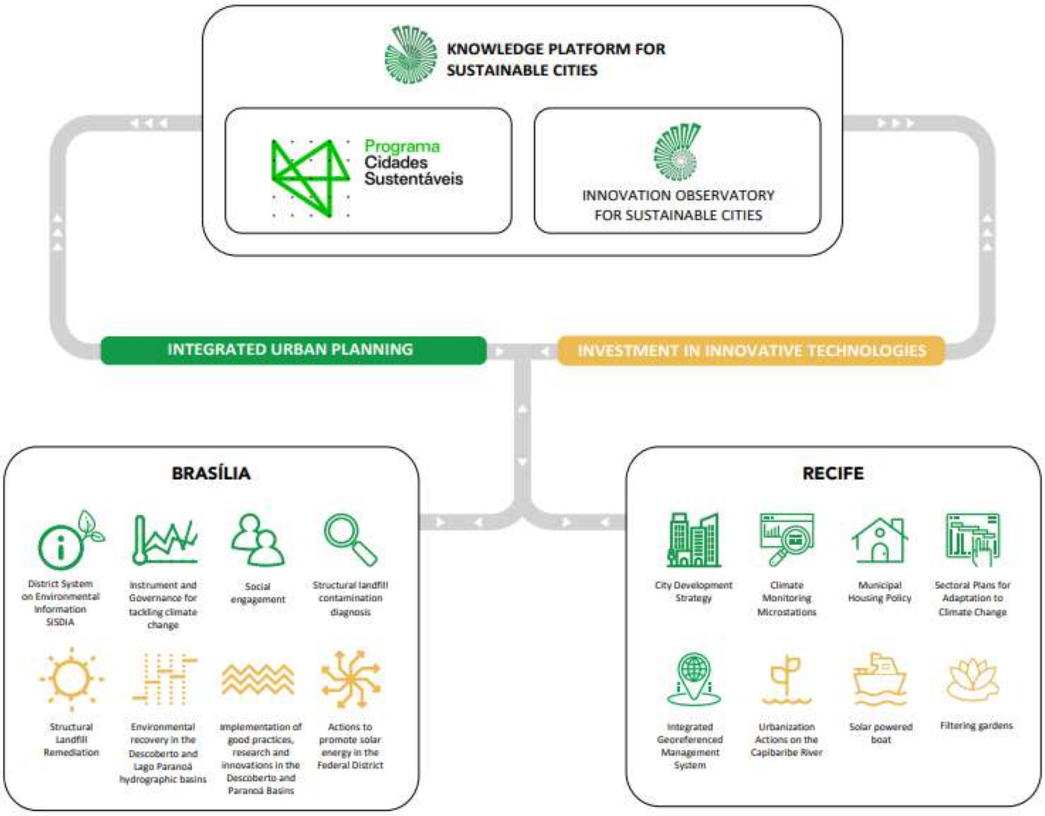
*Panel 4.10. Key Information about the CITinova Project*

| CITinova Project | Information | |
|---|---|---|
| Goals | The main goals are to develop innovative technological solutions and provide integrated urban planning approaches and tools to support public managers, encourage citizen participation and foster more equitable and sustainable cities. | |
| Challenges | I – Accelerating the transition of cities to sustainable urbanization; II – Using technology and innovation to improve the quality of life and well-being of citizens; and III – Preventing the direct emission of 3.8 million tons of $CO_2$. | |
| Vision | The CITinova Project offers the most advanced content, technological solutions and collaborative tools in order to promote integrated, inclusive, participatory, and sustainable public management. | |
| Structuring Pillars | Integrated Urban Planning | The goal is to produce knowledge and tools for integrated public policy management and citizen participation in order to promote sustainable cities in Brazil. The new systems will be accessible to public managers and citizens in general, and they will support, facilitate and strengthen local governance. |
| | Investments in Innovative Technologies | It consists of pilot projects in Brasilia and Recife with a view to tackling historical challenges faced by local residents and public managers in policy areas such as water, waste, energy, climate change, and mobility. The findings will be used as a template to be replicated on a large scale by public managers across the country. |
| | Knowledge Platform | A Web-based system that integrates the new platform of the Sustainable Cities Program (PCS) with more features and tools, and the Innovation Observatory of Innovation for Sustainable Cities (OICS), which was developed by the Center for Management and Strategic Studies (CGEE). It provides public managers and citizens in general with content, methodologies, indicators, best practices, solutions, innovative technologies, and much more. The lessons learned from the pilot projects will also be available from the platform. The following functionalities are expected to be provided through the PCS: i) metrics and indicators to monitor goals; ii) collecting and sharing best practices and case studies; iii) support to sustainable urban planning; iv) social control mechanism and encouragement to citizen participation; v) municipal financing mechanisms; vi) training programs; vii) partnerships with universities and research institutes; viii) encouragement to partnership opportunities with the private sector; ix) laws, plans and public policies; and x) an agenda of national and international events. And, in the case of the OICS, mapping and dissemination of |

| CITinova Project | Information | |
|---|---|---|
| | | country-specific content and innovative urban solutions on the following topics: i) low-carbon mobility and access inter- and intra-city; ii) renewable, decentralized and efficient energy; iii) low-carbon and socially built environment; iv) accessible and rationally used clean water and decentralized and efficient sanitation; v) solid waste, circular economy and efficient treatment; vi) Nature-Based Solutions, green and blue infrastructure for greater resilience to climate change; vii) participatory vision and integrated long-term planning; viii) innovation, vocational policies and strategies for regional development and the strengthening of value chains. |
| Institutional Arrangements and Governance | Coordination by the MCTI, with support from GEF and implementation by UNEP. It is jointly implemented by ARIES and Porto Digital, CGEE, PCS and SEMA/GDF. | |

Source: Based on MCTIC, 2020.

The project will run for four years, from 2018 to 2022, and consists of three major pillars, as shown in the figure below.




Source: MCTI, 2020.

*Figure 4.4. Action fronts of the CITinova Project*

### 4.1.13. Project for Strengthening National Strategy of Integrated Natural Disaster Risk Management (GIDES)

The GIDES Project was implemented by MCidades and MCTI through international technical cooperation from 2013 to 2017, with JICA as the funding institution. In addition, technical partners included the Japan Meteorological Agency, the Mineral Resources Research Company/Geological Survey of Brazil (CPRM/SGB), the National Centre for Monitoring and Early Warning of Natural Disasters (Cemaden); the Ministry of National Integration (MI) (represented by the National Center for Risk and Disaster Management (Cenad)). The municipal governments of Blumenau (SC), Nova Friburgo (RJ) and Petrópolis (RJ) also participated in this project. The project also relied on the collaboration of the governments of the states of Santa Catarina and Rio de Janeiro.

The cooperation consisted of regular technical activities to provide a more in-depth understanding of integrated risk management. This project is an important step forward in strengthening horizontal coordination (between federal agencies in charge of implementing the cooperation) and vertical coordination with municipal and state governments in the development of integrated approaches to risk management policies (Panel 4.11).

*Panel 4.11. Key elements in the Project for Strengthening National Strategy of Integrated Natural Disaster Risk Management (GIDES)*

| GIDES | Information |
|---|---|
| Goal | To work towards reducing the risks of geological disasters by means of non-structural preventive measures with a view to improving risk assessment and mapping, forecasting and warning systems, as well as urban planning in the disaster prevention work. Such improvements were implemented upon the preparation and validation of technical manuals that were deployed in the selected pilot municipalities, namely: Nova Friburgo and Petrópolis in the State of Rio de Janeiro and Blumenau in the State of Santa Catarina. |
| Coverage | National. |
| Main Results | Manual of Hazard Mapping and Risk to Mass Gravitational Movements, which was comprised of six technical manuals and was intended to assist state and municipal governments in the preparation strategies to respond to disasters and emergency situations experienced by the population; Staff trained in Japan: 38 in 2014, 46 in 2015, 16 in 2016; CPRM staff trained in Japan: 9; Brazilian counterparts: 45 experts in risk mapping, urban planning and monitoring and warnings; experts from Japan to Brazil: 23 experts; Interministerial and sub-national meetings totaled 72; Technical meetings: 4 meetings on urban expansion planning, 4 meetings on risk assessment and mapping (with more than 70 experts attending each event and each event running for 3 days) and 6 meetings on forecasting and warning (along the same lines); Seminars: 2 (Rio Bousai: 500 risk experts and civil defense personnel. Brasilia Bousai: 150 experts); Workshops: 3. |

Source: Based on MME, 2018.

## 4.1.14. Brazil PMR Project

The Brazil PMR Project (Partnership for Market Readiness) is an initiative sponsored by the World Bank in 41 national and subnational jurisdictions, in addition to the European Commission[19]. In Brazil, the coordinating body is an Executive Committee comprised of the Ministry of Economy and the World Bank, which is responsible for its implementation. In order to monitor the activities and performance of the Project, an Advisory Committee comprised of representatives from private sector organizations, civil society and Federal Government bodies was set up. Panel 4.12 summarizes relevant information about the Project.

The purpose of the project is to consider the adoption of a carbon pricing instrument as part of the national climate policy in the post-2020 period, and how to leverage the relationship between environmental and socio-economic development objectives.

*Panel 4.12. Key Information about the Brazil PMR Project*

| PMR Brasil Project | Information |
|---|---|
| Legal Framework | Directive No. 853, of October 19, 2015. |
| Specific Objectives and Scope | Review various instrument options: (i) price regulation, via an emissions tax; (ii) regulation of quantities, through the adoption of an emissions trading system (ETS, commonly known as carbon market); or (iii) some combination of the two instruments. The project was approved in September 2014, and intends to answer such key questions by focusing its analysis on the following sectors: energy (electricity generation and fuels); the seven subsectors in the Sectoral Plan for Mitigation and Adaptation in the Manufacturing Industry (namely, steel, cement, aluminum, chemistry, lime, glass, and paper and cellulose); and in agriculture. |
| Components | 1. Sectoral Studies to inform the policy and modeling of Carbon Pricing impacts. |
| | 2a. Modeling for Estimating the Socioeconomic Impacts of Adopting Carbon Pricing Instruments. |
| | 2b. Regulatory Impact Analysis. |
| | 3. Communication, Consultation and Engagement. |

Source: Based on FGV/EAESP, 2018; ME, 2017c.

19 From the countries that have hosted the initiative, 19 have now completed road maps for their markets.

## 4.2. INITIATIVES AND INVESTMENTS TO PROMOTE MITIGATION ACTIONS

Climate finance is a broad topic as it involves a large number of institutions. These entities include funding sources, banks, programs either with or without a limited duration, initiatives by donor or recipient governments, non-governmental organizations, and other actors. As such, the National Fund on Climate Change (FNMC) and the Amazon Fund deserve special notice at the national level.

### *National Fund on Climate Change (FNMC)*

The FNMC is an accounting instrument under the National Policy on Climate Change created by Law No. 12,114/2009 and initially regulated by Decree No. 7,343/2010, recently overridden by Decree No. 10,143/2016 intended to secure resources to support projects or studies and to fund projects aimed at mitigating and adapting to climate change and its effects.

According to the legislation above, FNMC funds may be allocated to the following activities: I - education, qualification, training and engagement on climate change; II - climate science, impact analysis and vulnerability; III - adaptation of society and ecosystems to the impacts of climate change; IV - greenhouse gas (GHG) emissions reduction projects; V - projects to reduce carbon emissions due to deforestation and forest degradation, with priority for endangered natural areas that are relevant to biodiversity conservation strategies; VI - development and dissemination of technology to mitigate GHG emissions; VII - design of public policies to solve problems related to the emission and mitigation of GHG emissions; VIII - research and development of systems and methodologies for design and inventories that contribute to the reduction of net emissions of greenhouse gases and to the reduction of emissions from deforestation and land use changes; IX - development of products and services that contribute to environmental conservation and stabilization of the concentration of greenhouse gases; X - support to sustainable supply chains; XI - payments for environmental services to communities and individuals whose activities are proven to contribute to carbon storage, linked to other environmental services; XII - agroforestry systems that contribute to reducing deforestation and carbon absorption by sinks and to generating income; and XIII - recovery of degraded areas and forest restoration, with priority to legal reserve areas, permanent preservation areas and priority areas for the generation and assurance of the quality of environmental services; XIV) environmentally appropriate final disposal of solid waste, including reuse, recycling, composting, co-processing, energy recovery and utilization, the final disposal of waste in landfills and the closure of dumps and controlled landfills; XV) efficient collection of biogas and its combustion or utilization as energy in landfills and effluent treatment plants; XVI) basic sanitation, including drinking water supply, sewage, urban cleaning, solid waste management, rainwater drainage, and management and cleaning and preventive inspection of the relevant urban networks; XVII) urban mobility and efficient low carbon transport; XVIII) pollution control and monitoring of air quality; and XIX) creation, rehabilitation and expansion of urban green areas. Table 4.1 summarizes the projects supported by the National Fund on Climate Change by domain, in a total of approximately BRL 103.8 million.

*Table 4.1. Numbers of projects commissioned by the National Fund on Climate Change by Domain*

| Project Theme | Number of Projects |
|---|---|
| Domain 1 – Technological development and dissemination | 7 |
| Domain 2 – Adaptive practices for sustainable development in the semi-arid region | 85 |
| Domain 3 – Education, qualification, training, and engagement | 2 |
| Domain 4 – Adaptation of society and ecosystems | 91 |
| Domain 5 – Monitoring and evaluation | 7 |

Source: Based on MMA, 2020.

*Amazon Fund*

The Amazon Fund is managed by the National Bank for Economic and Social Development (BNDES), which is also responsible for raising funds, commissioning and monitoring the projects and actions supported. The purpose of this fund is to collect donations to non-reimbursable investments in actions to prevent, monitor and combat deforestation, and to promote conservation and sustainable use of the Legal Amazon. Panel 4.13 summarizes the main information about the Amazon Fund.

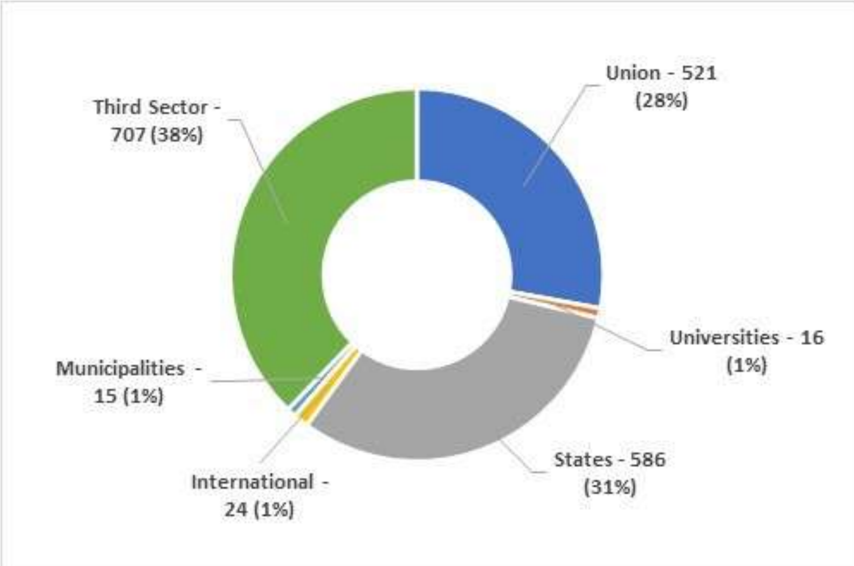
*Panel 4.13. Main Elements in the Amazon Fund*

| Amazon Fund | Information |
|---|---|
| Funding Themes | (i) Mitigation; (ii) REDD+. |
| Pillars of action | (i) Sustainable production; (ii) Monitoring and control; (iii) Land use planning; (iv) Science, Innovation and economic instruments. |
| Financeable Amounts (in Original Currency) | (i) 90% coverage for projects involving micro and small enterprises, cooperatives or associations of producers with annual gross operating revenue less than or equal to BRL 3.6 million; (ii) For-profit projects: (a) up to 70% for projects involving medium-sized enterprises, cooperatives or associations of producers with annual gross operating revenue greater than BRL 3.6 million and less than or equal to BR 300 million; and (b) up to 50% for projects involving large enterprises, cooperatives or associations of producers with annual gross operating revenue greater than BRL 300 million; (iii) For-profit projects to support vulnerable social groups, 100% coverage; (iv) For-profit scientific and technological research projects developed in cooperation between technological institutions (TIs) and for-profit organizations: (a) 90% for projects involving micro and small-sized enterprises, cooperatives or associations of producers with annual gross operating revenue less than or equal to BRL 3.6 million; and (b) 80% for projects involving medium-sized enterprises, cooperatives or associations of producers with annual gross operating revenue greater than BRL 3.6 million and less than or equal to BRL 300 million; (c) 80% for projects involving large enterprises, cooperatives or associations of producers with annual gross operating revenue greater than BRL 300 million. |

Source: Based on MMA, 2015b; 2019; BNDES/ME/MMA/GOVERNO FEDERAL, 2019b.

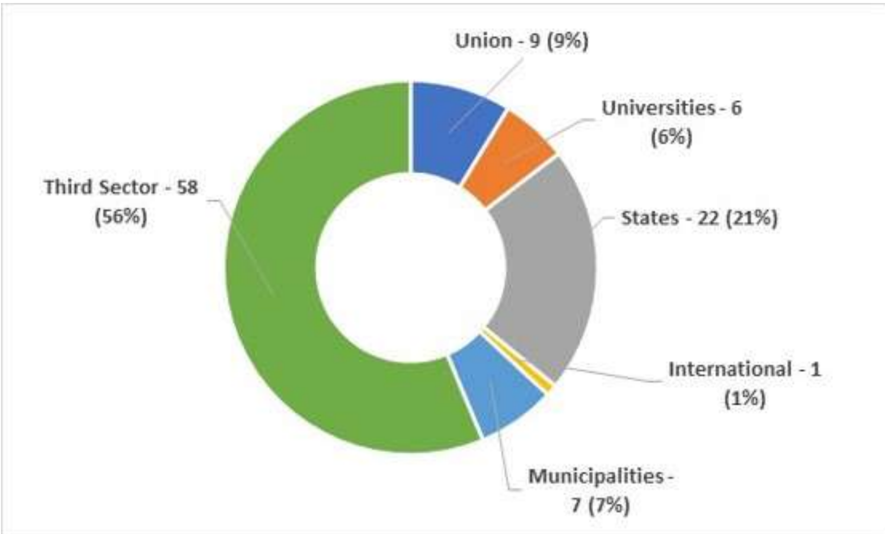
Since 2008[20], the Amazon Fund has financed projects in several themes, accounting for a total amount of BRL 1.86 billion (Figure 4.5), and a total amount disbursed of BRL 1,066 million for projects with Municipalities, States, the Federal Government, the Third sector, Universities and for International projects (Figure 4.6).

20 Decree No. 6,527, of August 1, 2008.




Source: Based on BNDES/ME/MMA/GOVERNO FEDERAL, 2019ª.

*Figure 4.5. Share in the total amount of support funding received by the Amazon Fund, in BRL million*




Source: Based on BNDES/ME/MMA/GOVERNO FEDERAL, 2019ª.

*Figure 4.6 Number of projects implemented with funding from the Amazon Fund*

In 2019, the Amazon Fund's portfolio reached 103 supported projects. Each supported project contributes to at least one of the pillars in the PPCDAm (there are projects that contribute to the four pillars, and other projects contribute to three or two pillars), as summarized in Table 4.2.

*Table 4.2. Distribution of Amazon Fund resources by domain.*

| Thematic Pillar | % of amount allocated |
|---|---|
| Sustainable Production | 26 |
| Monitoring and Control | 48 |
| Land Use Planning | 14 |
| Science, Innovation and Economic Instruments | 13 |

Source: Based on BNDES/ME/MMA/GOVERNO FEDERAL, 2019a[21].

*21 Monitoring and evaluation of Amazon Fund performance. Available in: http://www.fundoamazonia.gov.br/pt/home/*

# CHAPTER 5

## SUMMARY

# 5. OTHER RELEVANT INFORMATION TO ACHIEVE THE OBJECTIVES OF THE CONVENTION IN BRAZIL

## 5.1. AWARENESS INITIATIVES ON CLIMATE CHANGE ISSUES

Public awareness plays an extremely important role for society and the government to join efforts to mitigate GHG effects and to adapt to climate change. Therefore, relevant national and subnational organizations were encouraged to develop and implement initiatives to ensure availability of content on climate change and its effects in order to facilitate access to information and public participation in discussions on the issue.

### 5.1.1. Integrated Information System of the Sectoral Plan for the Consolidation of a Low Carbon Emission Economy in Agriculture (SIN-ABC)

The Integrated Information System of the Sectoral Plan for the Consolidation of a Low Carbon Emission Economy in Agriculture (SIN-ABC, for its acronym in Portuguese), created and coordinated by the Ministry of Agriculture, Livestock and Supply (Mapa, for its acronym in Portuguese), is responsible for consolidating and systematizing the outcomes of the ABC Plan implementation. Its framework merges the Governance System of the ABC Plan (SIGABC, for its acronym in Portuguese), the Rural Credit and Proagro Operations System (SICOR, for its acronym in Portuguese) and the Multi-Institutional Platform for Monitoring Greenhouse Gas Emission Reduction in Agriculture (ABC Platform).

The SIGABC provides data on the direct implementation of the ABC Plan by Mapa, obtained from the monitoring of established actions and goals, which are also carried out in a decentralized manner by the ABC Plan across the states. The Sicor provides data on the implementation of the ABC Credit Plan, a credit line designed to support the adoption of technologies in the ABC Plan, through borrowing activities (credit contracts) by rural producers.

The ABC Platform provides data on the technologies adopted by the ABC Plan and their respective contribution towards Greenhouse Gas (GHG) mitigation for the monitoring of the ABC Plan's pre-established goals. Also, the ABC Platform is responsible for the conceptual validation of the MRV (Monitoring, Reporting and Verification) mechanism, based on expertise and the use of different tools and information technology developed, or under validation stage, by Embrapa and partner institutions.

The ABC Platform was established in 2015 during a meeting with Embrapa directorates, with its Technical Steering Committee originally instituted in 2017. It aims at monitoring GHG emissions reduction and soil carbon stocks from the implementation of technologies endorsed by the ABC Plan. The ABC Platform also coordinates the efforts of the institutions involved towards the development of valid GHG standards and metrics for the Brazilian agricultural sector. The ABC Platform, under Embrapa, counts on the expertise and work of several institutions and experts towards successfully meeting its objectives. Embrapa is responsible for the Platform's executive management.

The Brazilian Government, through Mapa's sectoral competencies, is responsible for developing and validating a wide and integrated system for the identification, qualification and monitoring of the technologies adopted by the ABC Plan. The assessment standards and methodologies follow international GHG emissions monitoring protocols and the guidelines issued by the Intergovernmental Panel on Climate Change (IPCC).

The main beneficiaries are Brazilian rural producers, along with the whole agricultural sector, which get a public policy that is more responsive to their needs. The scientific strength that characterizes the Plan ABC, particularly the SIN-ABC monitoring capacity, reinforces the importance of an increasingly more strategic public policy towards the country's development and the building of a positive image for the Brazilian agribusiness both at the domestic and international levels.

*Panel 5.1. Key elements in the Multi-Institutional Platform for Monitoring Greenhouse Gas Emissions Reduction GEE (ABC Platform)*

| ABC Platform | Information |
|---|---|
| Legal Framework | Law No. 12,187/2009; Interministerial Directive No. 984, of 8 October 2013; Directive No. 2,277/2017 (under updating); Decree No. 9,172/2017; Decree No. 7,390/2010 – overridden by Decree No. 9,578/2018. |
| Goals | (i) to consolidate and systematize the outcomes of the ABC Plan implementation, in their actions to promote adaption to climate change and GEE mitigation in the agricultural sector, (ii) to monitor reduction of GHG emissions in Brazilian agriculture; (iii) to collect, analyze, organize, and store information regarding GHG emissions from the agricultural segments; (iv) to inform, develop and improve public programs and policies for mitigating and adapting to climate change for the agricultural sector. |
| Mission | To consolidate and systematize the outcomes of the ABC Plan implementation, particularly those obtained from the Governance System of the ABC Plan (SIGABC), the Rural Credit and Proagro Operations System (Sicor), and the Multi-Institutional Platform for Monitoring Greenhouse Gas Emission Reduction in Agriculture (ABC Platform). |
| Regulation | Decree No. 7,390/2010 – overridden by Decree No. 9,578, of 2018; Law No. 12,187/2010; Embrapa Deliberation No. 9/1996; Interministerial Directive No. 984, of 8 October 2013; Directive No. 2,277/2017 (under updating). |
| This covers | (i) Monitoring the impacts of the ABC Plan as a public policy; (ii) monitoring the Brazilian agricultural sector's resilience and capacity to adapt to climate change;and (iii) monitoring the reduction of GHG emissions in Brazilian agriculture. |

Source: Based on Embrapa, 2015 and MAPA, 2018.

## 5.1.2. National Emissions Registry System (SIRENE)

In October 2017, Brazil established the National Emissions Registry System (SIRENE) through Decree No. 9,172/2017. Panel 5.2 describes key elements in this Decree.

*Panel 5.2. Key elements in the National Emissions Registry System (SIRENE)*

| SIRENE | Information |
|---|---|
| Legal Framework | Law No. 12,187/2009; Decree No. 9,172/ 2017. |

| SIRENE | Information |
|---|---|
| Goals | To make available the results of the Brazilian Inventory of Anthropogenic Emissions by Sources and Removal by Sinks of GHG not Controlled by the Montreal Protocol, and other initiatives to account for emissions, such as the Annual Estimates of GHG Emissions in Brazil. |
| Mission | To provide continuity, accessibility, security, and transparency to the preparation of the Brazilian Inventory of Anthropogenic Emissions, in order to estimate (for the purposes of quantification and accounting) greenhouse gas emissions, in accordance with the guidelines for the preparation of national inventories set forth in a UNFCCC decision. And to serve as an input to decision making in government actions related to climate change with regard to the generation of scientific knowledge and the adoption of mitigation measures. |
| Applicability | This is considered by the Brazilian Government as the national MRV (Measurement, Reporting and Verification) system for emissions at the aggregate level regarding the sectors covered by the National Inventory. |
| Coverage | (i) direct and indirect GHGs[1]; (ii) emission sources and removals by sinks[2]; and (iii) the historical series of emissions of the results published in the National Inventory as part of its National Communications, the Biennial Update Reports, as well as the Annual Emissions Estimates reports[3]. |
| Base-documents | National Communication of Brazil and other reports prepared for submission to the UNFCCC; Annual Estimates of Greenhouse Gas Emissions in Brazil, referred to in Article 11 of Decree No. 7,390, of 2010, overridden by Article 24 of Decree 9,578, of 2018; Organizational inventories, pursuant to Article 4th of Decree 9,172, of 2017. |

Source: Based on MCTIC (2017; 2017a; 2017b; 2017c).

The MCTI's General Coordination on Climate Science and Sustainability (CGCL) is responsible for coordinating, managing and maintaining SIRENE. Various public and private entities contribute by providing activity data, or by developing updated national parameters and emission factors that are relevant to the methodology to be used in the development of GHG emissions and removals estimates for the country.

This system ensures national official results are released. Graphs and tables are provided, which can be exported in an editable format based on user-selected filters. In addition, all official publications and transparency reports are made available to the general public on this platform. Finally, SIRENE also provides the emission scenarios for 2012-2035 and 2035-2050, which are generated from the project "Mitigation Options of Greenhouse Gas Emissions in Key Sectors in Brazil."

*See **item 5.2.3**. for more information on the "Mitigation Options" project.*

[1] *Carbon dioxide – $CO_2$; methane – $CH_4$; nitrous oxide – $N_2O$; hydrofluorocarbons – HFCs; perfluorocarbons – PFCs; sulfur hexafluoride – $SF_6$; nitrogen oxides – $NO_x$; carbon monoxide – CO and other non-methane volatile organic compounds – NMVOC.*

[2] *These refer to the Energy; Industrial Processes and Other Products; Agriculture, Land Use, Land Use Change and Forestry; and Waste sectors.*

[3] *This corresponds to what is established domestically through the National Policy on Climate Change.*

### 5.1.3. Climate Vulnerability System (SisVuClima)

The Climate Vulnerability System (SisVuClima) was one of the studies developed under the project "Construction of Population Vulnerability Indicators as an Input for the Development of Climate Change Adaptation Actions in Brazil (Vulnerability Project)". This was a joint initiative implemented in 2014-2018, and its purpose was to develop a system of indicators at the municipal level to assess the population's vulnerability to climate change in six states of Brazil: Amazonas, Espírito Santo, Mato Grosso do Sul, Maranhão, Paraná, and Pernambuco. The following Panel summarizes the main elements in this project.

*Panel 5.3. Key elements in the project Construction of Population Vulnerability Indicators as an Input for the Development of Climate Change Adaptation Actions in Brazil*

| Vulnerability Project | Information |
|---|---|
| Goals | The purpose of this initiative was to facilitate the identification of populations and territories vulnerable to climate change; to develop a conceptual model and an analysis tool (a system of socio-environmental indicators and a calculation platform) to assess the vulnerability of municipal populations. |
| Products | In addition to the development of a conceptual model for this vulnerability assessment, a tool (Municipal Vulnerability Index) and a software program (SisVuClima) will be built, which will be applied on a pilot basis to municipalities in six states in Brazil: Paraná, Espírito Santo, Mato Grosso do Sul, Pernambuco, Maranhão, and Amazonas. |
| Source of funding | National Fund on Climate Change. |
| Governance and institutional arrangements | This initiative is the culmination of a partnership between the Ministry of the Environment's Secretariat for Climate Change and Forests and the Oswaldo Cruz Foundation's Vice-Presidency for Environment, Health Care and Promotion (Fiocruz/Ministry of Health). |

Source: Based on MMA, 2020; MS, 2020.

Through SisVuClima, state managers and officials can assess and compare the municipalities' vulnerabilities and risk factors and subsequently plan actions to reduce the impacts of climate change and enhance the population's capacity to adapt. SisVuClima was designed to automate the calculation and generation of thematic maps used in the construction of the Municipal Index of Human Vulnerability to Climate Change in the cities and towns covered by the study, as well as to help update and enter new data and to calculate new indexes and monitor their trends (MMA, 2020; MS, 2020).

The system consists of three modules: i) entry of information necessary for the calculation of indicators; ii) generation of indexes and sub-indexes; and iii) visualization of outputs on thematic maps, tables and graphs. Data on the population, environmental preservation, extreme events (storms), and climate-related diseases in the individual states are considered in the studies. Once this information is entered in the software, one can calculate the Municipal Vulnerability Index to the Impacts of Climate Change, among other indicators, such as environmental exposure, sensitivity, external factors, diseases, and demographic conditions, as well as the adaptive capacity of municipalities (SISVUCLIMA, 2020).

### 5.1.4. Modular System for Monitoring Actions of Greenhouse Gas Emissions Reductions (SMMARE)

In 2013, the Center for Management and Strategic Studies (CGEE) developed as part of an Administrative Contract executed with the Ministry of the Environment (MMA) the project "Assessment of the National Plan on Climate Change and design of the Greenhouse Gases Monitoring System in the actions included in Mitigation and Adaptation Sector Plans." This project included two pillars: (i) preparation of an assessment of the National Plan on Climate Change, of 2008, to support its update process; and (ii) design of a GHG monitoring system in the actions included in the Sectoral Plans for Climate Change Mitigation and Adaptation and Action Plans for Prevention and Control of Deforestation. The project included a proposal to develop the Modular System for Monitoring Actions of Greenhouse Gas Emissions Reductions (SMMARE in the Portuguese acronym), for which guidelines were established in 2014.

SMMARE was initially designed to monitor actions and reductions in GHG emissions achieved through sectoral mitigation plans under Brazil's climate policy, whose goals involve specific plans for the Amazon and the Cerrado.

Although a description of the system's theoretical framework is available, the development of SMMARE is being revised in light of the Paris Agreement and national commitments thereto. One of the objectives of this revision is to streamline financial and human resources, thus avoiding duplicated efforts, and it is part of the MRV strategy for mitigation actions as stipulated in Article 10 of Decree No. 7,390/2010 - overridden by Article 23 of Decree No. 9,578, of 2018, of the National Policy on Climate Change in all its themes summarized in Panel 5.4.

*Panel 5.4. Key elements in the Modular System for Monitoring Actions of GHG Emissions Reductions*

| SMMARE | Information |
|---|---|
| Legal Framework | Article 10 of Decree No. 7,390/2010 – overridden by Article 23 of Decree No. 9,578, of 2018. |
| Goal | To monitor actions and reductions in GHG emissions achieved through sectoral mitigation plans under Brazil's climate policy. |
| Application | For the planning, organization, implementation, measurement, reporting, and verification of actions that will lead to the reductions indicated in the PNMC and in the Brazilian NDC. |
| Instruments | PNMC; NDC; Action Plans for the Prevention and Control of Deforestation in the Amazon and Cerrado; and Plans for Mitigation and Adaptation in Agriculture, Energy and Charcoal. |

Source: Based on MMA, 2014; CGEE, 2013; 2014.

Panel 5.5 summarizes the operation of SMMARE.

*Panel 5.5. Operational Arrangements of the Modular System for Monitoring Actions of GHG Emissions Reductions*

| SMMARE | Information | |
|---|---|---|
| | I | II |
| Monitoring Possibilities (Scenarios) | Monitor reductions in GHG emissions based on existing data and/or data that could be easily obtained, which could be implemented at the national level in the short term. | Monitor the reduction in GHG emissions at the disaggregated level, which would require a better data collection to allow for spatial analysis of emissions reductions. |
| Monitoring Elements | (i) list of mitigation actions evaluated, including their implementation phase; (ii) methodological assumptions; (iii) results by mitigation action evaluated through indicators disaggregated at the appropriate level and, as far as possible, according to the scenario under which monitoring is conducted; and (iv) assurance and quality control of evaluations. | |
| Monitoring Modules | Each Plan will have a "Monitoring Module" within SMMARE, to be implemented in specific steps based on methodologies included in the IPCC guidelines for National Greenhouse Gas Inventories. | |

Source: Based on MMA, 2014; CGEE, 2013; 2014.

It should be pointed out that since 2014 there has been no progress in any modular computer system nor in the full engagement of the line ministries for the production of information.

Regarding the latest approach to reporting emission reductions, it should be noted that initially it aggregated data for mitigating greenhouse gas emissions from the forestry and agriculture sectors, with some emission reduction estimates up to 2018. Running in parallel to this, the need for an information dissemination tool that would allow for the monitoring of the main mitigation and adaptation actions to climate change continued to be met and enhanced through the Educaclima portal (www.educaclima.mma.gov.br). The portal was launched in early 2018 and provides some preliminary data on the reporting of emissions reduction mentioned above.

*See **item 5.2.5**. for more information on "Educaclima".*

In order to avoid duplication of work and any increased costs, among other obstacles, the Government is waiting for the conclusion of the New Enhanced Transparency Framework under the Paris Agreement in order to, if appropriate, resume implementation of a transparency arrangement, but no longer for NAMAs, which will be discontinued as of 2020.

## 5.2. CAPACITY BUILDING ON CLIMATE CHANGE

The Brazilian academic and scientific sector has played a major role in the development of knowledge to bridge the information gaps and expand understanding of the implications of climate change for the various national contexts. This section describes actions that are contributing to capacity building on climate change in Brazil.

### 5.2.1. AdaptaBrasil MCTI

The Brazilian Government is making important efforts to map, identify and consolidate information related to the risks of impacts caused by extreme climate variations in the country's natural and social system (BRASIL, 2009). These actions are intended to provide an environment of solid, robust, centralized, and easily accessible information on this topic with a view to informing and guiding strategic planning. As such, the collaboration of INPE and RNP with support from the MCTI for the development of the AdaptaBrasil MCTI platform aims at "consolidating, integrating and disseminating information to further the analysis of actual and estimated impacts in the country, thus providing inputs to decision makers for adaptation actions."

AdaptaBrasil MCTI will provide information on the actual and estimated impacts of climate change in all regions of Brazil. To this end, this platform was designed from the aggregation of indexes and indicators to capture the causality relationships and the influence of risk factors. Indicators are based on the steps indicated by the Competence Center on Composite Indicators and Scoreboards of the Joint European Research Center (JRC) (NARDO et al., 2008), but with adaptations to national needs. The weighting and consolidation of the indicators was based questionnaires and workshops with specialists, in addition to analyzes at multiple spatial (national, regional, state, and municipal) and temporal scales (interval of decadal analysis), with multiple stressors (physical-climatic, socioeconomic, public policies, etc.).

The structure and format for providing information on climate change impact risk drives the purpose of informing the proposed adaptation actions to be planned by public and private actors from various segments. The distinguished perception of the target audience warrants a hierarchical layout of indicators for climate change impact risks and their implications, as shown in Figure 5.1.

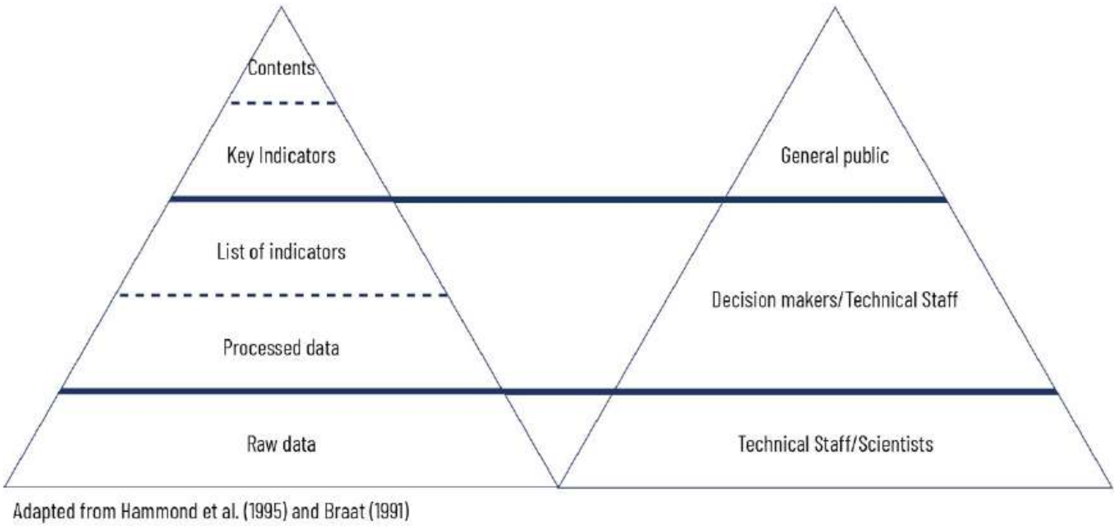



Figure 5.1. Structure between the level of information and the target audience.
Source: Adapted from Braat (1991).

## 5.2.2. AdaptaCLIMA

Launched in December 2017, AdaptaClima was designed to help to bridge the knowledge gap on climate change adaptation, as well as to achieve the first objective in the National Adaptation Plan, which is intended to be an "on-line platform for the management of adaptation knowledge on adaptation available to all". In addition to providing content about adaptation, the platform is intended to provide an interface between knowledge providers and users. When creating a profile on AdaptaClima, users can recommend content, rate the content available, share their contact details, have access to contact details of registered professionals, in addition to receiving customized reports. Panel 5.6 describes the main elements in this platform.

*Panel 5.6. Key Elements in the AdaptaClima platform*

| AdaptaClima | Information |
|---|---|
| Characteristic | Freely accessible digital platform designed to share insights into climate change. |
| Goals | (i) to curate and make available current information and tools on thematic areas in the climate agenda, with a focus on Brazil; (ii) to connect knowledge providers and users by promoting an exchange of knowledge and building partnerships; and (iii) to foster production of knowledge in an appropriate format based on the gaps identified and connections established. |
| Impacts | Contribute to strengthening Brazil's capacity to adapt to climate change. |
| Challenges | (i) the information landscape is vast and fragmented, with information that is difficult to access; (ii) broad range of actors providing and using the information; and (iii) gaps between research, policies and practices. |
| Products | (i) outreach and engagement actions; (ii) an effective, transparent and participatory governance structure; and (iii) a Web-based platform. |
| Institutional Arrangements | Coordinated by the Ministry of the Environment, implemented by the Center for Sustainability Studies at FGV-EAESP (GVces) and by the International Institute for Environment and Development (IIED), with support from the British Council through the Newton Fund. The platform was built collaboratively throughout 2016 and 2017, with more than 65 organizations involved in Brazil and the United Kingdom. |

Source: Based on MMA, 2016.

### 5.2.3. Training on the construction of mitigation scenarios and estimates of GHG emissions and climate impacts in Brazil

The Brazilian Government adopts climate policies based on technical capabilities obtained from the implementation of programs and projects. This is intended to boost the capacity and technical skills of both governmental and non-governmental actors to identify cost-effective mitigation and adaptation options, which are reflected in terms of multidisciplinary public policies.

Training takes into account three aspects: (i) the institutional capacity to promote the development of policies, procedures, regulations and the systems of goals and incentives that comprise the actions to mitigate GHG emissions; (ii) the organizational capacity to expand the planning and management capacity of individuals by creating internal goals and mechanisms and resources; and finally (iii) the human resources capacity to train official personnel on the establishment of goals, design and management of climate policy programs, commitment of resources, and implementation of the climate policy.

As such, two initiatives deserve special notice: (i) Mitigation Options of Greenhouse Gas Emissions in Key Sectors in Brazil, conducted by the MCTI; and (ii) Economic and Social Implications (IES Brasil), led by the Brazilian Forum on Climate Change. The main elements in these initiatives are summarized on Panel 5.7 and Panel 5.8, respectively.

*Panel 5.7. Key elements in the Mitigation Options of GHG Emissions in Key Sectors in Brazil*

| Mitigation Options Project | Information |
|---|---|
| Characteristics | This is an initiative by the MCTI in collaboration with the UN Environment that relied on resources from the Global Environment Facility (GEF) with the purpose of assisting in the decision-making process on actions that can potentially reduce GHG emissions in key sectors of the Brazilian economy: industry, energy, transport, built environment, AFOLU (Agriculture, Forestry and Other Land Use), waste management and other cross-sector alternatives. |
| Goals | To strengthen the technical capacity of the Brazilian Government in order to implement GHG Mitigation actions. The project estimated the potentials and costs of reducing GHG emissions by means of an integrated economic-energy analysis for 2012-2050 in the various key sectors mentioned. |
| Strategy | To achieve the stated goal, Project implementation was based on three components: (I) Mitigation alternatives identified and their respective potentials and costs quantified for 2012-2035 and 2035-2050; (ii) integrated analysis of the various mitigation alternatives within an integrated optimization framework, considering non-additivity of the various mitigation alternatives and other economic considerations; and an assessment of the potential impacts of different climate policies on the Brazilian economy; measurement, reporting and verification (MRV) testing of alternative proposals of mitigation at the national level; and (iii) training provided to federal and state government institutions and to the cities hosting the FIFA 2014 World Cup as well as to civil society organizations to implement actions to mitigate GHG emissions in sectors of the economy. |
| Institutional Arrangements | MCTI, with GEF funds and a partnership with UN Environment. |
| Results | Several events were successfully held that contributed to the dissemination of the project, including a review of assumptions and training of both governmental and non-governmental stakeholders. Training sessions were held in March, May and October 2015, and in April and June 2016 with a focus on abatement cost modeling and draft public policies. Six regional seminars were held in São Paulo, Rio de Janeiro, Curitiba, Manaus, Salvador, and Brasilia to share project results regionally and to allow stakeholders to use the findings from the National GHG Inventory as a tool to monitor and implement environmental mitigation actions. Finally, all studies were published, with emphasis on the publication “Mitigation trajectories and public policies to meet the Brazilian Paris Agreement Targets.” |

Source: Based on MCTIC, 2018a; 2018b

*Panel 5.8. Key Elements in the IES-Brasil Project*

| IES-Brasil | Information |
|---|---|
| Description | Under the participatory coordination of the FBMC, it represents efforts from different segments of the Brazilian society with experts in the identification of various development trajectories that reconcile socioeconomic and environmental goals. Emission scenarios up to 2030 were developed and mitigation policies were identified that showed better responses to |

| IES-Brasil | Information |
|---|---|
| | the economic and social impacts resulting from the implementation of emission mitigation scenarios. |
| Goal | To establish development trajectories that reconcile socioeconomic and environmental goals by putting together future scenarios of GHG emissions until 2030. |
| Strategy | Various GHG emission scenarios for 2030 for Brazil were developed by a Scenario Development Committee (CEC), involving the government, the private sector, the academic community, and civil society from its inception. The engagement of various segments of society in the preparation of scenarios aimed at achieving legitimate and plausible visions of the future. |
| Characteristics | (i) focus on an analysis of the macroeconomic and social implications of different GHG emissions scenarios, going beyond the analysis of sector-specific technologies and costs. In particular, by treating the behavior of the economy as suboptimal, the IMACLIM-BR model helps to assess the impact of mitigation policies on driving factors of poverty and income distribution; and, (ii) a participatory approach to the creation of scenarios. |

Source: Based on CENTRO CLIMA, 2015.

Examples also include initiatives to organize and make available information, materials and data on the impacts and risks of climate change, such as PROJETA[4], Climate Vulnerability System (SisVuClima)[5] and Projections of Climate Scenarios[6]. These provide broader access to different types of data on climate change.

In order to ensure that managers and officials have access to information in a relatively easy and user-friendly manner and based on the growing demand from users in strategic segments of society who needed to prepare their studies on vulnerability, impact and adaptation, the portal "Climate Projections in Brazil" was established[7]. The purpose of this portal is to facilitate visualization of climate projections, IPCC global climate models and regional models over the Brazilian territory, in addition to automating data retrieval and availability in a broad-based and unrestricted manner. By means of a graphical interface, users can easily obtain, for any area of Brazil, information on climate models necessary to understand how the climate system works, and they can also generate climate change scenarios.

### 5.2.4. Center for Monitoring and Early Warnings of Natural Disasters (CEMADEN)

The significant increase in the number of disaster events in Brazil from 2007 and to 2011 made it vitally important to put in place an early warning system based on a multidisciplinary scientific and technological approach. Until recently, no federal agency monitored meteorological, hydrological, agronomic and geological events in an integrated manner. Thus, in order to amplify the impact of government actions to prevent natural disasters and not just deal with alleviation of the consequences of these events, in 2011 a working group was set up with a view to drawing up a plan to prevent and tackle natural disasters.

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[4] *Available in Portuguese at:* https://projeta.cptec.inpe.br

[5] *Available in Portuguese at:* http://www.sisvuclima.com.br/

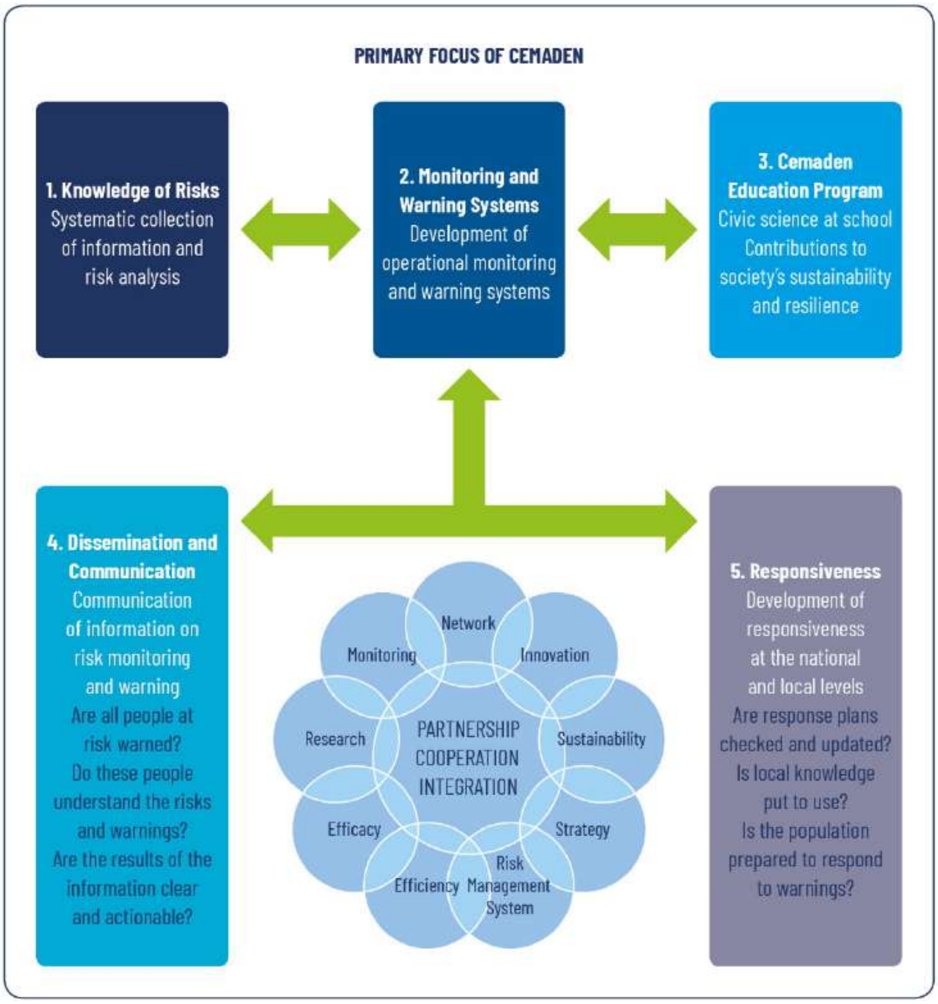
[6] *Available in Portuguese at:* http://pnud.cptec.inpe.br/pnud_ie.html

[7] *Available in Portuguese at:* http://pclima.inpe.br/

The MCTI was responsible for implementing an early warning system on the likelihood of natural disasters occurring, associated with the natural events that cause most fatalities in the country, i.e., landslides and floods. This set the stage for the creation of the National Center for Monitoring and Early Warnings of Natural Disasters (Cemaden), the idea being to use state-of-the-art monitoring technologies and hydrometeorological and geodynamic forecasting.

Cemaden is committed to promoting science, technology and innovation developments to further improve quality and reliability of alerts, and also to preventing and mitigating natural hazards. In addition, it fosters society's qualification and capacity-building towards coping with disasters.

In addition to the actions for the immediate relief and support to rebuild the affected areas, there was a clear need for concerted action to bolster the capacity of the Brazilian society to tackle natural disasters, and primarily to prevent and warn in advance in order to avoid disasters and to reduce the number of victims and social and economic damage resulting from these disasters. Thus, in tandem with the generation and management of knowledge supported by Cemaden, the strategy for disaster risk reduction in the country includes actions for the issuance of early warnings, as well as the development of local response capacity, especially in Brazilian municipalities susceptible to natural disasters (Figure 5.2).




Source: CEMADEN[8].

Figure 5.2. Strategy to reduce the risk of natural disasters.

[8] *Available in Portuguese at: http://www.cemaden.gov.br/estrategia-para-reducao-de-desastres-no-pais/. Accessed on: September 2020.*

## 5.2.5. EducaClima

EducaClima is a knowledge management platform developed by the Ministry of the Environment on education and public awareness regarding climate change. It was launched on March 16, 2018, the National Climate Change Awareness Day. The EducaClima platform (www.educaclima.mma.gov.br) also hosts key information on monitoring and tracking Brazil's greenhouse gas emissions, actions to reduce emissions and information for monitoring key climate change mitigation and adaptation actions.

Panel 5.9 briefly describes the main features of EducaClima.

*Panel 5.9. Key Elements in EducaClima*

| EducaClima | Information |
|---|---|
| Characteristics | A portal powered by Ministry of the Environment on education and public awareness regarding climate change. It brings together relevant content on climate change curated by theme, diversity of perspectives and actors. It is led by the Ministry of the Environment's Coordination Unit for Transparent Actions on Climate Change (CTAM), the Department for Monitoring, Support and Promotion of Actions on Climate Change (DMAF) and the Secretariat for Climate Change and Forests (SMCF). |
| Goals | To disseminate and disclose information, and to raise awareness of the public regarding climate change through the dissemination of up-to-date and reliable knowledge and information in order to facilitate access to information by providing direct access to reports, regulations, documents or websites. |
| Pillars | I. Climate empowerment[9] by means of education, training and public awareness; facilitation of conversations, exchange of knowledge, new lessons learned, evolution and also awareness regarding individual impacts on the environment so as to encourage sustainability, including encouragement to civic participation. |
| | II. Education and public awareness through promotion and dissemination of information, education, training and public awareness on climate change, according to the guidelines[10] of the National Policy on Climate Change. |

Source: Based on MMA, 2017a.

## 5.2.6. Brazilian Climate Change Forum (FBMC)

The Brazilian Forum on Climate Change provides room for coordination between the civil society and the government, at the national level. It aims at creating awareness and mobilizing society towards discussing and taking a stand on problems caused by climate change, as per Presidential Decrees No. 3,515/2000 and 28/8/2000 (Panel 5.10). The Forum Works via ten thematic chambers (TCs), which promote events and meetings, and foster capacity-building and thematic discussions on climate change with the civil society.

[9] *Article 6 of the UNFCCC text.*

[10] *Article 5, item XII of Law No. 12,187, of December 29, 2009.*

The thematic chambers (TCs) cover the following themes: TC1 (Agriculture, Forests and Biodiversity), TC2 (Energy), TC3 (Transport), TC4 (Industry), TC5 (Cities and Waste), TC6 (Finance), TC7 (National Defense and Security), TC8 (Long-term Vision), TC9 (Science, Technology and Innovation), and TC10 (Adaptation).

*Panel 5.10. Key Elements in the FBMC*

| FBMC | Information |
|---|---|
| Legal Framework | Decree No. 12,187/2009; Decree No. 9,082/2017. |
| Goals | To raise awareness of and engage society to discuss and take a position on the issues arising from climate change. |
| Mission | To produce deliberations and cooperate with other instances of climate governance in the country in order to develop strategic and far-reaching guidelines by consensus. |
| Characteristics | Hybrid arrangements, with the maximum authority of the State as Chairman and ministerial authorities as members, plus representatives from civil society. |
| Instruments | Institutional instrument of the National Policy on Climate Change. |
| Regulation | Presidential Decrees No. 3,515/2000; of August 28, 2000; Law No. 12,187/2009; and Decree No. 9,082/2017. |
| Governance and institutional arrangements | Ministers of State, and figures and representatives from civil society, the business sector and the academic community. In addition, it fosters the creation of regional, state and municipal climate change forums with a view to engaging with these forums in order to advance climate policy agendas in the various regions of Brazil. |

Source: Based on FBMC, 2017; 2018.

## 5.2.7. National Institute of Science and Technology (INCT) for Climate Change

The INCT for Climate Change acts as a pillar of research and development within the National Climate Change Adaptation Plan. It brings together more than 200 scientists from 38 research groups and from 15 states in Brazil and relies on support of 12 institutions from 11 countries. Phase 2 of the INCT Climate Change project (INCT-MC) has recently been submitted to CNPq. This new project follows up on the previous INCT-MC[11], which started in 2009 and ended in 2014. The new phase will build on the main results from the previous INCT. Panel 5.11 summarizes the main duties and features of the INCT with regard to Climate Change.

[11] *The previous INCT–MC had the involvement of more than 400 researchers from Brazil and from 18 other countries, and interfaced with several other INCTs. More information on the previous INCT–MC can be found at: http://inct.ccst.inpe.br/*

*Panel 5.11. Key elements in the National Institute of Science and Technology (INCT) for Climate Change*

| INCT for Climate Change | Information |
|---|---|
| Legal Framework | INCT for Climate Change (INCT-MC) – A submission to the CNPq INCT based on a call for proposals in 2014. |
| Goals | To support scientific, technological and innovative research activities in strategic domains and/or at the frontier of knowledge aimed at finding solutions to major national problems. The choice of researchers is based on the strategic themes contemplated in the CNPq call, in the following areas: Agriculture[12]; Health Care[13]; Urban Development[14]; Alternative Renewable Energy Sources[15]; and Information and Communication Technology[16]. |
| Objective of the Project Integrating Phase | To generate scientific information on the impacts of global environmental changes in key sectors to ensure the following actions are carried out in an integrated fashion throughout the project: (i) provide adaptive action options; (ii) identify areas in sectors where political decisions need to consider climate change more urgently; (iii) propose adaptation trajectories in various sectors, with a focus on building and or optimizing resilience to (iv) pinpoint or map priorities for adaptive actions, thereby supporting the country in key sectors, for more resilient trajectories and climate change adaptation so as to foster sustainability at the national scale. |
| Mission | To conduct integrated analyzes of the components and cross-cutting issues, decision-making processes and public policies with the purpose of providing trajectories and strategies related to Adaptation-Resilience-Sustainability in Brazil. |
| Organizational and functional structure of the institute | This covers six Thematic Pillars: (i) food security; (ii) water security; (iii) energy security; (iv) health care; (v) natural disasters, human dimensions, impacts on physical infrastructure in urban areas, and urban development; and (vi) impacts on Brazilian ecosystems in view of changes in land use and biodiversity.<br><br>All of these components are connected by three cross-cutting themes: (i) economy and impacts in key sectors; (ii) modeling of the land system and production of future climate scenarios for studies on Vulnerability-Impacts-Adaptation-Resilience-Sustainability (VIARS); and (iii) risk reporting, dissemination of scientific knowledge and education for sustainability. |

Source: Based on CNPq, 2014; CEMADEN, 2018.

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[12] *Food security.*

[13] *Environmental vulnerability to the spread of diseases related to climate and extreme climate events.*

[14] *Extreme climate events and natural disasters – human dimensions and their impacts on physical infrastructure: housing, roads, railways, water and sewage systems, ports, public transport, development of more resilient cities, and reduction of the risk of natural disasters.*

[15] *Energy and water security.*

[16] *More effective and comprehensive communication on the topic of global changes for society and government with a view to outlining public environmental policies. A core focus of the project is education for sustainability, including IT development to help the non-scientific community to understand and use the information generated.*

A large number of universities and national and international research institutions can come together to form a virtual network under the INCT-MC. In addition, all findings from these research efforts can be presented and shared with citizens and governments in a clear and precise manner, thus boosting understanding by decision-makers for the development of public policies to tackle the present and future challenges posed by global changes (Figure 5.3).

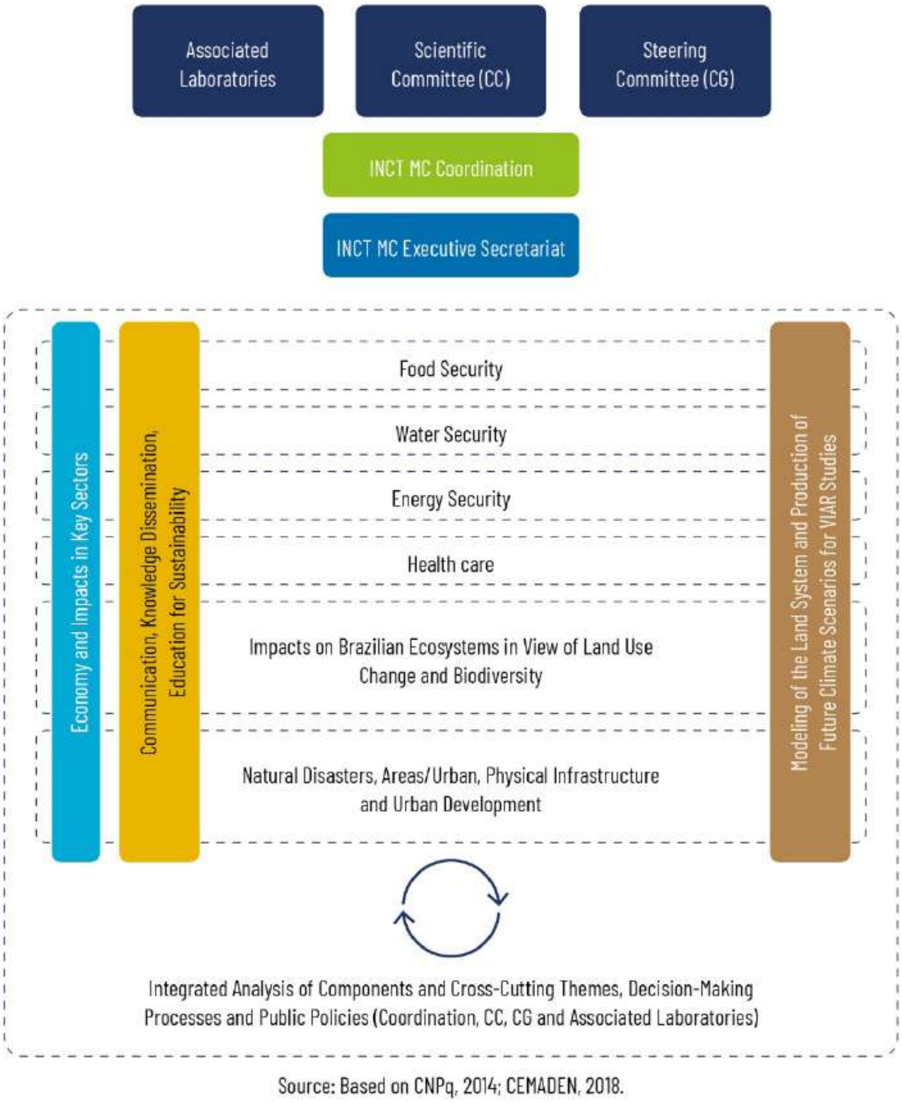



*Figure 5.3. Institutional Arrangements for the National Institute of Science and Technology (INCT) for Climate Change*

## 5.2.8. National Institute for Space Research (INPE) and Climate Change

The National Institute for Space Research (INPE, for its acronym in Portuguese), in addition to other activities, fosters technical, scientific and innovative capacity-building, aiming at broadening and consolidating competencies in science, technology and innovation towards space and environmental areas in order to respond to national challenges.

As summarized in Panel 5.12, The National Institute for Space Research (INPE), through its Center for Weather Forecasting and Climate Studies (CPTEC), has provided short and medium term forecasts, in addition to weather forecasts since 1995, and it also deploys highly complex techniques of numerical modeling of the atmosphere and oceans to predict future conditions (INPE, 2018b).

*Panel 5.12. Key elements in the National Institute for Space Research (INPE) related to Climate Change*

| INPE and Climate Change | Information |
|---|---|
| Characteristics | INPE is part of Brazilian Research Network on Global Climate Change (Rede CLIMA), and its role is to generate and disseminate knowledge and technology so that Brazil can respond to the demands and challenges posed by global climate change. It coordinates the National Institute of Science and Technology for Climate Change. |
| Goals | (i) to support design of the National Policy and Plan on Climate Change; (ii) to coordinate implementation of the São Paulo State Research Foundation's Program (FAPESP) for Research on Global Climate Change; (iii) to host the Executive Secretariat of the Brazilian Climate Change Research Network and of the INCT for Climate Change; (iv) to advance skills to generate global environmental change scenarios and their effects on Brazil and Latin America; (v) to support the Brazilian Forum on Climate Change and the Brazilian Panel on Climate Change; (vi) to democratize and disseminate global climate change science by disseminating knowledge to various audiences; (vii) to provide scientific and technological inputs to the government so it can actively participate in major international environmental negotiation forums. |
| Strategic Objectives | To develop and improve land system models, monitoring and socio-political analysis networks in order to build and analyze environmental changes and climate projection scenarios. |
| Mission | (i) to generate interdisciplinary, equity-based knowledge toward national development with a view to alleviating environmental impacts in Brazil and globally; and (ii) to provide quality scientific and technical information to guide public policies for the mitigation and adaptation to global environmental changes. |
| Vision | To expand the scientific, technological and institutional capacity of Brazil vis-a-vis global changes, with a view to expanding knowledge on the process, identifying the impacts on the country and informing public policies to tackle the issue at the national and international levels. |
| Targets | (i) to upgrade collection stations in the environmental variables monitoring networks; (ii) to set up new collection stations in the environmental variables monitoring networks; (iii) to update the land system models; (iv) to generate land system operation scenarios; (v) to develop an integrated land system model that supports weather and climate forecast data; (vi) to expand the network of innovative instrumentation for data collection operated by the Integrated Environmental Data System (SINIDA). |
| Pillars | (i) Climate change (including extreme climate events); (ii) Sector-specific vulnerability analyzes; (iii) Impact and adaptation studies; and (iv) Draft climate change adaptation policies. |
| Facilities and capabilities | Cray XE6 supercomputer; Dynamic downscaling technique using a BESM model, which is a set of computer programs that are coupled to the components of continental surface, ocean, |

| INPE and Climate Change | Information |
|---|---|
| | atmosphere and global chemistry to the primary goal of generating climate change scenarios from a Brazilian perspective. It incorporates cloud formation processes, vegetation dynamics and the knowledge generated in the country of influence of Brazilian biomes on the global climate, while providing detailed information on major tropical events that are not reflected in other foreign models. These events include, for instance, fires, which have the potential do amplify greenhouse effects and change rainfall and cloud regimes in a given region, and the effects of river discharges from the Amazon basin on marine biogeochemical cycles. |

Source: Based on CEMADEN, 2011; INPE, 2018b, 2018c.

In addition, the INPE has relevant expertise in tools to project climate change scenarios, which are global numerical models for the land system. These models were developed as the operational activities of the CPTEC/INPE started. Initially, the models were used only to make numerical predictions of time (days) and seasonal climate (seasons) (CAVALCANTI et al., 2002; MARENGO et al., 2012). The first climate change projections on South America were made using regional climate models (MARENGO; AMBRIZZI, 2006; AMBRIZZI et al., 2007). These initial studies were based on results of the following models: RegCM3 (GIORGI; MEARNS, 1999; PAL et al., 2007), HadRMP3 and Eta-CCS (PISNICHENKO; TARASOVA, 2009) for the period comprising 2070-2100, with horizontal resolution (50 km) and forced by the HadAM3P global atmospheric model (from the Met Office in the United Kingdom), from GHG emissions scenarios (A2 and B2).

In the subsequent years new projections were made with a new version of CPTEC/INPE's Eta model for three future periods: 2011-2040, 2041-2070 and 2071-2100, with a 40 km horizontal resolution and forced from 4 disturbance members provided by the HadCM3 global coupled model, considering the A1B GHG emissions scenario (MARENGO et al., 2012).

The regionalization results of global models of the "Coupled Model Intercomparison Project" (CMIP) through the Eta regional model supported several impact, vulnerability and adaptation (IVA) studies in Brazil, such as the TCN and PNA, in addition to other governmental and technical/scientific projects and studies, such as this National Communication.

The implementation of several research programs and projects related to climate studies in Brazil over the past few decades has leveraged the development of regional and global climate modeling in the country. Initiatives include the Fapesp Global Climate Change Research Program (PFPMCG), INCT-MC and Rede CLIMA.

Development of the Brazilian Earth System Model (BESM) started as part of these programs, and it is based on the CPTEC coupled ocean-atmosphere model, which is used to produce numerical weather and seasonal climate forecasts (NOBRE et al., 2009; 2012). BESM was used to generate climate projections for CMIP5 (Phase 5 of the CMIP) and also for the TCN, thereby contributing to global climate change scenarios for 2005-2100 (NOBRE et al., 2013).

### 5.2.9. Intergovernmental Panel on Climate Change (IPCC)

The participation of Brazilian scientists is vitally important and shows that Brazil's inputs have come to age across the drafting of all IPCC evaluation reports as summarized in Panel 5.13.

*Panel 5.13. Number of Brazilian scientists involved in the IPCC Evaluation Reports by year of publication and approach*

| **IPCC Evaluation Reports** | | **Information** | |
|---|---|---|---|
| **Report** | **Year of Cycle Completio n** | **Approach** | **Number of Brazilian scientists involved** |
| First | 1990 | Importance of climate change underscored as a challenge that requires international cooperation to counter its consequences. | 6 |
| Second | 1995 | Provision of key material prepared by negotiators in the period leading up to the adoption of the Kyoto Protocol in 1997. | 17 |
| Third | 2001 | Specifically addresses issues of interest to policy-makers in the context of Article 2 of the UNFCCC – issues such as the extent to which human activities have influenced and will influence global climate in the future, the impacts of climate on ecological and socio-economic systems and existing technical and policy capacity to address anthropogenic climate change. Briefly explores the interconnected nature of several multilateral environmental conventions. | 23 |
| Fourth | 2007 | More attention paid to integrating climate change with sustainable development policies and the links between mitigation and adaptation. | 35 |
| Fifth | 2014 | (AR5) was launched as a four-part report between September 2013 and November 2014. AR5 provides a clear and up-to-date view of the current state of scientific knowledge relevant to climate change in order to confirm that human influence on the climate system is clear and growing, with impacts observed on all continents and oceans. Many of the changes that have occurred since the 1950s are unprecedented in decades or millennia. The IPCC is now 95% certain that human beings are the main cause of the current global warming. | 28 |
| Sixth | 2022 | An overall appraisal of the commitments undertaken by the Parties to the UNFCCC Paris Agreement is expected. | 21 |

Source: Based on IPCC, 2018.

## 5.2.10. Brazilian Antarctic Program (Proantar)

The Brazilian Antarctic Program (PROANTAR) had its 38th anniversary in 2020, and it is an Official program whose primary objective is to produce scientific knowledge in Antarctica and its relations with the rest of the global climate system as it relates to the cryosphere, oceans, the atmosphere, and the biosphere.

Brazil currently participates with a diversified scientific program with international ramifications, comprised of research projects in the following domains: (i) biodiversity and environmental impacts in Antarctica; (ii) geology and geochemistry in Antarctica and the South Ocean; (iii) monitoring of the environment, climate and atmosphere in the Antarctic region; and (iv) technological, cultural and socioeconomic aspects in Antarctica.

CAPES joined Proantar in 2018, and advances the development of scientific, technological and innovation research in the region. The Coordination Unit will inject BRL 5.7 million in the Program through a public call for projects in the area (CAPES, 2018). The research work is expected to focus on follow nine thematic pillars: (i) the role of the cryosphere in the land system and the interactions with South America; (ii) the dynamics of the upper atmosphere in Antarctica, interactions with geospace and connections with South America; (iii) climate change and the Southern Ocean; (iv) biocomplexity of the Antarctic ecosystems, their connections with South America and climate change; (v) geodynamics and geological history of Antarctica and its relations with South America; (vi) ocean chemistry, marine geochemistry and marine pollution; (vii) human and social sciences; (viii) human biology and polar medicine; and (ix) innovation in new technologies (CNPQ, MCTIC, CAPES, FNDCT, 2018). Panel 5.14 provides additional information, while Figure 5.4 summarizes the Program's institutional arrangements.

*Panel 5.14. Key elements in the Brazilian Antarctic Program (Proantar)*

| PROANTAR | Information |
|---|---|
| Legal Framework | Decree No. 94,401, of June 3, 1987, which approves the National Policy for Antarctic Affairs, although the Brazilian Antarctic Program had been designed as far back as 1982. |
| Characteristics | It is an Official program[17] whose objectives are related to the production of scientific knowledge on Antarctica and its relations with the rest of the global climate system as it relates to the cryosphere, oceans, the atmosphere, and the biosphere. |
| Goal | Conducting high-quality scientific, technological or innovative research on the Antarctic continent enables Brazil to participate in the Antarctic Treaty Consultative Meetings (ATCM) in a position to propose measures to other countries that are parties to the Treaty and to make decisions and resolutions to pursue its principles and goals. |
| Base-documents | Antarctic Treaty (1975); Decree No. 75,963, of July 11, 1975; Madrid Protocol (1991); Directive No. 318; Decree No. 94,401/1987; Decree No. 86,829, of January 12, 1982. |
| Pillars | Scientific Pillar |

[17] *PROANTAR's general guidelines were approved by the National Commission for Antarctic Affairs (CONANTAR); it is the instrument for implementing the National Policy for Antarctic Affairs (POLANTAR).*

| PROANTAR | Information |
|---|---|
| | Under the responsibility of MCTI and CNPq, which are in charge of fostering and coordinating the implementation of scientific research carried out by universities and other research institutions. The National Antarctic Research Committee (CONAPA) – MCTI's advisory body for Antarctic scientific affairs – is responsible for PROANTAR's scientific guidelines. |
| | Logistic Pillar |
| | Under the responsibility of the Secretariat of the Interministerial Commission for Sea Resources (SECIRM), which provides logistical support to Antarctic Operations. |
| | Environmental Pillar |
| | Under the responsibility of the PROANTAR Environmental Assessment Group (GAAM), which is coordinated by the MMA. |

Source: Based on PROANTAR, 1987; MCTIC, 2017d; Marinha do Brasil, 2017.

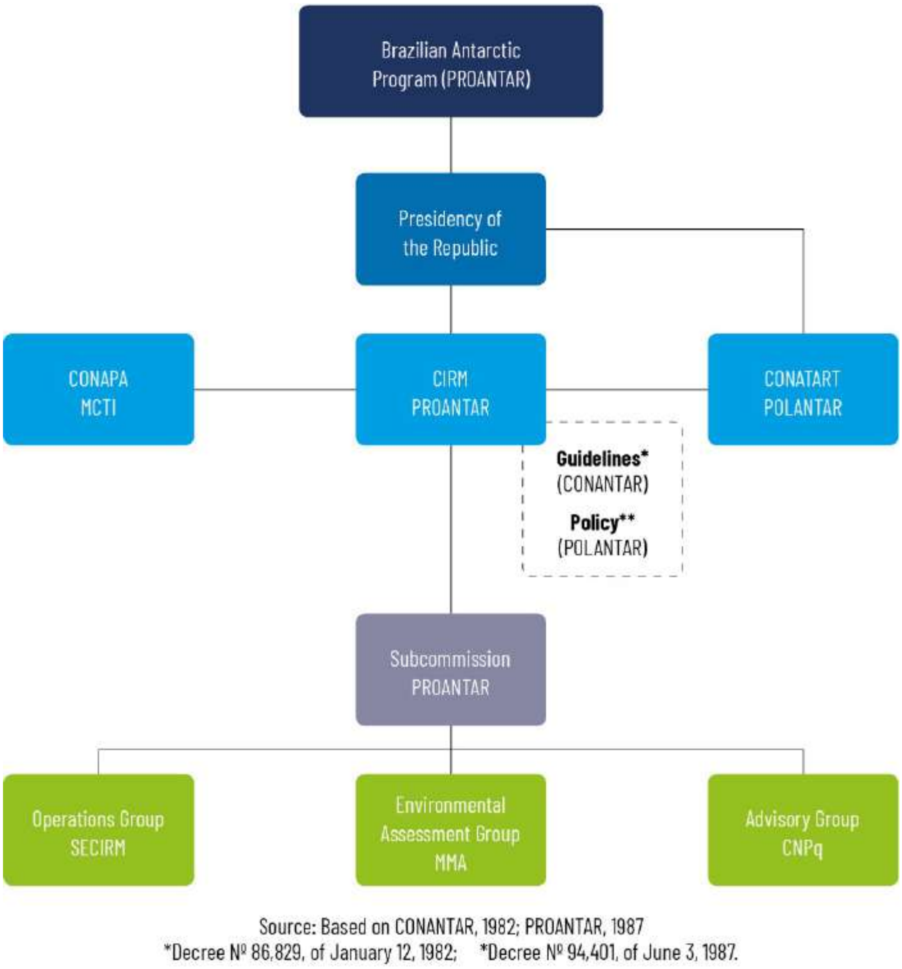



*Figure 5.4. Institutional Arrangements for the Brazilian Antarctic Program*

## 5.2.11. Large-scale Biosphere-Atmosphere in the Amazon Program (LBA)

Now in Phase 2, the Large Scale Biosphere-Atmosphere in the Amazon Program (LBA) is a multidisciplinary program that seeks to provide an understand of the functioning of Amazon's ecosystems in all their aspects and to study the Amazon system as a regional entity in the Earth system, as well as the causes and effects of changes currently underway in the region.

Research within the LBA is guided by the recognition that the Amazon is undergoing rapid and profound transformation related to its development and occupation. Hence, it seeks to provide insight into how changes in land use and land cover and climate can affect biological, chemical and physical processes, as well as sustainable development in the region, in addition to their interaction with the regional and global climate.

In Phase 1 of the LBA, four central issues comprised the component of land use and land cover changes: (i) what are the rates and mechanisms for converting forests into crop areas, and what is the relative importance of these land uses; (ii) at what rates are abandoned areas converted to secondary forests, what is the allocated use of these areas and what are the dynamic patterns of conversion and abandonment of lands; (iii) which area of forest is affected annually by logging; (iv) what are the potential scenarios for future land cover changes in the Amazon.

As of 2010, three research lines started to bring together the main issues to be addressed in Phase 2 of the program: (i) the changing Amazon environment (processes); (ii) sustainability of environmental services and land and aquatic production systems; and (iii) climate and hydrological variability and dynamics.

In summary, in 20 years of research, the program has played a major role in the training of human resources – more than 815 Brazilian researchers obtained their Master and PhD degrees. More than 150 research projects involving the so-called "cutting-edge science," under partnerships with around 280 national and foreign institutions (conducted by 1,400 Brazilian scientists and 900 other researchers from Amazonian countries), from eight European nations and from American institutions studied and improved the understanding of ongoing climate change so as to advance a sustainable development approach in the Amazon. Panel 5.15 describes the main elements in the LBA Program.

*Panel 5.15. Key elements in the Large-scale Biosphere-Atmosphere in the Amazon Program (LBA)*

| LBA | Information |
|---|---|
| Legal Framework | MCTIC Ministerial Directive No. 78/2010. |
| Characteristics | A Program managed by MCTI and coordinated by the National Amazon Research Institute (INPA), which plays an important role in the training of human resources, thus helping to understand some mechanisms that govern the interactions between the forest and the atmosphere, both in natural (of the pristine forest) and altered conditions; it has contributed to improve climate forecasting models; to measure carbon emissions from hydroelectric dams in the Amazon and the potential use of methane to generate additional electricity in power plants; to perform new actual measurements of wood density in southern Amazon, thus showing that the accumulated biomass is lower than in previous estimates. |
| Goals | (i) to broaden understanding of how the region's ecosystems function; and (ii) to integrate social and economic considerations with cutting-edge environmental research. |
| Base-documents | Directive on the Research under the LBA/INPA, PO 101/2014; Directive No. 78, of January 31, 2010 – Official Gazette of March 02, 2010; Directive No. 675, of October 18, 2007; Directive No. 75, of February 8, 2006, – Mentions the names of the members of the Board of Directors; MCT Directive No. 650, of October 19, 2005; MCT Directive No. 587, of August 15, 2003; MCT Directive No. 223, of May 12, 2003; MCT Directive No. 109, of May 7, 1998; Normative Instruction No. 109/97, of September 12, 1997; MCT Directive No. 55, of March 14, 1990; Decree No. 98,830, of January 15, 1990; Complementary Adjustment for Cooperation on Ecological Research at LBA between Brazil and the United States; Complementary Adjustment for Cooperation on Environmental Scientific Research at LBA between Brazil and the United States; Complementary Adjustment for Cooperation in Science and Technology at LBA between Brazil and the United States. |
| Domains | (i) biosphere-atmosphere interaction and the hydrological cycle; and (ii) socio-political and economic dimensions of environmental changes. |

| LBA | Information |
|---|---|
| Research Focus | (i) the changing Amazon environment; (ii) sustainability of environmental services and land and aquatic production systems; and (iii) climate and hydrological variability and dynamics. |

Source: Based on INPA, 2010.

### 5.2.12. Environmental Monitoring of Brazilian Biomes Program

The Ministry of the Environment, through Directive No. 365, of November 27, 2015, instituted the Environmental Monitoring of Brazilian Biomes Program (PMABB). The key elements in the Program are described in detail on Panel 5.16.

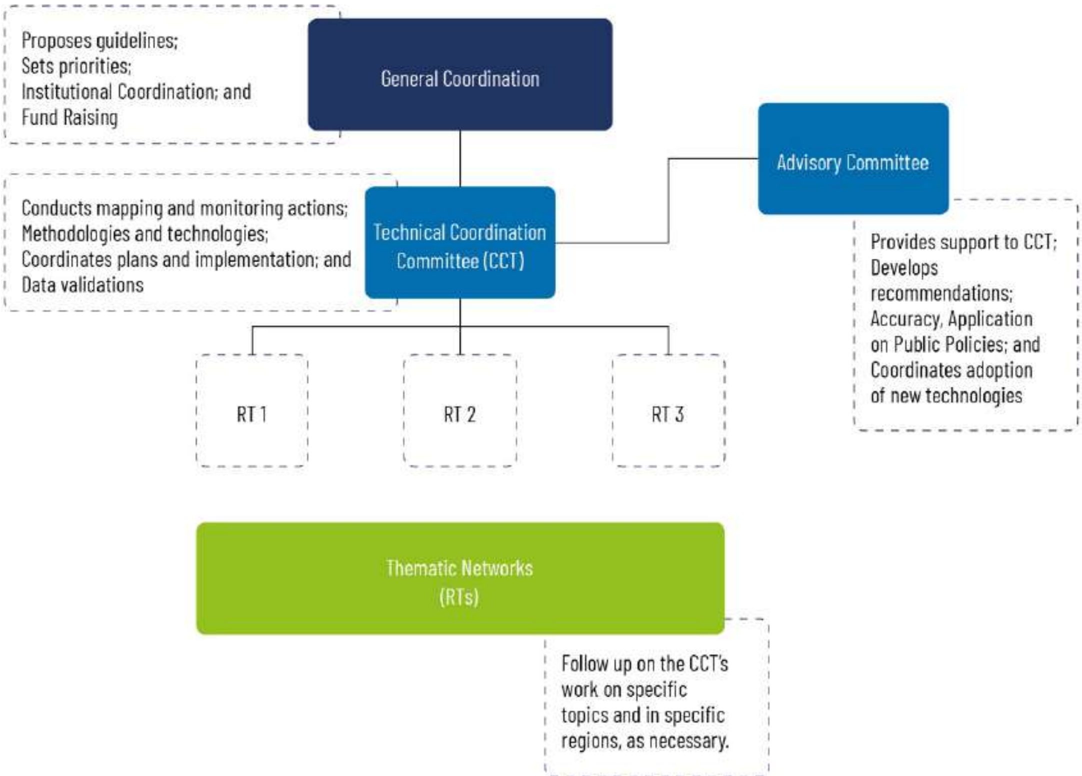
*Panel 5.16. Key elements in the Environmental Monitoring of Brazilian Biomes Program (PMABB)*

| PMABB | Information |
|---|---|
| Legal Framework | Ministerial Directive No. 365, of November 27, 2015. |
| Characteristics | The Program is based on seven different types of mapping, covering six biomes and a time series up to 2020. |
| Goal | To promote joint actions to standardize as much as possible the various mappings of Brazilian biomes, at different cartographic and temporal scales, according to the features of each theme in order to produce and share harmonized, systematic and updated official information in cooperation with various Federal Government agencies. |
| Mission | (i) to monitor the performance of public policies geared toward achieving the goals of reducing GHG emissions; (ii) to monitor the performance of public actions and policies associated with the National Biodiversity Goals[18] for 2020; and (iii) to assist in the implementation of the National Strategy for REDD+ in Brazil (ENREDD+). |
| Focus | (i) mapping and monitoring deforestation, including the deforestation rate; (ii) evaluation of vegetation cover and land use; (iii) monitoring of fires; and (iv) restoration of vegetation and selective logging. |
| Structure | Divided in three phases as set forth in MMA Directive No. 365/2015; covering the following biomes: (i) Amazon and Cerrado (2016-2017); (ii) Atlantic Forest (2016-2017); and (iii) Caatinga, Pampa and Pantanal Wetlands (2017-2018). |
| Base-documents | Directive 365, of November 27, 2015; Directive No. 51, of May 11, 2016; and Directive No. 223, of June 21, 2016. |

[18] *CONABIO Resolution No. 6, of September 3, 2013, particularly Goals 5 – Loss of Native Habitats, 7 – Sustainable Agricultural Practices, and 15 – Ecosystem Recovery), national counterparts of the Aichi Goals of the Convention on Biological Diversity (CBD).*

Source: Based on MMA, 2015a, 2017.

The institutional arrangements cover the following bodies: General Coordination, Advisory Board and Technical Coordination Committee, and, if necessary, Thematic Networks (Figure 5.5).




Source: Based on MMA, 2017.

*Figure 5.5. Institutional Arrangements for PMABB*

## 5.2.13. Programs to Raise Awareness Regarding Electric Energy Conservation and Rational Use of Oil and Natural Gas Derivatives

The Programs to Raise Awareness Regarding Electric Energy Conservation (PROCEL) and Rational Use of Oil and Natural Gas Derivatives (CONPET) were created in 1991 through a presidential decree, with the objective of promoting the development of a culture of conservation of non-renewable natural resources in Brazil.

CONPET's activities cover educational institutions and the transport, industrial, residential and commercial, agricultural, and power generation sectors. Since CONPET's inception, its activities have focused primarily on training personnel, disseminating information and carrying out assessments of cargo and passenger vehicles. The certification of gas-fired appliances (stoves, domestic ovens, and water boilers) began under the Brazilian Labeling Program (PBE, from INMETRO) in 2003, and in 2005 the CONPET Seal went on to be granted to the most efficient models of ovens, stoves and gas water boilers. As of 2009, CONPET and INMETRO launched an initiative for the voluntary labeling of light vehicles under the PBE.

In the industrial sector, CONPET's initiatives focus mainly on Petrobras, whose efforts typically complement those made by the company's energy management division. Indeed, the funds managed by CONPET are part of the various sources of funding for the projects covered by the Annual Conservation Plans of refineries. However, CONPET's performance is more pronounced in other business areas of the company, such as in E&P. As a result of the awareness of operators and the implementation of internal co-generation projects, CONPET's performance has been driving significant reductions in the consumption of electricity and fuels at Petrobras. Panel 5.17 briefly summarizes its main features.

*Panel 5.17. Key Elements in the CONPET Program*

| CONPET Program | Information |
|---|---|
| Legal Framework | Decree on the establishment of CONPET, of July 18, 1991; Law No. 10,295/2001. |
| Characteristics | A Federal Government program created in 1991 through a presidential decree to promote the development of a culture to avoid wastage in the use of non-renewable natural resources, thus ensuring a better country for future generations. |
| Goal | (i) to rationalize the consumption of oil products and natural gas; to reduce the emission of polluting gases into the atmosphere – generating a 25% gain in energy efficiency in the use of oil and natural gas products over the next 20 years without affecting the level of activity; (ii) to foster research and technological development; and (iii) to provide technical support to boost energy efficiency in the end use of energy. |
| Mission | To encourage the efficient use of energy in various sectors, with an emphasis on the household, industrial and transport sectors, in addition to developing environmental education actions. |
| Base-documents | Modification decree, of September 20, 1994; Decree No. 4,059, of December 19, 2001; Energy Efficiency Law No. 10,295; Decree establishing the Green Energy Efficiency Seal, of December 8, 1993; Law No. 10,295, of October 17, 2001; Regulated by Decree No. 4,059, of December 19, 2001; Law No. 12,187, of December 29, 2009; National Plan on Climate Change (PNMC); Directive No. 594, of October 18, 2011. |

Source: Based on Petrobras, 2012; MME, 2019.

The National Electricity Conservation Program (PROCEL) has the objective of promoting the efficient use of electric energy and preventing energy wastage. Panel 5.18 describes its main elements, including results achieved.

*Panel 5.18. Key Elements in the PROCEL Program*

| PROCEL Program | Information |
|---|---|
| Legal Framework | Ministerial Directive No. 1,877, of September 30, 1985. |

<table>
<tr><th>PROCEL Program</th><th colspan="2">Information</th></tr>
<tr><td>Characteristics</td><td colspan="2">A Government program implemented by Eletrobrás with several areas of activity. It promotes energy efficiency actions in various segments of the economy, which help the country to save electricity and which generate benefits for the entire society.</td></tr>
<tr><td>Goal</td><td colspan="2">To promote the efficient use of electric energy and to prevent energy wastage.</td></tr>
<tr><td>Mission</td><td colspan="2">To contribute to boosting the efficiency of goods and services, to the development of habits and knowledge about efficient energy consumption and, in addition, to postpone investments in the electricity sector while mitigating environmental impacts and collaborating for a more sustainable country.</td></tr>
<tr><td>Base-documents</td><td colspan="2">Law No. 13,280, of May 3, 2016; Law No. 9,991/2000</td></tr>
<tr><td rowspan="6">PROCEL’s Domains</td><td>Equipment</td><td>• Establishes consumption and performance ratings for each class of equipment.</td></tr>
<tr><td>Buildings</td><td>• Encourages conservation and efficient use of natural resources (water, electricity, ventilation, etc.) in Brazilian buildings, thereby reducing wastage and impacts on the environment.</td></tr>
<tr><td>Street lighting (Reluz)</td><td>• Supports the implementation of public lighting and traffic lighting projects.</td></tr>
<tr><td>Government authorities</td><td>• Development of solutions to combat electricity wastage.</td></tr>
<tr><td>Industry and retail trade</td><td>• Energy efficiency actions in this segment seek to reduce production costs, bolster profit margins and advance more competitive prices in the market.</td></tr>
<tr><td>Knowledge</td><td>• Awareness and dissemination of knowledge on the efficient consumption of electricity.</td></tr>
<tr><td>Instruments</td><td colspan="2">PROCEL Energy Savings Seal; Annual fund allocation plans established by law, which are drafted and approved following a public consultation process.</td></tr>
</table>

Source: Based on ELETROBRÁS, 2006.

### 5.2.14. 3E Project – Transformation of the Energy Efficiency Market in Brazil

The 3E Project is an initiative to foster better practices for the use of energy resources. Panel 5.19 shows the main characteristics of the 3E Project, and Panel 5.20 provides a brief description of training and awareness actions. Finally, Panel 5.21 provides information on energy efficiency actions adopted in the public sector.

*Panel 5.19. Key elements in the 3E Project – Transformation of the Energy Efficiency Market in Brazil*

| 3E Project | Information |
|---|---|
| Characteristics | Created in 2005 with approval by the Multilateral Fund for Implementation of the Montreal Protocol. |
| Goals | To strengthen the energy efficiency market in Brazil through capacity building; awareness-raising actions; promotion of energy efficiency in public buildings; and the Energy Efficiency Financing Guarantee Mechanism (EEGM). |
| Targets | To influence and develop the energy efficiency market in business and public buildings with in order to contribute to saving up to 106.7 TWh of electricity over the next 20 years and reduce greenhouse gas emissions by up to 3 million tons of dioxide of carbon.[19] |
| Components | (i) training and awareness; (ii) energy efficiency in the public sector; (iii) a demonstrative project for the integrated management of chillers; (iv) energy efficiency guarantee mechanism (EEGM); (v) project management; and (vi) monitoring and evaluation. |
| Institutional Arrangements | Cooperation between the of the Ministry of the Environment's Department of Climate Change Policies (DPMC), Secretariat for Climate Change and Forests (SMCF) and UNDP, and implemented with funds from GEF and the Inter-American Development Bank (IDB). |

Source: Based on MMA, 2017b.

*Panel 5.20. Training and awareness-raising actions implemented under the 3E Project*

| Training Actions | Information |
|---|---|
| Training on Labeling – PBE Edifica | Technical training[20] for the design, implementation and management of energy efficiency projects in buildings. The training sessions were held in 14 cities.[21] |
| Training on Measurement and Verification | There were four editions of the course for International Professional Certification in Measurement and Verification – CMVP Course[22]; and eight editions of the course on the |

[19] *The overall goal of the 3E Project was to achieve at least 35 projects implemented, thereby resulting in direct emission reductions of about 485,100 $tCO_2$ by 2020, and indirectly of about 2,910,600 $tCO_2$.*

[20] *From 2014 to 2017, 42 training sessions were conducted, including workshops and short, four-hour courses covering the public and private sectors. The target audience were technical personnel, including engineers and architects, and twenty-hour courses for managers and technical personnel.*

[21] *Belém, Belo-Horizonte, Brasília, Cuiabá, Curitiba, Florianópolis, Fortaleza, Maceió, Manaus, Porto Alegre, Recife, Rio de Janeiro, Salvador, and São Paulo.*

[22] *The CMVP Course covered the methodology of the International Measurement and Verification Protocol (IMVP) and used training materials from the Efficiency and Valuation Organization (EVO), a non-profit organization that manages the IMVP. This training*

| Training Actions | Information |
|---|---|
| | M&V Guide[23] for the Energy Efficiency Program (PEE) of the National Electric Energy Agency (ANEEL). |
| ProjetEEE – Designing Energy-Efficient Buildings | ProjetEEE is a public tool with a user-friendly interface. In addition to serving as educational aid to students of Architecture, this platform helps construction professionals to integrate the energy efficiency variable into their projects, especially through bioclimatic elements, thereby reducing energy requirements and ensuring users are comfortable inside buildings. |
| Market awareness | Components of technical training[24] and promotion of energy efficiency in the public sector. |

Source: Based on MMA, 2017b.

*Panel 5.21. Energy Efficiency Actions Implemented under the 3E Project*

| Energy efficiency actions | Description |
|---|---|
| Retrofit Project – Block B | Establishment of institutional arrangements for the development of energy efficiency projects in the public sector. An energy assessment of the current situation was conducted[25] and key opportunities for intervention and cost/benefit analysis were mapped to develop the executive project of the solutions incorporated in order to acquire the ENCE (National Energy Conservation Label) using the simulation method. |
| Benchmarking of Energy Consumption in Public Buildings | The purpose of this action[26] was (i) to contribute up to 880 thousand MWh of electricity savings over the next 20 years[27]; (ii) to understand the pattern of energy consumption and demand in buildings of various types, such as schools, hospitals, office buildings, shopping malls, etc. |

*course ran for a total of 24 hours spanning over 3 consecutive days, followed by an additional 4 hours for the CMVP certification exam, which was also included in the program. The CMVP Course is a prerequisite for the certification exam.*

[23] *The M&V Guide Course covered the measurement and verification procedures and rules required for the submission of projects to ANEEL's PEE public calls. This training course ran for a total of 24 hours spanning 3 consecutive days.*

[24] *Workshop "Funding Energy Efficiency in Buildings," where employees of financial institutions and Energy Conservation Service Companies (ESCOs) received training.*

[25] *Headquarters of the Ministry of the Environment (MMA) and Ministry of Culture (MinC), at Block B in the Esplanada dos Ministérios.*

[26] *This initiative is carried out in collaboration with Eletrobrás/Procel and the Brazilian Council for Sustainable Construction (CBCS).*

[27] *Resulting in a reduction of direct $CO_2$ emissions of 485,100 $tCO_2$ and indirect post projection emissions of 2,910,600 $tCO_2$.*

| Energy efficiency actions | Description |
|---|---|
| Performance Agreements | Performance Agreements[28] refer to investments[29] in equipment and engineering services raised by an ESCO[30] or an engineering company, which will be compensated through the financial benefits[31] obtained from the reduction in energy and water expenses by consumers. |
| Clean Development Mechanism (CDM) | Two CDM studies[32] were carried out under the 3E Project. The first study is intended to identify energy efficiency projects worldwide that sought these CDM incentives to become financially viable. The objective of the second study was to evaluate the technical and economic feasibility of an Activities Program (PoA) within the CDM that promotes the adoption of energy efficiency measures in public buildings at the municipal, state and federal levels. An evaluation of methodologies was also performed for energy efficiency CDM projects for application in public buildings. |

Source: Based on MMA, 2017b.

### 5.2.15. Brazilian Research Network on Global Climate Change (Rede CLIMA)

Rede CLIMA was established by the MCTI in 2007 and constitutes an important means of support for the research and development activities of the National Climate Change Plan to meet national needs for knowledge about climate change, including the production of information for public policy-making as described in Panel 5.22.

*Panel 5.22. Key elements in the Brazilian Research Network on Global Climate Change (Rede CLIMA)*

| Rede CLIMA | Information |
|---|---|
| Legal Framework | Directive No. 728, of November 2007; MCTI Directive No. 1,295, of December 16, 2013. |

[28] *These are also known as Performance Contracts.*

[29] *Compensation mechanism provided for in Law No. 11,079/2004 (PPP Act) and in the Differentiated Contracting Regime, instituted by Law No. 12,462/2011 (RDC Act), in response to Law No. 8,666/1993, which include performance as an element related to payment for the investments made.*

[30] *Energy Conservation Services Enterprise.*

[31] *This tool does not require large investments by the government to implement retrofits, while allowing the private sector to offer the best technology options with the best cost-benefit to the government.*

[32] *The development of projects under the UNFCCC Clean Development Mechanism (CDM) makes it possible to obtain financial incentives for investments in energy efficiency.*

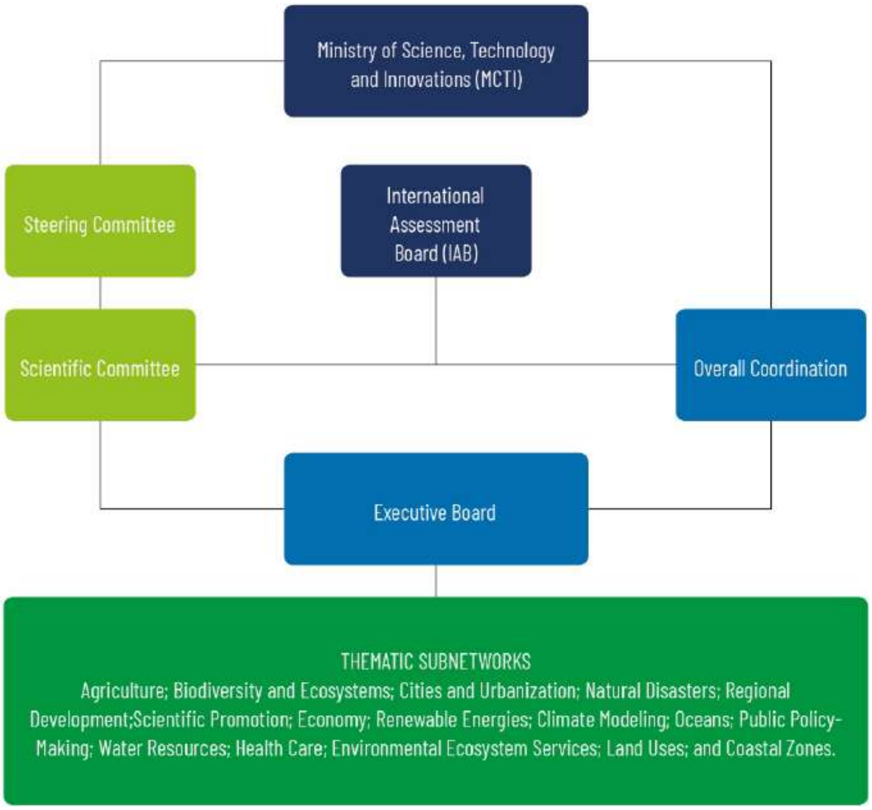
| Rede CLIMA | Information |
|---|---|
| Goals | (i) to generate and disseminate knowledge and technologies so that Brazil can respond to the challenges posed by the causes and effects of global climate change; (ii) to generate future global and regional climate change scenarios; (iii) to produce data and information needed to support Brazil's diplomacy in negotiations on the international climate change regime; (iv) to conduct studies on the impacts of global and regional climate change in Brazil, with an emphasis on the country's vulnerabilities to climate change; (v) to evaluate alternatives for adapting Brazil's social, economic and natural systems to climate change; (vi) to research the effects of changes in land use and social, economic and natural systems on Brazilian emissions of gases that contribute to global climate change; (vii) to contribute to the development and monitoring of public policies on global climate change within the Brazilian territory; (viii) to contribute to the design and implementation of a system for monitoring natural disaster warnings for the country; (ix) to carry out studies on greenhouse gas emissions in support of the regular implementation of national emission inventories; (x) to promote the integration of research carried out by Rede Clima's subnetworks from a multidisciplinary perspective; (xi) to contribute to the design and implementation of observational systems for detecting the impacts of climate change while attributing their causes and their effects on human and natural systems; and (xii) to support the Brazilian Panel on Climate Change. |
| Characteristics | To fulfill (i) national needs for scientific knowledge on Global Climate Change, and support Brazil's diplomacy in international negotiations on the issue; (ii) to carry out analyzes[33] on the state of knowledge of climate change in Brazil along the lines of the IPCC reports. |
| Structure | 16 thematic subnetworks: (i) agriculture; (ii) biodiversity; (ii) cities and urbanization; (iv) natural disasters; (v) regional development; (vi) scientific dissemination; (vii) economics; (viii) renewable energy; (ix) climate modeling; (x) oceans; (xi) public policies; (xii) water resources; (xiii) health; (xiv) environmental services of ecosystems; (xv) land uses; and (xvi) coastal areas. |
| Instruments | Integrative projects (IP)[34] intended to be the foundation of analyzes that take into account the cross-cutting nature of Climate Change; Social and Environmental Security IP; and Water, Food and Energy Security IP. |
| Base-documents | Directive No. 728, of November 20, 2007, as amended by Directives No. 262 of May 2, 2011 and No. 1,295, of December 16, 2013; Integrative projects regulated by MCTIC Directive No. 787, of September 3, 2015; and MCTIC Directive No. 1,295, of December 16, 2013. |

Source: Based on MCTIC, 2007; 2013; INPE, 2018a.

[33] *More specific sectoral approaches to support the development of national and international public policies.*

[34] *Integrative projects will focus on the São Francisco River Basin (BHSF), with a view to implementing BHSF revamping measures based on the transposition project while identifying the key role of the basin in adapting a vast region of the Northeast semiarid area and the incidence of several areas considered to be susceptible to desertification.*

Rede CLIMA is currently comprised of 16 thematic subnetworks led by a General Coordination with the support of a Steering Committee and assistance of a Scientific Committee and an Executive Secretariat as shown in Figure 5.6.




Source: Based on MCTIC, 2007; 2013.

*Figure 5.6. Institutional Arrangements for Rede CLIMA*

## 5.3. TECHNOLOGICAL, FINANCIAL AND TRAINING NEEDS RELATING TO ACHIEVING THE CONVENTION'S OBJECTIVES IN BRAZIL

International funding and cooperation from both bilateral and multilateral sources are fundamental elements for Brazil to continue to make progress regarding the actions to tackle the climate emergency. Training in activities aimed at fulfilling the objectives of the UNFCCC is also a priority, especially to ensure the systematization of data and the monitoring of the implementation of strategic mitigation and adaptation actions. Once these gaps and needs are addressed, it will be possible to expand the ambition in terms of actions aimed at mitigating and adapting to climate change in the country.

The need for support through the provision of funds for the periodic preparation of National Communications and Biennial Update Reports (BURs) in Brazil is emphasized, in particular to fulfill the commitments on the Transparency agenda. This helps hire key consultants and services to ensure the updating of information relevant to the reports, in particular, to prepare the national inventory of anthropogenic GHG emissions and removals and studies on impacts and vulnerability to climate change. Development of the Fourth National Communication (4NC) and three Biennial Update Reports of Brazil was supported by Project BRA/16/G31. This project relied on the donation of funds from the

Global Environment Facility (GEF), with an investment of USD 7,528,500, and (in-kind) matching contributions from the Federal Government and the United Nations Program for Development (UNDP), corresponding to USD 22,735,500 and USD 150,000, respectively.

With regard to funding intended to achieve technological development, support was obtained from the Green Climate Fund (GCF) for the implementation of the project "Assessment of Technological Needs for the Implementation of Climate Action Plans in Brazil (TNA_BRAZIL)." This initiative was implemented in a collaboration between the MCTI and UN Environment, and its purpose is to reach national consensus for the preparation of the Technological Action Plan, considering priority sectors and key technologies in order to achieve the mitigation goals in accordance with the NDC and Brazil's strategy for the GCF. It is, therefore, a relevant milestone for the development of local content in low-carbon technologies to fulfill the country's objectives under the Convention (BRASIL, 2018).

*See **item 4.1.11** for more information on TNA_BRAZIL.*

In view of the extent of Brazil and its socioeconomic and environmental diversity, the information presented below on technological, financial and training needs should be considered as non-exhaustive and not circumstantial. Hence, Panel 5.23 summarizes technical, capacity building and financial support needs in some areas of interest for further international cooperation, without prejudice to other areas to be covered that may further be identified.

*Panel 5.23. Constraints and gaps, and related financial, technical and capacity needs to the national climate agenda*

| Activity | Sector | Related NAMA | Gap | Constraint | Financial Needs | Capacity-Building Needs | Technology Transfer Needs |
|---|---|---|---|---|---|---|---|
| Measurement, reporting and verification of transformation and maintenance actions of resilient and sustainable production systems | Agriculture | ABC Plan | Lack of more detailed on-site data and of images for measurement and validation of efforts and results. | Vast territory for verification and validation coverage, and limited resources for the acquisition of supplies and travel throughout the national territory | Financial resources for acquisition or access to images and field trips for measurement and validation of interpretations | NA | NA |
| Measurement, reporting and verification of transformation and maintenance actions of resilient and sustainable production systems | Agriculture | ABC Plan | Lack of a participatory and integrated system to feed the monitoring system and fluid processes for data input and information output | Highly diverse systems and stakeholders involved in the various States, and dynamic evolution of actions and knowledge, which require an easily accessible, transparent and consistent system, and limited resources for hiring domestic experts in data storage and organization systems, with fluid processes for data input and information output | Financial resources for hiring staff necessary for the development and structuring of a participatory and integrated feeding system for the monitoring system | | |
| Measurement, reporting and verification of transformation and maintenance actions of resilient and sustainable production systems | Agriculture | ABC Plan | Absence of a participatory process and an integrated system for validation and verification of results by experts for monitoring and analysis purposes | Diverse stakeholders involved in the various States, and dynamic evolution of activities, technologies and knowledge, as well as differences in the behavior of technologies and systems in the various | Financial resources for the development and implementation of an integrated system and a participatory process for validating the results of analyzes | | |

| Activity | Sector | Related NAMA | Gap | Constraint | Financial Needs | Capacity-Building Needs | Technology Transfer Needs |
|---|---|---|---|---|---|---|---|
| | | | | biomes, and limited resources for hiring domestic experts and travel of stakeholders for consultations, verification, discussion, and data validation. | | | |
| Measurement, reporting and verification of transformation and maintenance actions of resilient and sustainable production systems | Agriculture | ABC Plan | Limited harmonized preliminary information for the development of a national traceability and certification system | Diverse data and institutions, as well as strategies to ensure the necessary transparency and reliability of a national traceability and certification system, and Limited resources for hiring domestic experts and conducting preliminary studies for a traceability and certification system | Financial resources for establishing an effective traceability and certification system | Training of experts on traceability and certification systems | |
| Improve the capacity of technical and financial assistance agents | Agriculture | ABC Plan | Knowledge gap in relation to best practices and technologies, and systems that are appropriate to the various biomes | Limited resources to promote the necessary training, consolidation and dissemination of knowledge, taking into consideration the diversity of stakeholders involved in the various States, the dynamic evolution of activities, technologies and knowledge as well as differences in behavior of technologies and systems | Financial resources to develop Infrastructure and studies, purchase equipment and promote capacity-building | Support to professional training and dissemination of knowledge | |

| Activity | Sector | Related NAMA | Gap | Constraint | Financial Needs | Capacity-Building Needs | Technology Transfer Needs |
|---|---|---|---|---|---|---|---|
| | | | | in different Brazilian biomes. | | | |
| Technology research and development | Agriculture | ABC Plan | Increased complexity and uncertainty due to climate change, need for new research in the biological and agricultural domains, statistics and data interpretation, and alternative and innovative solutions | Limited resources for data collection, studies and technological development | Financial resources for infrastructure, equipment and studies | Exchange of knowledge and technologies | Exchange of knowledge and technologies |
| Cooperation between the Federal Government and state governments to improve forest management | LULUCF | PPCDAm and PPCerrado | Shortfalls in the integration of systems for granting vegetation suppression licenses across the various levels of government | Limited resources, including budgetary constraints | Financial resources for technical and institutional cooperation | Awareness of the importance of the initiative for the country's reputation and the development of public policies to combat illegal practices and the promotion of legal compliance | NA |
| Strengthening of forest fire prevention and control actions | LULUCF | PPCDAm e PPCerrado | Techniques related to integrated fire management are | Limited resources, including budgetary constraints | Financial resources for the dissemination of techniques for the control and prevention of forest fires | Training on integrated fire management | NA |

| Activity | Sector | Related NAMA | Gap | Constraint | Financial Needs | Capacity-Building Needs | Technology Transfer Needs |
|---|---|---|---|---|---|---|---|
| | | | not yet widely disseminated. | | | | |
| Promotion of the bioeconomy and payment for environmental services | LULUCF | PPCDAm e PPCerrado | Enabling business environment and absence of legal certainty | Lack of recognition of the importance of the contribution of market mechanisms | NA | Management of quick, efficient and user-oriented administrative processes | Exchange of technologies for process management |
| Design and implementation of new pilot projects in regions that are not covered by the current project | LULUCF and Industry | Sustainable steel industry | Scarce sources of financing for new pilot projects | Limited financial resources | Financial resources for the design and implementation of new pilot projects | Training of stakeholders in regions that are not covered by the current project | Technology transfer to stakeholders in regions that are not covered by the current project |
| Expansion of the results-based payment mechanism for companies that are not covered by the current project | LULUCF and Industry | Sustainable steel industry | Scarce sources of financing for the extension of the results-based payment mechanism for companies that are not covered by the current project | Limited financial resources | Financial resources for the extension of results-based payment mechanism for companies that are not covered by the current project | Training of stakeholders that are not covered by the current project (e.g. MRV methodology, MRV platform) | NA |
| Promotion of gains of scale of the pilot project | LULUCF and Industry | Sustainable steel industry | Scarce sources of financing for gains of scale of the current pilot project | Limited financial resources | Financial resources to promote gains of scale of the current pilot project | Training of stakeholders who are not currently covered by the pilot project | Technology transfer to stakeholders who are not currently covered by the pilot project |
| Training to broaden the insertion of non-conventional renewable sources in the national energy mix | Energy | Alternative energy sources | Need for consolidating and disseminating technologies for energy exploration by concentrated solar thermal plants | Limited resources for consolidation and dissemination of knowledge | Financial resources for the technological development, consolidation and dissemination of knowledge in concentrated solar thermal plants | Support to professional training and dissemination of knowledge on concentrated solar thermal sources, including seminars, workshops, exchange | Cooperation for technological development in concentrated solar thermal sources |

| Activity | Sector | Related NAMA | Gap | Constraint | Financial Needs | Capacity-Building Needs | Technology Transfer Needs |
|---|---|---|---|---|---|---|---|
| | | | | | | of experiences on the topic | |
| Training to broaden the insertion of energy storage technologies | Energy | Alternative energy sources | Needs related to consolidation and dissemination of energy storage technologies | Limited resources for consolidation and dissemination of knowledge | Financial resources for the technological development, consolidation and dissemination of knowledge on energy storage | Support to professional training and dissemination of knowledge on energy storage, including seminars, workshops, exchange of experiences on the topic | Cooperation for technological development in energy storage |
| Training to promote the consolidation of Monitoring, Reporting and Verification systems (MRV) of energy efficiency programs | Energy | Energy efficiency | Shortfalls in the Monitoring, Reporting and Verification processes of energy efficiency programs | Limited resources for consolidation and dissemination of knowledge | Financial resources for the development and dissemination of methodologies and procedures for the MRV of energy efficiency programs | Support to professional training and dissemination of knowledge on MRV related to energy efficiency, including seminars, workshops, exchange of experiences on the topic. | Cooperation for the development and dissemination of methodologies and procedures for the MRV of energy efficiency programs |
| Quantification of greenhouse gas emission reductions by production chain | Agriculture, Energy, LULUCF, and Industry | All | Methodological difficulties in quantifying emissions reductions by production chain | Lack of awareness of the importance of generating information on emissions/removals by economic activity | NA | Development, implementation and dissemination of methodologies | Methodologies and technologies for quantifying emission reductions by production chains |
| Encouragement to technology research and development | Agriculture, Waste, Energy, | NA | Lack of information and data on activities, and shortfalls persist in | Limited resources for technology research and development for climate sciences | Financial resources for infrastructure, equipment and encouragement of studies and | Exchanges, webinars, international exchange of experiences and training on how to | Exchange of technologies and knowledge |

| Activity | Sector | Related NAMA | Gap | Constraint | Financial Needs | Capacity-Building Needs | Technology Transfer Needs |
|---|---|---|---|---|---|---|---|
| | LULUCF, and Industry | | the scientific and technical production based on the country's reality | | research projects on climate change | transfer technologies and knowledge | |
| Improvement of the emission monitoring, reporting and verification system | Agriculture, Waste, Energy, LULUCF, and Industry | NA | Poor systematization, organization and availability of official information | Absence of a legal framework establishing responsibilities and operation of a national system for the country's national emissions inventory | Financial resources for infrastructure and agencies responsible for systematizing the information | Training on how to structure and assure information for the proper monitoring, reporting and verification of emissions | Exchange of technologies and knowledge |
| Strengthening of existing institutional arrangements through training and information generation via climate and economic modeling | Agriculture, Waste, Energy, LULUCF, and Industry | NA | Lack of an official information center to inform the climate change decision-making process | Limited resources to structure collaborative modeling of transparency | Financial resources to support the structuring of a platform, for infrastructure,,encouragement of studies and research projects to inform a long-term climate change strategy | Exchanges, webinars, international exchange of experiences on information modeling and networking to support the decision-making process | Exchange of technologies and knowledge |

Caption: NA – Not applicable.

### 5.3.1. Cooperation to Obtain Resources and Conduct Training Activities

Brazil was the first country to sign the United Nations Framework Convention on Climate Change at the Rio Summit and so a set of regulatory frameworks and management instruments was created. In order to respond to the vast and diversified scope of Brazilian mitigation and adaptation initiatives, the Government developed a governance structure that adopts a cross-cutting approach to climate change by aggregating the collective and coordinated production of various ministries and government agencies, including the actions that have been taken undertaken by the subnational governance levels in the states (BRASIL, 2016).

As such, Brazil set its national priorities and presented its strategy for engagement to the GCF to obtain funds to finance projects and programs. Under the coordination of the Ministry of Economy (ME), the Designated National Authority (DNA) of Brazil with the GCF, the Country Program document (BRASIL, 2018) was prepared. The document discusses opportunities for the preparation of funding proposals under the GCF, which not only meet the Fund's criteria, but are also consistent with national priorities, are economically viable and result in transformational impact.

Therefore, it is noted that public funds committed to Brazilian entities are obtained through multilateral institutions and bilateral channels (Parties included in Annex II of the Convention), with concessional loans and grants as the main funding instruments (BRASIL, 2014; 2017; 2019). From 1996 to 2006, the main source of funds for climate issues at the Federal Government level was the GEF. As of 2008, the number of actors responsible for the funding support provided to Brazil to tackle Climate Change was expanded. These included primarily the Inter-American Development Bank (IDB); GEF; World Bank (IBRD) and its arm for the private sector, the International Finance Corporation (IFC); New Development Bank (NDB); bilateral cooperation with Norway and Germany; Development Bank of Latin America (CAF); European Investment Bank (EIB); French Development Agency (AFD); German Development Bank (KfW); Japanese Bank for International Cooperation (JBIC); and the Plata Basin Financial Development Fund (FONPLATA) (BRASIL, 2014; 2017; 2019).

The allocation of funds to Brazil in 1996-2017 was over USD 6 billion, 53% of which came from multilateral channels and 47% came from bilateral channels (Table 5.1). Compared to 2008-2013, in 2014-2015 there was a significant increase in the funding received, in excess of USD 3 billion (BRASIL, 2014; 2017). However, in 2016-2017, there was a 12% reduction in relation to the support received in the previous biennium (BRASIL, 2019), with a noticeable reduction in the amounts contributed by the cooperating countries and entities also in the 2018-2019 period.

The contribution of resources to Brazil in 2018-2019 totaled approximately USD 1.874 billion, with less than 6% allocated through bilateral channels. There was a decrease in relation to the bilateral support received in previous biennia, from more than USD 437 million in 2016-2017 to about USD 100 million in 2018-2019. It should also be noted that the multilateral contributions for 2018 and 2019 did not reach 50% of contributions in 2017.

In view of the importance of international financing in catalyzing climate change action, Brazil has stressed the need for the financial contribution to be adequate, predictable, sustainable, new, and additional. In recalling the commitment of developed countries to commit USD 100 billion per year by 2020, Brazil stresses that the current status of implementation of the commitment is not clear.

*Table 5.1. Total support received by channel in 1996-2019 in Brazil*

| Channel | Support received in USD by period[35] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1996-2006 | 2008-2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
| Bilateral | 0.00 | 798,475,938 | 1,200,260,168 | 732,124,302 | 127,267,510 | 309,864,549 | 88,343,535 | 12,370,477 |
| Multilateral | 36,923,000 | 134,319,773 | 1,034,560,000 | 119,718,000 | 150,328,879 | 2,117,314,233 | 887,521,190 | 885,321,147 |
| Total | **36,923,000** | **932,795,711** | **2,234,820,168** | **851,842,302** | **277,596,389** | **2,427,178,782** | **975,864,725** | **897,691,624** |

Source: Based on Brasil (2014; 2017; 2019).

[35] *All amounts are in US dollars. When data was available in a currency other than the US dollar, the conversion rate used was based on that of the OECD annual exchange rate for the project commitment year. Available in Portuguese at: <https://data.oecd.org/conversion/exchange-rates.htm>*

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# APPENDIX

# APPENDIX I – TIME SERIES OF GREENHOUSE GAS EMISSIONS BY GAS AND BY SECTOR, 1990 TO 2016

## Results of the Fourth National Inventory — Year 1990

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **1,093,435** | **14,354.3** | **357.52** | **1,407** | **2,207** | **267** | **35,599** | **1,954** | **3,479** |
| **1** | **Energy** | **177,046** | **543.3** | **14.04** | - | - | - | **9,001** | **1,445** | **1,696** |
| **1.A** | **Fuel Combustion Activities** | 170,855 | 449.9 | 13.99 | - | - | - | 9,001 | 1,445 | 1,696 |
| **1.A.1** | **Energy Industries** | 23,706 | 24.9 | 3.42 | - | - | - | 1,372 | 221 | 338 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 6,248 | 0.1 | 0.05 | - | - | - | 3 | 53 | 1 |
| 1.A.1.b | Petroleum Refining | 11,968 | 0.2 | 0.08 | - | - | - | 8 | 92 | 1 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 5,490 | 24.6 | 3.29 | - | - | - | 1,361 | 76 | 336 |
| **1.A.2** | **Manufacturing Industries and Construction** | 36,470 | 16.3 | 2.66 | - | - | - | 788 | 140 | 32 |
| 1.A.2.a | Iron and Steel | 4,725 | 0.2 | 0.03 | - | - | - | 3 | 11 | 1 |
| 1.A.2.b | Non-ferrous Metals | 1,374 | 0.1 | 0.02 | - | - | - | 4 | 3 | 0 |
| 1.A.2.c | Chemicals | 8,932 | 0.8 | 0.12 | - | - | - | 30 | 28 | 2 |
| 1.A.2.d | Pulp, Paper and Print | 2,551 | 1.1 | 0.43 | - | - | - | 255 | 17 | 8 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 3,273 | 7.3 | 1.38 | - | - | - | 211 | 31 | 9 |
| 1.A.2.f | Non-metallic Minerals | 7,543 | 5.3 | 0.41 | - | - | - | 199 | 26 | 6 |
| 1.A.2.g | Transport Equipment | 4,012 | 0.9 | 0.19 | - | - | - | 63 | 13 | 3 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 2,440 | 0.4 | 0.03 | - | - | - | 10 | 7 | 1 |
| 1.A.2.l | Textile and Leather | 1,620 | 0.2 | 0.05 | - | - | - | 14 | 4 | 1 |
| **1.A.3** | **Transport** | 82,338 | 67.3 | 3.67 | - | - | - | 5,307 | 926 | 1,069 |
| 1.A.3.a.ii | Domestic Aviation | 5,151 | 0.0 | 0.14 | - | - | - | 4 | 5 | 1 |
| 1.A.3.b | Road Transportation | 72,062 | 66.9 | 2.81 | - | - | - | 5,289 | 806 | 1,063 |
| 1.A.3.c | Railways | 1,642 | 0.1 | 0.63 | - | - | - | 6 | 27 | 2 |
| 1.A.3.d.ii | Domestic Navigation | 3,484 | 0.3 | 0.09 | - | - | - | 8 | 88 | 3 |
| 1.A.3.e | Other Transportation | - | - | - | - | - | - | - | - | - |
| **1.A.4** | **Other Sectors** | 26,728 | 341.4 | 4.22 | - | - | - | 1,534 | 155 | 258 |
| 1.A.4.a | Commercial / Institutional | 2,611 | 3.8 | 0.05 | - | - | - | 5 | 7 | 3 |
| 1.A.4.b | Residential | 13,964 | 318.2 | 3.29 | - | - | - | 1,443 | 29 | 216 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 10,154 | 19.3 | 0.88 | - | - | - | 87 | 119 | 38 |
| **1.A.5** | **Non-Specified** | 1,612 | 0.1 | 0.02 | - | - | - | 1 | 2 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 6,191 | 93.4 | 0.06 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 51.9 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 6,191 | 41.5 | 0.06 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **45,192** | **42.9** | **11.55** | **1,407** | **2,207** | **267** | **1,096** | **27** | **1,783** |
| **2.A** | **Mineral Industry** | 15,171 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 11,062 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 3,502 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 145 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 462 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 3,875 | 5.3 | 10.81 | 1,407 | - | - | 1 | 1 | 26 |
| 2.B.1 | Ammonia Production | 286 | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 1.81 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 8.63 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | 0.38 | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 0 | NO | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 3,589 | 5.3 | - | - | - | - | - | 0 | 7 |
| 2.B.9 | Fluorochemicals Production | - | - | - | 1,407 | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.B.10 | Other Chemicals | NO | - | - | - | - | - | - | - | 19 |
| **2.C** | **Metal Industry** | 25,625 | 37.6 | 0.74 | - | 2,207 | 138 | 1,076 | 20 | 18 |
| 2.C.1 | Iron and Steel Production | 23,724 | 37.4 | 0.74 | - | - | - | 731 | 18 | 18 |
| 2.C.2 | Ferroalloy Production | 122 | 0.2 | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 1,574 | - | - | - | 2,207 | - | 345 | 2 | - |
| 2.C.4 | Magnesium Production | 29 | - | - | - | - | 138 | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | 176 | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 520 | - | - | - | - | - | - | - | 1,441 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | NE/NO | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 130 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 20 | 5 | 297 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 20 | 5 | 13 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 284 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 113 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 170 |
| **3** | **Agriculture** | **9,771** | **11,102.7** | **279.30** | **-** | **-** | **-** | **1,682** | **61** | **-** |
| **3.A** | **Enteric Fermentation** | - | 10,178.2 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 9,763.3 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 7,991.4 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 1,771.9 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 100.2 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 33.7 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 281.0 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 553.7 | 8.73 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 248.4 | 3.15 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 185.6 | 0.26 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 62.8 | 2.89 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 3.4 | NO | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 269.0 | 1.28 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 32.9 | 0.34 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 3.96 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 1.20 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 0.18 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 1.01 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 1.15 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | NO | 1.61 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 331.1 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 267.78 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 208.98 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 11.73 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 8.06 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 135.21 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 121.23 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 87.61 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 33.62 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 2.95 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 11.03 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 45.66 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 5.73 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 4.32 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 2.05 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 1.28 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 0.92 | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.vi | Manioc | - | - | 0.99 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 0.46 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 28.85 | - | - | - | - | - | - |
| 3.D.1.d.ix | Other annual crops | - | - | 1.07 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 2.90 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 5.42 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 58.80 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 22.42 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 2.44 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 1.51 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 18.47 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 16.16 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 11.68 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 4.48 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.29 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 2.01 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 36.37 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 2.76 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 1.91 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 20.78 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 18.19 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.33 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 2.26 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 10.27 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 1.29 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 0.97 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 0.46 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.29 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.21 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.22 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.10 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 6.49 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.24 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 0.65 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 39.6 | 2.79 | - | - | - | 1,682 | 61 | - |
| **3.G** | **Liming** | 9,141 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 631 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | - | - | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **860,893** | **1,520.1** | **47.43** | **-** | **-** | **-** | **23,819** | **422** | **-** |
| **4.A** | **Forest Land** | -46,138 | 68.4 | 2.04 | - | - | - | 1,052 | 17 | - |
| 4.A.1 | Forest Land remaining Forest Land | -22,641 | 68.0 | 2.00 | - | - | - | 1,039 | 16 | - |
| 4.A.2 | Land converted to Forest Land | -23,497 | 0.4 | 0.04 | - | - | - | 12 | 1 | - |
| **4.B** | **Cropland** | 75,950 | 92.3 | 3.47 | - | - | - | 1,571 | 40 | - |
| 4.B.1 | Cropland remaining Cropland | NE | IE | IE | - | - | - | IE | IE | IE |
| 4.B.2 | Land converted to Cropland | 75,950 | 92.3 | 3.47 | - | - | - | 1,571 | 40 | - |
| **4.C** | **Grassland** | 828,009 | 1,345.6 | 41.50 | - | - | - | 20,983 | 362 | - |
| 4.C.1 | Grassland remaining Grassland | 15,890 | 31.0 | 2.83 | - | - | - | 877 | 53 | NE |
| 4.C.2 | Land converted to Grassland | 812,119 | 1,314.6 | 38.67 | - | - | - | 20,106 | 309 | - |
| **4.D** | **Wetlands** | 6,158 | 7.5 | 0.22 | - | - | - | 115 | 2 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 6,158 | 7.5 | 0.22 | - | - | - | 115 | 2 | - |
| **4.E** | **Settlements** | 6,711 | 4.9 | 0.15 | - | - | - | 77 | 1 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.E.2 | Land converted to Settlements | 6,711 | 4.9 | 0.15 | - | - | - | 77 | 1 | - |
| **4.F** | **Other Land** | 1,226 | 1.4 | 0.04 | - | - | - | 21 | 0 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |
| 4.F.2 | Land converted to Other Land | 1,226 | 1.4 | 0.04 | - | - | - | 21 | 0 | - |
| **4.G** | **Harvested Wood Products** | -11,025 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **533** | **1,145.2** | **5.20** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 522.8 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 181.3 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 341.5 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 0.5 | 0.03 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 533 | 19.1 | 0.30 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 602.9 | 4.87 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 541.9 | 4.87 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 61.0 | - | - | - | - | - | - | - |
| **5.E** | **Other** | NO | NO | NO | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 3,228 | 1.8 | 1.79 | - | - | - | 2 | 2 | 2 |
| 1.A.3.a.i | Aviation | 1,475 | 0.0 | 0.04 | - | - | - | 0 | 0 | 0 |
| 1.A.3.d.i | Navigation | 1,753 | 1.8 | 1.75 | - | - | - | 2 | 2 | 2 |
| | **$CO_2$ emissions from biomass** | 165,951 | | | | | | | | |

Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

## Results of the Fourth National Inventory — Year 1991

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **923,867** | **14,616.5** | **360.70** | **1,609** | **2,455** | **263** | **33,017** | **1,966** | **3,257** |
| **1** | **Energy** | **180,564** | **545.7** | **14.04** | - | - | - | **9,164** | **1,501** | **1,704** |
| **1.A** | **Fuel Combustion Activities** | 174,530 | 448.4 | 13.98 | - | - | - | 9,164 | 1,501 | 1,704 |
| **1.A.1** | **Energy Industries** | 21,893 | 23.9 | 3.29 | - | - | - | 1,275 | 231 | 300 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 7,161 | 0.1 | 0.05 | - | - | - | 3 | 60 | 1 |
| 1.A.1.b | Petroleum Refining | 10,039 | 0.2 | 0.07 | - | - | - | 8 | 91 | 1 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 4,693 | 23.6 | 3.16 | - | - | - | 1,264 | 80 | 298 |
| **1.A.2** | **Manufacturing Industries and Construction** | 38,428 | 15.5 | 2.65 | - | - | - | 781 | 145 | 31 |
| 1.A.2.a | Iron and Steel | 4,946 | 0.2 | 0.03 | - | - | - | 3 | 12 | 1 |
| 1.A.2.b | Non-ferrous Metals | 1,330 | 0.1 | 0.02 | - | - | - | 3 | 3 | 0 |
| 1.A.2.c | Chemicals | 9,560 | 0.8 | 0.12 | - | - | - | 28 | 29 | 2 |
| 1.A.2.d | Pulp, Paper and Print | 2,822 | 1.2 | 0.43 | - | - | - | 268 | 18 | 8 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 3,283 | 7.4 | 1.40 | - | - | - | 216 | 32 | 10 |
| 1.A.2.f | Non-metallic Minerals | 8,430 | 4.4 | 0.40 | - | - | - | 178 | 29 | 6 |
| 1.A.2.g | Transport Equipment | 4,092 | 0.9 | 0.19 | - | - | - | 62 | 13 | 3 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 2,415 | 0.4 | 0.03 | - | - | - | 11 | 7 | 1 |
| 1.A.2.l | Textile and Leather | 1,549 | 0.2 | 0.05 | - | - | - | 13 | 3 | 1 |
| **1.A.3** | **Transport** | 86,105 | 70.8 | 3.80 | - | - | - | 5,583 | 964 | 1,117 |
| 1.A.3.a.ii | Domestic Aviation | 5,390 | 0.0 | 0.15 | - | - | - | 4 | 5 | 1 |
| 1.A.3.b | Road Transportation | 75,747 | 70.4 | 2.94 | - | - | - | 5,565 | 848 | 1,111 |
| 1.A.3.c | Railways | 1,630 | 0.1 | 0.63 | - | - | - | 6 | 27 | 2 |
| 1.A.3.d.ii | Domestic Navigation | 3,337 | 0.3 | 0.09 | - | - | - | 8 | 85 | 3 |
| 1.A.3.e | Other Transportation | - | - | - | - | - | - | - | - | - |
| **1.A.4** | **Other Sectors** | 27,366 | 338.2 | 4.22 | - | - | - | 1,524 | 159 | 256 |
| 1.A.4.a | Commercial / Institutional | 2,479 | 3.8 | 0.05 | - | - | - | 5 | 6 | 3 |
| 1.A.4.b | Residential | 14,345 | 316.7 | 3.28 | - | - | - | 1,433 | 29 | 215 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 10,542 | 17.7 | 0.89 | - | - | - | 87 | 124 | 38 |
| **1.A.5** | **Non-Specified** | 739 | 0.0 | 0.02 | - | - | - | 1 | 1 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 6,034 | 97.3 | 0.06 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 56.4 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 6,034 | 40.9 | 0.06 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **48,834** | **37.1** | **14.23** | **1,609** | **2,455** | **263** | **1,085** | **25** | **1,553** |
| **2.A** | **Mineral Industry** | 15,980 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 11,776 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 3,566 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 145 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 494 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 3,690 | 5.2 | 13.60 | 1,609 | - | - | 1 | 1 | 21 |
| 2.B.1 | Ammonia Production | 251 | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 1.93 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 11.25 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | 0.42 | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 0 | - | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 3,439 | 5.2 | - | - | - | - | - | 0 | 6 |
| 2.B.9 | Fluorochemicals Production | - | - | - | 1,609 | - | - | - | - | - |
| 2.B.10 | Other Chemicals | NO | - | - | - | - | - | - | - | 16 |
| **2.C** | **Metal Industry** | 28,652 | 31.9 | 0.62 | - | 2,455 | 139 | 1,062 | 18 | 15 |
| 2.C.1 | Iron and Steel Production | 26,596 | 31.7 | 0.62 | - | - | - | 616 | 15 | 15 |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.C.2 | Ferroalloy Production | 125 | 0.2 | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 1,901 | - | - | - | 2,455 | - | 446 | 2 | - |
| 2.C.4 | Magnesium Production | 30 | - | - | - | - | 139 | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | - | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 512 | - | - | - | - | - | - | - | 1,220 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | NE/NO | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 124 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 23 | 6 | 296 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 23 | 6 | 15 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 282 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 118 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 164 |
| **3** | **Agriculture** | **9,328** | **11,470.7** | **284.96** | **-** | **-** | **-** | **1,659** | **60** | **-** |
| **3.A** | **Enteric Fermentation** | - | 10,498.8 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 10,078.0 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 8,230.9 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 1,847.1 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 100.6 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 34.3 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 285.9 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 572.6 | 9.14 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 257.1 | 3.25 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 191.5 | 0.27 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 65.6 | 2.98 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 3.4 | - | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 277.7 | 1.31 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 34.4 | 0.38 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 4.20 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 1.23 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 0.19 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 1.04 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 1.18 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | NO | 1.78 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 360.3 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 273.06 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 213.00 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 11.68 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 8.26 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 139.44 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 125.30 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 90.23 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 35.06 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 2.96 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 11.19 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 45.26 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 4.30 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 4.78 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 2.04 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 1.63 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 1.13 | - | - | - | - | - | - |
| 3.D.1.d.vi | Manioc | - | - | 0.99 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 0.44 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 28.85 | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.ix | Other annual crops | - | - | 1.10 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 2.90 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 5.45 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 60.06 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 23.09 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 2.49 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 1.56 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 19.04 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 16.71 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 12.03 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 4.68 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.30 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 2.04 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 36.98 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 2.76 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 1.96 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 21.42 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 18.79 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.33 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 2.29 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 10.18 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 0.97 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 1.07 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 0.46 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.37 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.25 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.22 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.10 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 6.49 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.25 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 0.65 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 39.0 | 2.76 | - | - | - | 1,659 | 60 | - |
| **3.G** | **Liming** | 8,673 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 655 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | | | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **684,597** | **1,343.2** | **42.21** | - | - | - | **21,109** | **380** | - |
| **4.A** | **Forest Land** | -68,871 | 57.6 | 1.72 | - | - | - | 886 | 14 | - |
| 4.A.1 | Forest Land remaining Forest Land | -44,533 | 57.1 | 1.68 | - | - | - | 874 | 13 | - |
| 4.A.2 | Land converted to Forest Land | -24,339 | 0.4 | 0.04 | - | - | - | 12 | 1 | - |
| **4.B** | **Cropland** | 73,183 | 91.0 | 3.44 | - | - | - | 1,552 | 39 | - |
| 4.B.1 | Cropland remaining Cropland | - | - | - | - | - | - | - | - | - |
| 4.B.2 | Land converted to Cropland | 73,183 | 91.0 | 3.44 | - | - | - | 1,552 | 39 | - |
| **4.C** | **Grassland** | 681,831 | 1,181.2 | 36.63 | - | - | - | 18,462 | 323 | - |
| 4.C.1 | Grassland remaining Grassland | 13,384 | 30.6 | 2.79 | - | - | - | 865 | 52 | - |
| 4.C.2 | Land converted to Grassland | 668,447 | 1,150.6 | 33.84 | - | - | - | 17,597 | 271 | - |
| **4.D** | **Wetlands** | 6,056 | 7.6 | 0.23 | - | - | - | 116 | 2 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 6,056 | 7.6 | 0.23 | - | - | - | 116 | 2 | - |
| **4.E** | **Settlements** | 6,441 | 4.8 | 0.15 | - | - | - | 75 | 1 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |
| 4.E.2 | Land converted to Settlements | 6,441 | 4.8 | 0.15 | - | - | - | 75 | 1 | - |
| **4.F** | **Other Land** | 1,069 | 1.2 | 0.04 | - | - | - | 18 | 0 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.F.2 | Land converted to Other Land | 1,069 | 1.2 | 0.04 | - | - | - | 18 | 0 | - |
| **4.G** | **Harvested Wood Products** | -15,112 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **544** | **1,219.7** | **5.26** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 582.4 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 212.2 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 370.2 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 0.5 | 0.03 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 544 | 18.1 | 0.28 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 618.6 | 4.95 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 554.3 | 4.95 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 64.3 | - | - | - | - | - | - | - |
| **5.E** | **Other** | NO | NO | NO | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 4,023 | 2.5 | 2.52 | - | - | - | 3 | 3 | 3 |
| 1.A.3.a.i | Aviation | 1,550 | 0.0 | 0.04 | - | - | - | 0 | 0 | 0 |
| 1.A.3.d.i | Navigation | 2,473 | 2.5 | 2.47 | - | - | - | 2 | 2 | 2 |
| | **$CO_2$ emissions from biomass** | 166,366 | | | | | | | | |

Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

## Results of the Fourth National Inventory — Year 1992

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **1,031,526** | **15,062.5** | **375.36** | **1,914** | **2,603** | **291** | **36,400** | **2,064** | **3,278** |
| **1** | **Energy** | **186,066** | **530.8** | **13.93** | - | - | - | **8,879** | **1,539** | **1,640** |
| **1.A** | **Fuel Combustion Activities** | 179,832 | 442.9 | 13.87 | - | - | - | 8,879 | 1,539 | 1,640 |
| **1.A.1** | **Energy Industries** | 23,753 | 22.6 | 3.11 | - | - | - | 1,201 | 249 | 276 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 7,821 | 0.1 | 0.06 | - | - | - | 4 | 66 | 1 |
| 1.A.1.b | Petroleum Refining | 10,247 | 0.2 | 0.07 | - | - | - | 9 | 100 | 1 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 5,685 | 22.3 | 2.98 | - | - | - | 1,188 | 82 | 274 |
| **1.A.2** | **Manufacturing Industries and Construction** | 39,897 | 15.8 | 2.69 | - | - | - | 750 | 150 | 30 |
| 1.A.2.a | Iron and Steel | 5,449 | 0.2 | 0.04 | - | - | - | 3 | 13 | 1 |
| 1.A.2.b | Non-ferrous Metals | 1,438 | 0.1 | 0.02 | - | - | - | 3 | 3 | 0 |
| 1.A.2.c | Chemicals | 10,356 | 0.8 | 0.11 | - | - | - | 24 | 30 | 2 |
| 1.A.2.d | Pulp, Paper and Print | 3,334 | 1.3 | 0.48 | - | - | - | 315 | 21 | 9 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 3,586 | 8.3 | 1.48 | - | - | - | 183 | 34 | 9 |
| 1.A.2.f | Non-metallic Minerals | 7,460 | 3.8 | 0.35 | - | - | - | 156 | 25 | 5 |
| 1.A.2.g | Transport Equipment | 4,044 | 0.7 | 0.15 | - | - | - | 47 | 13 | 2 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 2,678 | 0.4 | 0.03 | - | - | - | 10 | 7 | 1 |
| 1.A.2.l | Textile and Leather | 1,552 | 0.1 | 0.04 | - | - | - | 9 | 3 | 0 |
| **1.A.3** | **Transport** | 86,863 | 68.9 | 3.82 | - | - | - | 5,413 | 975 | 1,081 |
| 1.A.3.a.ii | Domestic Aviation | 5,067 | 0.0 | 0.14 | - | - | - | 4 | 5 | 1 |
| 1.A.3.b | Road Transportation | 76,624 | 68.5 | 2.95 | - | - | - | 5,395 | 854 | 1,075 |
| 1.A.3.c | Railways | 1,674 | 0.1 | 0.65 | - | - | - | 6 | 28 | 2 |
| 1.A.3.d.ii | Domestic Navigation | 3,498 | 0.3 | 0.09 | - | - | - | 8 | 89 | 3 |
| 1.A.3.e | Other Transportation | - | - | - | - | - | - | - | - | - |
| **1.A.4** | **Other Sectors** | 28,198 | 335.6 | 4.22 | - | - | - | 1,515 | 162 | 253 |
| 1.A.4.a | Commercial / Institutional | 2,506 | 3.8 | 0.05 | - | - | - | 5 | 6 | 3 |
| 1.A.4.b | Residential | 14,846 | 316.8 | 3.29 | - | - | - | 1,427 | 30 | 214 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 10,846 | 15.1 | 0.88 | - | - | - | 83 | 126 | 36 |
| **1.A.5** | **Non-Specified** | 1,121 | 0.0 | 0.02 | - | - | - | 1 | 3 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 6,234 | 87.8 | 0.06 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 46.3 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 6,234 | 41.5 | 0.06 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **46,739** | **35.3** | **13.25** | **1,914** | **2,603** | **291** | **1,077** | **25** | **1,638** |
| **2.A** | **Mineral Industry** | 14,060 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 9,770 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 3,749 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 105 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 435 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 3,842 | 5.4 | 12.67 | 1,914 | - | - | 1 | 1 | 25 |
| 2.B.1 | Ammonia Production | 258 | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 1.89 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 10.41 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | 0.38 | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 0 | - | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 3,584 | 5.4 | - | - | - | - | - | 0 | 6 |
| 2.B.9 | Fluorochemicals Production | - | - | - | 1,914 | - | - | - | - | - |
| 2.B.10 | Other Chemicals | - | - | - | - | - | - | - | - | 19 |
| **2.C** | **Metal Industry** | 28,455 | 29.9 | 0.58 | - | 2,603 | 167 | 1,051 | 17 | 14 |
| 2.C.1 | Iron and Steel Production | 26,200 | 29.7 | 0.58 | - | - | - | 575 | 14 | 14 |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.C.2 | Ferroalloy Production | 208 | 0.2 | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 2,011 | - | - | - | 2,603 | - | 476 | 3 | - |
| 2.C.4 | Magnesium Production | 36 | - | - | - | - | 167 | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | - | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 383 | - | - | - | - | - | - | - | 1,294 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | NE/NO | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 125 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 25 | 7 | 305 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 25 | 7 | 17 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 288 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 131 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 157 |
| **3** | **Agriculture** | **8,019** | **11,655.7** | **293.53** | **-** | **-** | **-** | **1,688** | **62** | **-** |
| **3.A** | **Enteric Fermentation** | - | 10,646.4 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 10,224.8 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 8,326.3 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 1,898.5 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 99.8 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 34.5 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 287.3 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 584.2 | 9.42 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 263.0 | 3.33 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 194.0 | 0.29 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 69.0 | 3.05 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 3.4 | - | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 282.3 | 1.33 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 35.6 | 0.40 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 4.35 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 1.27 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 0.20 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 1.07 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 1.20 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | - | 1.88 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 385.6 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 281.27 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 219.38 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 12.94 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 8.74 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 141.37 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 127.23 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 91.26 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 35.97 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 2.92 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 11.22 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 47.93 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 5.53 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 6.17 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 2.12 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 1.72 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 1.15 | - | - | - | - | - | - |
| 3.D.1.d.vi | Manioc | - | - | 0.89 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 0.42 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 28.85 | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.ix | Other annual crops | - | - | 1.08 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 2.90 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 5.49 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 61.89 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 23.61 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 2.66 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 1.64 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 19.30 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 16.96 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 12.17 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 4.80 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.29 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 2.05 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 38.29 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 3.06 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 2.07 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 21.72 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 19.09 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.33 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 2.30 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 10.79 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 1.24 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 1.39 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 0.48 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.39 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.26 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.20 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.09 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 6.49 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.24 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 0.65 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 39.4 | 2.84 | - | - | - | 1,688 | 62 | - |
| **3.G** | **Liming** | 7,344 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 674 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | - | - | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **790,137** | **1,580.0** | **49.29** | - | - | - | **24,757** | **438** | - |
| **4.A** | **Forest Land** | -121,928 | 71.2 | 2.12 | - | - | - | 1,094 | 17 | - |
| 4.A.1 | Forest Land remaining Forest Land | -100,291 | 70.7 | 2.08 | - | - | - | 1,081 | 17 | - |
| 4.A.2 | Land converted to Forest Land | -21,636 | 0.5 | 0.04 | - | - | - | 13 | 1 | - |
| **4.B** | **Cropland** | 76,170 | 95.8 | 3.60 | - | - | - | 1,630 | 41 | - |
| 4.B.1 | Cropland remaining Cropland | - | - | - | - | - | - | - | - | - |
| 4.B.2 | Land converted to Cropland | 76,170 | 95.8 | 3.60 | - | - | - | 1,630 | 41 | - |
| **4.C** | **Grassland** | 837,102 | 1,398.8 | 43.13 | - | - | - | 21,811 | 376 | - |
| 4.C.1 | Grassland remaining Grassland | 12,895 | 32.2 | 2.94 | - | - | - | 910 | 55 | - |
| 4.C.2 | Land converted to Grassland | 824,208 | 1,366.6 | 40.20 | - | - | - | 20,902 | 322 | - |
| **4.D** | **Wetlands** | 6,160 | 7.8 | 0.23 | - | - | - | 120 | 2 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 6,160 | 7.8 | 0.23 | - | - | - | 120 | 2 | - |
| **4.E** | **Settlements** | 6,716 | 5.1 | 0.16 | - | - | - | 80 | 1 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |
| 4.E.2 | Land converted to Settlements | 6,716 | 5.1 | 0.16 | - | - | - | 80 | 1 | - |
| **4.F** | **Other Land** | 1,230 | 1.4 | 0.04 | - | - | - | 22 | 0 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.F.2 | Land converted to Other Land | 1,230 | 1.4 | 0.04 | - | - | - | 22 | 0 | - |
| **4.G** | **Harvested Wood Products** | -15,314 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **565** | **1,260.7** | **5.35** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 634.6 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 230.7 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 403.8 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 0.6 | 0.04 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 565 | 19.4 | 0.29 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 606.1 | 5.02 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 538.2 | 5.02 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 67.9 | - | - | - | - | - | - | - |
| **5.E** | **Other** | - | - | - | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 4,102 | 2.7 | 2.71 | - | - | - | 3 | 3 | 3 |
| 1.A.3.a.i | Aviation | 1,433 | 0.0 | 0.04 | - | - | - | 0 | 0 | 0 |
| 1.A.3.d.i | Navigation | 2,670 | 2.7 | 2.67 | - | - | - | 3 | 3 | 3 |
| | **$CO_2$ emissions from biomass** | 165,211 | | | | | | | | |

Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

## Results of the Fourth National Inventory — Year 1993

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **1,074,939** | **15,305.9** | **385.46** | **2,016** | **2,443** | **367** | **37,482** | **2,129** | **3,361** |
| **1** | **Energy** | **191,351** | **493.7** | **13.82** | - | - | - | **8,745** | **1,587** | **1,616** |
| **1.A** | **Fuel Combustion Activities** | 185,032 | 402.2 | 13.77 | - | - | - | 8,745 | 1,587 | 1,616 |
| **1.A.1** | **Energy Industries** | 23,802 | 22.9 | 3.15 | - | - | - | 1,234 | 251 | 289 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 6,862 | 0.1 | 0.05 | - | - | - | 4 | 58 | 1 |
| 1.A.1.b | Petroleum Refining | 11,443 | 0.2 | 0.08 | - | - | - | 10 | 111 | 1 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 5,497 | 22.6 | 3.03 | - | - | - | 1,221 | 82 | 287 |
| **1.A.2** | **Manufacturing Industries and Construction** | 40,582 | 16.0 | 2.76 | - | - | - | 807 | 155 | 30 |
| 1.A.2.a | Iron and Steel | 5,774 | 0.3 | 0.04 | - | - | - | 4 | 14 | 1 |
| 1.A.2.b | Non-ferrous Metals | 1,667 | 0.1 | 0.02 | - | - | - | 3 | 3 | 0 |
| 1.A.2.c | Chemicals | 9,667 | 0.8 | 0.12 | - | - | - | 25 | 30 | 2 |
| 1.A.2.d | Pulp, Paper and Print | 3,202 | 1.4 | 0.51 | - | - | - | 357 | 22 | 9 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 3,665 | 8.3 | 1.48 | - | - | - | 184 | 35 | 9 |
| 1.A.2.f | Non-metallic Minerals | 7,696 | 4.2 | 0.37 | - | - | - | 168 | 25 | 5 |
| 1.A.2.g | Transport Equipment | 4,435 | 0.7 | 0.16 | - | - | - | 50 | 14 | 2 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 2,831 | 0.2 | 0.03 | - | - | - | 6 | 8 | 1 |
| 1.A.2.l | Textile and Leather | 1,645 | 0.1 | 0.04 | - | - | - | 9 | 3 | 0 |
| **1.A.3** | **Transport** | 90,078 | 68.5 | 3.94 | - | - | - | 5,359 | 1,006 | 1,069 |
| 1.A.3.a.ii | Domestic Aviation | 5,351 | 0.0 | 0.15 | - | - | - | 4 | 5 | 1 |
| 1.A.3.b | Road Transportation | 79,058 | 68.0 | 3.03 | - | - | - | 5,340 | 872 | 1,062 |
| 1.A.3.c | Railways | 1,701 | 0.1 | 0.66 | - | - | - | 6 | 28 | 3 |
| 1.A.3.d.ii | Domestic Navigation | 3,969 | 0.4 | 0.10 | - | - | - | 9 | 101 | 3 |
| 1.A.3.e | Other Transportation | - | - | - | - | - | - | - | - | - |
| **1.A.4** | **Other Sectors** | 29,835 | 294.9 | 3.89 | - | - | - | 1,345 | 174 | 228 |
| 1.A.4.a | Commercial / Institutional | 2,462 | 3.8 | 0.04 | - | - | - | 5 | 7 | 3 |
| 1.A.4.b | Residential | 15,392 | 277.3 | 2.92 | - | - | - | 1,254 | 28 | 188 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 11,982 | 13.7 | 0.93 | - | - | - | 86 | 139 | 36 |
| **1.A.5** | **Non-Specified** | 734 | 0.0 | 0.02 | - | - | - | 1 | 1 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 6,319 | 91.5 | 0.06 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 49.1 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 6,319 | 42.4 | 0.06 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **48,279** | **38.8** | **16.93** | **2,016** | **2,443** | **367** | **1,131** | **26** | **1,745** |
| **2.A** | **Mineral Industry** | 14,777 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 10,164 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 4,028 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 126 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 459 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 4,361 | 6.1 | 16.30 | 2,016 | - | - | 1 | 1 | 29 |
| 2.B.1 | Ammonia Production | 286 | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 2.00 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 13.84 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | 0.46 | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 0 | - | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 4,075 | 6.1 | - | - | - | - | - | 0 | 8 |
| 2.B.9 | Fluorochemicals Production | - | - | - | 2,016 | - | - | - | - | - |
| 2.B.10 | Other Chemicals | - | - | - | - | - | - | - | - | 21 |
| **2.C** | **Metal Industry** | 28,717 | 32.7 | 0.64 | - | 2,443 | 241 | 1,104 | 18 | 16 |
| 2.C.1 | Iron and Steel Production | 25,991 | 32.5 | 0.64 | - | - | - | 630 | 16 | 16 |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.C.2 | Ferroalloy Production | 201 | 0.2 | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 1,946 | - | - | - | 2,443 | - | 474 | 3 | - |
| 2.C.4 | Magnesium Production | 52 | - | - | - | - | 241 | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | 527 | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 424 | - | - | - | - | - | - | - | 1,378 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | NE/NO | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 126 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 26 | 7 | 322 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 26 | 7 | 17 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 304 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 141 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 164 |
| **3** | **Agriculture** | **10,321** | **11,746.0** | **297.11** | **-** | **-** | **-** | **1,489** | **55** | **-** |
| **3.A** | **Enteric Fermentation** | - | 10,723.1 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 10,316.0 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 8,451.5 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 1,864.4 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 90.2 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 34.3 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 282.6 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 577.2 | 9.46 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 262.4 | 3.34 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 195.6 | 0.28 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 66.8 | 3.06 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 3.1 | - | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 276.2 | 1.33 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 35.5 | 0.40 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 4.38 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 1.27 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 0.20 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 1.07 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 1.20 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | - | 1.90 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 411.2 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 285.11 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 221.94 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 15.23 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 8.68 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 141.38 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 127.77 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 92.53 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 35.24 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 2.78 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 10.83 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 48.23 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 6.50 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 6.08 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 1.92 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 1.74 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 1.02 | - | - | - | - | - | - |
| 3.D.1.d.vi | Manioc | - | - | 0.89 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 0.33 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 28.85 | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.ix | Other annual crops | - | - | 0.89 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 2.90 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 5.52 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 63.16 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 24.34 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 3.43 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 1.64 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 19.27 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 17.04 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 12.34 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 4.70 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.28 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 1.96 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 38.82 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 3.59 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 2.05 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 21.68 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 19.17 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.31 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 2.20 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 10.85 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 1.46 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 1.37 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 0.43 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.39 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.23 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.20 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.07 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 6.49 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.20 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 0.65 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 34.6 | 2.55 | - | - | - | 1,489 | 55 | - |
| **3.G** | **Liming** | 9,371 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 950 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | - | - | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **824,453** | **1,668.5** | **51.93** | - | - | - | **26,117** | **460** | - |
| **4.A** | **Forest Land** | -143,493 | 76.3 | 2.27 | - | - | - | 1,173 | 19 | - |
| 4.A.1 | Forest Land remaining Forest Land | -121,320 | 75.9 | 2.23 | - | - | - | 1,160 | 18 | - |
| 4.A.2 | Land converted to Forest Land | -22,174 | 0.5 | 0.04 | - | - | - | 13 | 1 | - |
| **4.B** | **Cropland** | 77,225 | 97.2 | 3.65 | - | - | - | 1,653 | 42 | - |
| 4.B.1 | Cropland remaining Cropland | - | - | - | - | - | - | - | - | - |
| 4.B.2 | Land converted to Cropland | 77,225 | 97.2 | 3.65 | - | - | - | 1,653 | 42 | - |
| **4.C** | **Grassland** | 891,870 | 1,480.4 | 45.56 | - | - | - | 23,065 | 396 | - |
| 4.C.1 | Grassland remaining Grassland | 12,825 | 32.7 | 2.98 | - | - | - | 923 | 55 | - |
| 4.C.2 | Land converted to Grassland | 879,045 | 1,447.7 | 42.58 | - | - | - | 22,142 | 341 | - |
| **4.D** | **Wetlands** | 6,202 | 7.8 | 0.23 | - | - | - | 120 | 2 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 6,202 | 7.8 | 0.23 | - | - | - | 120 | 2 | - |
| **4.E** | **Settlements** | 6,827 | 5.2 | 0.16 | - | - | - | 82 | 1 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |
| 4.E.2 | Land converted to Settlements | 6,827 | 5.2 | 0.16 | - | - | - | 82 | 1 | - |
| **4.F** | **Other Land** | 1,294 | 1.5 | 0.05 | - | - | - | 23 | 0 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.F.2 | Land converted to Other Land | 1,294 | 1.5 | 0.05 | - | - | - | 23 | 0 | - |
| **4.G** | **Harvested Wood Products** | -15,473 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **536** | **1,358.9** | **5.66** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 692.7 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 247.6 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 445.1 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 0.6 | 0.04 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 536 | 20.3 | 0.30 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 645.2 | 5.32 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 577.1 | 5.32 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 68.1 | - | - | - | - | - | - | - |
| **5.E** | **Other** | - | - | - | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 4,858 | 3.3 | 3.39 | - | - | - | 4 | 4 | 3 |
| 1.A.3.a.i | Aviation | 1,514 | 0.0 | 0.04 | - | - | - | 0 | 0 | 0 |
| 1.A.3.d.i | Navigation | 3,344 | 3.3 | 3.34 | - | - | - | 3 | 3 | 3 |
| | **$CO_2$ emissions from biomass** | 163,211 | | | | | | | | |

Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

## Results of the Fourth National Inventory — Year 1994

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **1,061,961** | **15,576.9** | **396.23** | **1,832** | **2,357** | **363** | **37,933** | **2,192** | **3,588** |
| **1** | **Energy** | **200,128** | **487.4** | **14.45** | - | - | - | **8,833** | **1,638** | **1,620** |
| **1.A** | **Fuel Combustion Activities** | 193,483 | 398.3 | 14.39 | - | - | - | 8,833 | 1,638 | 1,620 |
| **1.A.1** | **Energy Industries** | 24,953 | 24.0 | 3.31 | - | - | - | 1,276 | 258 | 294 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 7,518 | 0.1 | 0.05 | - | - | - | 4 | 62 | 1 |
| 1.A.1.b | Petroleum Refining | 12,162 | 0.2 | 0.08 | - | - | - | 11 | 114 | 1 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 5,273 | 23.7 | 3.17 | - | - | - | 1,261 | 82 | 292 |
| **1.A.2** | **Manufacturing Industries and Construction** | 41,744 | 18.1 | 3.05 | - | - | - | 855 | 170 | 32 |
| 1.A.2.a | Iron and Steel | 5,766 | 0.2 | 0.04 | - | - | - | 3 | 14 | 1 |
| 1.A.2.b | Non-ferrous Metals | 1,640 | 0.1 | 0.02 | - | - | - | 4 | 4 | 0 |
| 1.A.2.c | Chemicals | 9,998 | 0.8 | 0.12 | - | - | - | 28 | 34 | 3 |
| 1.A.2.d | Pulp, Paper and Print | 3,308 | 1.3 | 0.54 | - | - | - | 382 | 24 | 9 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 3,694 | 10.1 | 1.72 | - | - | - | 194 | 40 | 9 |
| 1.A.2.f | Non-metallic Minerals | 7,665 | 4.5 | 0.38 | - | - | - | 176 | 26 | 6 |
| 1.A.2.g | Transport Equipment | 4,844 | 0.8 | 0.17 | - | - | - | 52 | 16 | 2 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 3,445 | 0.2 | 0.03 | - | - | - | 7 | 10 | 1 |
| 1.A.2.l | Textile and Leather | 1,383 | 0.1 | 0.04 | - | - | - | 9 | 3 | 0 |
| **1.A.3** | **Transport** | 94,432 | 69.8 | 4.17 | - | - | - | 5,392 | 1,025 | 1,071 |
| 1.A.3.a.ii | Domestic Aviation | 5,493 | 0.0 | 0.15 | - | - | - | 4 | 5 | 1 |
| 1.A.3.b | Road Transportation | 84,068 | 69.4 | 3.44 | - | - | - | 5,375 | 908 | 1,066 |
| 1.A.3.c | Railways | 1,274 | 0.1 | 0.49 | - | - | - | 4 | 21 | 2 |
| 1.A.3.d.ii | Domestic Navigation | 3,597 | 0.3 | 0.09 | - | - | - | 9 | 91 | 3 |
| 1.A.3.e | Other Transportation | - | - | - | - | - | - | - | - | - |
| **1.A.4** | **Other Sectors** | 31,608 | 286.4 | 3.84 | - | - | - | 1,310 | 184 | 223 |
| 1.A.4.a | Commercial / Institutional | 3,580 | 3.6 | 0.05 | - | - | - | 5 | 11 | 3 |
| 1.A.4.b | Residential | 15,374 | 269.3 | 2.85 | - | - | - | 1,218 | 27 | 183 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 12,654 | 13.5 | 0.95 | - | - | - | 87 | 146 | 37 |
| **1.A.5** | **Non-Specified** | 746 | 0.0 | 0.02 | - | - | - | 1 | 1 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 6,645 | 89.0 | 0.06 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 44.9 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 6,645 | 44.1 | 0.06 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **48,409** | **40.4** | **17.11** | **1,832** | **2,357** | **363** | **1,160** | **28** | **1,968** |
| **2.A** | **Mineral Industry** | 14,595 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 10,086 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 3,892 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 115 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 502 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 4,712 | 6.7 | 16.46 | 1,832 | - | - | 1 | 1 | 30 |
| 2.B.1 | Ammonia Production | 287 | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 2.01 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 13.99 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | 0.46 | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 0 | - | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 4,425 | 6.7 | - | - | - | - | - | 0 | 7 |
| 2.B.9 | Fluorochemicals Production | - | - | - | 1,832 | - | - | - | - | - |
| 2.B.10 | Other Chemicals | - | - | - | - | - | - | - | - | 23 |
| **2.C** | **Metal Industry** | 28,646 | 33.7 | 0.66 | - | 2,357 | 236 | 1,130 | 19 | 16 |
| 2.C.1 | Iron and Steel Production | 26,140 | 33.5 | 0.66 | - | - | - | 650 | 16 | 16 |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.C.2 | Ferroalloy Production | 188 | 0.2 | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 1,955 | - | - | - | 2,357 | - | 480 | 3 | - |
| 2.C.4 | Magnesium Production | 50 | - | - | - | - | 236 | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | 312 | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 457 | - | - | - | - | - | - | - | 1,601 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | NE/NO | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 127 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 29 | 8 | 321 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 29 | 8 | 19 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 302 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 145 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 157 |
| **3** | **Agriculture** | **10,729** | **11,947.0** | **306.62** | **-** | **-** | **-** | **1,753** | **65** | **-** |
| **3.A** | **Enteric Fermentation** | - | 10,908.9 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 10,492.8 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 8,631.9 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 1,860.8 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 92.3 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 35.1 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 288.7 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 594.1 | 9.77 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 269.7 | 3.43 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 200.2 | 0.35 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 69.5 | 3.08 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 3.1 | - | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 284.9 | 1.38 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 36.4 | 0.42 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 4.54 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 1.32 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 0.25 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 1.08 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 1.25 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | - | 1.97 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 403.4 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 293.83 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 228.67 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 17.77 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 8.80 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 143.36 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 129.53 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 94.40 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 35.14 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 2.78 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 11.05 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 50.36 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 7.17 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 6.57 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 2.29 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 1.81 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 1.39 | - | - | - | - | - | - |
| 3.D.1.d.vi | Manioc | - | - | 0.99 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 0.31 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 28.85 | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.ix | Other annual crops | - | - | 0.96 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 2.90 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 5.47 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 65.16 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 24.96 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 3.76 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 1.67 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 19.54 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 17.27 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 12.59 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 4.68 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.28 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 1.99 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 40.20 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 4.16 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 2.07 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 21.98 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 19.43 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.31 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 2.24 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 11.33 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 1.61 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 1.48 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 0.52 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.41 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.31 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.22 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.07 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 6.49 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.22 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 0.65 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 40.5 | 3.02 | - | - | - | 1,753 | 65 | - |
| **3.G** | **Liming** | 9,741 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 988 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | - | - | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **802,131** | **1,673.0** | **52.07** | - | - | - | **26,187** | **461** | - |
| **4.A** | **Forest Land** | -156,246 | 76.5 | 2.28 | - | - | - | 1,177 | 19 | - |
| 4.A.1 | Forest Land remaining Forest Land | -133,083 | 76.1 | 2.24 | - | - | - | 1,163 | 18 | - |
| 4.A.2 | Land converted to Forest Land | -23,163 | 0.5 | 0.04 | - | - | - | 13 | 1 | - |
| **4.B** | **Cropland** | 77,141 | 97.5 | 3.66 | - | - | - | 1,657 | 42 | - |
| 4.B.1 | Cropland remaining Cropland | - | - | - | - | - | - | - | - | - |
| 4.B.2 | Land converted to Cropland | 77,141 | 97.5 | 3.66 | - | - | - | 1,657 | 42 | - |
| **4.C** | **Grassland** | 886,450 | 1,484.4 | 45.69 | - | - | - | 23,127 | 397 | - |
| 4.C.1 | Grassland remaining Grassland | 12,383 | 32.8 | 2.99 | - | - | - | 926 | 56 | - |
| 4.C.2 | Land converted to Grassland | 874,067 | 1,451.6 | 42.70 | - | - | - | 22,202 | 342 | - |
| **4.D** | **Wetlands** | 6,202 | 7.8 | 0.23 | - | - | - | 121 | 2 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 6,202 | 7.8 | 0.23 | - | - | - | 121 | 2 | - |
| **4.E** | **Settlements** | 6,827 | 5.2 | 0.16 | - | - | - | 82 | 1 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |
| 4.E.2 | Land converted to Settlements | 6,827 | 5.2 | 0.16 | - | - | - | 82 | 1 | - |
| **4.F** | **Other Land** | 1,294 | 1.5 | 0.05 | - | - | - | 23 | 0 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.F.2 | Land converted to Other Land | 1,294 | 1.5 | 0.05 | - | - | - | 23 | 0 | - |
| **4.G** | **Harvested Wood Products** | -19,538 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **564** | **1,429.2** | **5.97** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 752.4 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 263.8 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 488.6 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 0.7 | 0.04 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 564 | 21.0 | 0.31 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 655.0 | 5.62 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 585.4 | 5.62 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 69.6 | - | - | - | - | - | - | - |
| **5.E** | **Other** | - | - | - | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 5,669 | 3.9 | 3.93 | - | - | - | 4 | 4 | 4 |
| 1.A.3.a.i | Aviation | 1,787 | 0.0 | 0.05 | - | - | - | 0 | 0 | 0 |
| 1.A.3.d.i | Navigation | 3,882 | 3.9 | 3.88 | - | - | - | 4 | 4 | 4 |
| | **$CO_2$ emissions from biomass** | 173,798 | | | | | | | | |

Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

**Results of the Fourth National Inventory — Year 1995**

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **2,152,596** | **17,188.2** | **442.84** | **1,791** | **2,232** | **369** | **58,129** | **2,598** | **3,636** |
| **1** | **Energy** | **216,613** | **463.9** | **14.93** | - | - | - | **8,692** | **1,721** | **1,596** |
| **1.A** | **Fuel Combustion Activities** | 210,030 | 375.0 | 14.87 | - | - | - | 8,692 | 1,721 | 1,596 |
| **1.A.1** | **Energy Industries** | 26,255 | 22.5 | 3.12 | - | - | - | 1,190 | 268 | 272 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 9,099 | 0.2 | 0.07 | - | - | - | 6 | 80 | 1 |
| 1.A.1.b | Petroleum Refining | 11,558 | 0.2 | 0.08 | - | - | - | 11 | 104 | 1 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 5,599 | 22.1 | 2.96 | - | - | - | 1,174 | 83 | 270 |
| **1.A.2** | **Manufacturing Industries and Construction** | 45,149 | 18.5 | 3.08 | - | - | - | 836 | 181 | 32 |
| 1.A.2.a | Iron and Steel | 5,763 | 0.2 | 0.03 | - | - | - | 4 | 13 | 1 |
| 1.A.2.b | Non-ferrous Metals | 1,936 | 0.1 | 0.02 | - | - | - | 4 | 5 | 0 |
| 1.A.2.c | Chemicals | 11,080 | 0.8 | 0.12 | - | - | - | 25 | 39 | 3 |
| 1.A.2.d | Pulp, Paper and Print | 3,811 | 1.3 | 0.54 | - | - | - | 370 | 24 | 9 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 4,132 | 10.4 | 1.75 | - | - | - | 194 | 41 | 9 |
| 1.A.2.f | Non-metallic Minerals | 8,716 | 4.6 | 0.38 | - | - | - | 174 | 29 | 6 |
| 1.A.2.g | Transport Equipment | 5,002 | 0.8 | 0.17 | - | - | - | 55 | 16 | 2 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 3,352 | 0.1 | 0.03 | - | - | - | 2 | 11 | 0 |
| 1.A.2.l | Textile and Leather | 1,357 | 0.1 | 0.04 | - | - | - | 9 | 3 | 0 |
| **1.A.3** | **Transport** | 104,411 | 73.0 | 5.00 | - | - | - | 5,471 | 1,078 | 1,086 |
| 1.A.3.a.ii | Domestic Aviation | 6,376 | 0.0 | 0.18 | - | - | - | 4 | 6 | 1 |
| 1.A.3.b | Road Transportation | 93,132 | 72.6 | 4.20 | - | - | - | 5,454 | 960 | 1,080 |
| 1.A.3.c | Railways | 1,367 | 0.1 | 0.53 | - | - | - | 5 | 23 | 2 |
| 1.A.3.d.ii | Domestic Navigation | 3,537 | 0.3 | 0.09 | - | - | - | 8 | 90 | 3 |
| 1.A.3.e | Other Transportation | - | - | - | - | - | - | - | - | - |
| **1.A.4** | **Other Sectors** | 33,343 | 261.0 | 3.66 | - | - | - | 1,194 | 192 | 206 |
| 1.A.4.a | Commercial / Institutional | 3,694 | 3.5 | 0.05 | - | - | - | 5 | 11 | 3 |
| 1.A.4.b | Residential | 16,083 | 243.6 | 2.62 | - | - | - | 1,098 | 26 | 165 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 13,567 | 13.8 | 0.99 | - | - | - | 91 | 155 | 38 |
| **1.A.5** | **Non-Specified** | 871 | 0.0 | 0.02 | - | - | - | 1 | 1 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 6,583 | 88.9 | 0.06 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 43.7 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 6,583 | 45.1 | 0.06 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **53,139** | **37.7** | **18.20** | **1,791** | **2,232** | **369** | **1,106** | **27** | **2,040** |
| **2.A** | **Mineral Industry** | 16,149 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 11,528 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 3,897 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 139 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 586 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 4,684 | 6.6 | 17.60 | 1,791 | - | - | 1 | 1 | 31 |
| 2.B.1 | Ammonia Production | 303 | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 2.05 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 15.08 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | 0.47 | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 4 | - | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 4,377 | 6.6 | - | - | - | - | - | 0 | 7 |
| 2.B.9 | Fluorochemicals Production | - | - | - | 1,791 | - | - | - | - | - |
| 2.B.10 | Other Chemicals | - | - | - | - | - | - | - | - | 24 |
| **2.C** | **Metal Industry** | 31,836 | 31.1 | 0.60 | - | 2,232 | 241 | 1,076 | 17 | 15 |
| 2.C.1 | Iron and Steel Production | 28,853 | 30.8 | 0.60 | - | - | - | 597 | 15 | 15 |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.C.2 | Ferroalloy Production | 227 | 0.2 | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 1,965 | - | - | - | 2,232 | - | 480 | 3 | - |
| 2.C.4 | Magnesium Production | 52 | - | - | - | - | 241 | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | 738 | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 470 | - | - | - | - | - | - | - | 1,617 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | NE/NO | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 128 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 29 | 8 | 377 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 29 | 8 | 19 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 358 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 184 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 174 |
| **3** | **Agriculture** | **6,765** | **12,179.7** | **311.96** | **-** | **-** | **-** | **1,806** | **67** | **-** |
| **3.A** | **Enteric Fermentation** | - | 11,113.0 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 10,690.2 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 8,780.6 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 1,909.6 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 91.7 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 36.1 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 295.1 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 612.9 | 10.13 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 277.9 | 3.58 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 204.7 | 0.43 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 73.2 | 3.15 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 3.1 | - | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 294.4 | 1.43 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 37.5 | 0.43 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 4.69 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 1.41 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 0.30 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 1.10 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 1.29 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | - | 1.99 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 412.1 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 298.70 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 232.57 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 17.10 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 9.54 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 145.97 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 131.96 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 95.91 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 36.05 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 2.78 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 11.22 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 51.47 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 7.39 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 7.33 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 2.38 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 1.93 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 1.21 | - | - | - | - | - | - |
| 3.D.1.d.vi | Manioc | - | - | 1.03 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 0.23 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 29.05 | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.ix | Other annual crops | - | - | 0.90 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 2.90 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 5.59 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 66.13 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 25.25 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 3.56 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 1.80 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 19.89 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 17.59 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 12.79 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 4.81 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.28 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 2.02 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 40.88 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 4.01 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 2.25 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 22.38 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 19.79 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.31 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 2.27 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 11.58 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 1.66 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 1.65 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 0.54 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.43 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.27 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.23 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.05 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 6.54 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.20 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 0.65 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 41.7 | 3.13 | - | - | - | 1,806 | 67 | - |
| **3.G** | **Liming** | 5,845 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 920 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | - | - | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **1,875,495** | **2,996.2** | **91.47** | - | - | - | **46,525** | **784** | - |
| **4.A** | **Forest Land** | -80,960 | 154.0 | 4.57 | - | - | - | 2,364 | 37 | - |
| 4.A.1 | Forest Land remaining Forest Land | -68,244 | 153.4 | 4.51 | - | - | - | 2,345 | 36 | - |
| 4.A.2 | Land converted to Forest Land | -12,717 | 0.7 | 0.06 | - | - | - | 19 | 1 | - |
| **4.B** | **Cropland** | 109,489 | 132.7 | 4.88 | - | - | - | 2,234 | 54 | - |
| 4.B.1 | Cropland remaining Cropland | - | - | - | - | - | - | - | - | - |
| 4.B.2 | Land converted to Cropland | 109,489 | 132.7 | 4.88 | - | - | - | 2,234 | 54 | - |
| **4.C** | **Grassland** | 1,845,499 | 2,686.3 | 81.32 | - | - | - | 41,568 | 687 | - |
| 4.C.1 | Grassland remaining Grassland | 26,834 | 37.3 | 3.41 | - | - | - | 1,054 | 63 | - |
| 4.C.2 | Land converted to Grassland | 1,818,665 | 2,649.0 | 77.91 | - | - | - | 40,513 | 623 | - |
| **4.D** | **Wetlands** | 10,164 | 12.5 | 0.37 | - | - | - | 191 | 3 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 10,164 | 12.5 | 0.37 | - | - | - | 191 | 3 | - |
| **4.E** | **Settlements** | 9,673 | 7.9 | 0.25 | - | - | - | 124 | 2 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |
| 4.E.2 | Land converted to Settlements | 9,673 | 7.9 | 0.25 | - | - | - | 124 | 2 | - |
| **4.F** | **Other Land** | 2,327 | 2.8 | 0.09 | - | - | - | 44 | 1 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.F.2 | Land converted to Other Land | 2,327 | 2.8 | 0.09 | - | - | - | 44 | 1 | - |
| **4.G** | **Harvested Wood Products** | -20,697 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **585** | **1,510.7** | **6.28** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 817.9 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 294.7 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 523.2 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 0.7 | 0.04 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 585 | 21.6 | 0.32 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 670.4 | 5.92 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 593.6 | 5.92 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 76.8 | - | - | - | - | - | - | - |
| **5.E** | **Other** | - | - | - | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 6,217 | 4.1 | 4.20 | - | - | - | 5 | 5 | 4 |
| 1.A.3.a.i | Aviation | 2,074 | 0.0 | 0.06 | - | - | - | 0 | 1 | 0 |
| 1.A.3.d.i | Navigation | 4,143 | 4.1 | 4.14 | - | - | - | 4 | 4 | 4 |
| | **$CO_2$ emissions from biomass** | 168,703 | | | | | | | | |

Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

## Results of the Fourth National Inventory — Year 1996

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **1,478,147** | **15,480.0** | **396.63** | **1,123** | **2,174** | **362** | **43,673** | **2,471** | **3,654** |
| **1** | **Energy** | **233,816** | **452.3** | **15.80** | - | - | - | **8,702** | **1,825** | **1,567** |
| **1.A** | **Fuel Combustion Activities** | 226,662 | 373.6 | 15.73 | - | - | - | 8,702 | 1,825 | 1,567 |
| **1.A.1** | **Energy Industries** | 28,322 | 21.8 | 3.04 | - | - | - | 1,124 | 290 | 244 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 10,135 | 0.2 | 0.07 | - | - | - | 5 | 79 | 1 |
| 1.A.1.b | Petroleum Refining | 12,319 | 0.2 | 0.09 | - | - | - | 13 | 118 | 1 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 5,868 | 21.4 | 2.87 | - | - | - | 1,106 | 93 | 242 |
| **1.A.2** | **Manufacturing Industries and Construction** | 50,684 | 19.7 | 3.15 | - | - | - | 888 | 194 | 31 |
| 1.A.2.a | Iron and Steel | 5,852 | 0.2 | 0.03 | - | - | - | 5 | 12 | 1 |
| 1.A.2.b | Non-ferrous Metals | 2,832 | 0.1 | 0.02 | - | - | - | 1 | 7 | 0 |
| 1.A.2.c | Chemicals | 12,800 | 0.8 | 0.11 | - | - | - | 21 | 44 | 2 |
| 1.A.2.d | Pulp, Paper and Print | 4,468 | 1.3 | 0.51 | - | - | - | 388 | 26 | 8 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 4,603 | 10.8 | 1.80 | - | - | - | 204 | 43 | 10 |
| 1.A.2.f | Non-metallic Minerals | 9,807 | 5.5 | 0.43 | - | - | - | 201 | 32 | 7 |
| 1.A.2.g | Transport Equipment | 5,000 | 0.7 | 0.17 | - | - | - | 54 | 15 | 2 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 3,841 | 0.2 | 0.03 | - | - | - | 4 | 12 | 1 |
| 1.A.2.l | Textile and Leather | 1,481 | 0.1 | 0.04 | - | - | - | 10 | 3 | 0 |
| **1.A.3** | **Transport** | 112,671 | 76.2 | 5.87 | - | - | - | 5,521 | 1,143 | 1,089 |
| 1.A.3.a.ii | Domestic Aviation | 6,807 | 0.0 | 0.19 | - | - | - | 5 | 6 | 1 |
| 1.A.3.b | Road Transportation | 100,174 | 75.8 | 5.08 | - | - | - | 5,501 | 1,003 | 1,083 |
| 1.A.3.c | Railways | 1,258 | 0.1 | 0.49 | - | - | - | 4 | 21 | 2 |
| 1.A.3.d.ii | Domestic Navigation | 4,431 | 0.4 | 0.12 | - | - | - | 11 | 113 | 4 |
| 1.A.3.e | Other Transportation | - | - | - | - | - | - | - | - | - |
| **1.A.4** | **Other Sectors** | 34,059 | 255.9 | 3.65 | - | - | - | 1,169 | 197 | 202 |
| 1.A.4.a | Commercial / Institutional | 3,151 | 3.7 | 0.04 | - | - | - | 5 | 8 | 3 |
| 1.A.4.b | Residential | 16,745 | 238.5 | 2.59 | - | - | - | 1,072 | 27 | 161 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 14,163 | 13.7 | 1.01 | - | - | - | 93 | 162 | 39 |
| **1.A.5** | **Non-Specified** | 926 | 0.0 | 0.03 | - | - | - | 1 | 1 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 7,154 | 78.7 | 0.07 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 28.1 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 7,154 | 50.6 | 0.07 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **54,509** | **33.7** | **14.31** | **1,123** | **2,174** | **362** | **1,028** | **25** | **2,087** |
| **2.A** | **Mineral Industry** | 18,690 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 13,884 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 4,034 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 141 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 631 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 4,703 | 6.6 | 13.78 | 1,042 | - | - | 1 | 1 | 30 |
| 2.B.1 | Ammonia Production | 298 | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 2.07 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 11.22 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | 0.49 | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 23 | - | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 4,382 | 6.6 | - | - | - | - | - | 0 | 8 |
| 2.B.9 | Fluorochemicals Production | - | - | - | 1,042 | - | - | - | - | - |
| 2.B.10 | Other Chemicals | - | - | - | - | - | - | - | - | 23 |
| **2.C** | **Metal Industry** | 30,538 | 27.1 | 0.52 | - | 2,174 | 233 | 997 | 16 | 13 |
| 2.C.1 | Iron and Steel Production | 27,372 | 26.9 | 0.52 | - | - | - | 518 | 13 | 13 |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.C.2 | Ferroalloy Production | 250 | 0.2 | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 1,981 | - | - | - | 2,174 | - | 480 | 3 | - |
| 2.C.4 | Magnesium Production | 50 | - | - | - | - | 233 | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | 885 | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 578 | - | - | - | - | - | - | - | 1,654 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | 81 | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 129 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 31 | 8 | 390 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 31 | 8 | 20 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 369 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 193 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 177 |
| **3** | **Agriculture** | **8,456** | **11,344.3** | **296.56** | **-** | **-** | **-** | **1,774** | **66** | **-** |
| **3.A** | **Enteric Fermentation** | - | 10,416.8 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 10,091.4 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 8,581.6 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 1,509.8 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 73.6 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 29.2 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 222.6 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 529.2 | 8.79 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 275.8 | 2.96 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 198.5 | 0.50 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 77.3 | 2.47 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 2.6 | - | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 217.6 | 1.16 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 33.3 | 0.43 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 4.24 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 1.21 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 0.35 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 0.86 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 1.06 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | - | 1.97 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 357.4 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 284.70 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 221.63 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 18.18 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 8.81 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 136.39 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 125.71 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 97.17 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 28.55 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 2.03 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 8.64 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 49.71 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 6.67 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 5.99 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 2.76 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 1.49 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 1.01 | - | - | - | - | - | - |
| 3.D.1.d.vi | Manioc | - | - | 0.72 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 0.49 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 29.70 | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.ix | Other annual crops | - | - | 0.88 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 2.90 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 5.63 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 63.07 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 24.04 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 3.83 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 1.66 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 18.55 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 16.76 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 12.96 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 3.81 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.20 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 1.58 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 39.03 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 4.23 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 2.09 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 20.87 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 18.86 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.23 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 1.78 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 11.19 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 1.50 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 1.35 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 0.62 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.33 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.23 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.16 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.11 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 6.68 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.20 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 0.65 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 40.9 | 3.07 | - | - | - | 1,774 | 66 | - |
| **3.G** | **Liming** | 7,444 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 1,012 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | - | - | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **1,180,685** | **2,062.9** | **63.63** | - | - | - | **32,169** | **555** | - |
| **4.A** | **Forest Land** | -134,291 | 99.2 | 2.95 | - | - | - | 1,525 | 24 | - |
| 4.A.1 | Forest Land remaining Forest Land | -116,523 | 98.7 | 2.90 | - | - | - | 1,509 | 23 | - |
| 4.A.2 | Land converted to Forest Land | -17,768 | 0.6 | 0.05 | - | - | - | 16 | 1 | - |
| **4.B** | **Cropland** | 96,577 | 115.6 | 4.31 | - | - | - | 1,959 | 49 | - |
| 4.B.1 | Cropland remaining Cropland | - | - | - | - | - | - | - | - | - |
| 4.B.2 | Land converted to Cropland | 96,577 | 115.6 | 4.31 | - | - | - | 1,959 | 49 | - |
| **4.C** | **Grassland** | 1,220,250 | 1,828.4 | 55.76 | - | - | - | 28,380 | 477 | - |
| 4.C.1 | Grassland remaining Grassland | 19,018 | 32.1 | 2.93 | - | - | - | 908 | 54 | - |
| 4.C.2 | Land converted to Grassland | 1,201,232 | 1,796.2 | 52.83 | - | - | - | 27,472 | 423 | - |
| **4.D** | **Wetlands** | 9,269 | 11.2 | 0.33 | - | - | - | 173 | 3 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 9,269 | 11.2 | 0.33 | - | - | - | 173 | 3 | - |
| **4.E** | **Settlements** | 8,375 | 6.6 | 0.21 | - | - | - | 103 | 2 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |
| 4.E.2 | Land converted to Settlements | 8,375 | 6.6 | 0.21 | - | - | - | 103 | 2 | - |
| **4.F** | **Other Land** | 1,648 | 1.9 | 0.06 | - | - | - | 30 | 1 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.F.2 | Land converted to Other Land | 1,648 | 1.9 | 0.06 | - | - | - | 30 | 1 | - |
| **4.G** | **Harvested Wood Products** | -21,143 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **681** | **1,586.7** | **6.34** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 876.6 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 308.1 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 568.5 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 0.7 | 0.04 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 681 | 22.8 | 0.34 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 686.6 | 5.95 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 605.8 | 5.95 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 80.8 | - | - | - | - | - | - | - |
| **5.E** | **Other** | - | - | - | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 6,663 | 4.2 | 4.31 | - | - | - | 5 | 5 | 4 |
| 1.A.3.a.i | Aviation | 2,418 | 0.0 | 0.07 | - | - | - | 0 | 1 | 0 |
| 1.A.3.d.i | Navigation | 4,245 | 4.2 | 4.25 | - | - | - | 4 | 4 | 4 |
| | **$CO_2$ emissions from biomass** | 170,947 | | | | | | | | |

Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

## Results of the Fourth National Inventory — Year 1997

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **1,177,340** | **15,315.8** | **394.58** | **1,296** | **1,462** | **434** | **37,199** | **2,439** | **3,595** |
| **1** | **Energy** | **249,335** | **465.5** | **16.85** | - | - | - | **8,404** | **1,891** | **1,490** |
| **1.A** | **Fuel Combustion Activities** | 241,647 | 375.2 | 16.78 | - | - | - | 8,404 | 1,891 | 1,490 |
| **1.A.1** | **Energy Industries** | 31,438 | 22.8 | 3.18 | - | - | - | 1,143 | 332 | 238 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 11,966 | 0.2 | 0.09 | - | - | - | 7 | 100 | 2 |
| 1.A.1.b | Petroleum Refining | 13,460 | 0.3 | 0.11 | - | - | - | 15 | 126 | 1 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 6,012 | 22.3 | 2.98 | - | - | - | 1,121 | 106 | 235 |
| **1.A.2** | **Manufacturing Industries and Construction** | 53,525 | 19.9 | 3.28 | - | - | - | 885 | 208 | 31 |
| 1.A.2.a | Iron and Steel | 5,726 | 0.2 | 0.03 | - | - | - | 7 | 13 | 1 |
| 1.A.2.b | Non-ferrous Metals | 2,886 | 0.1 | 0.02 | - | - | - | 1 | 6 | 0 |
| 1.A.2.c | Chemicals | 14,562 | 0.9 | 0.12 | - | - | - | 19 | 50 | 2 |
| 1.A.2.d | Pulp, Paper and Print | 4,149 | 1.3 | 0.51 | - | - | - | 397 | 25 | 8 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 4,179 | 11.7 | 1.92 | - | - | - | 206 | 45 | 10 |
| 1.A.2.f | Non-metallic Minerals | 11,420 | 4.6 | 0.43 | - | - | - | 187 | 36 | 6 |
| 1.A.2.g | Transport Equipment | 5,557 | 0.8 | 0.18 | - | - | - | 54 | 17 | 2 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 3,765 | 0.2 | 0.03 | - | - | - | 4 | 13 | 1 |
| 1.A.2.l | Textile and Leather | 1,282 | 0.1 | 0.04 | - | - | - | 9 | 3 | 0 |
| **1.A.3** | **Transport** | 119,489 | 73.9 | 6.57 | - | - | - | 5,188 | 1,139 | 1,015 |
| 1.A.3.a.ii | Domestic Aviation | 7,661 | 0.0 | 0.21 | - | - | - | 5 | 7 | 1 |
| 1.A.3.b | Road Transportation | 107,607 | 73.5 | 5.89 | - | - | - | 5,172 | 1,034 | 1,010 |
| 1.A.3.c | Railways | 1,021 | 0.1 | 0.39 | - | - | - | 3 | 17 | 2 |
| 1.A.3.d.ii | Domestic Navigation | 3,200 | 0.3 | 0.08 | - | - | - | 8 | 81 | 3 |
| 1.A.3.e | Other Transportation | - | - | - | - | - | - | - | - | - |
| **1.A.4** | **Other Sectors** | 34,865 | 258.6 | 3.71 | - | - | - | 1,183 | 204 | 205 |
| 1.A.4.a | Commercial / Institutional | 3,384 | 3.6 | 0.05 | - | - | - | 5 | 9 | 3 |
| 1.A.4.b | Residential | 16,765 | 241.4 | 2.62 | - | - | - | 1,084 | 27 | 163 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 14,717 | 13.6 | 1.03 | - | - | - | 94 | 168 | 39 |
| **1.A.5** | **Non-Specified** | 2,330 | 0.0 | 0.04 | - | - | - | 5 | 8 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 7,688 | 90.3 | 0.07 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 36.0 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 7,688 | 54.3 | 0.07 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **58,302** | **35.8** | **12.83** | **1,296** | **1,462** | **434** | **1,048** | **26** | **2,105** |
| **2.A** | **Mineral Industry** | 20,292 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 15,267 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 4,119 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 153 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 753 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 5,249 | 7.4 | 12.29 | 1,115 | - | - | 1 | 1 | 33 |
| 2.B.1 | Ammonia Production | 311 | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 2.12 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 9.66 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | 0.50 | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 32 | - | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 4,906 | 7.4 | - | - | - | - | - | 0 | 8 |
| 2.B.9 | Fluorochemicals Production | - | - | - | 1,115 | - | - | - | - | - |
| 2.B.10 | Other Chemicals | - | - | - | - | - | - | - | - | 25 |
| **2.C** | **Metal Industry** | 32,115 | 28.4 | 0.55 | - | 1,462 | 305 | 1,016 | 16 | 14 |
| 2.C.1 | Iron and Steel Production | 29,754 | 28.2 | 0.55 | - | - | - | 542 | 14 | 14 |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.C.2 | Ferroalloy Production | 180 | 0.2 | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 1,975 | - | - | - | 1,462 | - | 474 | 3 | - |
| 2.C.4 | Magnesium Production | 65 | - | - | - | - | 305 | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | 140 | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 646 | - | - | - | - | - | - | - | 1,652 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | 181 | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 130 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 32 | 8 | 407 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 32 | 8 | 21 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 386 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 206 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 180 |
| **3** | **Agriculture** | **9,263** | **11,514.8** | **306.82** | **-** | **-** | **-** | **1,767** | **66** | **-** |
| **3.A** | **Enteric Fermentation** | - | 10,598.6 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 10,272.3 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 8,695.5 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 1,576.8 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 72.7 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 29.6 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 224.0 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 538.5 | 9.06 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 278.9 | 3.12 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 201.7 | 0.54 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 77.1 | 2.58 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 2.6 | - | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 222.9 | 1.17 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 34.2 | 0.44 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 4.34 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 1.29 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 0.38 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 0.90 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 1.06 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | - | 2.00 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 336.8 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 294.69 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 229.25 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 19.87 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 9.36 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 138.91 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 128.19 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 98.28 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 29.91 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 2.00 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 8.72 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 52.53 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 7.60 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 6.66 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 3.08 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 1.44 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 1.17 | - | - | - | - | - | - |
| 3.D.1.d.vi | Manioc | - | - | 0.81 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 0.37 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 30.35 | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.ix | Other annual crops | - | - | 1.05 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 2.90 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 5.67 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 65.45 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 24.88 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 4.23 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 1.75 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 18.90 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 17.09 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 13.10 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 3.99 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.20 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 1.61 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 40.57 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 4.60 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 2.23 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 21.26 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 19.23 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.23 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 1.81 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 11.82 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 1.71 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 1.50 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 0.69 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.32 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.26 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.18 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.08 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 6.83 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.24 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 0.65 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 40.8 | 3.06 | - | - | - | 1,767 | 66 | - |
| **3.G** | **Liming** | 8,132 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 1,131 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | - | - | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **859,706** | **1,660.3** | **51.63** | - | - | - | **25,979** | **457** | - |
| **4.A** | **Forest Land** | -160,191 | 75.6 | 2.26 | - | - | - | 1,163 | 19 | - |
| 4.A.1 | Forest Land remaining Forest Land | -140,217 | 75.1 | 2.21 | - | - | - | 1,148 | 18 | - |
| 4.A.2 | Land converted to Forest Land | -19,973 | 0.5 | 0.05 | - | - | - | 15 | 1 | - |
| **4.B** | **Cropland** | 91,416 | 109.3 | 4.10 | - | - | - | 1,857 | 47 | - |
| 4.B.1 | Cropland remaining Cropland | - | - | - | - | - | - | - | - | - |
| 4.B.2 | Land converted to Cropland | 91,416 | 109.3 | 4.10 | - | - | - | 1,857 | 47 | - |
| **4.C** | **Grassland** | 939,177 | 1,456.8 | 44.71 | - | - | - | 22,670 | 387 | - |
| 4.C.1 | Grassland remaining Grassland | 14,839 | 30.0 | 2.74 | - | - | - | 849 | 51 | - |
| 4.C.2 | Land converted to Grassland | 924,338 | 1,426.8 | 41.96 | - | - | - | 21,821 | 336 | - |
| **4.D** | **Wetlands** | 9,076 | 11.1 | 0.33 | - | - | - | 170 | 3 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 9,076 | 11.1 | 0.33 | - | - | - | 170 | 3 | - |
| **4.E** | **Settlements** | 7,868 | 6.1 | 0.19 | - | - | - | 95 | 2 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |
| 4.E.2 | Land converted to Settlements | 7,868 | 6.1 | 0.19 | - | - | - | 95 | 2 | - |
| **4.F** | **Other Land** | 1,351 | 1.5 | 0.05 | - | - | - | 24 | 0 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.F.2 | Land converted to Other Land | 1,351 | 1.5 | 0.05 | - | - | - | 24 | 0 | - |
| **4.G** | **Harvested Wood Products** | -28,992 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **733** | **1,639.4** | **6.44** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 919.6 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 345.8 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 573.8 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 0.8 | 0.05 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 733 | 23.5 | 0.35 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 695.6 | 6.04 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 615.2 | 6.04 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 80.4 | - | - | - | - | - | - | - |
| **5.E** | **Other** | - | - | - | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 7,231 | 4.6 | 4.71 | - | - | - | 5 | 5 | 5 |
| 1.A.3.a.i | Aviation | 2,596 | 0.0 | 0.07 | - | - | - | 0 | 1 | 0 |
| 1.A.3.d.i | Navigation | 4,635 | 4.6 | 4.64 | - | - | - | 5 | 5 | 5 |
| | **$CO_2$ emissions from biomass** | 177,139 | | | | | | | | |

Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

## Results of the Fourth National Inventory — Year 1998

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **1,435,494** | **15,914.9** | **421.56** | **434** | **1,638** | **388** | **42,487** | **2,566** | **3,748** |
| **1** | **Energy** | **256,470** | **473.0** | **17.57** | - | - | - | **7,984** | **1,926** | **1,396** |
| **1.A** | **Fuel Combustion Activities** | 248,026 | 375.5 | 17.49 | - | - | - | 7,984 | 1,926 | 1,396 |
| **1.A.1** | **Energy Industries** | 32,153 | 20.4 | 2.87 | - | - | - | 1,031 | 339 | 217 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 12,450 | 0.3 | 0.09 | - | - | - | 8 | 106 | 2 |
| 1.A.1.b | Petroleum Refining | 13,829 | 0.3 | 0.11 | - | - | - | 16 | 135 | 1 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 5,874 | 19.9 | 2.66 | - | - | - | 1,007 | 97 | 214 |
| **1.A.2** | **Manufacturing Industries and Construction** | 54,305 | 21.4 | 3.57 | - | - | - | 953 | 215 | 35 |
| 1.A.2.a | Iron and Steel | 5,350 | 0.2 | 0.03 | - | - | - | 7 | 12 | 1 |
| 1.A.2.b | Non-ferrous Metals | 3,322 | 0.1 | 0.02 | - | - | - | 1 | 7 | 0 |
| 1.A.2.c | Chemicals | 13,332 | 1.0 | 0.12 | - | - | - | 18 | 48 | 2 |
| 1.A.2.d | Pulp, Paper and Print | 4,425 | 1.6 | 0.60 | - | - | - | 443 | 27 | 10 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 4,377 | 13.3 | 2.13 | - | - | - | 218 | 50 | 10 |
| 1.A.2.f | Non-metallic Minerals | 12,495 | 4.3 | 0.42 | - | - | - | 197 | 36 | 8 |
| 1.A.2.g | Transport Equipment | 5,779 | 0.7 | 0.18 | - | - | - | 56 | 19 | 2 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 3,929 | 0.2 | 0.03 | - | - | - | 4 | 13 | 1 |
| 1.A.2.l | Textile and Leather | 1,297 | 0.1 | 0.04 | - | - | - | 9 | 3 | 0 |
| **1.A.3** | **Transport** | 125,674 | 70.0 | 7.28 | - | - | - | 4,794 | 1,172 | 938 |
| 1.A.3.a.ii | Domestic Aviation | 8,395 | 0.0 | 0.23 | - | - | - | 6 | 8 | 1 |
| 1.A.3.b | Road Transportation | 112,767 | 69.6 | 6.54 | - | - | - | 4,777 | 1,059 | 932 |
| 1.A.3.c | Railways | 1,085 | 0.1 | 0.42 | - | - | - | 4 | 18 | 2 |
| 1.A.3.d.ii | Domestic Navigation | 3,427 | 0.3 | 0.09 | - | - | - | 8 | 87 | 3 |
| 1.A.3.e | Other Transportation | - | - | - | - | - | - | - | - | - |
| **1.A.4** | **Other Sectors** | 34,568 | 263.6 | 3.73 | - | - | - | 1,202 | 198 | 207 |
| 1.A.4.a | Commercial / Institutional | 3,702 | 3.4 | 0.05 | - | - | - | 5 | 10 | 3 |
| 1.A.4.b | Residential | 16,821 | 247.1 | 2.69 | - | - | - | 1,107 | 27 | 166 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 14,046 | 13.0 | 0.99 | - | - | - | 91 | 161 | 37 |
| **1.A.5** | **Non-Specified** | 1,326 | 0.0 | 0.03 | - | - | - | 3 | 1 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 8,443 | 97.6 | 0.08 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 35.5 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 8,443 | 62.1 | 0.08 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **61,621** | **33.9** | **19.71** | **434** | **1,638** | **388** | **1,012** | **25** | **2,351** |
| **2.A** | **Mineral Industry** | 20,958 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 16,175 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 3,933 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 153 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 697 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 5,486 | 7.9 | 19.20 | 153 | - | - | 1 | 1 | 34 |
| 2.B.1 | Ammonia Production | 292 | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 2.06 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 16.75 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | 0.39 | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 25 | - | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 5,170 | 7.9 | - | - | - | - | - | 0 | 8 |
| 2.B.9 | Fluorochemicals Production | - | - | - | 153 | - | - | - | - | - |
| 2.B.10 | Other Chemicals | - | - | - | - | - | - | - | - | 26 |
| **2.C** | **Metal Industry** | 34,567 | 26.0 | 0.50 | - | 1,638 | 241 | 977 | 15 | 12 |
| 2.C.1 | Iron and Steel Production | 31,951 | 25.9 | 0.50 | - | - | - | 497 | 12 | 12 |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.C.2 | Ferroalloy Production | 558 | 0.2 | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 2,007 | - | - | - | 1,638 | - | 480 | 3 | - |
| 2.C.4 | Magnesium Production | 51 | - | - | - | - | 241 | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | - | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 610 | - | - | - | - | - | - | - | 1,892 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | 281 | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 147 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 33 | 9 | 413 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 33 | 9 | 22 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 391 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 208 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 183 |
| **3** | **Agriculture** | **9,002** | **11,679.4** | **314.99** | **-** | **-** | **-** | **1,816** | **67** | **-** |
| **3.A** | **Enteric Fermentation** | - | 10,759.9 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 10,430.9 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 8,833.1 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 1,597.8 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 71.3 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 30.0 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 227.6 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 544.6 | 9.13 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 281.2 | 3.12 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 204.1 | 0.49 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 77.1 | 2.63 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 2.5 | - | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 226.5 | 1.19 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 34.4 | 0.44 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 4.37 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 1.27 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 0.35 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 0.92 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 1.08 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | - | 2.02 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 333.0 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 302.71 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 235.16 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 22.25 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 9.62 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 141.07 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 130.30 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 100.00 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 30.29 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 1.98 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 8.80 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 53.61 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 9.01 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 5.98 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 3.27 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 1.33 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 0.90 | - | - | - | - | - | - |
| 3.D.1.d.vi | Manioc | - | - | 0.79 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 0.34 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 31.00 | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.ix | Other annual crops | - | - | 0.98 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 2.90 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 5.71 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 67.54 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 25.80 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 4.82 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 1.80 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 19.19 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 17.37 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 13.33 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 4.04 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.20 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 1.62 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 41.74 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 5.15 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 2.29 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 21.59 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 19.54 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.22 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 1.82 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 12.06 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 2.03 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 1.35 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 0.73 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.30 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.20 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.18 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.08 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 6.98 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.22 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 0.65 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 41.9 | 3.14 | - | - | - | 1,816 | 67 | - |
| **3.G** | **Liming** | 7,691 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 1,311 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | - | - | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **1,107,623** | **2,030.3** | **62.69** | - | - | - | **31,675** | **548** | - |
| **4.A** | **Forest Land** | -148,211 | 97.0 | 2.89 | - | - | - | 1,491 | 24 | - |
| 4.A.1 | Forest Land remaining Forest Land | -130,095 | 96.4 | 2.84 | - | - | - | 1,475 | 23 | - |
| 4.A.2 | Land converted to Forest Land | -18,116 | 0.6 | 0.05 | - | - | - | 16 | 1 | - |
| **4.B** | **Cropland** | 95,763 | 116.4 | 4.34 | - | - | - | 1,973 | 49 | - |
| 4.B.1 | Cropland remaining Cropland | - | - | - | - | - | - | - | - | - |
| 4.B.2 | Land converted to Cropland | 95,763 | 116.4 | 4.34 | - | - | - | 1,973 | 49 | - |
| **4.C** | **Grassland** | 1,174,299 | 1,797.2 | 54.86 | - | - | - | 27,905 | 470 | - |
| 4.C.1 | Grassland remaining Grassland | 16,728 | 32.3 | 2.95 | - | - | - | 913 | 55 | - |
| 4.C.2 | Land converted to Grassland | 1,157,571 | 1,764.9 | 51.91 | - | - | - | 26,992 | 415 | - |
| **4.D** | **Wetlands** | 9,239 | 11.4 | 0.34 | - | - | - | 175 | 3 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 9,239 | 11.4 | 0.34 | - | - | - | 175 | 3 | - |
| **4.E** | **Settlements** | 8,295 | 6.6 | 0.21 | - | - | - | 103 | 2 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |
| 4.E.2 | Land converted to Settlements | 8,295 | 6.6 | 0.21 | - | - | - | 103 | 2 | - |
| **4.F** | **Other Land** | 1,601 | 1.9 | 0.06 | - | - | - | 29 | 1 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.F.2 | Land converted to Other Land | 1,601 | 1.9 | 0.06 | - | - | - | 29 | 1 | - |
| **4.G** | **Harvested Wood Products** | -33,364 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **778** | **1,698.2** | **6.60** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 968.1 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 360.9 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 607.2 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 0.9 | 0.05 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 778 | 24.2 | 0.36 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 705.1 | 6.19 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 623.9 | 6.19 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 81.1 | - | - | - | - | - | - | - |
| **5.E** | **Other** | - | - | - | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 8,036 | 5.4 | 5.43 | - | - | - | 6 | 6 | 5 |
| 1.A.3.a.i | Aviation | 2,678 | 0.0 | 0.08 | - | - | - | 0 | 1 | 0 |
| 1.A.3.d.i | Navigation | 5,358 | 5.4 | 5.36 | - | - | - | 5 | 5 | 5 |
| | **$CO_2$ emissions from biomass** | 177,178 | | | | | | | | |

Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

## Results of the Fourth National Inventory — Year 1999

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **1,397,021** | **16,184.3** | **425.73** | **1,501** | **1,450** | **386** | **42,008** | **2,623** | **3,649** |
| **1** | **Energy** | **265,728** | **484.2** | **18.10** | - | - | - | **7,603** | **1,985** | **1,320** |
| **1.A** | **Fuel Combustion Activities** | 256,773 | 377.9 | 18.01 | - | - | - | 7,603 | 1,985 | 1,320 |
| **1.A.1** | **Energy Industries** | 38,347 | 20.5 | 2.90 | - | - | - | 1,058 | 384 | 232 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 19,238 | 0.4 | 0.14 | - | - | - | 11 | 153 | 3 |
| 1.A.1.b | Petroleum Refining | 13,641 | 0.3 | 0.11 | - | - | - | 16 | 142 | 1 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 5,467 | 19.8 | 2.65 | - | - | - | 1,030 | 89 | 229 |
| **1.A.2** | **Manufacturing Industries and Construction** | 58,045 | 22.6 | 3.78 | - | - | - | 1,043 | 233 | 40 |
| 1.A.2.a | Iron and Steel | 5,341 | 0.2 | 0.04 | - | - | - | 8 | 13 | 1 |
| 1.A.2.b | Non-ferrous Metals | 3,859 | 0.1 | 0.03 | - | - | - | 2 | 8 | 0 |
| 1.A.2.c | Chemicals | 14,577 | 1.1 | 0.13 | - | - | - | 20 | 57 | 3 |
| 1.A.2.d | Pulp, Paper and Print | 4,720 | 1.6 | 0.63 | - | - | - | 472 | 29 | 10 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 4,469 | 14.3 | 2.27 | - | - | - | 228 | 53 | 10 |
| 1.A.2.f | Non-metallic Minerals | 13,140 | 4.3 | 0.43 | - | - | - | 235 | 37 | 11 |
| 1.A.2.g | Transport Equipment | 6,130 | 0.7 | 0.18 | - | - | - | 62 | 19 | 3 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 4,623 | 0.2 | 0.04 | - | - | - | 8 | 15 | 1 |
| 1.A.2.l | Textile and Leather | 1,187 | 0.1 | 0.04 | - | - | - | 8 | 3 | 0 |
| **1.A.3** | **Transport** | 123,106 | 63.5 | 7.46 | - | - | - | 4,264 | 1,160 | 835 |
| 1.A.3.a.ii | Domestic Aviation | 7,825 | 0.0 | 0.22 | - | - | - | 5 | 7 | 1 |
| 1.A.3.b | Road Transportation | 110,693 | 63.1 | 6.74 | - | - | - | 4,247 | 1,046 | 829 |
| 1.A.3.c | Railways | 1,084 | 0.1 | 0.42 | - | - | - | 4 | 18 | 2 |
| 1.A.3.d.ii | Domestic Navigation | 3,503 | 0.3 | 0.09 | - | - | - | 8 | 89 | 3 |
| 1.A.3.e | Other Transportation | - | - | - | - | - | - | - | - | - |
| **1.A.4** | **Other Sectors** | 36,206 | 271.3 | 3.84 | - | - | - | 1,238 | 206 | 212 |
| 1.A.4.a | Commercial / Institutional | 4,412 | 3.4 | 0.06 | - | - | - | 5 | 12 | 3 |
| 1.A.4.b | Residential | 17,156 | 255.2 | 2.78 | - | - | - | 1,142 | 28 | 171 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 14,638 | 12.6 | 1.00 | - | - | - | 91 | 166 | 37 |
| **1.A.5** | **Non-Specified** | 1,070 | 0.0 | 0.03 | - | - | - | 1 | 1 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 8,955 | 106.3 | 0.09 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 37.2 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 8,955 | 69.1 | 0.09 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **59,890** | **38.0** | **19.71** | **1,501** | **1,450** | **386** | **1,101** | **28** | **2,329** |
| **2.A** | **Mineral Industry** | 21,392 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 16,439 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 4,133 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 174 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 646 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 5,885 | 8.4 | 19.14 | 1,137 | - | - | 1 | 1 | 36 |
| 2.B.1 | Ammonia Production | 330 | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 2.06 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 16.62 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | 0.45 | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 40 | - | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 5,515 | 8.4 | - | - | - | - | - | 0 | 8 |
| 2.B.9 | Fluorochemicals Production | - | - | - | 1,137 | - | - | - | - | - |
| 2.B.10 | Other Chemicals | - | - | - | - | - | - | - | - | 28 |
| **2.C** | **Metal Industry** | 32,029 | 29.6 | 0.57 | - | 1,450 | 234 | 1,064 | 17 | 14 |
| 2.C.1 | Iron and Steel Production | 29,413 | 29.4 | 0.57 | - | - | - | 568 | 14 | 14 |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.C.2 | Ferroalloy Production | 487 | 0.2 | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 2,079 | - | - | - | 1,450 | - | 496 | 3 | - |
| 2.C.4 | Magnesium Production | 50 | - | - | - | - | 234 | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | - | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 584 | - | - | - | - | - | - | - | 1,826 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | 365 | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 152 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 36 | 10 | 453 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 36 | 10 | 24 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 429 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 243 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 186 |
| **3** | **Agriculture** | **8,616** | **11,857.4** | **318.63** | **-** | **-** | **-** | **1,728** | **64** | **-** |
| **3.A** | **Enteric Fermentation** | - | 10,863.9 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 10,528.5 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 8,920.9 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 1,607.6 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 72.0 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 30.8 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 232.5 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 559.4 | 9.50 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 287.1 | 3.19 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 207.0 | 0.55 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 80.2 | 2.64 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 2.6 | - | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 234.3 | 1.28 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 35.4 | 0.46 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 4.58 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 1.31 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 0.39 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 0.92 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 1.15 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | - | 2.11 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 394.3 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 306.14 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 237.91 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 21.16 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 9.83 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 142.43 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 131.45 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 100.95 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 30.51 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 2.02 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 8.96 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 55.84 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 8.92 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 6.52 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 3.24 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 2.01 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 1.17 | - | - | - | - | - | - |
| 3.D.1.d.vi | Manioc | - | - | 0.85 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 0.37 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 31.65 | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.ix | Other annual crops | - | - | 1.12 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 2.90 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 5.75 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 68.22 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 25.96 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 4.74 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 1.85 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 19.37 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 17.53 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 13.46 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 4.07 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.20 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 1.64 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 42.26 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 4.93 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 2.33 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 21.79 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 19.72 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.23 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 1.85 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 12.56 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 2.01 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 1.47 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 0.73 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.45 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.26 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.19 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.08 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 7.12 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.25 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 0.65 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 39.9 | 2.99 | - | - | - | 1,728 | 64 | - |
| **3.G** | **Liming** | 7,295 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 1,320 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | - | - | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **1,061,880** | **2,023.9** | **62.50** | - | - | - | **31,577** | **546** | - |
| **4.A** | **Forest Land** | -180,850 | 96.6 | 2.87 | - | - | - | 1,484 | 24 | - |
| 4.A.1 | Forest Land remaining Forest Land | -162,678 | 96.0 | 2.82 | - | - | - | 1,468 | 23 | - |
| 4.A.2 | Land converted to Forest Land | -18,171 | 0.6 | 0.05 | - | - | - | 16 | 1 | - |
| **4.B** | **Cropland** | 95,633 | 116.4 | 4.35 | - | - | - | 1,974 | 49 | - |
| 4.B.1 | Cropland remaining Cropland | - | - | - | - | - | - | - | - | - |
| 4.B.2 | Land converted to Cropland | 95,633 | 116.4 | 4.35 | - | - | - | 1,974 | 49 | - |
| **4.C** | **Grassland** | 1,162,818 | 1,791.0 | 54.68 | - | - | - | 27,811 | 469 | - |
| 4.C.1 | Grassland remaining Grassland | 12,206 | 32.3 | 2.95 | - | - | - | 913 | 55 | - |
| 4.C.2 | Land converted to Grassland | 1,150,612 | 1,758.7 | 51.73 | - | - | - | 26,898 | 414 | - |
| **4.D** | **Wetlands** | 9,234 | 11.4 | 0.34 | - | - | - | 175 | 3 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 9,234 | 11.4 | 0.34 | - | - | - | 175 | 3 | - |
| **4.E** | **Settlements** | 8,283 | 6.6 | 0.21 | - | - | - | 103 | 2 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |
| 4.E.2 | Land converted to Settlements | 8,283 | 6.6 | 0.21 | - | - | - | 103 | 2 | - |
| **4.F** | **Other Land** | 1,594 | 1.9 | 0.06 | - | - | - | 29 | 1 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.F.2 | Land converted to Other Land | 1,594 | 1.9 | 0.06 | - | - | - | 29 | 1 | - |
| **4.G** | **Harvested Wood Products** | -34,832 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **907** | **1,780.8** | **6.78** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 1,033.3 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 384.2 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 649.1 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 0.8 | 0.05 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 907 | 25.0 | 0.39 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 721.7 | 6.34 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 635.6 | 6.34 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 86.1 | - | - | - | - | - | - | - |
| **5.E** | **Other** | - | - | - | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 10,737 | 8.2 | 8.29 | - | - | - | 9 | 9 | 8 |
| 1.A.3.a.i | Aviation | 2,522 | 0.0 | 0.07 | - | - | - | 0 | 1 | 0 |
| 1.A.3.d.i | Navigation | 8,215 | 8.2 | 8.22 | - | - | - | 8 | 8 | 8 |
| | **$CO_2$ emissions from biomass** | 180,784 | | | | | | | | |

Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

## Results of the Fourth National Inventory — Year 2000

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **1,458,729** | **16,736.8** | **443.43** | **505** | **1,060** | **400** | **42,731** | **2,616** | **3,730** |
| **1** | **Energy** | **272,173** | **496.7** | **17.94** | - | - | - | **7,052** | **1,959** | **1,222** |
| **1.A** | **Fuel Combustion Activities** | 262,738 | 372.7 | 17.83 | - | - | - | 7,052 | 1,959 | 1,222 |
| **1.A.1** | **Energy Industries** | 39,781 | 19.9 | 2.84 | - | - | - | 1,071 | 391 | 249 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 19,092 | 0.4 | 0.14 | - | - | - | 9 | 138 | 2 |
| 1.A.1.b | Petroleum Refining | 14,194 | 0.3 | 0.12 | - | - | - | 17 | 153 | 1 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 6,495 | 19.2 | 2.58 | - | - | - | 1,045 | 100 | 246 |
| **1.A.2** | **Manufacturing Industries and Construction** | 61,798 | 20.6 | 3.48 | - | - | - | 1,074 | 238 | 43 |
| 1.A.2.a | Iron and Steel | 5,660 | 0.2 | 0.04 | - | - | - | 9 | 14 | 1 |
| 1.A.2.b | Non-ferrous Metals | 4,254 | 0.1 | 0.03 | - | - | - | 2 | 9 | 0 |
| 1.A.2.c | Chemicals | 15,001 | 1.2 | 0.14 | - | - | - | 21 | 62 | 3 |
| 1.A.2.d | Pulp, Paper and Print | 4,746 | 1.6 | 0.66 | - | - | - | 484 | 30 | 10 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 4,530 | 11.6 | 1.91 | - | - | - | 216 | 46 | 10 |
| 1.A.2.f | Non-metallic Minerals | 13,735 | 4.6 | 0.44 | - | - | - | 259 | 39 | 13 |
| 1.A.2.g | Transport Equipment | 7,017 | 0.8 | 0.19 | - | - | - | 67 | 20 | 4 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 5,535 | 0.3 | 0.05 | - | - | - | 9 | 17 | 1 |
| 1.A.2.l | Textile and Leather | 1,319 | 0.1 | 0.04 | - | - | - | 7 | 3 | 0 |
| **1.A.3** | **Transport** | 124,262 | 55.7 | 7.61 | - | - | - | 3,642 | 1,130 | 715 |
| 1.A.3.a.ii | Domestic Aviation | 8,327 | 0.0 | 0.23 | - | - | - | 6 | 7 | 1 |
| 1.A.3.b | Road Transportation | 111,723 | 55.3 | 6.82 | - | - | - | 3,625 | 1,027 | 709 |
| 1.A.3.c | Railways | 1,251 | 0.1 | 0.48 | - | - | - | 4 | 21 | 2 |
| 1.A.3.d.ii | Domestic Navigation | 2,961 | 0.3 | 0.08 | - | - | - | 7 | 75 | 3 |
| 1.A.3.e | Other Transportation | - | - | - | - | - | - | - | - | - |
| **1.A.4** | **Other Sectors** | 35,745 | 276.6 | 3.86 | - | - | - | 1,263 | 199 | 215 |
| 1.A.4.a | Commercial / Institutional | 4,357 | 3.1 | 0.06 | - | - | - | 5 | 10 | 3 |
| 1.A.4.b | Residential | 17,195 | 261.4 | 2.85 | - | - | - | 1,172 | 28 | 176 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 14,193 | 12.0 | 0.96 | - | - | - | 87 | 160 | 36 |
| **1.A.5** | **Non-Specified** | 1,152 | 0.0 | 0.03 | - | - | - | 1 | 1 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 9,434 | 124.0 | 0.11 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 47.4 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 9,434 | 76.6 | 0.11 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **64,506** | **41.0** | **20.73** | **505** | **1,060** | **400** | **1,155** | **29** | **2,508** |
| **2.A** | **Mineral Industry** | 21,702 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 16,047 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 4,756 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 193 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 706 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 6,321 | 9.0 | 20.11 | - | - | - | 1 | 1 | 43 |
| 2.B.1 | Ammonia Production | 283 | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 2.09 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 17.51 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | 0.50 | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 51 | - | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 5,988 | 9.0 | - | - | - | - | - | 0 | 10 |
| 2.B.9 | Fluorochemicals Production | - | - | - | - | - | - | - | - | - |
| 2.B.10 | Other Chemicals | - | - | - | - | - | - | - | - | 33 |
| **2.C** | **Metal Industry** | 35,858 | 32.0 | 0.62 | - | 1,060 | 246 | 1,117 | 18 | 15 |
| 2.C.1 | Iron and Steel Production | 33,135 | 31.8 | 0.62 | - | - | - | 613 | 15 | 15 |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.C.2 | Ferroalloy Production | 550 | 0.2 | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 2,116 | - | - | - | 1,060 | - | 504 | 3 | - |
| 2.C.4 | Magnesium Production | 53 | - | - | - | - | 246 | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | 5 | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 624 | - | - | - | - | - | - | - | 1,979 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | 505 | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 154 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 37 | 10 | 471 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 37 | 10 | 25 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 446 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 257 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 189 |
| **3** | **Agriculture** | **10,645** | **12,208.4** | **332.56** | **-** | **-** | **-** | **1,596** | **59** | **-** |
| **3.A** | **Enteric Fermentation** | - | 11,222.3 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 10,878.6 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 9,222.3 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 1,656.3 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 73.9 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 31.6 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 238.2 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 581.1 | 10.12 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 300.4 | 3.39 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 215.6 | 0.68 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 84.8 | 2.71 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 2.6 | - | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 241.5 | 1.36 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 36.5 | 0.49 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 4.88 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 1.43 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 0.48 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 0.95 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 1.23 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | - | 2.23 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 368.2 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 319.67 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 248.53 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 25.51 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 10.16 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 146.86 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 135.63 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 104.25 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 31.38 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 2.05 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 9.18 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 57.32 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 9.45 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 6.53 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 3.36 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 1.92 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 1.26 | - | - | - | - | - | - |
| 3.D.1.d.vi | Manioc | - | - | 0.93 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 0.26 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 32.30 | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.ix | Other annual crops | - | - | 1.30 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 2.90 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 5.78 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 71.15 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 26.83 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 4.94 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 1.93 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 19.97 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 18.08 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 13.90 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 4.18 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.20 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 1.68 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 44.31 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 5.90 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 2.40 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 22.47 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 20.34 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.23 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 1.89 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 12.90 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 2.13 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 1.47 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 0.76 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.43 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.28 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.21 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.06 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 7.27 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.29 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 0.65 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 36.8 | 2.76 | - | - | - | 1,596 | 59 | - |
| **3.G** | **Liming** | 9,444 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 1,201 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | - | - | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **1,110,480** | **2,111.6** | **65.12** | - | - | - | **32,928** | **568** | - |
| **4.A** | **Forest Land** | -185,076 | 101.6 | 3.02 | - | - | - | 1,562 | 25 | - |
| 4.A.1 | Forest Land remaining Forest Land | -167,337 | 101.0 | 2.97 | - | - | - | 1,545 | 24 | - |
| 4.A.2 | Land converted to Forest Land | -17,739 | 0.6 | 0.05 | - | - | - | 16 | 1 | - |
| **4.B** | **Cropland** | 96,645 | 118.1 | 4.40 | - | - | - | 2,001 | 50 | - |
| 4.B.1 | Cropland remaining Cropland | - | - | - | - | - | - | - | - | - |
| 4.B.2 | Land converted to Cropland | 96,645 | 118.1 | 4.40 | - | - | - | 2,001 | 50 | - |
| **4.C** | **Grassland** | 1,217,144 | 1,871.8 | 57.08 | - | - | - | 29,053 | 488 | - |
| 4.C.1 | Grassland remaining Grassland | 12,265 | 32.8 | 3.00 | - | - | - | 928 | 56 | - |
| 4.C.2 | Land converted to Grassland | 1,204,879 | 1,838.9 | 54.09 | - | - | - | 28,125 | 433 | - |
| **4.D** | **Wetlands** | 9,272 | 11.5 | 0.34 | - | - | - | 176 | 3 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 9,272 | 11.5 | 0.34 | - | - | - | 176 | 3 | - |
| **4.E** | **Settlements** | 8,382 | 6.7 | 0.21 | - | - | - | 105 | 2 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |
| 4.E.2 | Land converted to Settlements | 8,382 | 6.7 | 0.21 | - | - | - | 105 | 2 | - |
| **4.F** | **Other Land** | 1,652 | 2.0 | 0.06 | - | - | - | 31 | 1 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.F.2 | Land converted to Other Land | 1,652 | 2.0 | 0.06 | - | - | - | 31 | 1 | - |
| **4.G** | **Harvested Wood Products** | -37,539 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **926** | **1,878.9** | **7.08** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 1,086.6 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 421.4 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 665.3 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 0.9 | 0.05 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 926 | 25.3 | 0.40 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 766.1 | 6.63 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 676.4 | 6.63 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 89.6 | - | - | - | - | - | - | - |
| **5.E** | **Other** | - | - | - | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 11,313 | 9.3 | 9.31 | - | - | - | 10 | 10 | 9 |
| 1.A.3.a.i | Aviation | 2,063 | 0.0 | 0.06 | - | - | - | 0 | 1 | 0 |
| 1.A.3.d.i | Navigation | 9,250 | 9.3 | 9.25 | - | - | - | 9 | 9 | 9 |
| | **$CO_2$ emissions from biomass** | 166,349 | | | | | | | | |

Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

## Results of the Fourth National Inventory — Year 2001

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **1,410,297** | **17,336.8** | **451.19** | **637** | **830** | **385** | **41,412** | **2,629** | **3,671** |
| **1** | **Energy** | **279,460** | **524.1** | **18.77** | - | - | - | **6,656** | **1,985** | **1,135** |
| **1.A** | **Fuel Combustion Activities** | 269,687 | 381.3 | 18.66 | - | - | - | 6,656 | 1,985 | 1,135 |
| **1.A.1** | **Energy Industries** | 43,224 | 19.8 | 2.86 | - | - | - | 1,036 | 410 | 234 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 21,623 | 0.5 | 0.18 | - | - | - | 11 | 142 | 2 |
| 1.A.1.b | Petroleum Refining | 14,842 | 0.3 | 0.14 | - | - | - | 17 | 157 | 1 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 6,759 | 18.9 | 2.54 | - | - | - | 1,008 | 111 | 231 |
| **1.A.2** | **Manufacturing Industries and Construction** | 61,093 | 23.1 | 3.80 | - | - | - | 1,085 | 240 | 45 |
| 1.A.2.a | Iron and Steel | 5,619 | 0.2 | 0.04 | - | - | - | 8 | 13 | 1 |
| 1.A.2.b | Non-ferrous Metals | 3,977 | 0.1 | 0.03 | - | - | - | 2 | 8 | 0 |
| 1.A.2.c | Chemicals | 15,070 | 1.4 | 0.14 | - | - | - | 19 | 61 | 3 |
| 1.A.2.d | Pulp, Paper and Print | 4,575 | 1.7 | 0.67 | - | - | - | 482 | 29 | 11 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 4,501 | 14.3 | 2.25 | - | - | - | 228 | 53 | 10 |
| 1.A.2.f | Non-metallic Minerals | 14,172 | 4.3 | 0.42 | - | - | - | 265 | 37 | 14 |
| 1.A.2.g | Transport Equipment | 6,534 | 0.7 | 0.18 | - | - | - | 64 | 18 | 3 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 5,435 | 0.3 | 0.05 | - | - | - | 9 | 17 | 1 |
| 1.A.2.l | Textile and Leather | 1,210 | 0.1 | 0.04 | - | - | - | 7 | 2 | 0 |
| **1.A.3** | **Transport** | 126,788 | 50.6 | 7.93 | - | - | - | 3,216 | 1,121 | 632 |
| 1.A.3.a.ii | Domestic Aviation | 8,561 | 0.0 | 0.24 | - | - | - | 6 | 8 | 1 |
| 1.A.3.b | Road Transportation | 113,535 | 50.2 | 7.07 | - | - | - | 3,198 | 1,006 | 626 |
| 1.A.3.c | Railways | 1,419 | 0.1 | 0.55 | - | - | - | 5 | 24 | 2 |
| 1.A.3.d.ii | Domestic Navigation | 3,274 | 0.3 | 0.09 | - | - | - | 8 | 83 | 3 |
| 1.A.3.e | Other Transportation | - | - | - | - | - | - | - | - | - |
| **1.A.4** | **Other Sectors** | 37,390 | 287.8 | 4.04 | - | - | - | 1,317 | 214 | 223 |
| 1.A.4.a | Commercial / Institutional | 4,572 | 3.0 | 0.06 | - | - | - | 4 | 10 | 3 |
| 1.A.4.b | Residential | 17,233 | 272.7 | 2.96 | - | - | - | 1,221 | 29 | 183 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 15,586 | 12.0 | 1.01 | - | - | - | 91 | 174 | 37 |
| **1.A.5** | **Non-Specified** | 1,192 | 0.0 | 0.03 | - | - | - | 1 | 1 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 9,773 | 142.8 | 0.11 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 62.6 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 9,773 | 80.2 | 0.11 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **62,487** | **38.7** | **16.98** | **637** | **830** | **385** | **1,063** | **28** | **2,536** |
| **2.A** | **Mineral Industry** | 20,641 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 15,227 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 4,568 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 194 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 652 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 5,906 | 8.6 | 16.40 | - | - | - | 1 | 1 | 41 |
| 2.B.1 | Ammonia Production | 237 | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 2.06 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 13.90 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | 0.44 | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 42 | - | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 5,627 | 8.6 | - | - | - | - | - | 0 | 9 |
| 2.B.9 | Fluorochemicals Production | - | - | - | - | - | - | - | - | - |
| 2.B.10 | Other Chemicals | - | - | - | - | - | - | - | - | 32 |
| **2.C** | **Metal Industry** | 35,372 | 30.1 | 0.58 | - | 830 | 226 | 1,025 | 17 | 14 |
| 2.C.1 | Iron and Steel Production | 32,762 | 29.9 | 0.58 | - | - | - | 576 | 14 | 14 |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.C.2 | Ferroalloy Production | 616 | 0.2 | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 1,879 | - | - | - | 830 | - | 449 | 2 | - |
| 2.C.4 | Magnesium Production | 48 | - | - | - | - | 226 | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | 67 | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 569 | - | - | - | - | - | - | - | 2,037 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | 637 | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 159 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 37 | 10 | 444 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 37 | 10 | 25 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 420 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 228 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 192 |
| **3** | **Agriculture** | **9,908** | **12,724.1** | **344.97** | **-** | **-** | **-** | **1,705** | **63** | **-** |
| **3.A** | **Enteric Fermentation** | - | 11,712.6 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 11,367.3 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 9,679.5 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 1,687.9 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 73.2 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 32.6 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 239.5 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 612.7 | 10.21 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 315.6 | 3.38 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 227.0 | 0.65 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 88.6 | 2.73 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 2.6 | - | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 257.1 | 1.38 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 37.4 | 0.51 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 4.94 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 1.42 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 0.47 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 0.96 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 1.19 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | - | 2.32 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 359.4 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 331.81 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 258.11 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 25.06 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 9.79 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 153.02 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 141.75 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 109.82 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 31.92 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 2.07 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 9.20 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 61.51 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 10.91 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 8.48 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 3.51 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 1.75 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 1.01 | - | - | - | - | - | - |
| 3.D.1.d.vi | Manioc | - | - | 0.92 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 0.51 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 32.95 | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.ix | Other annual crops | - | - | 1.47 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 2.90 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 5.82 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 73.70 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 27.73 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 5.07 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 1.87 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 20.79 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 18.90 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 14.64 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 4.26 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.21 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 1.68 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 45.97 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 5.80 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 2.29 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 23.39 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 21.26 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.23 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 1.89 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 13.84 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 2.45 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 1.91 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 0.79 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.39 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.23 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.21 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.11 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 7.41 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.33 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 0.65 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 39.4 | 2.95 | - | - | - | 1,705 | 63 | - |
| **3.G** | **Liming** | 8,617 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 1,291 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | - | - | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **1,057,520** | **2,050.8** | **63.29** | - | - | - | **31,988** | **553** | - |
| **4.A** | **Forest Land** | -192,802 | 96.1 | 2.86 | - | - | - | 1,476 | 23 | - |
| 4.A.1 | Forest Land remaining Forest Land | -174,132 | 95.5 | 2.81 | - | - | - | 1,461 | 22 | - |
| 4.A.2 | Land converted to Forest Land | -18,670 | 0.5 | 0.05 | - | - | - | 15 | 1 | - |
| **4.B** | **Cropland** | 89,029 | 112.5 | 4.22 | - | - | - | 1,912 | 48 | - |
| 4.B.1 | Cropland remaining Cropland | - | - | - | - | - | - | - | - | - |
| 4.B.2 | Land converted to Cropland | 89,029 | 112.5 | 4.22 | - | - | - | 1,912 | 48 | - |
| **4.C** | **Grassland** | 1,184,180 | 1,826.2 | 55.72 | - | - | - | 28,352 | 477 | - |
| 4.C.1 | Grassland remaining Grassland | 11,858 | 32.5 | 2.97 | - | - | - | 918 | 55 | - |
| 4.C.2 | Land converted to Grassland | 1,172,321 | 1,793.8 | 52.76 | - | - | - | 27,434 | 422 | - |
| **4.D** | **Wetlands** | 6,934 | 8.3 | 0.25 | - | - | - | 128 | 2 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 6,934 | 8.3 | 0.25 | - | - | - | 128 | 2 | - |
| **4.E** | **Settlements** | 7,499 | 5.8 | 0.18 | - | - | - | 92 | 2 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |
| 4.E.2 | Land converted to Settlements | 7,499 | 5.8 | 0.18 | - | - | - | 92 | 2 | - |
| **4.F** | **Other Land** | 1,532 | 1.8 | 0.06 | - | - | - | 28 | 0 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.F.2 | Land converted to Other Land | 1,532 | 1.8 | 0.06 | - | - | - | 28 | 0 | - |
| **4.G** | **Harvested Wood Products** | -38,851 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **921** | **1,999.2** | **7.18** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 1,160.0 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 472.4 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 687.6 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 0.9 | 0.06 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 921 | 24.2 | 0.38 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 814.1 | 6.74 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 714.6 | 6.74 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 99.5 | - | - | - | - | - | - | - |
| **5.E** | **Other** | - | - | - | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 12,231 | 10.4 | 10.47 | - | - | - | 11 | 11 | 10 |
| 1.A.3.a.i | Aviation | 1,812 | 0.0 | 0.05 | - | - | - | 0 | 0 | 0 |
| 1.A.3.d.i | Navigation | 10,419 | 10.4 | 10.42 | - | - | - | 10 | 10 | 10 |
| | **$CO_2$ emissions from biomass** | 174,694 | | | | | | | | |

Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

## Results of the Fourth National Inventory — Year 2002

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **1,612,275** | **17,949.3** | **480.83** | **761** | **986** | **456** | **46,321** | **2,694** | **3,535** |
| **1** | **Energy** | **277,150** | **551.1** | **20.14** | - | - | - | **6,707** | **1,970** | **1,132** |
| **1.A** | **Fuel Combustion Activities** | 267,097 | 415.8 | 20.02 | - | - | - | 6,707 | 1,970 | 1,132 |
| **1.A.1** | **Energy Industries** | 37,786 | 21.0 | 3.01 | - | - | - | 1,094 | 372 | 245 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 17,136 | 0.6 | 0.17 | - | - | - | 11 | 108 | 2 |
| 1.A.1.b | Petroleum Refining | 14,543 | 0.3 | 0.14 | - | - | - | 17 | 149 | 1 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 6,106 | 20.1 | 2.69 | - | - | - | 1,067 | 115 | 242 |
| **1.A.2** | **Manufacturing Industries and Construction** | 61,835 | 25.1 | 4.03 | - | - | - | 1,119 | 246 | 44 |
| 1.A.2.a | Iron and Steel | 6,084 | 0.3 | 0.04 | - | - | - | 10 | 14 | 1 |
| 1.A.2.b | Non-ferrous Metals | 4,179 | 0.1 | 0.03 | - | - | - | 2 | 9 | 0 |
| 1.A.2.c | Chemicals | 15,326 | 1.7 | 0.15 | - | - | - | 18 | 63 | 3 |
| 1.A.2.d | Pulp, Paper and Print | 4,772 | 1.8 | 0.69 | - | - | - | 524 | 31 | 11 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 4,425 | 16.0 | 2.46 | - | - | - | 237 | 57 | 10 |
| 1.A.2.f | Non-metallic Minerals | 13,708 | 4.2 | 0.39 | - | - | - | 255 | 34 | 14 |
| 1.A.2.g | Transport Equipment | 6,454 | 0.7 | 0.17 | - | - | - | 57 | 17 | 3 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 5,602 | 0.3 | 0.05 | - | - | - | 8 | 18 | 1 |
| 1.A.2.l | Textile and Leather | 1,284 | 0.1 | 0.04 | - | - | - | 7 | 2 | 0 |
| **1.A.3** | **Transport** | 129,522 | 48.9 | 8.59 | - | - | - | 3,032 | 1,136 | 596 |
| 1.A.3.a.ii | Domestic Aviation | 8,201 | 0.0 | 0.23 | - | - | - | 6 | 7 | 1 |
| 1.A.3.b | Road Transportation | 115,860 | 48.4 | 7.44 | - | - | - | 3,011 | 1,009 | 589 |
| 1.A.3.c | Railways | 2,146 | 0.1 | 0.83 | - | - | - | 7 | 36 | 3 |
| 1.A.3.d.ii | Domestic Navigation | 3,315 | 0.3 | 0.09 | - | - | - | 8 | 84 | 3 |
| 1.A.3.e | Other Transportation | - | - | - | - | - | - | - | - | - |
| **1.A.4** | **Other Sectors** | 36,817 | 320.9 | 4.37 | - | - | - | 1,460 | 214 | 246 |
| 1.A.4.a | Commercial / Institutional | 4,901 | 2.8 | 0.06 | - | - | - | 4 | 11 | 3 |
| 1.A.4.b | Residential | 16,675 | 304.9 | 3.27 | - | - | - | 1,362 | 31 | 204 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 15,241 | 13.2 | 1.04 | - | - | - | 94 | 172 | 39 |
| **1.A.5** | **Non-Specified** | 1,137 | 0.0 | 0.03 | - | - | - | 1 | 1 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 10,053 | 135.3 | 0.12 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 46.6 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 10,053 | 88.7 | 0.12 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **65,061** | **39.6** | **21.06** | **761** | **986** | **456** | **1,167** | **30** | **2,403** |
| **2.A** | **Mineral Industry** | 19,905 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 14,390 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 4,707 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 223 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 585 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 5,867 | 8.4 | 20.46 | - | - | - | 1 | 1 | 42 |
| 2.B.1 | Ammonia Production | 266 | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 2.14 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 17.80 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | 0.52 | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 54 | - | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 5,547 | 8.4 | - | - | - | - | - | 0 | 9 |
| 2.B.9 | Fluorochemicals Production | - | - | - | - | - | - | - | - | - |
| 2.B.10 | Other Chemicals | - | - | - | - | - | - | - | - | 33 |
| **2.C** | **Metal Industry** | 38,619 | 31.2 | 0.60 | - | 986 | 292 | 1,126 | 18 | 15 |
| 2.C.1 | Iron and Steel Production | 35,810 | 31.1 | 0.60 | - | - | - | 597 | 15 | 15 |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.C.2 | Ferroalloy Production | 581 | 0.1 | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 2,176 | - | - | - | 986 | - | 529 | 3 | - |
| 2.C.4 | Magnesium Production | 52 | - | - | - | - | 292 | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | - | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 670 | - | - | - | - | - | - | - | 1,864 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | 761 | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 164 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 40 | 11 | 482 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 40 | 11 | 27 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 455 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 260 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 195 |
| **3** | **Agriculture** | **11,966** | **12,933.5** | **360.07** | **-** | **-** | **-** | **1,816** | **67** | **-** |
| **3.A** | **Enteric Fermentation** | - | 11,907.7 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 11,566.5 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 9,877.0 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 1,689.5 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 71.4 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 31.9 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 237.9 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 610.2 | 10.21 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 320.1 | 3.41 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 228.7 | 0.66 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 91.5 | 2.74 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 2.6 | - | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 250.3 | 1.37 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 37.2 | 0.51 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 4.92 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 1.44 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 0.48 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 0.96 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 1.18 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | - | 2.30 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 373.7 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 346.72 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 269.62 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 27.80 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 10.12 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 160.22 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 149.07 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 115.99 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 33.08 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 2.03 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 9.11 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 62.55 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 12.12 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 7.27 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 3.69 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 1.80 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 1.26 | - | - | - | - | - | - |
| 3.D.1.d.vi | Manioc | - | - | 0.94 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 0.47 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 33.60 | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.ix | Other annual crops | - | - | 1.41 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 2.90 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 6.03 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 77.10 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 29.12 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 5.44 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 1.93 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 21.75 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 19.88 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 15.47 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 4.41 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.20 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 1.67 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 47.99 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 6.42 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 2.37 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 24.47 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 22.36 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.23 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 1.88 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 14.07 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 2.73 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 1.63 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 0.83 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.40 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.28 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.21 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.10 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 7.56 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.32 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 0.65 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 41.9 | 3.14 | - | - | - | 1,816 | 67 | - |
| **3.G** | **Liming** | 10,623 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 1,342 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | - | - | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **1,257,137** | **2,352.7** | **72.30** | - | - | - | **36,632** | **627** | - |
| **4.A** | **Forest Land** | -191,990 | 113.6 | 3.38 | - | - | - | 1,745 | 28 | - |
| 4.A.1 | Forest Land remaining Forest Land | -174,877 | 113.0 | 3.32 | - | - | - | 1,729 | 27 | - |
| 4.A.2 | Land converted to Forest Land | -17,113 | 0.6 | 0.05 | - | - | - | 16 | 1 | - |
| **4.B** | **Cropland** | 92,674 | 117.9 | 4.40 | - | - | - | 1,998 | 50 | - |
| 4.B.1 | Cropland remaining Cropland | - | - | - | - | - | - | - | - | - |
| 4.B.2 | Land converted to Cropland | 92,674 | 117.9 | 4.40 | - | - | - | 1,998 | 50 | - |
| **4.C** | **Grassland** | 1,380,217 | 2,104.3 | 64.01 | - | - | - | 32,627 | 545 | - |
| 4.C.1 | Grassland remaining Grassland | 12,319 | 34.2 | 3.12 | - | - | - | 966 | 58 | - |
| 4.C.2 | Land converted to Grassland | 1,367,898 | 2,070.2 | 60.89 | - | - | - | 31,661 | 487 | - |
| **4.D** | **Wetlands** | 7,070 | 8.5 | 0.25 | - | - | - | 131 | 2 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 7,070 | 8.5 | 0.25 | - | - | - | 131 | 2 | - |
| **4.E** | **Settlements** | 7,858 | 6.2 | 0.20 | - | - | - | 98 | 2 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |
| 4.E.2 | Land converted to Settlements | 7,858 | 6.2 | 0.20 | - | - | - | 98 | 2 | - |
| **4.F** | **Other Land** | 1,741 | 2.1 | 0.06 | - | - | - | 33 | 1 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.F.2 | Land converted to Other Land | 1,741 | 2.1 | 0.06 | - | - | - | 33 | 1 | - |
| **4.G** | **Harvested Wood Products** | -40,434 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **962** | **2,072.4** | **7.25** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 1,214.8 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 494.1 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 720.6 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 1.0 | 0.06 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 962 | 24.3 | 0.39 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 832.4 | 6.81 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 735.3 | 6.81 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 97.1 | - | - | - | - | - | - | - |
| **5.E** | **Other** | - | - | - | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 13,679 | 11.4 | 11.51 | - | - | - | 12 | 12 | 12 |
| 1.A.3.a.i | Aviation | 2,237 | 0.0 | 0.06 | - | - | - | 0 | 1 | 0 |
| 1.A.3.d.i | Navigation | 11,442 | 11.4 | 11.44 | - | - | - | 11 | 11 | 11 |
| | **$CO_2$ emissions from biomass** | 190,585 | | | | | | | | |

Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

## Results of the Fourth National Inventory — Year 2003

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **2,647,725** | **20,094.2** | **558.51** | **888** | **991** | **527** | **68,590** | **3,036** | **3,455** |
| **1** | **Energy** | **269,839** | **541.0** | **21.12** | - | - | - | **6,849** | **1,941** | **1,141** |
| **1.A** | **Fuel Combustion Activities** | 259,898 | 432.6 | 20.99 | - | - | - | 6,849 | 1,941 | 1,141 |
| **1.A.1** | **Energy Industries** | 38,047 | 23.7 | 3.37 | - | - | - | 1,241 | 404 | 287 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 16,068 | 0.6 | 0.17 | - | - | - | 12 | 121 | 3 |
| 1.A.1.b | Petroleum Refining | 14,904 | 0.4 | 0.15 | - | - | - | 19 | 152 | 1 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 7,075 | 22.8 | 3.05 | - | - | - | 1,211 | 131 | 283 |
| **1.A.2** | **Manufacturing Industries and Construction** | 59,338 | 28.0 | 4.40 | - | - | - | 1,275 | 249 | 47 |
| 1.A.2.a | Iron and Steel | 6,235 | 0.3 | 0.04 | - | - | - | 11 | 14 | 2 |
| 1.A.2.b | Non-ferrous Metals | 4,997 | 0.2 | 0.03 | - | - | - | 2 | 10 | 0 |
| 1.A.2.c | Chemicals | 14,584 | 1.9 | 0.16 | - | - | - | 21 | 62 | 3 |
| 1.A.2.d | Pulp, Paper and Print | 4,466 | 2.0 | 0.75 | - | - | - | 603 | 33 | 13 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 4,278 | 18.0 | 2.72 | - | - | - | 291 | 62 | 11 |
| 1.A.2.f | Non-metallic Minerals | 12,286 | 4.5 | 0.40 | - | - | - | 254 | 32 | 12 |
| 1.A.2.g | Transport Equipment | 5,818 | 0.8 | 0.20 | - | - | - | 76 | 17 | 4 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 5,586 | 0.3 | 0.05 | - | - | - | 10 | 18 | 1 |
| 1.A.2.l | Textile and Leather | 1,086 | 0.1 | 0.04 | - | - | - | 8 | 2 | 0 |
| **1.A.3** | **Transport** | 127,048 | 46.4 | 8.69 | - | - | - | 2,809 | 1,074 | 550 |
| 1.A.3.a.ii | Domestic Aviation | 5,868 | 0.0 | 0.16 | - | - | - | 4 | 5 | 1 |
| 1.A.3.b | Road Transportation | 116,008 | 46.0 | 7.63 | - | - | - | 2,790 | 955 | 543 |
| 1.A.3.c | Railways | 2,118 | 0.1 | 0.82 | - | - | - | 7 | 35 | 3 |
| 1.A.3.d.ii | Domestic Navigation | 3,054 | 0.3 | 0.08 | - | - | - | 7 | 78 | 3 |
| 1.A.3.e | Other Transportation | - | - | - | - | - | - | - | - | - |
| **1.A.4** | **Other Sectors** | 34,696 | 334.5 | 4.52 | - | - | - | 1,523 | 213 | 257 |
| 1.A.4.a | Commercial / Institutional | 3,849 | 3.2 | 0.06 | - | - | - | 5 | 8 | 3 |
| 1.A.4.b | Residential | 15,532 | 316.7 | 3.37 | - | - | - | 1,419 | 31 | 213 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 15,315 | 14.6 | 1.09 | - | - | - | 100 | 175 | 41 |
| **1.A.5** | **Non-Specified** | 770 | 0.0 | 0.02 | - | - | - | 1 | 1 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 9,941 | 108.4 | 0.12 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 43.4 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 9,941 | 65.0 | 0.12 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **65,828** | **44.3** | **19.46** | **888** | **991** | **527** | **1,254** | **33** | **2,314** |
| **2.A** | **Mineral Industry** | 18,771 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 13,096 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 4,809 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 223 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 644 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 6,236 | 8.9 | 18.78 | - | - | - | 1 | 1 | 46 |
| 2.B.1 | Ammonia Production | 287 | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 2.14 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 16.19 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | 0.44 | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 49 | - | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 5,900 | 8.9 | - | - | - | - | - | 0 | 10 |
| 2.B.9 | Fluorochemicals Production | - | - | - | - | - | - | - | - | - |
| 2.B.10 | Other Chemicals | - | - | - | - | - | - | - | - | 36 |
| **2.C** | **Metal Industry** | 40,171 | 35.4 | 0.69 | - | 991 | 352 | 1,207 | 20 | 17 |
| 2.C.1 | Iron and Steel Production | 36,617 | 35.3 | 0.69 | - | - | - | 679 | 17 | 17 |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.C.2 | Ferroalloy Production | 954 | 0.2 | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 2,198 | - | - | - | 991 | - | 528 | 3 | - |
| 2.C.4 | Magnesium Production | 55 | - | - | - | - | 352 | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | 347 | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 649 | - | - | - | - | - | - | - | 1,727 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | 888 | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 175 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 46 | 12 | 524 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 46 | 12 | 30 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 494 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 296 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 198 |
| **3** | **Agriculture** | **14,422** | **13,583.8** | **395.48** | **-** | **-** | **-** | **2,006** | **74** | **-** |
| **3.A** | **Enteric Fermentation** | - | 12,537.1 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 12,190.5 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 10,461.9 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 1,728.6 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 72.8 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 32.3 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 241.5 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 639.2 | 10.51 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 339.9 | 3.49 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 243.0 | 0.70 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 97.0 | 2.79 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 2.6 | - | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 258.4 | 1.41 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 38.2 | 0.53 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 5.08 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 1.48 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 0.51 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 0.98 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 1.21 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | - | 2.38 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 361.2 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 381.50 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 296.25 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 34.21 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 10.73 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 167.87 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 156.70 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 122.78 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 33.92 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 1.92 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 9.25 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 72.55 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 14.94 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 9.77 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 3.94 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 1.78 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 1.36 | - | - | - | - | - | - |
| 3.D.1.d.vi | Manioc | - | - | 0.89 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 0.92 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 37.29 | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.ix | Other annual crops | - | - | 1.65 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 5.00 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 5.90 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 85.25 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 31.80 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 6.98 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 2.04 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 22.77 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 20.89 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 16.37 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 4.52 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.19 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 1.69 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 53.45 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 7.86 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 2.52 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 25.62 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 23.50 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.22 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 1.90 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 16.32 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 3.36 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 2.20 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 0.89 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.40 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.31 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.20 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.21 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 8.39 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.37 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 1.13 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 46.3 | 3.47 | - | - | - | 2,006 | 74 | - |
| **3.G** | **Liming** | 12,614 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 1,808 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | - | - | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **2,296,717** | **3,765.2** | **115.02** | - | - | - | **58,481** | **987** | - |
| **4.A** | **Forest Land** | -200,711 | 71.4 | 2.31 | - | - | - | 1,137 | 22 | - |
| 4.A.1 | Forest Land remaining Forest Land | -171,929 | 67.9 | 2.00 | - | - | - | 1,039 | 16 | - |
| 4.A.2 | Land converted to Forest Land | -28,782 | 3.4 | 0.31 | - | - | - | 97 | 6 | - |
| **4.B** | **Cropland** | 261,154 | 287.5 | 9.13 | - | - | - | 4,538 | 83 | - |
| 4.B.1 | Cropland remaining Cropland | - | - | - | - | - | - | - | - | - |
| 4.B.2 | Land converted to Cropland | 261,154 | 287.5 | 9.13 | - | - | - | 4,538 | 83 | - |
| **4.C** | **Grassland** | 2,252,123 | 3,375.8 | 102.63 | - | - | - | 52,330 | 873 | - |
| 4.C.1 | Grassland remaining Grassland | 46,702 | 54.0 | 4.93 | - | - | - | 1,527 | 92 | - |
| 4.C.2 | Land converted to Grassland | 2,205,421 | 3,321.7 | 97.70 | - | - | - | 50,803 | 782 | - |
| **4.D** | **Wetlands** | 15,202 | 17.2 | 0.54 | - | - | - | 269 | 5 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 15,202 | 17.2 | 0.54 | - | - | - | 269 | 5 | - |
| **4.E** | **Settlements** | 8,573 | 5.6 | 0.18 | - | - | - | 88 | 2 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |
| 4.E.2 | Land converted to Settlements | 8,573 | 5.6 | 0.18 | - | - | - | 88 | 2 | - |
| **4.F** | **Other Land** | 6,178 | 7.7 | 0.23 | - | - | - | 120 | 2 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.F.2 | Land converted to Other Land | 6,178 | 7.7 | 0.23 | - | - | - | 120 | 2 | - |
| **4.G** | **Harvested Wood Products** | -45,801 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **919** | **2,160.0** | **7.43** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 1,274.4 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 539.7 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 734.7 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 1.0 | 0.06 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 919 | 25.1 | 0.39 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 859.4 | 6.98 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 752.7 | 6.98 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 106.7 | - | - | - | - | - | - | - |
| **5.E** | **Other** | - | - | - | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 13,463 | 10.1 | 10.16 | - | - | - | 11 | 11 | 10 |
| 1.A.3.a.i | Aviation | 3,405 | 0.0 | 0.10 | - | - | - | 1 | 1 | 0 |
| 1.A.3.d.i | Navigation | 10,058 | 10.1 | 10.06 | - | - | - | 10 | 10 | 10 |
| | **$CO_2$ emissions from biomass** | 207,549 | | | | | | | | |

Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

## Results of the Fourth National Inventory — Year 2004

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **2,849,186** | **21,082.4** | **585.82** | **1,039** | **899** | **592** | **73,146** | **3,201** | **3,834** |
| **1** | **Energy** | **284,503** | **580.6** | **22.46** | - | - | - | **7,084** | **2,033** | **1,187** |
| **1.A** | **Fuel Combustion Activities** | 275,107 | 443.3 | 22.36 | - | - | - | 7,084 | 2,033 | 1,187 |
| **1.A.1** | **Energy Industries** | 43,676 | 27.0 | 3.84 | - | - | - | 1,434 | 444 | 330 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 20,285 | 0.8 | 0.23 | - | - | - | 15 | 141 | 3 |
| 1.A.1.b | Petroleum Refining | 15,594 | 0.4 | 0.16 | - | - | - | 19 | 162 | 1 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 7,797 | 25.8 | 3.46 | - | - | - | 1,399 | 141 | 326 |
| **1.A.2** | **Manufacturing Industries and Construction** | 60,378 | 29.4 | 4.56 | - | - | - | 1,304 | 255 | 48 |
| 1.A.2.a | Iron and Steel | 6,556 | 0.3 | 0.05 | - | - | - | 13 | 15 | 2 |
| 1.A.2.b | Non-ferrous Metals | 5,264 | 0.2 | 0.03 | - | - | - | 2 | 10 | 0 |
| 1.A.2.c | Chemicals | 15,395 | 2.4 | 0.18 | - | - | - | 21 | 64 | 3 |
| 1.A.2.d | Pulp, Paper and Print | 4,219 | 1.9 | 0.79 | - | - | - | 637 | 34 | 12 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 4,119 | 18.3 | 2.78 | - | - | - | 258 | 63 | 11 |
| 1.A.2.f | Non-metallic Minerals | 11,663 | 5.0 | 0.42 | - | - | - | 271 | 30 | 13 |
| 1.A.2.g | Transport Equipment | 5,974 | 0.9 | 0.22 | - | - | - | 79 | 17 | 4 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 6,002 | 0.3 | 0.06 | - | - | - | 14 | 20 | 2 |
| 1.A.2.l | Textile and Leather | 1,187 | 0.1 | 0.04 | - | - | - | 8 | 2 | 0 |
| **1.A.3** | **Transport** | 135,236 | 47.2 | 9.33 | - | - | - | 2,800 | 1,120 | 548 |
| 1.A.3.a.ii | Domestic Aviation | 6,261 | 0.0 | 0.17 | - | - | - | 4 | 6 | 1 |
| 1.A.3.b | Road Transportation | 123,053 | 46.7 | 8.14 | - | - | - | 2,779 | 985 | 540 |
| 1.A.3.c | Railways | 2,414 | 0.1 | 0.93 | - | - | - | 8 | 40 | 4 |
| 1.A.3.d.ii | Domestic Navigation | 3,508 | 0.3 | 0.09 | - | - | - | 8 | 89 | 3 |
| 1.A.3.e | Other Transportation | - | - | - | - | - | - | - | - | - |
| **1.A.4** | **Other Sectors** | 34,988 | 339.7 | 4.60 | - | - | - | 1,546 | 213 | 262 |
| 1.A.4.a | Commercial / Institutional | 4,023 | 3.0 | 0.07 | - | - | - | 5 | 8 | 3 |
| 1.A.4.b | Residential | 15,863 | 321.1 | 3.42 | - | - | - | 1,439 | 31 | 216 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 15,102 | 15.6 | 1.11 | - | - | - | 102 | 173 | 43 |
| **1.A.5** | **Non-Specified** | 828 | 0.0 | 0.02 | - | - | - | 1 | 1 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 9,396 | 137.3 | 0.11 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 50.6 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 9,396 | 86.7 | 0.11 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **67,043** | **52.0** | **26.97** | **1,039** | **899** | **592** | **1,433** | **38** | **2,646** |
| **2.A** | **Mineral Industry** | 19,401 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 13,273 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 5,228 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 245 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 655 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 6,535 | 9.4 | 26.14 | - | - | - | 1 | 1 | 49 |
| 2.B.1 | Ammonia Production | 329 | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 2.21 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 23.48 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | 0.45 | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 41 | - | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 6,166 | 9.4 | - | - | - | - | - | 0 | 10 |
| 2.B.9 | Fluorochemicals Production | - | - | - | - | - | - | - | - | - |
| 2.B.10 | Other Chemicals | - | - | - | - | - | - | - | - | 39 |
| **2.C** | **Metal Industry** | 40,445 | 42.5 | 0.83 | - | 899 | 407 | 1,383 | 24 | 21 |
| 2.C.1 | Iron and Steel Production | 36,783 | 42.4 | 0.83 | - | - | - | 821 | 21 | 21 |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.C.2 | Ferroalloy Production | 960 | 0.2 | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 2,408 | - | - | - | 899 | - | 562 | 3 | - |
| 2.C.4 | Magnesium Production | 62 | - | - | - | - | 407 | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | 232 | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 662 | - | - | - | - | - | - | - | 2,020 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | 1,039 | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 185 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 49 | 13 | 556 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 49 | 13 | 32 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 523 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 323 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 201 |
| **3** | **Agriculture** | **14,330** | **14,226.5** | **405.71** | **-** | **-** | **-** | **2,075** | **77** | **-** |
| **3.A** | **Enteric Fermentation** | - | 13,112.5 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 12,761.8 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 10,962.9 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 1,798.9 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 75.3 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 33.1 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 242.3 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 663.6 | 11.11 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 361.2 | 3.74 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 256.8 | 0.85 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 104.4 | 2.89 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 2.7 | - | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 260.9 | 1.46 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 38.7 | 0.55 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 5.35 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 1.63 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 0.61 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 1.01 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 1.25 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | - | 2.48 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 402.6 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 391.01 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 303.51 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 34.48 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 11.64 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 174.77 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 163.48 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 128.18 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 35.30 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 1.96 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 9.33 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 71.67 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 14.26 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 8.45 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 4.20 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 2.28 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 1.22 | - | - | - | - | - | - |
| 3.D.1.d.vi | Manioc | - | - | 0.97 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 0.87 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 37.41 | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.ix | Other annual crops | - | - | 2.01 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 5.00 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 5.94 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 87.50 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 32.88 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 6.97 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 2.21 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 23.70 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 21.80 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 17.09 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 4.71 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.20 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 1.71 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 54.62 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 7.94 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 2.74 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 26.66 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 24.52 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.22 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 1.92 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 16.15 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 3.21 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 1.90 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 0.94 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.51 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.28 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.22 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.20 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 8.42 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.48 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 1.13 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 47.9 | 3.59 | - | - | - | 2,075 | 77 | - |
| **3.G** | **Liming** | 12,546 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 1,784 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | - | - | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **2,482,398** | **4,029.3** | **122.94** | - | - | - | **62,553** | **1,053** | - |
| **4.A** | **Forest Land** | -200,066 | 73.7 | 2.39 | - | - | - | 1,173 | 22 | - |
| 4.A.1 | Forest Land remaining Forest Land | -175,270 | 70.2 | 2.06 | - | - | - | 1,073 | 17 | - |
| 4.A.2 | Land converted to Forest Land | -24,797 | 3.5 | 0.32 | - | - | - | 100 | 6 | - |
| **4.B** | **Cropland** | 273,041 | 301.3 | 9.55 | - | - | - | 4,751 | 87 | - |
| 4.B.1 | Cropland remaining Cropland | - | - | - | - | - | - | - | - | - |
| 4.B.2 | Land converted to Cropland | 273,041 | 301.3 | 9.55 | - | - | - | 4,751 | 87 | - |
| **4.C** | **Grassland** | 2,426,472 | 3,622.6 | 110.03 | - | - | - | 56,134 | 935 | - |
| 4.C.1 | Grassland remaining Grassland | 49,680 | 56.3 | 5.14 | - | - | - | 1,590 | 95 | - |
| 4.C.2 | Land converted to Grassland | 2,376,792 | 3,566.4 | 104.89 | - | - | - | 54,544 | 839 | - |
| **4.D** | **Wetlands** | 15,518 | 17.6 | 0.55 | - | - | - | 276 | 5 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 15,518 | 17.6 | 0.55 | - | - | - | 276 | 5 | - |
| **4.E** | **Settlements** | 8,790 | 5.8 | 0.18 | - | - | - | 91 | 2 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |
| 4.E.2 | Land converted to Settlements | 8,790 | 5.8 | 0.18 | - | - | - | 91 | 2 | - |
| **4.F** | **Other Land** | 6,590 | 8.3 | 0.25 | - | - | - | 128 | 2 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.F.2 | Land converted to Other Land | 6,590 | 8.3 | 0.25 | - | - | - | 128 | 2 | - |
| **4.G** | **Harvested Wood Products** | -47,947 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **912** | **2,194.0** | **7.74** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 1,271.1 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 530.6 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 740.5 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 1.1 | 0.07 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 912 | 25.5 | 0.40 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 896.3 | 7.27 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 771.7 | 7.27 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 124.7 | - | - | - | - | - | - | - |
| **5.E** | **Other** | - | - | - | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 13,463 | 10.1 | 10.16 | - | - | - | 11 | 11 | 10 |
| 1.A.3.a.i | Aviation | 3,405 | 0.0 | 0.10 | - | - | - | 1 | 1 | 0 |
| 1.A.3.d.i | Navigation | 10,058 | 10.1 | 10.06 | - | - | - | 10 | 10 | 10 |
| | **$CO_2$ emissions from biomass** | 219,905 | | | | | | | | |

Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

## Results of the Fourth National Inventory — Year 2005

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **1,850,825** | **20,111.8** | **548.25** | **1,231** | **901** | **646** | **53,586** | **2,894** | **3,761** |
| **1** | **Energy** | **292,351** | **660.4** | **23.15** | - | - | - | **7,057** | **2,037** | **1,164** |
| **1.A** | **Fuel Combustion Activities** | 279,894 | 450.1 | 22.95 | - | - | - | 7,057 | 2,037 | 1,164 |
| **1.A.1** | **Energy Industries** | 45,514 | 27.7 | 3.94 | - | - | - | 1,453 | 471 | 328 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 20,909 | 0.8 | 0.23 | - | - | - | 15 | 145 | 3 |
| 1.A.1.b | Petroleum Refining | 16,960 | 0.4 | 0.16 | - | - | - | 21 | 178 | 1 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 7,646 | 26.5 | 3.55 | - | - | - | 1,417 | 148 | 324 |
| **1.A.2** | **Manufacturing Industries and Construction** | 63,308 | 30.0 | 4.71 | - | - | - | 1,372 | 265 | 50 |
| 1.A.2.a | Iron and Steel | 6,876 | 0.3 | 0.05 | - | - | - | 13 | 16 | 2 |
| 1.A.2.b | Non-ferrous Metals | 5,402 | 0.2 | 0.03 | - | - | - | 2 | 10 | 0 |
| 1.A.2.c | Chemicals | 15,192 | 2.5 | 0.18 | - | - | - | 22 | 62 | 3 |
| 1.A.2.d | Pulp, Paper and Print | 4,572 | 2.1 | 0.84 | - | - | - | 675 | 38 | 13 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 4,102 | 18.8 | 2.84 | - | - | - | 267 | 66 | 11 |
| 1.A.2.f | Non-metallic Minerals | 12,926 | 4.9 | 0.44 | - | - | - | 286 | 33 | 14 |
| 1.A.2.g | Transport Equipment | 6,169 | 0.8 | 0.21 | - | - | - | 78 | 17 | 4 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 6,889 | 0.4 | 0.07 | - | - | - | 20 | 22 | 2 |
| 1.A.2.l | Textile and Leather | 1,181 | 0.1 | 0.04 | - | - | - | 8 | 2 | 0 |
| **1.A.3** | **Transport** | 135,530 | 45.8 | 9.61 | - | - | - | 2,654 | 1,089 | 519 |
| 1.A.3.a.ii | Domestic Aviation | 5,889 | 0.0 | 0.16 | - | - | - | 4 | 5 | 1 |
| 1.A.3.b | Road Transportation | 123,488 | 45.3 | 8.37 | - | - | - | 2,633 | 950 | 511 |
| 1.A.3.c | Railways | 2,556 | 0.1 | 0.99 | - | - | - | 9 | 43 | 4 |
| 1.A.3.d.ii | Domestic Navigation | 3,598 | 0.3 | 0.09 | - | - | - | 9 | 91 | 3 |
| 1.A.3.e | Other Transportation | - | - | - | - | - | - | - | - | - |
| **1.A.4** | **Other Sectors** | 34,398 | 346.6 | 4.66 | - | - | - | 1,577 | 211 | 267 |
| 1.A.4.a | Commercial / Institutional | 3,786 | 3.1 | 0.06 | - | - | - | 4 | 7 | 3 |
| 1.A.4.b | Residential | 15,591 | 327.6 | 3.48 | - | - | - | 1,468 | 31 | 220 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 15,022 | 15.9 | 1.12 | - | - | - | 104 | 173 | 43 |
| **1.A.5** | **Non-Specified** | 1,144 | 0.0 | 0.03 | - | - | - | 1 | 1 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 12,457 | 210.2 | 0.21 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 52.1 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 12,457 | 158.2 | 0.21 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **67,660** | **51.1** | **23.79** | **1,231** | **901** | **646** | **1,430** | **39** | **2,597** |
| **2.A** | **Mineral Industry** | 20,444 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 14,349 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 5,087 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 250 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 759 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 6,844 | 9.4 | 22.98 | - | - | - | 1 | 1 | 49 |
| 2.B.1 | Ammonia Production | 522 | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 2.24 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 20.29 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | 0.45 | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 35 | - | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 6,287 | 9.4 | - | - | - | - | - | 0 | 10 |
| 2.B.9 | Fluorochemicals Production | - | - | - | - | - | - | - | - | - |
| 2.B.10 | Other Chemicals | - | - | - | - | - | - | - | - | 39 |
| **2.C** | **Metal Industry** | 39,711 | 41.7 | 0.81 | - | 901 | 455 | 1,376 | 23 | 20 |
| 2.C.1 | Iron and Steel Production | 35,973 | 41.5 | 0.81 | - | - | - | 804 | 20 | 20 |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.C.2 | Ferroalloy Production | 949 | 0.2 | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 2,472 | - | - | - | 901 | - | 572 | 3 | - |
| 2.C.4 | Magnesium Production | 74 | - | - | - | - | 455 | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | 243 | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 661 | - | - | - | - | - | - | - | 1,985 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | 1,231 | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 190 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 53 | 14 | 543 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 53 | 14 | 35 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 508 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 343 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 165 |
| **3** | **Agriculture** | **9,975** | **14,352.9** | **408.30** | **-** | **-** | **-** | **2,078** | **77** | **-** |
| **3.A** | **Enteric Fermentation** | - | 13,243.7 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 12,885.7 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 11,027.5 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 1,858.1 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 77.9 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 34.1 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 246.1 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 675.7 | 11.44 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 367.8 | 3.75 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 258.9 | 0.80 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 108.9 | 2.95 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 2.8 | - | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 265.1 | 1.53 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 40.0 | 0.59 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 5.56 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 1.61 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 0.58 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 1.03 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 1.31 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | - | 2.64 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 385.6 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 393.26 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 305.08 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 33.82 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 12.21 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 176.99 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 165.48 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 129.07 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 36.41 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 2.01 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 9.50 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 71.08 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 14.73 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 7.10 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 4.36 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 2.27 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 1.25 | - | - | - | - | - | - |
| 3.D.1.d.vi | Manioc | - | - | 1.05 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 0.70 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 37.52 | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.ix | Other annual crops | - | - | 2.11 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 5.00 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 5.98 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 88.17 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 33.40 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 7.08 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 2.32 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 24.00 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 22.06 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 17.21 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 4.85 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.20 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 1.74 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 54.78 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 7.78 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 2.88 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 27.00 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 24.82 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.23 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 1.95 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 15.99 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 3.31 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 1.60 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 0.98 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.51 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.28 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.24 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.16 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 8.44 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.47 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 1.13 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 48.0 | 3.60 | - | - | - | 2,078 | 77 | - |
| **3.G** | **Liming** | 8,097 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 1,878 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | - | - | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **1,479,731** | **2,760.2** | **85.03** | - | - | - | **43,020** | **740** | - |
| **4.A** | **Forest Land** | -271,068 | 56.4 | 1.85 | - | - | - | 902 | 18 | - |
| 4.A.1 | Forest Land remaining Forest Land | -219,889 | 53.3 | 1.57 | - | - | - | 815 | 13 | - |
| 4.A.2 | Land converted to Forest Land | -51,178 | 3.1 | 0.28 | - | - | - | 88 | 5 | - |
| **4.B** | **Cropland** | 189,353 | 207.4 | 6.70 | - | - | - | 3,298 | 63 | - |
| 4.B.1 | Cropland remaining Cropland | - | - | - | - | - | - | - | - | - |
| 4.B.2 | Land converted to Cropland | 189,353 | 207.4 | 6.70 | - | - | - | 3,298 | 63 | - |
| **4.C** | **Grassland** | 1,590,192 | 2,473.4 | 75.75 | - | - | - | 38,458 | 653 | - |
| 4.C.1 | Grassland remaining Grassland | 21,515 | 48.6 | 4.43 | - | - | - | 1,372 | 82 | - |
| 4.C.2 | Land converted to Grassland | 1,568,677 | 2,424.8 | 71.32 | - | - | - | 37,086 | 571 | - |
| **4.D** | **Wetlands** | 11,873 | 12.9 | 0.40 | - | - | - | 202 | 4 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 11,873 | 12.9 | 0.40 | - | - | - | 202 | 4 | - |
| **4.E** | **Settlements** | 6,920 | 4.3 | 0.14 | - | - | - | 67 | 1 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |
| 4.E.2 | Land converted to Settlements | 6,920 | 4.3 | 0.14 | - | - | - | 67 | 1 | - |
| **4.F** | **Other Land** | 4,819 | 5.9 | 0.18 | - | - | - | 92 | 2 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.F.2 | Land converted to Other Land | 4,819 | 5.9 | 0.18 | - | - | - | 92 | 2 | - |
| **4.G** | **Harvested Wood Products** | -52,357 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **1,108** | **2,287.2** | **7.99** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 1,334.4 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 578.1 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 756.3 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 1.2 | 0.07 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 1,108 | 28.1 | 0.45 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 923.6 | 7.48 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 788.9 | 7.48 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 134.6 | - | - | - | - | - | - | - |
| **5.E** | **Other** | - | - | - | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 15,255 | 10.9 | 11.05 | - | - | - | 12 | 12 | 11 |
| 1.A.3.a.i | Aviation | 4,323 | 0.0 | 0.12 | - | - | - | 1 | 1 | 0 |
| 1.A.3.d.i | Navigation | 10,932 | 10.9 | 10.93 | - | - | - | 11 | 11 | 11 |
| | **$CO_2$ emissions from biomass** | 228,317 | | | | | | | | |

Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

## Results of the Fourth National Inventory — Year 2006

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **1,509,776** | **19,409.8** | **534.25** | **1,492** | **888** | **710** | **42,752** | **2,729** | **4,427** |
| **1** | **Energy** | **297,469** | **630.8** | **23.81** | - | - | - | **7,005** | **2,042** | **1,133** |
| **1.A** | **Fuel Combustion Activities** | 285,827 | 454.2 | 23.65 | - | - | - | 7,005 | 2,042 | 1,133 |
| **1.A.1** | **Energy Industries** | 45,552 | 28.4 | 4.05 | - | - | - | 1,466 | 480 | 322 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 20,658 | 0.8 | 0.23 | - | - | - | 13 | 141 | 3 |
| 1.A.1.b | Petroleum Refining | 16,605 | 0.4 | 0.16 | - | - | - | 21 | 176 | 1 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 8,288 | 27.2 | 3.65 | - | - | - | 1,431 | 163 | 319 |
| **1.A.2** | **Manufacturing Industries and Construction** | 64,389 | 33.2 | 5.17 | - | - | - | 1,458 | 278 | 54 |
| 1.A.2.a | Iron and Steel | 6,868 | 0.3 | 0.05 | - | - | - | 13 | 15 | 2 |
| 1.A.2.b | Non-ferrous Metals | 5,628 | 0.2 | 0.03 | - | - | - | 2 | 11 | 0 |
| 1.A.2.c | Chemicals | 15,892 | 2.5 | 0.19 | - | - | - | 23 | 65 | 3 |
| 1.A.2.d | Pulp, Paper and Print | 3,997 | 2.2 | 0.90 | - | - | - | 729 | 38 | 15 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 3,704 | 21.5 | 3.22 | - | - | - | 279 | 72 | 12 |
| 1.A.2.f | Non-metallic Minerals | 13,837 | 5.1 | 0.46 | - | - | - | 302 | 35 | 15 |
| 1.A.2.g | Transport Equipment | 6,164 | 0.9 | 0.22 | - | - | - | 81 | 17 | 4 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 7,120 | 0.4 | 0.07 | - | - | - | 20 | 22 | 2 |
| 1.A.2.l | Textile and Leather | 1,180 | 0.1 | 0.04 | - | - | - | 9 | 2 | 0 |
| **1.A.3** | **Transport** | 140,238 | 44.0 | 9.70 | - | - | - | 2,497 | 1,070 | 488 |
| 1.A.3.a.ii | Domestic Aviation | 6,150 | 0.0 | 0.17 | - | - | - | 4 | 5 | 1 |
| 1.A.3.b | Road Transportation | 127,782 | 43.6 | 8.35 | - | - | - | 2,476 | 929 | 481 |
| 1.A.3.c | Railways | 2,830 | 0.2 | 1.09 | - | - | - | 10 | 47 | 4 |
| 1.A.3.d.ii | Domestic Navigation | 3,476 | 0.3 | 0.09 | - | - | - | 8 | 88 | 3 |
| 1.A.3.e | Other Transportation | - | - | - | - | - | - | - | - | - |
| **1.A.4** | **Other Sectors** | 34,559 | 348.6 | 4.70 | - | - | - | 1,583 | 213 | 268 |
| 1.A.4.a | Commercial / Institutional | 3,778 | 3.2 | 0.07 | - | - | - | 5 | 7 | 3 |
| 1.A.4.b | Residential | 15,616 | 329.0 | 3.49 | - | - | - | 1,473 | 31 | 221 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 15,165 | 16.4 | 1.14 | - | - | - | 106 | 175 | 44 |
| **1.A.5** | **Non-Specified** | 1,089 | 0.0 | 0.03 | - | - | - | 1 | 1 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 11,642 | 176.6 | 0.16 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 50.8 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 11,642 | 125.8 | 0.16 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **67,549** | **52.7** | **25.69** | **1,492** | **888** | **710** | **1,449** | **40** | **3,294** |
| **2.A** | **Mineral Industry** | 21,715 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 15,440 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 5,137 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 213 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 924 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 6,930 | 12.5 | 24.91 | - | - | - | 1 | 2 | 52 |
| 2.B.1 | Ammonia Production | 258 | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 2.20 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 22.31 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | 0.40 | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 46 | - | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 6,626 | 12.5 | - | - | - | - | - | 0 | 12 |
| 2.B.9 | Fluorochemicals Production | - | - | - | - | - | - | - | - | - |
| 2.B.10 | Other Chemicals | - | - | - | - | - | - | - | - | 41 |
| **2.C** | **Metal Industry** | 38,317 | 40.3 | 0.78 | - | 888 | 515 | 1,390 | 23 | 19 |
| 2.C.1 | Iron and Steel Production | 34,379 | 40.0 | 0.78 | - | - | - | 776 | 19 | 19 |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.C.2 | Ferroalloy Production | 959 | 0.2 | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 2,646 | - | - | - | 888 | - | 614 | 3 | - |
| 2.C.4 | Magnesium Production | 85 | - | - | - | - | 515 | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | 247 | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 588 | - | - | - | - | - | - | - | 2,553 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | 1,492 | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 195 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 57 | 15 | 669 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 57 | 15 | 38 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 632 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 337 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 295 |
| **3** | **Agriculture** | **9,925** | **14,297.5** | **412.94** | **-** | **-** | **-** | **2,233** | **83** | **-** |
| **3.A** | **Enteric Fermentation** | - | 13,178.1 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 12,817.9 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 10,931.3 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 1,886.6 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 80.1 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 35.2 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 244.9 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 687.3 | 11.77 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 371.1 | 3.83 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 257.1 | 0.81 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 114.0 | 3.02 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 2.9 | - | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 273.1 | 1.61 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 40.3 | 0.61 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 5.72 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 1.64 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 0.59 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 1.06 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 1.38 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | - | 2.70 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 380.6 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 397.31 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 308.23 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 35.31 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 12.47 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 176.34 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 164.89 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 127.97 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 36.93 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 1.95 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 9.50 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 73.08 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 15.10 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 8.62 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 5.20 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 1.98 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 1.43 | - | - | - | - | - | - |
| 3.D.1.d.vi | Manioc | - | - | 1.08 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 0.37 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 37.44 | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.ix | Other annual crops | - | - | 1.86 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 5.00 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 6.01 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 89.08 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 33.55 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 7.26 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 2.37 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 23.92 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 21.99 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 17.06 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 4.92 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.19 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 1.74 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 55.54 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 8.12 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 2.94 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 26.91 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 24.73 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.22 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 1.96 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 16.44 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 3.40 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 1.94 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 1.17 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.45 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.32 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.24 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.08 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 8.42 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.42 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 1.13 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 51.5 | 3.87 | - | - | - | 2,233 | 83 | - |
| **3.G** | **Liming** | 8,032 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 1,894 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | - | - | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **1,133,831** | **2,048.3** | **63.77** | - | - | - | **32,066** | **565** | - |
| **4.A** | **Forest Land** | -274,196 | 59.8 | 1.96 | - | - | - | 957 | 19 | - |
| 4.A.1 | Forest Land remaining Forest Land | -218,165 | 56.5 | 1.66 | - | - | - | 864 | 13 | - |
| 4.A.2 | Land converted to Forest Land | -56,030 | 3.3 | 0.30 | - | - | - | 92 | 6 | - |
| **4.B** | **Cropland** | 120,244 | 123.6 | 4.20 | - | - | - | 2,010 | 43 | - |
| 4.B.1 | Cropland remaining Cropland | - | - | - | - | - | - | - | - | - |
| 4.B.2 | Land converted to Cropland | 120,244 | 123.6 | 4.20 | - | - | - | 2,010 | 43 | - |
| **4.C** | **Grassland** | 1,319,924 | 1,844.7 | 56.97 | - | - | - | 28,783 | 498 | - |
| 4.C.1 | Grassland remaining Grassland | 20,765 | 43.9 | 4.01 | - | - | - | 1,240 | 74 | - |
| 4.C.2 | Land converted to Grassland | 1,299,159 | 1,800.9 | 52.97 | - | - | - | 27,543 | 424 | - |
| **4.D** | **Wetlands** | 10,336 | 10.8 | 0.34 | - | - | - | 170 | 3 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 10,336 | 10.8 | 0.34 | - | - | - | 170 | 3 | - |
| **4.E** | **Settlements** | 6,422 | 4.1 | 0.13 | - | - | - | 64 | 1 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |
| 4.E.2 | Land converted to Settlements | 6,422 | 4.1 | 0.13 | - | - | - | 64 | 1 | - |
| **4.F** | **Other Land** | 4,538 | 5.3 | 0.16 | - | - | - | 83 | 1 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.F.2 | Land converted to Other Land | 4,538 | 5.3 | 0.16 | - | - | - | 83 | 1 | - |
| **4.G** | **Harvested Wood Products** | -53,438 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **1,001** | **2,380.4** | **8.04** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 1,403.5 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 605.9 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 797.6 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 1.1 | 0.07 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 1,001 | 25.3 | 0.41 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 950.5 | 7.56 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 810.3 | 7.56 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 140.1 | - | - | - | - | - | - | - |
| **5.E** | **Other** | - | - | - | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 14,763 | 10.6 | 10.72 | - | - | - | 11 | 12 | 11 |
| 1.A.3.a.i | Aviation | 4,157 | 0.0 | 0.12 | - | - | - | 1 | 1 | 0 |
| 1.A.3.d.i | Navigation | 10,606 | 10.6 | 10.61 | - | - | - | 11 | 11 | 11 |
| | **$CO_2$ emissions from biomass** | 242,189 | | | | | | | | |

Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

## Results of the Fourth National Inventory — Year 2007

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **1,201,242** | **18,277.8** | **515.96** | **1,752** | **854** | **819** | **37,885** | **2,749** | **2,998** |
| **1** | **Energy** | **310,634** | **615.9** | **25.15** | - | - | - | **7,257** | **2,138** | **1,164** |
| **1.A** | **Fuel Combustion Activities** | 298,680 | 444.4 | 25.00 | - | - | - | 7,257 | 2,138 | 1,164 |
| **1.A.1** | **Energy Industries** | 45,302 | 30.9 | 4.36 | - | - | - | 1,570 | 489 | 332 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 19,364 | 0.6 | 0.19 | - | - | - | 11 | 127 | 2 |
| 1.A.1.b | Petroleum Refining | 17,500 | 0.4 | 0.16 | - | - | - | 22 | 186 | 1 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 8,439 | 29.9 | 4.00 | - | - | - | 1,537 | 175 | 329 |
| **1.A.2** | **Manufacturing Industries and Construction** | 70,142 | 34.9 | 5.49 | - | - | - | 1,555 | 303 | 59 |
| 1.A.2.a | Iron and Steel | 7,588 | 0.3 | 0.06 | - | - | - | 14 | 16 | 2 |
| 1.A.2.b | Non-ferrous Metals | 6,001 | 0.2 | 0.03 | - | - | - | 3 | 12 | 0 |
| 1.A.2.c | Chemicals | 16,194 | 2.6 | 0.20 | - | - | - | 24 | 71 | 4 |
| 1.A.2.d | Pulp, Paper and Print | 4,085 | 2.4 | 0.95 | - | - | - | 773 | 41 | 16 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 4,120 | 22.9 | 3.41 | - | - | - | 298 | 78 | 13 |
| 1.A.2.f | Non-metallic Minerals | 15,647 | 5.0 | 0.49 | - | - | - | 324 | 39 | 16 |
| 1.A.2.g | Transport Equipment | 6,989 | 0.9 | 0.23 | - | - | - | 86 | 19 | 4 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 8,210 | 0.4 | 0.08 | - | - | - | 25 | 25 | 3 |
| 1.A.2.l | Textile and Leather | 1,309 | 0.1 | 0.04 | - | - | - | 9 | 3 | 0 |
| **1.A.3** | **Transport** | 145,937 | 47.0 | 10.52 | - | - | - | 2,616 | 1,120 | 513 |
| 1.A.3.a.ii | Domestic Aviation | 6,695 | 0.0 | 0.18 | - | - | - | 4 | 6 | 0 |
| 1.A.3.b | Road Transportation | 131,953 | 46.4 | 9.06 | - | - | - | 2,592 | 954 | 505 |
| 1.A.3.c | Railways | 3,009 | 0.2 | 1.17 | - | - | - | 10 | 51 | 5 |
| 1.A.3.d.ii | Domestic Navigation | 4,280 | 0.4 | 0.11 | - | - | - | 10 | 109 | 4 |
| 1.A.3.e | Other Transportation | - | - | - | - | - | - | - | - | - |
| **1.A.4** | **Other Sectors** | 36,116 | 331.6 | 4.60 | - | - | - | 1,515 | 225 | 260 |
| 1.A.4.a | Commercial / Institutional | 3,989 | 3.3 | 0.07 | - | - | - | 5 | 8 | 3 |
| 1.A.4.b | Residential | 16,123 | 311.1 | 3.33 | - | - | - | 1,398 | 31 | 210 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 16,004 | 17.2 | 1.21 | - | - | - | 112 | 186 | 47 |
| **1.A.5** | **Non-Specified** | 1,182 | 0.0 | 0.03 | - | - | - | 1 | 1 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 11,954 | 171.6 | 0.15 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 57.3 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 11,954 | 114.3 | 0.15 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **82,971** | **54.4** | **3.90** | **1,752** | **854** | **819** | **1,486** | **42** | **1,834** |
| **2.A** | **Mineral Industry** | 23,755 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 17,200 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 5,381 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 213 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 960 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 7,225 | 12.7 | 3.09 | - | - | - | 1 | 2 | 53 |
| 2.B.1 | Ammonia Production | 200 | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 2.07 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 0.57 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | 0.45 | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 41 | - | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 6,984 | 12.7 | - | - | - | - | - | 0 | 12 |
| 2.B.9 | Fluorochemicals Production | - | - | - | - | - | - | - | - | - |
| 2.B.10 | Other Chemicals | - | - | - | - | - | - | - | - | 42 |
| **2.C** | **Metal Industry** | 51,307 | 41.7 | 0.81 | - | 854 | 620 | 1,423 | 24 | 20 |
| 2.C.1 | Iron and Steel Production | 47,055 | 41.4 | 0.81 | - | - | - | 800 | 20 | 20 |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.C.2 | Ferroalloy Production | 1,099 | 0.2 | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 2,739 | - | - | - | 854 | - | 623 | 4 | - |
| 2.C.4 | Magnesium Production | 93 | - | - | - | - | 620 | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | 319 | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 685 | - | - | - | - | - | - | - | 1,144 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | 1,752 | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 199 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 61 | 16 | 617 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 61 | 16 | 41 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 576 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 382 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 194 |
| **3** | **Agriculture** | **12,823** | **13,526.2** | **425.66** | **-** | **-** | **-** | **2,445** | **91** | **-** |
| **3.A** | **Enteric Fermentation** | - | 12,437.9 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 12,085.4 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 10,223.3 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 1,862.1 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 81.2 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 35.9 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 235.4 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 669.6 | 12.36 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 353.3 | 3.98 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 239.9 | 0.90 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 113.4 | 3.08 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 2.9 | - | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 271.3 | 1.65 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 42.1 | 0.66 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 6.07 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 1.73 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 0.65 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 1.08 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 1.41 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | - | 2.93 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 362.2 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 409.07 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 316.74 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 42.60 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 13.56 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 171.76 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 160.70 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 123.51 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 37.19 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 1.86 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 9.20 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 77.75 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 16.65 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 10.53 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 6.28 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 1.90 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 1.31 | - | - | - | - | - | - |
| 3.D.1.d.vi | Manioc | - | - | 1.08 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 0.62 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 37.46 | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.ix | Other annual crops | - | - | 1.93 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 5.00 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 6.05 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 92.33 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 34.55 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 8.69 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 2.57 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 23.30 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 21.43 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 16.47 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 4.96 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.19 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 1.68 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 57.78 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 9.75 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 3.20 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 26.21 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 24.11 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.21 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 1.89 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 17.49 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 3.75 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 2.37 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 1.41 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.43 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.29 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.24 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.14 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 8.43 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.43 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 1.13 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 56.4 | 4.23 | - | - | - | 2,445 | 91 | - |
| **3.G** | **Liming** | 10,563 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 2,260 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | - | - | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **793,759** | **1,699.8** | **53.34** | - | - | - | **26,698** | **479** | - |
| **4.A** | **Forest Land** | -336,495 | 53.0 | 1.75 | - | - | - | 850 | 17 | - |
| 4.A.1 | Forest Land remaining Forest Land | -271,333 | 49.9 | 1.47 | - | - | - | 762 | 12 | - |
| 4.A.2 | Land converted to Forest Land | -65,162 | 3.1 | 0.28 | - | - | - | 88 | 5 | - |
| **4.B** | **Cropland** | 102,876 | 105.6 | 3.65 | - | - | - | 1,729 | 38 | - |
| 4.B.1 | Cropland remaining Cropland | - | - | - | - | - | - | - | - | - |
| 4.B.2 | Land converted to Cropland | 102,876 | 105.6 | 3.65 | - | - | - | 1,729 | 38 | - |
| **4.C** | **Grassland** | 1,061,751 | 1,523.7 | 47.38 | - | - | - | 23,841 | 419 | - |
| 4.C.1 | Grassland remaining Grassland | 10,411 | 41.4 | 3.78 | - | - | - | 1,171 | 70 | - |
| 4.C.2 | Land converted to Grassland | 1,051,340 | 1,482.3 | 43.60 | - | - | - | 22,670 | 349 | - |
| **4.D** | **Wetlands** | 9,372 | 9.5 | 0.30 | - | - | - | 151 | 3 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 9,372 | 9.5 | 0.30 | - | - | - | 151 | 3 | - |
| **4.E** | **Settlements** | 5,830 | 3.6 | 0.11 | - | - | - | 56 | 1 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |
| 4.E.2 | Land converted to Settlements | 5,830 | 3.6 | 0.11 | - | - | - | 56 | 1 | - |
| **4.F** | **Other Land** | 3,897 | 4.5 | 0.14 | - | - | - | 70 | 1 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.F.2 | Land converted to Other Land | 3,897 | 4.5 | 0.14 | - | - | - | 70 | 1 | - |
| **4.G** | **Harvested Wood Products** | -53,472 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **1,054** | **2,381.5** | **7.90** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 1,395.2 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 563.2 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 832.0 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 1.2 | 0.07 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 1,054 | 26.7 | 0.43 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 958.3 | 7.40 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 811.8 | 7.40 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 146.5 | - | - | - | - | - | - | - |
| **5.E** | **Other** | - | - | - | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 16,004 | 11.4 | 11.54 | - | - | - | 12 | 13 | 12 |
| 1.A.3.a.i | Aviation | 4,594 | 0.0 | 0.13 | - | - | - | 1 | 1 | 0 |
| 1.A.3.d.i | Navigation | 11,410 | 11.4 | 11.41 | - | - | - | 11 | 11 | 11 |
| | **$CO_2$ emissions from biomass** | 263,119 | | | | | | | | |

Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

## Results of the Fourth National Inventory — Year 2008

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **1,324,648** | **18,697.8** | **527.33** | **2,065** | **891** | **871** | **39,858** | **2,900** | **4,381** |
| **1** | **Energy** | **329,701** | **622.1** | **26.96** | - | - | - | **7,362** | **2,259** | **1,154** |
| **1.A** | **Fuel Combustion Activities** | 317,169 | 445.9 | 26.79 | - | - | - | 7,362 | 2,259 | 1,154 |
| **1.A.1** | **Energy Industries** | 54,625 | 35.1 | 4.97 | - | - | - | 1,705 | 567 | 337 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 26,472 | 1.1 | 0.30 | - | - | - | 18 | 150 | 3 |
| 1.A.1.b | Petroleum Refining | 18,081 | 0.4 | 0.18 | - | - | - | 22 | 197 | 1 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 10,072 | 33.6 | 4.49 | - | - | - | 1,665 | 220 | 332 |
| **1.A.2** | **Manufacturing Industries and Construction** | 71,573 | 34.7 | 5.53 | - | - | - | 1,647 | 303 | 61 |
| 1.A.2.a | Iron and Steel | 8,073 | 0.4 | 0.07 | - | - | - | 15 | 17 | 2 |
| 1.A.2.b | Non-ferrous Metals | 5,665 | 0.2 | 0.03 | - | - | - | 2 | 12 | 0 |
| 1.A.2.c | Chemicals | 15,519 | 2.6 | 0.19 | - | - | - | 22 | 64 | 3 |
| 1.A.2.d | Pulp, Paper and Print | 4,449 | 2.5 | 1.02 | - | - | - | 821 | 44 | 17 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 4,187 | 21.9 | 3.30 | - | - | - | 298 | 76 | 13 |
| 1.A.2.f | Non-metallic Minerals | 17,079 | 5.7 | 0.55 | - | - | - | 364 | 43 | 18 |
| 1.A.2.g | Transport Equipment | 7,805 | 1.0 | 0.25 | - | - | - | 90 | 20 | 5 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 7,622 | 0.4 | 0.07 | - | - | - | 26 | 23 | 3 |
| 1.A.2.l | Textile and Leather | 1,174 | 0.1 | 0.04 | - | - | - | 9 | 2 | 0 |
| **1.A.3** | **Transport** | 151,247 | 47.1 | 11.55 | - | - | - | 2,499 | 1,141 | 493 |
| 1.A.3.a.ii | Domestic Aviation | 6,621 | 0.0 | 0.18 | - | - | - | 3 | 6 | 0 |
| 1.A.3.b | Road Transportation | 136,924 | 46.5 | 10.04 | - | - | - | 2,474 | 965 | 484 |
| 1.A.3.c | Railways | 3,055 | 0.2 | 1.21 | - | - | - | 11 | 52 | 5 |
| 1.A.3.d.ii | Domestic Navigation | 4,648 | 0.4 | 0.12 | - | - | - | 11 | 118 | 4 |
| 1.A.3.e | Other Transportation | - | - | - | - | - | - | - | - | - |
| **1.A.4** | **Other Sectors** | 37,848 | 329.0 | 4.69 | - | - | - | 1,510 | 246 | 262 |
| 1.A.4.a | Commercial / Institutional | 3,829 | 3.4 | 0.07 | - | - | - | 5 | 9 | 3 |
| 1.A.4.b | Residential | 16,530 | 307.1 | 3.30 | - | - | - | 1,382 | 31 | 207 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 17,489 | 18.6 | 1.33 | - | - | - | 123 | 206 | 51 |
| **1.A.5** | **Non-Specified** | 1,874 | 0.0 | 0.05 | - | - | - | 1 | 2 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 12,532 | 176.2 | 0.17 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 62.0 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 12,532 | 114.2 | 0.17 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **80,998** | **52.4** | **3.63** | **2,065** | **891** | **871** | **1,473** | **42** | **3,228** |
| **2.A** | **Mineral Industry** | 25,562 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 18,884 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 5,404 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 220 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 1,054 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 6,531 | 11.5 | 2.84 | - | - | - | 1 | 1 | 49 |
| 2.B.1 | Ammonia Production | - | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 1.98 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 0.37 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | 0.50 | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 43 | - | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 6,487 | 11.5 | - | - | - | - | - | 0 | 11 |
| 2.B.9 | Fluorochemicals Production | - | - | - | - | - | - | - | - | - |
| 2.B.10 | Other Chemicals | - | - | - | - | - | - | - | - | 38 |
| **2.C** | **Metal Industry** | 48,081 | 40.9 | 0.79 | - | 891 | 620 | 1,407 | 23 | 20 |
| 2.C.1 | Iron and Steel Production | 43,736 | 40.7 | 0.79 | - | - | - | 784 | 20 | 20 |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.C.2 | Ferroalloy Production | 1,165 | 0.2 | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 2,753 | - | - | - | 891 | - | 623 | 4 | - |
| 2.C.4 | Magnesium Production | 103 | - | - | - | - | 620 | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | 324 | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 824 | - | - | - | - | - | - | - | 2,514 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | 2,064 | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 251 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 65 | 17 | 646 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 65 | 17 | 43 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 602 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 394 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 209 |
| **3** | **Agriculture** | **13,533** | **13,785.5** | **431.33** | **-** | **-** | **-** | **2,369** | **88** | **-** |
| **3.A** | **Enteric Fermentation** | - | 12,644.7 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 12,290.7 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 10,385.5 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 1,905.2 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 83.2 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 36.8 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 234.0 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 688.8 | 12.85 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 366.4 | 4.07 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 243.0 | 0.87 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 123.4 | 3.20 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 3.0 | - | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 275.9 | 1.71 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 43.5 | 0.71 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 6.35 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 1.75 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 0.63 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 1.12 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 1.45 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | - | 3.15 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 397.3 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 414.38 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 321.32 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 38.51 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 14.82 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 174.20 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 163.20 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 125.25 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 37.95 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 1.82 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 9.18 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 82.69 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 17.22 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 11.91 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 8.54 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 2.07 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 1.43 | - | - | - | - | - | - |
| 3.D.1.d.vi | Manioc | - | - | 1.08 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 0.90 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 37.47 | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.ix | Other annual crops | - | - | 2.05 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 5.00 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 6.09 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 93.06 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 34.39 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 7.99 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 2.78 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 23.62 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 21.76 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 16.70 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 5.06 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.18 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 1.68 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 58.67 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 8.85 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 3.52 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 26.57 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 24.48 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.20 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 1.89 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 18.60 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 3.87 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 2.68 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 1.92 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.47 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.32 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.24 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.20 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 8.43 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.46 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 1.13 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 54.7 | 4.10 | - | - | - | 2,369 | 88 | - |
| **3.G** | **Liming** | 11,427 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 2,106 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | - | - | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **899,085** | **1,826.4** | **57.16** | - | - | - | **28,654** | **511** | - |
| **4.A** | **Forest Land** | -330,356 | 55.0 | 1.82 | - | - | - | 883 | 18 | - |
| 4.A.1 | Forest Land remaining Forest Land | -267,824 | 51.8 | 1.52 | - | - | - | 793 | 12 | - |
| 4.A.2 | Land converted to Forest Land | -62,532 | 3.2 | 0.29 | - | - | - | 90 | 5 | - |
| **4.B** | **Cropland** | 105,260 | 108.0 | 3.73 | - | - | - | 1,768 | 39 | - |
| 4.B.1 | Cropland remaining Cropland | - | - | - | - | - | - | - | - | - |
| 4.B.2 | Land converted to Cropland | 105,260 | 108.0 | 3.73 | - | - | - | 1,768 | 39 | - |
| **4.C** | **Grassland** | 1,155,753 | 1,645.1 | 51.03 | - | - | - | 25,715 | 450 | - |
| 4.C.1 | Grassland remaining Grassland | 12,115 | 42.8 | 3.90 | - | - | - | 1,208 | 73 | - |
| 4.C.2 | Land converted to Grassland | 1,143,638 | 1,602.4 | 47.13 | - | - | - | 24,507 | 377 | - |
| **4.D** | **Wetlands** | 9,465 | 9.7 | 0.31 | - | - | - | 153 | 3 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 9,465 | 9.7 | 0.31 | - | - | - | 153 | 3 | - |
| **4.E** | **Settlements** | 5,954 | 3.7 | 0.12 | - | - | - | 58 | 1 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |
| 4.E.2 | Land converted to Settlements | 5,954 | 3.7 | 0.12 | - | - | - | 58 | 1 | - |
| **4.F** | **Other Land** | 4,166 | 4.9 | 0.15 | - | - | - | 76 | 1 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.F.2 | Land converted to Other Land | 4,166 | 4.9 | 0.15 | - | - | - | 76 | 1 | - |
| **4.G** | **Harvested Wood Products** | -51,156 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **1,332** | **2,411.5** | **8.25** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 1,388.4 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 546.7 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 841.7 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 1.4 | 0.08 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 1,332 | 31.9 | 0.51 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 989.8 | 7.65 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 836.9 | 7.65 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 152.9 | - | - | - | - | - | - | - |
| **5.E** | **Other** | - | - | - | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 19,452 | 14.3 | 14.47 | - | - | - | 15 | 16 | 14 |
| 1.A.3.a.i | Aviation | 5,129 | 0.0 | 0.14 | - | - | - | 1 | 1 | 0 |
| 1.A.3.d.i | Navigation | 14,322 | 14.3 | 14.32 | - | - | - | 14 | 14 | 14 |
| | **$CO_2$ emissions from biomass** | 284,889 | | | | | | | | |

Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

## Results of the Fourth National Inventory — Year 2009

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **685,733** | **18,336.3** | **509.28** | **2,429** | **632** | **542** | **27,376** | **2,597** | **4,017** |
| **1** | **Energy** | **317,026** | **669.8** | **26.41** | - | - | - | **6,819** | **2,163** | **998** |
| **1.A** | **Fuel Combustion Activities** | 300,476 | 429.3 | 26.12 | - | - | - | 6,819 | 2,163 | 998 |
| **1.A.1** | **Energy Industries** | 45,188 | 28.4 | 4.00 | - | - | - | 1,329 | 539 | 227 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 16,536 | 0.6 | 0.16 | - | - | - | 11 | 118 | 2 |
| 1.A.1.b | Petroleum Refining | 17,855 | 0.4 | 0.17 | - | - | - | 21 | 196 | 1 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 10,796 | 27.4 | 3.67 | - | - | - | 1,296 | 225 | 224 |
| **1.A.2** | **Manufacturing Industries and Construction** | 67,430 | 34.1 | 5.65 | - | - | - | 1,696 | 298 | 61 |
| 1.A.2.a | Iron and Steel | 6,168 | 0.3 | 0.05 | - | - | - | 11 | 14 | 2 |
| 1.A.2.b | Non-ferrous Metals | 4,665 | 0.1 | 0.03 | - | - | - | 2 | 9 | 0 |
| 1.A.2.c | Chemicals | 15,448 | 2.6 | 0.19 | - | - | - | 22 | 65 | 3 |
| 1.A.2.d | Pulp, Paper and Print | 4,042 | 2.6 | 1.05 | - | - | - | 871 | 46 | 17 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 4,142 | 23.2 | 3.47 | - | - | - | 318 | 79 | 14 |
| 1.A.2.f | Non-metallic Minerals | 18,312 | 4.0 | 0.52 | - | - | - | 351 | 43 | 17 |
| 1.A.2.g | Transport Equipment | 7,913 | 1.0 | 0.25 | - | - | - | 90 | 21 | 5 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 5,619 | 0.3 | 0.05 | - | - | - | 22 | 19 | 2 |
| 1.A.2.l | Textile and Leather | 1,121 | 0.1 | 0.04 | - | - | - | 8 | 2 | 0 |
| **1.A.3** | **Transport** | 149,793 | 44.9 | 11.87 | - | - | - | 2,309 | 1,086 | 454 |
| 1.A.3.a.ii | Domestic Aviation | 7,769 | 0.0 | 0.21 | - | - | - | 4 | 7 | 0 |
| 1.A.3.b | Road Transportation | 134,715 | 44.3 | 10.36 | - | - | - | 2,284 | 917 | 445 |
| 1.A.3.c | Railways | 2,959 | 0.2 | 1.18 | - | - | - | 10 | 51 | 5 |
| 1.A.3.d.ii | Domestic Navigation | 4,351 | 0.4 | 0.11 | - | - | - | 10 | 111 | 4 |
| 1.A.3.e | Other Transportation | - | - | - | - | - | - | - | - | - |
| **1.A.4** | **Other Sectors** | 36,890 | 321.9 | 4.57 | - | - | - | 1,485 | 239 | 256 |
| 1.A.4.a | Commercial / Institutional | 3,321 | 3.5 | 0.06 | - | - | - | 5 | 9 | 3 |
| 1.A.4.b | Residential | 16,738 | 300.8 | 3.24 | - | - | - | 1,362 | 31 | 204 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 16,831 | 17.6 | 1.27 | - | - | - | 118 | 200 | 49 |
| **1.A.5** | **Non-Specified** | 1,175 | 0.0 | 0.03 | - | - | - | 1 | 1 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 16,550 | 240.5 | 0.29 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 54.9 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 16,550 | 185.7 | 0.29 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **72,337** | **36.0** | **1.65** | **2,429** | **632** | **542** | **1,093** | **35** | **3,018** |
| **2.A** | **Mineral Industry** | 25,045 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 19,031 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 4,805 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 222 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 987 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 6,969 | 11.9 | 1.18 | - | - | - | 1 | 2 | 56 |
| 2.B.1 | Ammonia Production | 168 | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 0.92 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 0.14 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | NO | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 41 | - | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 6,760 | 11.9 | - | - | - | - | - | 0 | 11 |
| 2.B.9 | Fluorochemicals Production | - | - | - | - | - | - | - | - | - |
| 2.B.10 | Other Chemicals | - | - | - | - | - | - | - | - | 45 |
| **2.C** | **Metal Industry** | 39,662 | 24.2 | 0.46 | - | 632 | 310 | 1,023 | 15 | 11 |
| 2.C.1 | Iron and Steel Production | 35,495 | 24.0 | 0.46 | - | - | - | 456 | 11 | 11 |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.C.2 | Ferroalloy Production | 1,036 | 0.2 | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 2,544 | - | - | - | 632 | - | 567 | 3 | - |
| 2.C.4 | Magnesium Production | 112 | - | - | - | - | 310 | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | 474 | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 661 | - | - | - | - | - | - | - | 2,300 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | 2,429 | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 232 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 69 | 18 | 651 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 69 | 18 | 45 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 605 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 398 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 207 |
| **3** | **Agriculture** | **11,188** | **14,037.7** | **437.97** | **-** | **-** | **-** | **2,073** | **77** | **-** |
| **3.A** | **Enteric Fermentation** | - | 12,874.7 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 12,522.3 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 10,541.9 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 1,980.4 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 84.1 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 38.0 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 230.3 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 706.1 | 13.60 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 377.1 | 4.36 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 247.8 | 1.03 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 129.3 | 3.32 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 3.0 | - | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 282.1 | 1.83 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 43.9 | 0.73 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 6.69 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 1.91 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 0.75 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 1.16 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 1.55 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | - | 3.22 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 409.0 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 420.78 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 326.11 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 39.32 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 16.19 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 177.79 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 166.90 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 127.45 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 39.45 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 1.82 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 9.08 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 81.67 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 16.50 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 10.25 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 10.25 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 2.18 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 1.44 | - | - | - | - | - | - |
| 3.D.1.d.vi | Manioc | - | - | 0.99 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 0.76 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 37.49 | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.ix | Other annual crops | - | - | 1.82 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 5.00 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 6.13 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 94.68 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 35.16 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 8.05 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 3.01 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 24.09 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 22.25 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 16.99 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 5.26 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.18 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 1.66 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 59.52 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 9.04 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 3.88 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 27.10 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 25.03 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.20 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 1.86 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 18.38 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 3.71 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 2.31 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 2.31 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.49 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.32 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.22 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.17 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 8.43 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.41 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 1.13 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 47.8 | 3.59 | - | - | - | 2,073 | 77 | - |
| **3.G** | **Liming** | 9,094 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 2,094 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | - | - | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **284,056** | **1,100.6** | **35.04** | - | - | - | **17,391** | **322** | - |
| **4.A** | **Forest Land** | -392,979 | 32.6 | 1.13 | - | - | - | 534 | 12 | - |
| 4.A.1 | Forest Land remaining Forest Land | -311,566 | 29.9 | 0.88 | - | - | - | 457 | 7 | - |
| 4.A.2 | Land converted to Forest Land | -81,413 | 2.7 | 0.25 | - | - | - | 78 | 5 | - |
| **4.B** | **Cropland** | 71,646 | 75.2 | 2.71 | - | - | - | 1,253 | 29 | - |
| 4.B.1 | Cropland remaining Cropland | - | - | - | - | - | - | - | - | - |
| 4.B.2 | Land converted to Cropland | 71,646 | 75.2 | 2.71 | - | - | - | 1,253 | 29 | - |
| **4.C** | **Grassland** | 634,771 | 981.2 | 30.83 | - | - | - | 15,420 | 277 | - |
| 4.C.1 | Grassland remaining Grassland | -6,674 | 31.8 | 2.91 | - | - | - | 900 | 54 | - |
| 4.C.2 | Land converted to Grassland | 641,444 | 949.4 | 27.92 | - | - | - | 14,520 | 223 | - |
| **4.D** | **Wetlands** | 6,889 | 6.4 | 0.21 | - | - | - | 102 | 2 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 6,889 | 6.4 | 0.21 | - | - | - | 102 | 2 | - |
| **4.E** | **Settlements** | 4,422 | 2.3 | 0.07 | - | - | - | 37 | 1 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |
| 4.E.2 | Land converted to Settlements | 4,422 | 2.3 | 0.07 | - | - | - | 37 | 1 | - |
| **4.F** | **Other Land** | 2,612 | 2.8 | 0.09 | - | - | - | 44 | 1 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.F.2 | Land converted to Other Land | 2,612 | 2.8 | 0.09 | - | - | - | 44 | 1 | - |
| **4.G** | **Harvested Wood Products** | -43,305 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **1,125** | **2,492.2** | **8.21** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 1,457.3 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 561.4 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 895.9 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 1.1 | 0.07 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 1,125 | 25.9 | 0.43 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 1,007.9 | 7.72 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 851.4 | 7.72 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 156.5 | - | - | - | - | - | - | - |
| **5.E** | **Other** | - | - | - | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 16,787 | 11.9 | 12.01 | - | - | - | 13 | 13 | 12 |
| 1.A.3.a.i | Aviation | 4,915 | 0.0 | 0.14 | - | - | - | 1 | 1 | 0 |
| 1.A.3.d.i | Navigation | 11,872 | 11.9 | 11.87 | - | - | - | 12 | 12 | 12 |
| | **$CO_2$ emissions from biomass** | 281,133 | | | | | | | | |

Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

## Results of the Fourth National Inventory — Year 2010

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **670,265** | **18,617.9** | **529.34** | **2,872** | **593** | **241** | **26,472** | **2,678** | **4,023** |
| **1** | **Energy** | **352,903** | **609.6** | **28.92** | - | - | - | **7,028** | **2,265** | **1,008** |
| **1.A** | **Fuel Combustion Activities** | 339,596 | 426.5 | 28.72 | - | - | - | 7,028 | 2,265 | 1,008 |
| **1.A.1** | **Energy Industries** | 56,526 | 31.4 | 4.51 | - | - | - | 1,458 | 539 | 251 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 26,577 | 1.2 | 0.32 | - | - | - | 19 | 157 | 4 |
| 1.A.1.b | Petroleum Refining | 15,827 | 0.4 | 0.16 | - | - | - | 17 | 168 | 1 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 14,122 | 29.9 | 4.03 | - | - | - | 1,422 | 215 | 246 |
| **1.A.2** | **Manufacturing Industries and Construction** | 75,552 | 37.7 | 6.27 | - | - | - | 1,906 | 327 | 68 |
| 1.A.2.a | Iron and Steel | 7,299 | 0.3 | 0.06 | - | - | - | 13 | 16 | 2 |
| 1.A.2.b | Non-ferrous Metals | 8,544 | 0.2 | 0.05 | - | - | - | 6 | 23 | 1 |
| 1.A.2.c | Chemicals | 14,187 | 2.6 | 0.18 | - | - | - | 23 | 60 | 3 |
| 1.A.2.d | Pulp, Paper and Print | 4,434 | 2.8 | 1.13 | - | - | - | 942 | 48 | 19 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 4,548 | 26.0 | 3.89 | - | - | - | 415 | 90 | 15 |
| 1.A.2.f | Non-metallic Minerals | 19,727 | 4.4 | 0.56 | - | - | - | 373 | 47 | 20 |
| 1.A.2.g | Transport Equipment | 8,172 | 1.0 | 0.28 | - | - | - | 98 | 20 | 5 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 7,585 | 0.3 | 0.07 | - | - | - | 27 | 23 | 3 |
| 1.A.2.l | Textile and Leather | 1,055 | 0.1 | 0.04 | - | - | - | 8 | 2 | 0 |
| **1.A.3** | **Transport** | 169,010 | 45.0 | 13.37 | - | - | - | 2,227 | 1,153 | 439 |
| 1.A.3.a.ii | Domestic Aviation | 9,157 | 0.0 | 0.25 | - | - | - | 5 | 8 | 0 |
| 1.A.3.b | Road Transportation | 151,403 | 44.4 | 11.82 | - | - | - | 2,200 | 960 | 430 |
| 1.A.3.c | Railways | 2,925 | 0.2 | 1.18 | - | - | - | 10 | 51 | 5 |
| 1.A.3.d.ii | Domestic Navigation | 4,414 | 0.4 | 0.12 | - | - | - | 10 | 112 | 4 |
| 1.A.3.e | Other Transportation | 1,110 | 0.0 | 0.00 | - | - | - | 2 | 22 | 0 |
| **1.A.4** | **Other Sectors** | 37,365 | 312.3 | 4.54 | - | - | - | 1,436 | 244 | 250 |
| 1.A.4.a | Commercial / Institutional | 2,799 | 3.8 | 0.06 | - | - | - | 5 | 5 | 3 |
| 1.A.4.b | Residential | 17,249 | 290.1 | 3.15 | - | - | - | 1,307 | 31 | 196 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 17,316 | 18.5 | 1.33 | - | - | - | 124 | 208 | 51 |
| **1.A.5** | **Non-Specified** | 1,144 | 0.0 | 0.03 | - | - | - | 1 | 1 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 13,307 | 183.1 | 0.20 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 42.5 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 13,307 | 140.7 | 0.20 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **82,049** | **41.9** | **1.51** | **2,872** | **593** | **241** | **1,200** | **39** | **3,015** |
| **2.A** | **Mineral Industry** | 28,359 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 21,288 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 5,651 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 246 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 1,175 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 7,472 | 12.0 | 0.93 | - | - | - | 1 | 1 | 56 |
| 2.B.1 | Ammonia Production | 296 | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 0.80 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 0.13 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | NO | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 42 | - | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 7,134 | 12.0 | - | - | - | - | - | 0 | 10 |
| 2.B.9 | Fluorochemicals Production | - | - | - | - | - | - | - | - | - |
| 2.B.10 | Other Chemicals | - | - | - | - | - | - | - | - | 46 |
| **2.C** | **Metal Industry** | 45,418 | 29.9 | 0.57 | - | 593 | - | 1,125 | 17 | 14 |
| 2.C.1 | Iron and Steel Production | 40,930 | 29.7 | 0.57 | - | - | - | 565 | 14 | 14 |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.C.2 | Ferroalloy Production | 1,214 | 0.2 | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 2,543 | - | - | - | 593 | - | 561 | 3 | - |
| 2.C.4 | Magnesium Production | 95 | - | - | - | - | - | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | 636 | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 800 | - | - | - | - | - | - | - | 2,274 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | 2,872 | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 241 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 73 | 20 | 670 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 73 | 20 | 48 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 622 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 425 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 197 |
| **3** | **Agriculture** | **13,698** | **14,406.5** | **457.60** | **-** | **-** | **-** | **1,832** | **68** | **-** |
| **3.A** | **Enteric Fermentation** | - | 13,250.1 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 12,890.5 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 10,860.6 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 2,029.9 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 86.9 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 39.0 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 233.8 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 728.6 | 13.92 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 391.7 | 4.43 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 255.4 | 1.00 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 136.4 | 3.43 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 3.2 | - | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 289.5 | 1.91 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 44.2 | 0.75 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 6.83 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 1.93 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 0.73 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 1.20 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 1.61 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | - | 3.29 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 385.5 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 440.51 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 341.08 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 44.05 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 16.20 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 182.91 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 171.85 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 131.58 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 40.27 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 1.84 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 9.23 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 86.84 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 19.79 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 11.19 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 11.37 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 1.93 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 1.30 | - | - | - | - | - | - |
| 3.D.1.d.vi | Manioc | - | - | 1.01 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 0.93 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 37.50 | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.ix | Other annual crops | - | - | 1.81 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 5.00 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 6.08 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 99.42 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 36.93 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 9.13 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 3.03 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 24.78 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 22.91 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 17.54 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 5.37 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.18 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 1.68 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 62.49 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 10.09 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 3.86 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 27.87 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 25.78 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.21 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 1.89 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 19.54 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 4.45 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 2.52 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 2.56 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.43 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.29 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.23 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.21 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 8.44 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.40 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 1.13 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 42.3 | 3.17 | - | - | - | 1,832 | 68 | - |
| **3.G** | **Liming** | 11,292 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 2,406 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | - | - | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **220,461** | **1,036.8** | **33.14** | - | - | - | **16,411** | **306** | - |
| **4.A** | **Forest Land** | -401,061 | 32.6 | 1.13 | - | - | - | 535 | 12 | - |
| 4.A.1 | Forest Land remaining Forest Land | -317,462 | 29.7 | 0.87 | - | - | - | 455 | 7 | - |
| 4.A.2 | Land converted to Forest Land | -83,599 | 2.8 | 0.26 | - | - | - | 80 | 5 | - |
| **4.B** | **Cropland** | 69,033 | 71.4 | 2.60 | - | - | - | 1,196 | 28 | - |
| 4.B.1 | Cropland remaining Cropland | - | - | - | - | - | - | - | - | - |
| 4.B.2 | Land converted to Cropland | 69,033 | 71.4 | 2.60 | - | - | - | 1,196 | 28 | - |
| **4.C** | **Grassland** | 586,650 | 922.7 | 29.08 | - | - | - | 14,520 | 263 | - |
| 4.C.1 | Grassland remaining Grassland | -7,574 | 31.4 | 2.87 | - | - | - | 889 | 53 | - |
| 4.C.2 | Land converted to Grassland | 594,223 | 891.3 | 26.21 | - | - | - | 13,631 | 210 | - |
| **4.D** | **Wetlands** | 6,084 | 5.4 | 0.18 | - | - | - | 86 | 2 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 6,084 | 5.4 | 0.18 | - | - | - | 86 | 2 | - |
| **4.E** | **Settlements** | 4,286 | 2.2 | 0.07 | - | - | - | 35 | 1 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |
| 4.E.2 | Land converted to Settlements | 4,286 | 2.2 | 0.07 | - | - | - | 35 | 1 | - |
| **4.F** | **Other Land** | 2,402 | 2.6 | 0.08 | - | - | - | 40 | 1 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.F.2 | Land converted to Other Land | 2,402 | 2.6 | 0.08 | - | - | - | 40 | 1 | - |
| **4.G** | **Harvested Wood Products** | -46,933 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **1,154** | **2,523.1** | **8.17** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 1,470.3 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 610.3 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 860.0 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 1.1 | 0.06 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 1,154 | 26.3 | 0.43 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 1,025.4 | 7.67 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 860.5 | 7.67 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 164.9 | - | - | - | - | - | - | - |
| **5.E** | **Other** | - | - | - | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 18,350 | 12.8 | 12.92 | - | - | - | 14 | 14 | 13 |
| 1.A.3.a.i | Aviation | 5,585 | 0.0 | 0.16 | - | - | - | 1 | 2 | 0 |
| 1.A.3.d.i | Navigation | 12,765 | 12.8 | 12.76 | - | - | - | 13 | 13 | 13 |
| | **$CO_2$ emissions from biomass** | 302,004 | | | | | | | | |

Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

## Results of the Fourth National Inventory — Year 2011

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **775,650** | **18,378.1** | **541.06** | **3,422** | **493** | **250** | **24,156** | **2,646** | **3,886** |
| **1** | **Energy** | **368,824** | **561.3** | **29.39** | - | - | - | **6,783** | **2,283** | **979** |
| **1.A** | **Fuel Combustion Activities** | 356,153 | 392.9 | 29.21 | - | - | - | 6,783 | 2,283 | 979 |
| **1.A.1** | **Energy Industries** | 51,394 | 28.8 | 4.10 | - | - | - | 1,406 | 550 | 262 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 19,941 | 0.8 | 0.23 | - | - | - | 15 | 138 | 3 |
| 1.A.1.b | Petroleum Refining | 16,229 | 0.4 | 0.15 | - | - | - | 18 | 191 | 1 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 15,224 | 27.6 | 3.72 | - | - | - | 1,373 | 221 | 258 |
| **1.A.2** | **Manufacturing Industries and Construction** | 81,528 | 38.8 | 6.32 | - | - | - | 1,975 | 345 | 72 |
| 1.A.2.a | Iron and Steel | 7,177 | 0.4 | 0.06 | - | - | - | 13 | 16 | 2 |
| 1.A.2.b | Non-ferrous Metals | 9,559 | 0.2 | 0.06 | - | - | - | 7 | 25 | 1 |
| 1.A.2.c | Chemicals | 15,548 | 2.7 | 0.19 | - | - | - | 23 | 60 | 3 |
| 1.A.2.d | Pulp, Paper and Print | 4,534 | 2.7 | 1.13 | - | - | - | 943 | 49 | 19 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 4,488 | 25.6 | 3.84 | - | - | - | 419 | 90 | 15 |
| 1.A.2.f | Non-metallic Minerals | 22,314 | 5.7 | 0.63 | - | - | - | 431 | 54 | 23 |
| 1.A.2.g | Transport Equipment | 8,933 | 1.1 | 0.29 | - | - | - | 103 | 22 | 5 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 7,901 | 0.4 | 0.07 | - | - | - | 29 | 27 | 3 |
| 1.A.2.l | Textile and Leather | 1,076 | 0.1 | 0.04 | - | - | - | 7 | 2 | 0 |
| **1.A.3** | **Transport** | 184,966 | 43.6 | 14.54 | - | - | - | 2,102 | 1,149 | 415 |
| 1.A.3.a.ii | Domestic Aviation | 10,434 | 0.0 | 0.28 | - | - | - | 5 | 9 | 1 |
| 1.A.3.b | Road Transportation | 166,579 | 43.1 | 12.95 | - | - | - | 2,074 | 966 | 406 |
| 1.A.3.c | Railways | 2,952 | 0.2 | 1.20 | - | - | - | 11 | 52 | 5 |
| 1.A.3.d.ii | Domestic Navigation | 4,239 | 0.4 | 0.11 | - | - | - | 10 | 108 | 4 |
| 1.A.3.e | Other Transportation | 763 | 0.0 | 0.00 | - | - | - | 1 | 15 | 0 |
| **1.A.4** | **Other Sectors** | 37,350 | 281.7 | 4.23 | - | - | - | 1,300 | 238 | 229 |
| 1.A.4.a | Commercial / Institutional | 3,049 | 4.1 | 0.07 | - | - | - | 5 | 5 | 3 |
| 1.A.4.b | Residential | 17,487 | 259.7 | 2.86 | - | - | - | 1,173 | 29 | 176 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 16,814 | 17.9 | 1.30 | - | - | - | 121 | 204 | 50 |
| **1.A.5** | **Non-Specified** | 914 | 0.0 | 0.02 | - | - | - | 0 | 1 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 12,671 | 168.4 | 0.19 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 47.0 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 12,671 | 121.4 | 0.19 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **88,632** | **44.1** | **1.53** | **3,422** | **493** | **250** | **1,211** | **38** | **2,907** |
| **2.A** | **Mineral Industry** | 29,983 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 22,496 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 6,018 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 284 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 1,185 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 8,080 | 13.3 | 0.93 | - | - | - | 1 | 1 | 58 |
| 2.B.1 | Ammonia Production | 274 | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 0.75 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 0.18 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | NO | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 42 | - | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 7,765 | 13.3 | - | - | - | - | - | 0 | 10 |
| 2.B.9 | Fluorochemicals Production | - | - | - | - | - | - | - | - | - |
| 2.B.10 | Other Chemicals | - | - | - | - | - | - | - | - | 48 |
| **2.C** | **Metal Industry** | 49,723 | 30.9 | 0.60 | - | 493 | - | 1,138 | 18 | 15 |
| 2.C.1 | Iron and Steel Production | 44,508 | 30.7 | 0.60 | - | - | - | 585 | 15 | 15 |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.C.2 | Ferroalloy Production | 1,090 | 0.2 | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 2,375 | - | - | - | 493 | - | 553 | 3 | - |
| 2.C.4 | Magnesium Production | 92 | - | - | - | - | - | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | 1,658 | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 846 | - | - | - | - | - | - | - | 2,070 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | 3,422 | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 250 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 72 | 19 | 765 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 72 | 19 | 48 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 718 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 482 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 236 |
| **3** | **Agriculture** | **16,827** | **14,263.4** | **472.42** | **-** | **-** | **-** | **1,500** | **56** | **-** |
| **3.A** | **Enteric Fermentation** | - | 13,006.3 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 12,639.8 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 10,630.1 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 2,009.6 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 88.3 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 39.3 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 238.9 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 790.0 | 15.44 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 382.3 | 4.73 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 249.0 | 1.22 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 133.4 | 3.51 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 3.2 | - | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 359.4 | 2.45 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 45.1 | 0.77 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 7.50 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 2.11 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 0.88 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 1.23 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 2.02 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | - | 3.37 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 432.5 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 454.38 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 350.92 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 52.02 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 16.83 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 184.14 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 172.99 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 132.24 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 40.75 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 1.77 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 9.38 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 87.55 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 21.54 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 11.25 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 12.50 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 2.32 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 1.42 | - | - | - | - | - | - |
| 3.D.1.d.vi | Manioc | - | - | 1.03 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 0.85 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 34.46 | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.ix | Other annual crops | - | - | 2.18 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 4.18 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 6.20 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 103.46 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 38.84 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 10.76 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 3.14 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 24.94 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 23.07 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 17.63 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 5.43 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.18 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 1.70 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 64.62 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 11.90 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 4.02 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 28.06 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 25.95 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.20 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 1.91 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 19.70 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 4.85 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 2.53 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 2.81 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.52 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.32 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.23 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.19 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 7.75 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.49 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 0.94 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 34.6 | 2.60 | - | - | - | 1,500 | 56 | - |
| **3.G** | **Liming** | 13,992 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 2,835 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | - | - | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **300,253** | **929.1** | **29.48** | **-** | **-** | **-** | **14,662** | **269** | **-** |
| **4.A** | **Forest Land** | -346,974 | 51.3 | 1.65 | - | - | - | 814 | 15 | - |
| 4.A.1 | Forest Land remaining Forest Land | -309,367 | 49.1 | 1.44 | - | - | - | 751 | 12 | - |
| 4.A.2 | Land converted to Forest Land | -37,607 | 2.2 | 0.20 | - | - | - | 63 | 4 | - |
| **4.B** | **Cropland** | 133,218 | 102.5 | 3.73 | - | - | - | 1,718 | 41 | - |
| 4.B.1 | Cropland remaining Cropland | - | - | - | - | - | - | - | - | - |
| 4.B.2 | Land converted to Cropland | 133,218 | 102.5 | 3.73 | - | - | - | 1,718 | 41 | - |
| **4.C** | **Grassland** | 540,860 | 757.0 | 23.54 | - | - | - | 11,845 | 208 | - |
| 4.C.1 | Grassland remaining Grassland | -487 | 20.6 | 1.88 | - | - | - | 582 | 35 | - |
| 4.C.2 | Land converted to Grassland | 541,347 | 736.4 | 21.66 | - | - | - | 11,263 | 173 | - |
| **4.D** | **Wetlands** | 7,142 | 7.9 | 0.25 | - | - | - | 123 | 2 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 7,142 | 7.9 | 0.25 | - | - | - | 123 | 2 | - |
| **4.E** | **Settlements** | 4,328 | 2.2 | 0.07 | - | - | - | 35 | 1 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |
| 4.E.2 | Land converted to Settlements | 4,328 | 2.2 | 0.07 | - | - | - | 35 | 1 | - |
| **4.F** | **Other Land** | 7,152 | 8.2 | 0.25 | - | - | - | 127 | 2 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.F.2 | Land converted to Other Land | 7,152 | 8.2 | 0.25 | - | - | - | 127 | 2 | - |
| **4.G** | **Harvested Wood Products** | -45,474 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **1,114** | **2,580.2** | **8.23** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 1,507.1 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 637.5 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 869.6 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 1.1 | 0.07 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 1,114 | 26.9 | 0.44 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 1,045.1 | 7.72 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 870.9 | 7.72 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 174.1 | - | - | - | - | - | - | - |
| **5.E** | **Other** | - | - | - | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 19,979 | 13.7 | 13.84 | - | - | - | 15 | 15 | 14 |
| 1.A.3.a.i | Aviation | 6,314 | 0.0 | 0.18 | - | - | - | 1 | 2 | 0 |
| 1.A.3.d.i | Navigation | 13,665 | 13.7 | 13.67 | - | - | - | 14 | 14 | 14 |
| | **$CO_2$ emissions from biomass** | 286,450 | | | | | | | | |

Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

## Results of the Fourth National Inventory — Year 2012

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **665,884** | **18,138.9** | **535.15** | **3,906** | **508** | **259** | **21,144** | **2,691** | **3,943** |
| **1** | **Energy** | **400,894** | **575.8** | **30.93** | - | - | - | **6,738** | **2,382** | **960** |
| **1.A** | **Fuel Combustion Activities** | 387,400 | 393.1 | 30.76 | - | - | - | 6,738 | 2,382 | 960 |
| **1.A.1** | **Energy Industries** | 66,158 | 30.6 | 4.44 | - | - | - | 1,466 | 637 | 254 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 34,894 | 1.7 | 0.44 | - | - | - | 26 | 199 | 4 |
| 1.A.1.b | Petroleum Refining | 16,209 | 0.4 | 0.15 | - | - | - | 18 | 195 | 1 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 15,055 | 28.6 | 3.85 | - | - | - | 1,423 | 243 | 249 |
| **1.A.2** | **Manufacturing Industries and Construction** | 80,256 | 38.7 | 6.36 | - | - | - | 1,921 | 346 | 71 |
| 1.A.2.a | Iron and Steel | 7,258 | 0.4 | 0.06 | - | - | - | 13 | 17 | 2 |
| 1.A.2.b | Non-ferrous Metals | 9,533 | 0.2 | 0.05 | - | - | - | 7 | 25 | 1 |
| 1.A.2.c | Chemicals | 15,270 | 2.5 | 0.19 | - | - | - | 22 | 60 | 3 |
| 1.A.2.d | Pulp, Paper and Print | 4,507 | 2.6 | 1.11 | - | - | - | 929 | 48 | 17 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 4,562 | 26.0 | 3.91 | - | - | - | 380 | 93 | 16 |
| 1.A.2.f | Non-metallic Minerals | 22,350 | 5.5 | 0.65 | - | - | - | 436 | 54 | 24 |
| 1.A.2.g | Transport Equipment | 8,164 | 1.1 | 0.28 | - | - | - | 101 | 21 | 5 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 7,591 | 0.3 | 0.07 | - | - | - | 27 | 26 | 3 |
| 1.A.2.l | Textile and Leather | 1,021 | 0.1 | 0.04 | - | - | - | 7 | 2 | 0 |
| **1.A.3** | **Transport** | 201,834 | 43.5 | 15.69 | - | - | - | 2,055 | 1,152 | 406 |
| 1.A.3.a.ii | Domestic Aviation | 10,616 | 0.0 | 0.29 | - | - | - | 6 | 9 | 1 |
| 1.A.3.b | Road Transportation | 183,002 | 42.9 | 14.07 | - | - | - | 2,027 | 963 | 397 |
| 1.A.3.c | Railways | 3,027 | 0.2 | 1.23 | - | - | - | 11 | 53 | 5 |
| 1.A.3.d.ii | Domestic Navigation | 4,153 | 0.4 | 0.11 | - | - | - | 10 | 105 | 4 |
| 1.A.3.e | Other Transportation | 1,035 | 0.0 | 0.00 | - | - | - | 2 | 20 | 0 |
| **1.A.4** | **Other Sectors** | 37,943 | 280.2 | 4.24 | - | - | - | 1,295 | 246 | 229 |
| 1.A.4.a | Commercial / Institutional | 2,874 | 4.1 | 0.07 | - | - | - | 5 | 5 | 3 |
| 1.A.4.b | Residential | 17,598 | 258.4 | 2.85 | - | - | - | 1,167 | 29 | 175 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 17,471 | 17.7 | 1.32 | - | - | - | 123 | 212 | 50 |
| **1.A.5** | **Non-Specified** | 1,209 | 0.0 | 0.03 | - | - | - | 1 | 1 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 13,494 | 182.7 | 0.17 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 50.1 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 13,494 | 132.7 | 0.17 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **89,473** | **41.0** | **1.34** | **3,906** | **508** | **259** | **1,165** | **38** | **2,982** |
| **2.A** | **Mineral Industry** | 31,995 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 24,438 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 6,080 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 265 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 1,211 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 7,175 | 11.5 | 0.77 | - | - | - | 1 | 1 | 56 |
| 2.B.1 | Ammonia Production | 210 | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 0.65 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 0.12 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | NO | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 42 | - | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 6,924 | 11.5 | - | - | - | - | - | 0 | 10 |
| 2.B.9 | Fluorochemicals Production | - | - | - | - | - | - | - | - | - |
| 2.B.10 | Other Chemicals | - | - | - | - | - | - | - | - | 46 |
| **2.C** | **Metal Industry** | 49,525 | 29.4 | 0.57 | - | 508 | - | 1,093 | 17 | 14 |
| 2.C.1 | Iron and Steel Production | 44,252 | 29.2 | 0.57 | - | - | - | 559 | 14 | 14 |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.C.2 | Ferroalloy Production | 1,063 | 0.2 | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 2,378 | - | - | - | 508 | - | 534 | 3 | - |
| 2.C.4 | Magnesium Production | 108 | - | - | - | - | - | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | 1,724 | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 777 | - | - | - | - | - | - | - | 2,202 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | 3,906 | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 259 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 72 | 19 | 710 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 72 | 19 | 47 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 662 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 463 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 199 |
| **3** | **Agriculture** | **18,932** | **14,148.5** | **470.26** | **-** | **-** | **-** | **1,222** | **45** | **-** |
| **3.A** | **Enteric Fermentation** | - | 12,943.6 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 12,590.4 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 10,614.4 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 1,976.0 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 83.9 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 38.8 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 230.4 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 792.1 | 15.50 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 388.6 | 4.90 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 249.4 | 1.37 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 139.3 | 3.53 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 3.0 | - | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 356.5 | 2.34 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 44.0 | 0.76 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 7.50 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 2.23 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 0.99 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 1.24 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 1.92 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | - | 3.35 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 384.6 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 452.65 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 349.81 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 53.69 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 15.80 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 182.50 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 171.85 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 131.96 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 39.89 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 1.64 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 9.01 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 87.40 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 18.95 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 14.37 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 12.88 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 1.99 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 1.15 | - | - | - | - | - | - |
| 3.D.1.d.vi | Manioc | - | - | 0.93 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 0.66 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 34.46 | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.ix | Other annual crops | - | - | 2.00 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 4.18 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 6.24 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 102.84 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 38.44 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 10.76 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 2.98 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 24.70 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 22.91 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 17.59 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 5.32 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.16 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 1.63 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 64.40 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 12.26 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 3.75 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 27.79 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 25.78 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.18 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 1.83 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 19.66 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 4.26 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 3.23 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 2.90 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.45 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.26 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.21 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.15 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 7.75 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.45 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 0.94 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 28.2 | 2.12 | - | - | - | 1,222 | 45 | - |
| **3.G** | **Liming** | 16,179 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 2,753 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | - | - | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **155,421** | **758.1** | **24.32** | - | - | - | **12,019** | **226** | - |
| **4.A** | **Forest Land** | -362,364 | 45.0 | 1.46 | - | - | - | 717 | 14 | - |
| 4.A.1 | Forest Land remaining Forest Land | -322,211 | 42.8 | 1.26 | - | - | - | 654 | 10 | - |
| 4.A.2 | Land converted to Forest Land | -40,153 | 2.2 | 0.20 | - | - | - | 63 | 4 | - |
| **4.B** | **Cropland** | 122,707 | 94.3 | 3.44 | - | - | - | 1,581 | 38 | - |
| 4.B.1 | Cropland remaining Cropland | - | - | - | - | - | - | - | - | - |
| 4.B.2 | Land converted to Cropland | 122,707 | 94.3 | 3.44 | - | - | - | 1,581 | 38 | - |
| **4.C** | **Grassland** | 422,778 | 604.2 | 18.97 | - | - | - | 9,492 | 170 | - |
| 4.C.1 | Grassland remaining Grassland | -2,502 | 19.4 | 1.77 | - | - | - | 547 | 33 | - |
| 4.C.2 | Land converted to Grassland | 425,280 | 584.9 | 17.20 | - | - | - | 8,945 | 138 | - |
| **4.D** | **Wetlands** | 6,011 | 6.3 | 0.20 | - | - | - | 99 | 2 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 6,011 | 6.3 | 0.20 | - | - | - | 99 | 2 | - |
| **4.E** | **Settlements** | 4,344 | 2.1 | 0.07 | - | - | - | 34 | 1 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |
| 4.E.2 | Land converted to Settlements | 4,344 | 2.1 | 0.07 | - | - | - | 34 | 1 | - |
| **4.F** | **Other Land** | 5,503 | 6.1 | 0.18 | - | - | - | 94 | 2 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.F.2 | Land converted to Other Land | 5,503 | 6.1 | 0.18 | - | - | - | 94 | 2 | - |
| **4.G** | **Harvested Wood Products** | -43,558 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **1,164** | **2,615.5** | **8.30** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 1,533.1 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 657.9 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 875.2 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 1.3 | 0.08 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 1,164 | 28.9 | 0.46 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 1,052.3 | 7.76 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 868.7 | 7.76 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 183.6 | - | - | - | - | - | - | - |
| **5.E** | **Other** | - | - | - | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 18,850 | 12.2 | 12.34 | - | - | - | 13 | 14 | 12 |
| 1.A.3.a.i | Aviation | 6,698 | 0.0 | 0.19 | - | - | - | 1 | 2 | 0 |
| 1.A.3.d.i | Navigation | 12,152 | 12.2 | 12.15 | - | - | - | 12 | 12 | 12 |
| | **$CO_2$ emissions from biomass** | 289,817 | | | | | | | | |

Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

## Results of the Fourth National Inventory — Year 2013

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **897,306** | **18,551.4** | **559.03** | **4,472** | **444** | **268** | **24,346** | **2,851** | **3,970** |
| **1** | **Energy** | **432,346** | **551.3** | **32.31** | - | - | - | **6,648** | **2,490** | **906** |
| **1.A** | **Fuel Combustion Activities** | 418,400 | 366.9 | 32.14 | - | - | - | 6,648 | 2,490 | 906 |
| **1.A.1** | **Energy Industries** | 89,266 | 33.9 | 5.04 | - | - | - | 1,544 | 753 | 238 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 55,296 | 2.6 | 0.72 | - | - | - | 36 | 276 | 5 |
| 1.A.1.b | Petroleum Refining | 18,362 | 0.5 | 0.18 | - | - | - | 19 | 206 | 1 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 15,607 | 30.8 | 4.15 | - | - | - | 1,490 | 271 | 231 |
| **1.A.2** | **Manufacturing Industries and Construction** | 80,720 | 38.0 | 6.33 | - | - | - | 1,998 | 347 | 73 |
| 1.A.2.a | Iron and Steel | 7,100 | 0.4 | 0.06 | - | - | - | 12 | 16 | 2 |
| 1.A.2.b | Non-ferrous Metals | 9,578 | 0.2 | 0.05 | - | - | - | 7 | 24 | 1 |
| 1.A.2.c | Chemicals | 14,588 | 2.3 | 0.18 | - | - | - | 22 | 58 | 3 |
| 1.A.2.d | Pulp, Paper and Print | 4,480 | 2.7 | 1.18 | - | - | - | 994 | 50 | 19 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 4,439 | 25.1 | 3.78 | - | - | - | 370 | 91 | 15 |
| 1.A.2.f | Non-metallic Minerals | 23,141 | 5.7 | 0.68 | - | - | - | 455 | 56 | 25 |
| 1.A.2.g | Transport Equipment | 8,771 | 1.1 | 0.29 | - | - | - | 103 | 23 | 5 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 7,611 | 0.3 | 0.07 | - | - | - | 28 | 27 | 3 |
| 1.A.2.l | Textile and Leather | 1,012 | 0.1 | 0.04 | - | - | - | 7 | 2 | 0 |
| **1.A.3** | **Transport** | 209,051 | 42.7 | 16.72 | - | - | - | 1,940 | 1,143 | 385 |
| 1.A.3.a.ii | Domestic Aviation | 10,187 | 0.0 | 0.28 | - | - | - | 5 | 9 | 1 |
| 1.A.3.b | Road Transportation | 189,874 | 42.1 | 15.12 | - | - | - | 1,911 | 940 | 376 |
| 1.A.3.c | Railways | 3,003 | 0.2 | 1.22 | - | - | - | 11 | 53 | 5 |
| 1.A.3.d.ii | Domestic Navigation | 4,158 | 0.4 | 0.11 | - | - | - | 10 | 106 | 4 |
| 1.A.3.e | Other Transportation | 1,829 | 0.0 | 0.00 | - | - | - | 3 | 36 | 0 |
| **1.A.4** | **Other Sectors** | 38,306 | 252.4 | 4.01 | - | - | - | 1,166 | 245 | 211 |
| 1.A.4.a | Commercial / Institutional | 2,829 | 4.1 | 0.07 | - | - | - | 5 | 5 | 3 |
| 1.A.4.b | Residential | 17,994 | 229.0 | 2.57 | - | - | - | 1,032 | 28 | 155 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 17,484 | 19.3 | 1.37 | - | - | - | 128 | 213 | 53 |
| **1.A.5** | **Non-Specified** | 1,057 | 0.0 | 0.03 | - | - | - | 1 | 1 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 13,947 | 184.4 | 0.17 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 62.6 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 13,947 | 121.8 | 0.17 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **90,395** | **38.9** | **1.32** | **4,472** | **444** | **268** | **1,078** | **38** | **3,064** |
| **2.A** | **Mineral Industry** | 34,050 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 25,867 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 6,159 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 309 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 1,714 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 7,399 | 12.1 | 0.80 | - | - | - | 1 | 1 | 58 |
| 2.B.1 | Ammonia Production | 60 | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 0.66 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 0.14 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | NO | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 42 | - | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 7,297 | 12.1 | - | - | - | - | - | 0 | 11 |
| 2.B.9 | Fluorochemicals Production | - | - | - | - | - | - | - | - | - |
| 2.B.10 | Other Chemicals | - | - | - | - | - | - | - | - | 47 |
| **2.C** | **Metal Industry** | 48,076 | 26.8 | 0.52 | - | 444 | - | 999 | 15 | 13 |
| 2.C.1 | Iron and Steel Production | 43,079 | 26.6 | 0.52 | - | - | - | 506 | 13 | 13 |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.C.2 | Ferroalloy Production | 974 | 0.2 | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 2,156 | - | - | - | 444 | - | 493 | 3 | - |
| 2.C.4 | Magnesium Production | 119 | - | - | - | - | - | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | 1,749 | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 871 | - | - | - | - | - | - | - | 2,282 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | 4,471 | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 268 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 78 | 21 | 712 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 78 | 21 | 52 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 660 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 489 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 172 |
| **3** | **Agriculture** | **19,114** | **14,167.5** | **485.66** | **-** | **-** | **-** | **1,096** | **41** | **-** |
| **3.A** | **Enteric Fermentation** | - | 12,965.2 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 12,608.6 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 10,610.1 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 1,998.6 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 86.5 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 36.7 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 233.4 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 785.2 | 15.76 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 400.3 | 5.19 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 251.1 | 1.56 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 149.2 | 3.63 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 3.1 | - | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 337.7 | 2.20 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 44.1 | 0.77 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 7.61 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 2.40 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 1.13 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 1.27 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 1.80 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | - | 3.40 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 391.8 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 468.00 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 361.37 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 57.29 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 16.10 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 182.25 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 171.56 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 131.50 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 40.06 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 1.56 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 9.13 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 95.28 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 23.52 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 16.23 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 14.20 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 2.03 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 1.19 | - | - | - | - | - | - |
| 3.D.1.d.vi | Manioc | - | - | 0.87 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 0.86 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 34.46 | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.ix | Other annual crops | - | - | 1.91 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 4.18 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 6.28 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 106.63 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 39.60 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 11.90 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 3.03 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 24.67 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 22.87 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 17.53 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 5.34 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.16 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 1.64 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 67.03 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 13.08 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 3.82 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 27.75 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 25.73 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.18 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 1.84 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 21.44 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 5.29 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 3.65 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 3.19 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.46 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.27 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.20 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.19 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 7.75 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.43 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 0.94 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 25.3 | 1.90 | - | - | - | 1,096 | 41 | - |
| **3.G** | **Liming** | 15,955 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 3,159 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | - | - | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **354,221** | **985.6** | **31.14** | **-** | **-** | **-** | **15,525** | **283** | **-** |
| **4.A** | **Forest Land** | -343,473 | 57.9 | 1.86 | - | - | - | 918 | 17 | - |
| 4.A.1 | Forest Land remaining Forest Land | -309,707 | 55.5 | 1.63 | - | - | - | 848 | 13 | - |
| 4.A.2 | Land converted to Forest Land | -33,766 | 2.4 | 0.22 | - | - | - | 69 | 4 | - |
| **4.B** | **Cropland** | 156,328 | 122.0 | 4.28 | - | - | - | 2,011 | 45 | - |
| 4.B.1 | Cropland remaining Cropland | - | - | - | - | - | - | - | - | - |
| 4.B.2 | Land converted to Cropland | 156,328 | 122.0 | 4.28 | - | - | - | 2,011 | 45 | - |
| **4.C** | **Grassland** | 567,886 | 787.1 | 24.43 | - | - | - | 12,306 | 215 | - |
| 4.C.1 | Grassland remaining Grassland | 5,587 | 20.6 | 1.88 | - | - | - | 583 | 35 | - |
| 4.C.2 | Land converted to Grassland | 562,299 | 766.5 | 22.55 | - | - | - | 11,723 | 180 | - |
| **4.D** | **Wetlands** | 7,397 | 8.1 | 0.25 | - | - | - | 127 | 2 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 7,397 | 8.1 | 0.25 | - | - | - | 127 | 2 | - |
| **4.E** | **Settlements** | 4,932 | 2.6 | 0.08 | - | - | - | 41 | 1 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |
| 4.E.2 | Land converted to Settlements | 4,932 | 2.6 | 0.08 | - | - | - | 41 | 1 | - |
| **4.F** | **Other Land** | 6,849 | 7.9 | 0.24 | - | - | - | 122 | 2 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.F.2 | Land converted to Other Land | 6,849 | 7.9 | 0.24 | - | - | - | 122 | 2 | - |
| **4.G** | **Harvested Wood Products** | -45,698 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **1,230** | **2,808.0** | **8.61** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 1,669.7 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 795.9 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 873.8 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 1.2 | 0.07 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 1,230 | 30.6 | 0.49 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 1,106.5 | 8.04 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 881.2 | 8.04 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 225.3 | - | - | - | - | - | - | - |
| **5.E** | **Other** | - | - | - | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 17,972 | 10.9 | 11.06 | - | - | - | 12 | 13 | 11 |
| 1.A.3.a.i | Aviation | 7,110 | 0.0 | 0.20 | - | - | - | 1 | 2 | 0 |
| 1.A.3.d.i | Navigation | 10,861 | 10.9 | 10.86 | - | - | - | 11 | 11 | 11 |
| | **$CO_2$ emissions from biomass** | 302,887 | | | | | | | | |

Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

## Results of the Fourth National Inventory — Year 2014

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **782,646** | **18,486.5** | **565.20** | **5,001** | **320** | **277** | **21,916** | **2,888** | **3,991** |
| **1** | **Energy** | **458,908** | **567.1** | **33.74** | - | - | - | **6,766** | **2,568** | **900** |
| **1.A** | **Fuel Combustion Activities** | 443,238 | 381.5 | 33.51 | - | - | - | 6,766 | 2,568 | 900 |
| **1.A.1** | **Energy Industries** | 106,878 | 35.2 | 5.31 | - | - | - | 1,585 | 849 | 236 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 69,818 | 3.2 | 0.88 | - | - | - | 44 | 337 | 7 |
| 1.A.1.b | Petroleum Refining | 19,383 | 0.4 | 0.18 | - | - | - | 20 | 229 | 2 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 17,677 | 31.6 | 4.25 | - | - | - | 1,521 | 284 | 227 |
| **1.A.2** | **Manufacturing Industries and Construction** | 81,628 | 36.5 | 6.20 | - | - | - | 2,073 | 352 | 71 |
| 1.A.2.a | Iron and Steel | 7,540 | 0.5 | 0.08 | - | - | - | 12 | 17 | 2 |
| 1.A.2.b | Non-ferrous Metals | 9,968 | 0.2 | 0.06 | - | - | - | 7 | 26 | 1 |
| 1.A.2.c | Chemicals | 13,980 | 2.3 | 0.17 | - | - | - | 21 | 55 | 3 |
| 1.A.2.d | Pulp, Paper and Print | 4,847 | 2.6 | 1.22 | - | - | - | 1,074 | 55 | 17 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 4,497 | 23.7 | 3.60 | - | - | - | 363 | 88 | 15 |
| 1.A.2.f | Non-metallic Minerals | 23,313 | 5.7 | 0.69 | - | - | - | 457 | 57 | 25 |
| 1.A.2.g | Transport Equipment | 8,840 | 1.1 | 0.29 | - | - | - | 102 | 24 | 5 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 7,792 | 0.3 | 0.07 | - | - | - | 29 | 29 | 3 |
| 1.A.2.l | Textile and Leather | 850 | 0.1 | 0.04 | - | - | - | 6 | 2 | 0 |
| **1.A.3** | **Transport** | 214,361 | 41.8 | 17.74 | - | - | - | 1,862 | 1,108 | 369 |
| 1.A.3.a.ii | Domestic Aviation | 10,281 | 0.0 | 0.28 | - | - | - | 6 | 9 | 1 |
| 1.A.3.b | Road Transportation | 194,349 | 41.1 | 16.13 | - | - | - | 1,832 | 886 | 360 |
| 1.A.3.c | Railways | 2,943 | 0.2 | 1.20 | - | - | - | 11 | 52 | 5 |
| 1.A.3.d.ii | Domestic Navigation | 4,764 | 0.4 | 0.12 | - | - | - | 11 | 121 | 4 |
| 1.A.3.e | Other Transportation | 2,024 | 0.0 | 0.00 | - | - | - | 3 | 40 | 0 |
| **1.A.4** | **Other Sectors** | 39,137 | 268.0 | 4.23 | - | - | - | 1,245 | 257 | 224 |
| 1.A.4.a | Commercial / Institutional | 2,947 | 4.1 | 0.07 | - | - | - | 5 | 5 | 3 |
| 1.A.4.b | Residential | 18,002 | 244.2 | 2.72 | - | - | - | 1,106 | 29 | 166 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 18,188 | 19.7 | 1.44 | - | - | - | 133 | 223 | 55 |
| **1.A.5** | **Non-Specified** | 1,234 | 0.0 | 0.03 | - | - | - | 1 | 1 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 15,670 | 185.6 | 0.23 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 57.4 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 15,670 | 128.2 | 0.23 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **87,882** | **37.8** | **1.53** | **5,001** | **320** | **277** | **955** | **39** | **3,091** |
| **2.A** | **Mineral Industry** | 33,881 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 25,927 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 5,962 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 292 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 1,699 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 7,237 | 11.6 | 1.02 | - | - | - | 1 | 1 | 58 |
| 2.B.1 | Ammonia Production | 165 | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 0.66 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 0.36 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | NO | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 42 | - | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 7,030 | 11.6 | - | - | - | - | - | 0 | 11 |
| 2.B.9 | Fluorochemicals Production | - | - | - | - | - | - | - | - | - |
| 2.B.10 | Other Chemicals | - | - | - | - | - | - | - | - | 46 |
| **2.C** | **Metal Industry** | 45,977 | 26.3 | 0.51 | - | 320 | - | 869 | 14 | 12 |
| 2.C.1 | Iron and Steel Production | 41,271 | 26.1 | 0.51 | - | - | - | 496 | 12 | 12 |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.C.2 | Ferroalloy Production | 906 | 0.1 | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 1,589 | - | - | - | 320 | - | 373 | 2 | - |
| 2.C.4 | Magnesium Production | 121 | - | - | - | - | - | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | 2,089 | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 788 | - | - | - | - | - | - | - | 2,328 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | 5,001 | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 277 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 85 | 23 | 693 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 85 | 23 | 56 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 637 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 478 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 159 |
| **3** | **Agriculture** | **20,271** | **14,239.0** | **494.53** | **-** | **-** | **-** | **952** | **35** | **-** |
| **3.A** | **Enteric Fermentation** | - | 13,013.9 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 12,653.0 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 10,649.3 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 2,003.7 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 88.1 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 37.9 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 234.9 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 803.9 | 16.12 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 406.3 | 5.13 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 252.5 | 1.54 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 153.8 | 3.59 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 3.2 | - | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 348.5 | 2.27 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 45.9 | 0.83 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 7.88 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 2.37 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 1.12 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 1.26 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 1.86 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | - | 3.64 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 399.2 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 476.77 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 367.69 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 60.00 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 17.11 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 183.26 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 172.46 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 132.19 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 40.26 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 1.59 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 9.22 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 96.82 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 24.97 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 16.15 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 13.83 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 2.09 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 1.36 | - | - | - | - | - | - |
| 3.D.1.d.vi | Manioc | - | - | 0.94 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 0.94 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 34.46 | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.ix | Other annual crops | - | - | 2.06 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 4.18 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 6.32 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 109.08 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 40.67 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 12.66 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 3.20 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 24.81 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 22.99 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 17.63 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 5.37 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.16 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 1.66 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 68.41 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 13.69 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 4.08 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 27.91 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 25.87 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.18 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 1.87 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 21.78 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 5.62 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 3.63 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 3.11 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.47 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.31 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.21 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.21 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 7.75 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.46 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 0.94 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 22.0 | 1.65 | - | - | - | 952 | 35 | - |
| **3.G** | **Liming** | 16,863 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 3,408 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | - | - | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **214,254** | **837.4** | **26.71** | - | - | - | **13,243** | **246** | - |
| **4.A** | **Forest Land** | -357,076 | 49.1 | 1.59 | - | - | - | 781 | 15 | - |
| 4.A.1 | Forest Land remaining Forest Land | -318,883 | 46.8 | 1.38 | - | - | - | 716 | 11 | - |
| 4.A.2 | Land converted to Forest Land | -38,193 | 2.3 | 0.21 | - | - | - | 66 | 4 | - |
| **4.B** | **Cropland** | 133,290 | 104.4 | 3.75 | - | - | - | 1,739 | 41 | - |
| 4.B.1 | Cropland remaining Cropland | - | - | - | - | - | - | - | - | - |
| 4.B.2 | Land converted to Cropland | 133,290 | 104.4 | 3.75 | - | - | - | 1,739 | 41 | - |
| **4.C** | **Grassland** | 468,516 | 668.1 | 20.88 | - | - | - | 10,476 | 186 | - |
| 4.C.1 | Grassland remaining Grassland | 305 | 19.9 | 1.82 | - | - | - | 563 | 34 | - |
| 4.C.2 | Land converted to Grassland | 468,211 | 648.2 | 19.06 | - | - | - | 9,913 | 153 | - |
| **4.D** | **Wetlands** | 6,371 | 6.9 | 0.22 | - | - | - | 108 | 2 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 6,371 | 6.9 | 0.22 | - | - | - | 108 | 2 | - |
| **4.E** | **Settlements** | 4,367 | 2.2 | 0.07 | - | - | - | 35 | 1 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |
| 4.E.2 | Land converted to Settlements | 4,367 | 2.2 | 0.07 | - | - | - | 35 | 1 | - |
| **4.F** | **Other Land** | 5,914 | 6.7 | 0.20 | - | - | - | 103 | 2 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.F.2 | Land converted to Other Land | 5,914 | 6.7 | 0.20 | - | - | - | 103 | 2 | - |
| **4.G** | **Harvested Wood Products** | -47,127 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **1,331** | **2,805.1** | **8.69** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 1,681.2 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 787.5 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 893.7 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 1.3 | 0.08 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 1,331 | 30.5 | 0.50 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 1,092.0 | 8.11 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 894.7 | 8.11 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 197.3 | - | - | - | - | - | - | - |
| **5.E** | **Other** | - | - | - | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 18,583 | 11.1 | 11.33 | - | - | - | 12 | 13 | 11 |
| 1.A.3.a.i | Aviation | 7,457 | 0.0 | 0.21 | - | - | - | 1 | 2 | 0 |
| 1.A.3.d.i | Navigation | 11,127 | 11.1 | 11.13 | - | - | - | 11 | 11 | 11 |
| | **$CO_2$ emissions from biomass** | 311,108 | | | | | | | | |

Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

## Results of the Fourth National Inventory — Year 2015

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **874,531** | **18,998.5** | **569.39** | **5,409** | **255** | **286** | **23,565** | **2,730** | **3,297** |
| **1** | **Energy** | **433,397** | **576.5** | **33.62** | - | - | - | **6,662** | **2,387** | **866** |
| **1.A** | **Fuel Combustion Activities** | 418,006 | 387.9 | 33.39 | - | - | - | 6,662 | 2,387 | 866 |
| **1.A.1** | **Energy Industries** | 101,474 | 36.1 | 5.41 | - | - | - | 1,618 | 804 | 234 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 65,319 | 3.0 | 0.84 | - | - | - | 38 | 303 | 5 |
| 1.A.1.b | Petroleum Refining | 18,529 | 0.4 | 0.18 | - | - | - | 18 | 215 | 2 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 17,626 | 32.7 | 4.40 | - | - | - | 1,561 | 286 | 227 |
| **1.A.2** | **Manufacturing Industries and Construction** | 77,598 | 35.2 | 6.05 | - | - | - | 2,080 | 341 | 68 |
| 1.A.2.a | Iron and Steel | 7,231 | 0.4 | 0.07 | - | - | - | 12 | 16 | 2 |
| 1.A.2.b | Non-ferrous Metals | 8,976 | 0.2 | 0.05 | - | - | - | 6 | 25 | 1 |
| 1.A.2.c | Chemicals | 14,360 | 2.5 | 0.18 | - | - | - | 22 | 57 | 3 |
| 1.A.2.d | Pulp, Paper and Print | 4,546 | 2.8 | 1.30 | - | - | - | 1,153 | 57 | 18 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 4,505 | 22.9 | 3.47 | - | - | - | 351 | 85 | 14 |
| 1.A.2.f | Non-metallic Minerals | 21,056 | 5.0 | 0.60 | - | - | - | 405 | 51 | 22 |
| 1.A.2.g | Transport Equipment | 8,448 | 1.0 | 0.28 | - | - | - | 96 | 21 | 5 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 7,763 | 0.4 | 0.07 | - | - | - | 29 | 28 | 3 |
| 1.A.2.l | Textile and Leather | 714 | 0.1 | 0.03 | - | - | - | 6 | 1 | 0 |
| **1.A.3** | **Transport** | 199,110 | 39.1 | 17.54 | - | - | - | 1,676 | 980 | 332 |
| 1.A.3.a.ii | Domestic Aviation | 10,407 | 0.0 | 0.28 | - | - | - | 5 | 9 | 1 |
| 1.A.3.b | Road Transportation | 180,993 | 38.6 | 16.01 | - | - | - | 1,651 | 806 | 324 |
| 1.A.3.c | Railways | 2,800 | 0.2 | 1.16 | - | - | - | 10 | 50 | 4 |
| 1.A.3.d.ii | Domestic Navigation | 3,093 | 0.3 | 0.08 | - | - | - | 7 | 79 | 3 |
| 1.A.3.e | Other Transportation | 1,817 | 0.0 | 0.00 | - | - | - | 3 | 36 | 0 |
| **1.A.4** | **Other Sectors** | 39,111 | 277.6 | 4.36 | - | - | - | 1,287 | 263 | 231 |
| 1.A.4.a | Commercial / Institutional | 2,781 | 4.0 | 0.07 | - | - | - | 5 | 5 | 3 |
| 1.A.4.b | Residential | 18,021 | 252.9 | 2.80 | - | - | - | 1,143 | 29 | 172 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 18,309 | 20.7 | 1.49 | - | - | - | 138 | 228 | 57 |
| **1.A.5** | **Non-Specified** | 714 | 0.0 | 0.02 | - | - | - | 0 | 1 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 15,391 | 188.6 | 0.23 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 53.0 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 15,391 | 135.6 | 0.23 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **87,652** | **38.0** | **1.36** | **5,409** | **255** | **286** | **884** | **40** | **2,431** |
| **2.A** | **Mineral Industry** | 31,696 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 23,445 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 6,071 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 280 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 1,901 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 7,688 | 11.6 | 0.85 | - | - | - | 1 | 1 | 57 |
| 2.B.1 | Ammonia Production | 555 | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 0.65 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 0.20 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | NO | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 42 | - | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 7,092 | 11.6 | - | - | - | - | - | 0 | 10 |
| 2.B.9 | Fluorochemicals Production | - | - | - | - | - | - | - | - | - |
| 2.B.10 | Other Chemicals | - | - | - | - | - | - | - | - | 47 |
| **2.C** | **Metal Industry** | 47,516 | 26.4 | 0.51 | - | 255 | - | 793 | 14 | 13 |
| 2.C.1 | Iron and Steel Production | 43,391 | 26.4 | 0.51 | - | - | - | 500 | 13 | 13 |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.C.2 | Ferroalloy Production | 814 | - | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 1,281 | - | - | - | 255 | - | 292 | 2 | - |
| 2.C.4 | Magnesium Production | 129 | - | - | - | - | - | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | 1,902 | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 751 | - | - | - | - | - | - | - | 1,679 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | 5,409 | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 286 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 90 | 24 | 682 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 90 | 24 | 60 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 623 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 458 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 165 |
| **3** | **Agriculture** | **17,538** | **14,530.9** | **494.66** | **-** | **-** | **-** | **577** | **21** | **-** |
| **3.A** | **Enteric Fermentation** | - | 13,258.0 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 12,886.2 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 11,030.2 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 1,856.0 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 92.1 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 39.8 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 239.9 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 832.2 | 16.13 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 411.7 | 4.90 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 260.4 | 1.50 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 151.3 | 3.40 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 3.4 | - | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 370.9 | 2.47 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 46.2 | 0.83 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 7.93 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 2.27 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 1.09 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 1.19 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 2.01 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | - | 3.64 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 427.4 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 477.53 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 369.38 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 54.66 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 17.19 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 185.02 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 173.96 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 137.19 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 36.77 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 1.59 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 9.47 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 101.97 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 28.06 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 17.24 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 15.02 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 2.12 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 1.28 | - | - | - | - | - | - |
| 3.D.1.d.vi | Manioc | - | - | 0.93 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 0.83 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 34.46 | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.ix | Other annual crops | - | - | 2.04 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 4.18 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 6.36 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 108.16 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 39.48 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 11.21 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 3.21 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 25.06 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 23.19 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 18.29 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 4.90 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.16 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 1.71 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 68.68 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 12.49 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 4.11 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 28.20 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 26.09 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.18 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 1.92 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 22.94 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 6.31 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 3.88 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 3.38 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.48 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.29 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.21 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.19 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 7.75 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.46 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 0.94 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 13.3 | 1.00 | - | - | - | 577 | 21 | - |
| **3.G** | **Liming** | 14,606 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 2,932 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | - | - | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **334,796** | **979.9** | **31.00** | - | - | - | **15,442** | **282** | - |
| **4.A** | **Forest Land** | -347,581 | 55.9 | 1.79 | - | - | - | 886 | 17 | - |
| 4.A.1 | Forest Land remaining Forest Land | -312,373 | 53.5 | 1.57 | - | - | - | 819 | 13 | - |
| 4.A.2 | Land converted to Forest Land | -35,208 | 2.4 | 0.22 | - | - | - | 67 | 4 | - |
| **4.B** | **Cropland** | 147,479 | 115.5 | 4.11 | - | - | - | 1,917 | 44 | - |
| 4.B.1 | Cropland remaining Cropland | - | - | - | - | - | - | - | - | - |
| 4.B.2 | Land converted to Cropland | 147,479 | 115.5 | 4.11 | - | - | - | 1,917 | 44 | - |
| **4.C** | **Grassland** | 562,914 | 789.6 | 24.51 | - | - | - | 12,347 | 216 | - |
| 4.C.1 | Grassland remaining Grassland | 3,188 | 20.8 | 1.90 | - | - | - | 588 | 35 | - |
| 4.C.2 | Land converted to Grassland | 559,725 | 768.8 | 22.61 | - | - | - | 11,758 | 181 | - |
| **4.D** | **Wetlands** | 7,333 | 8.2 | 0.25 | - | - | - | 128 | 2 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 7,333 | 8.2 | 0.25 | - | - | - | 128 | 2 | - |
| **4.E** | **Settlements** | 4,645 | 2.4 | 0.08 | - | - | - | 38 | 1 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |
| 4.E.2 | Land converted to Settlements | 4,645 | 2.4 | 0.08 | - | - | - | 38 | 1 | - |
| **4.F** | **Other Land** | 7,054 | 8.2 | 0.25 | - | - | - | 126 | 2 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.F.2 | Land converted to Other Land | 7,054 | 8.2 | 0.25 | - | - | - | 126 | 2 | - |
| **4.G** | **Harvested Wood Products** | -47,047 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **1,149** | **2,873.2** | **8.75** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 1,751.5 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 837.1 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 914.4 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 1.5 | 0.09 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 1,149 | 32.3 | 0.49 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 1,087.8 | 8.17 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 888.7 | 8.17 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 199.1 | - | - | - | - | - | - | - |
| **5.E** | **Other** | - | - | - | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 20,792 | 13.3 | 13.48 | - | - | - | 14 | 15 | 13 |
| 1.A.3.a.i | Aviation | 7,518 | 0.0 | 0.21 | - | - | - | 1 | 2 | 0 |
| 1.A.3.d.i | Navigation | 13,274 | 13.3 | 13.27 | - | - | - | 13 | 13 | 13 |
| | **$CO_2$ emissions from biomass** | 322,978 | | | | | | | | |

Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

## Results of the Fourth National Inventory — Year 2016

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total Brazil** | **873,272** | **19,333.2** | **586.09** | **5,728** | **273** | **295** | **24,044** | **2,548** | **3,241** |
| **1** | **Energy** | **401,690** | **557.1** | **32.88** | - | - | - | **6,399** | **2,191** | **799** |
| **1.A** | **Fuel Combustion Activities** | 385,850 | 371.5 | 32.65 | - | - | - | 6,399 | 2,191 | 799 |
| **1.A.1** | **Energy Industries** | 76,693 | 32.6 | 4.81 | - | - | - | 1,485 | 695 | 202 |
| 1.A.1.a | Main Activity Electricity and Heat Production | 42,663 | 1.8 | 0.55 | - | - | - | 22 | 214 | 3 |
| 1.A.1.b | Petroleum Refining | 17,121 | 0.4 | 0.16 | - | - | - | 17 | 205 | 1 |
| 1.A.1.c | Manufacture of Solid Fuels and Other Energy Industries | 16,909 | 30.4 | 4.10 | - | - | - | 1,446 | 276 | 198 |
| **1.A.2** | **Manufacturing Industries and Construction** | 72,312 | 37.0 | 6.33 | - | - | - | 2,101 | 337 | 66 |
| 1.A.2.a | Iron and Steel | 6,816 | 0.4 | 0.06 | - | - | - | 11 | 16 | 2 |
| 1.A.2.b | Non-ferrous Metals | 8,956 | 0.2 | 0.05 | - | - | - | 6 | 25 | 1 |
| 1.A.2.c | Chemicals | 14,008 | 2.4 | 0.17 | - | - | - | 20 | 54 | 3 |
| 1.A.2.d | Pulp, Paper and Print | 4,886 | 2.9 | 1.37 | - | - | - | 1,232 | 63 | 19 |
| 1.A.2.e | Food Processing, Beverages and Tobacco | 4,373 | 25.3 | 3.78 | - | - | - | 349 | 92 | 15 |
| 1.A.2.f | Non-metallic Minerals | 19,055 | 4.5 | 0.54 | - | - | - | 364 | 46 | 20 |
| 1.A.2.g | Transport Equipment | 7,669 | 1.0 | 0.26 | - | - | - | 90 | 18 | 4 |
| 1.A.2.i | Mining (excluding fuels) and Quarrying | 5,904 | 0.3 | 0.05 | - | - | - | 22 | 23 | 3 |
| 1.A.2.l | Textile and Leather | 645 | 0.1 | 0.03 | - | - | - | 5 | 1 | 0 |
| **1.A.3** | **Transport** | 199,974 | 37.0 | 17.42 | - | - | - | 1,595 | 935 | 314 |
| 1.A.3.a.ii | Domestic Aviation | 9,733 | 0.0 | 0.26 | - | - | - | 5 | 8 | 1 |
| 1.A.3.b | Road Transportation | 182,869 | 36.5 | 15.96 | - | - | - | 1,571 | 773 | 307 |
| 1.A.3.c | Railways | 2,746 | 0.2 | 1.13 | - | - | - | 10 | 49 | 4 |
| 1.A.3.d.ii | Domestic Navigation | 2,367 | 0.2 | 0.06 | - | - | - | 6 | 60 | 2 |
| 1.A.3.e | Other Transportation | 2,260 | 0.0 | 0.00 | - | - | - | 3 | 45 | 0 |
| **1.A.4** | **Other Sectors** | 36,177 | 264.9 | 4.08 | - | - | - | 1,217 | 224 | 217 |
| 1.A.4.a | Commercial / Institutional | 2,758 | 3.8 | 0.07 | - | - | - | 5 | 5 | 3 |
| 1.A.4.b | Residential | 18,209 | 241.9 | 2.70 | - | - | - | 1,091 | 29 | 164 |
| 1.A.4.c | Agriculture / Forestry / Fishing / Fish Farms | 15,210 | 19.2 | 1.31 | - | - | - | 121 | 190 | 51 |
| **1.A.5** | **Non-Specified** | 693 | 0.0 | 0.02 | - | - | - | 0 | 1 | 0 |
| **1.B** | **Fugitive Emissions from Fuel** | 15,840 | 185.6 | 0.23 | - | - | - | - | - | - |
| **1.B.1** | **Solid Fuels** | NO | 48.1 | NO | - | - | - | NO | NO | NO |
| **1.B.2** | **Oil and Natural Gas** | 15,840 | 137.5 | 0.23 | - | - | - | NE | NE | NE |
| **1.C** | **$CO_2$ Transport and Storage** | NO | - | - | - | - | - | - | - | - |
| **2** | **Industrial Processes and Product Use (IPPU)** | **85,943** | **34.5** | **1.27** | **5,728** | **273** | **295** | **801** | **39** | **2,442** |
| **2.A** | **Mineral Industry** | 29,373 | - | - | - | - | - | - | - | - |
| 2.A.1 | Cement Production | 21,238 | - | - | - | - | - | - | - | - |
| 2.A.2 | Lime Production | 6,071 | - | - | - | - | - | - | - | - |
| 2.A.3 | Glass Production | 263 | - | - | - | - | - | - | - | - |
| 2.A.4 | Other Process Uses of Carbonates | 1,801 | - | - | - | - | - | - | - | - |
| **2.B** | **Chemical Industry** | 7,904 | 12.2 | 0.85 | - | - | - | 1 | 1 | 60 |
| 2.B.1 | Ammonia Production | 456 | - | - | - | - | - | - | - | - |
| 2.B.2 | Nitric Acid Production | - | - | 0.65 | - | - | - | - | 1 | - |
| 2.B.3 | Adipic Acid Production | - | - | 0.19 | - | - | - | 1 | 0 | - |
| 2.B.4 | Caprolactam, Glyoxal and Glyoxylic Acid Production | - | - | NO | - | - | - | - | - | - |
| 2.B.5 | Carbide Production | 42 | - | - | - | - | - | - | - | - |
| 2.B.6 | Titanium Dioxide Production | - | - | - | - | - | - | - | - | - |
| 2.B.7 | Soda Ash Production | - | - | - | - | - | - | - | - | - |
| 2.B.8 | Petrochemical and Carbon Black Production | 7,407 | 12.2 | - | - | - | - | - | 0 | 11 |
| 2.B.9 | Fluorochemicals Production | - | - | - | - | - | - | - | - | - |
| 2.B.10 | Other Chemicals | - | - | - | - | - | - | - | - | 49 |
| **2.C** | **Metal Industry** | 47,903 | 22.3 | 0.43 | - | 273 | - | 702 | 12 | 10 |
| 2.C.1 | Iron and Steel Production | 43,806 | 22.3 | 0.43 | - | - | - | 417 | 10 | 10 |

| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2.C.2 | Ferroalloy Production | 798 | - | - | - | - | - | - | - | - |
| 2.C.3 | Aluminum Production | 1,317 | - | - | - | 273 | - | 285 | 2 | - |
| 2.C.4 | Magnesium Production | 140 | - | - | - | - | - | - | - | - |
| 2.C.7 | Other (non-ferrous metals, except aluminum and magnesium) | 1,843 | - | - | - | - | - | - | - | - |
| **2.D** | **Non-Energy Products from Fuels and Solvent Use** | 763 | - | - | - | - | - | - | - | 1,670 |
| **2.E** | **Electronics Industry** | - | - | - | NE/NO | NE/NO | NO | - | - | - |
| **2.F** | **Product Uses as Substitutes for Ozone Depleting Substances** | - | - | - | 5,728 | NE/NO | - | - | - | - |
| **2.G** | **Other Product Manufacture and Use** | - | - | - | - | - | 295 | - | - | - |
| **2.H** | **Other** | - | - | - | - | - | - | 98 | 26 | 701 |
| 2.H.1 | Pulp and Paper Industry | - | - | - | - | - | - | 98 | 26 | 65 |
| 2.H.2 | Food and Beverage Industry | - | - | - | - | - | - | - | - | 637 |
| 2.H.2.a | Food | - | - | - | - | - | - | - | - | 450 |
| 2.H.2.b | Beverage | - | - | - | - | - | - | - | - | 187 |
| **3** | **Agriculture** | **19,732** | **14,715.7** | **510.46** | **-** | **-** | **-** | **498** | **18** | **-** |
| **3.A** | **Enteric Fermentation** | - | 13,462.5 | - | - | - | - | - | - | - |
| 3.A.1 | Cattle | - | 13,087.3 | - | - | - | - | - | - | - |
| 3.A.1.a | Beef Cattle | - | 11,350.6 | - | - | - | - | - | - | - |
| 3.A.1.b | Dairy Cattle | - | 1,736.7 | - | - | - | - | - | - | - |
| 3.A.2 | Sheep | - | 92.0 | - | - | - | - | - | - | - |
| 3.A.3 | Swine | - | 39.9 | - | - | - | - | - | - | - |
| 3.A.4 | Other Animals | - | 243.3 | - | - | - | - | - | - | - |
| **3.B** | **Manure Management** | - | 843.1 | 15.84 | - | - | - | - | - | - |
| 3.B.1 | Cattle | - | 419.3 | 4.67 | - | - | - | - | - | - |
| 3.B.1.a | Beef Cattle | - | 266.5 | 1.44 | - | - | - | - | - | - |
| 3.B.1.b | Dairy Cattle | - | 152.8 | 3.23 | - | - | - | - | - | - |
| 3.B.2 | Sheep | - | 3.4 | - | - | - | - | - | - | - |
| 3.B.3 | Swine | - | 373.9 | 2.49 | - | - | - | - | - | - |
| 3.B.4 | Other Animals | - | 46.6 | 0.83 | - | - | - | - | - | - |
| 3.B.5 | Indirect $N_2O$ Emissions | - | - | 7.85 | - | - | - | - | - | - |
| 3.B.5.a | Cattle | - | - | 2.18 | - | - | - | - | - | - |
| 3.B.5.a.i | Beef Cattle | - | - | 1.05 | - | - | - | - | - | - |
| 3.B.5.a.ii | Dairy Cattle | - | - | 1.13 | - | - | - | - | - | - |
| 3.B.5.b | Swine | - | - | 2.03 | - | - | - | - | - | - |
| 3.B.5.c.vii | Poultry | - | - | 3.64 | - | - | - | - | - | - |
| **3.C** | **Rice Cultivation** | - | 398.5 | - | - | - | - | - | - | - |
| **3.D** | **Managed Soils** | - | - | 493.76 | - | - | - | - | - | - |
| 3.D.1 | Direct $N_2O$ Emissions | - | - | 379.97 | - | - | - | - | - | - |
| 3.D.1.a | Synthetic Fertilizers | - | - | 67.80 | - | - | - | - | - | - |
| 3.D.1.b | Organic Fertilizers | - | - | 17.24 | - | - | - | - | - | - |
| 3.D.1.c | Animal manure applied to soils | - | - | 186.83 | - | - | - | - | - | - |
| 3.D.1.c.i | Cattle | - | - | 175.72 | - | - | - | - | - | - |
| 3.D.1.c.i.1 | Beef Cattle | - | - | 141.54 | - | - | - | - | - | - |
| 3.D.1.c.i.2 | Dairy Cattle | - | - | 34.18 | - | - | - | - | - | - |
| 3.D.1.c.ii | Swine | - | - | 1.54 | - | - | - | - | - | - |
| 3.D.1.c.iii | Other Animals | - | - | 9.57 | - | - | - | - | - | - |
| 3.D.1.d | Crop Residues | - | - | 97.52 | - | - | - | - | - | - |
| 3.D.1.d.i | Soybean | - | - | 27.75 | - | - | - | - | - | - |
| 3.D.1.d.ii | Maize | - | - | 12.97 | - | - | - | - | - | - |
| 3.D.1.d.iii | Sugar cane | - | - | 15.61 | - | - | - | - | - | - |
| 3.D.1.d.iv | Rice | - | - | 1.83 | - | - | - | - | - | - |
| 3.D.1.d.v | Bean | - | - | 1.08 | - | - | - | - | - | - |
| 3.D.1.d.vi | Manioc | - | - | 0.85 | - | - | - | - | - | - |
| 3.D.1.d.vii | Wheat | - | - | 1.03 | - | - | - | - | - | - |
| 3.D.1.d.viii | Pasture | - | - | 34.46 | - | - | - | - | - | - |

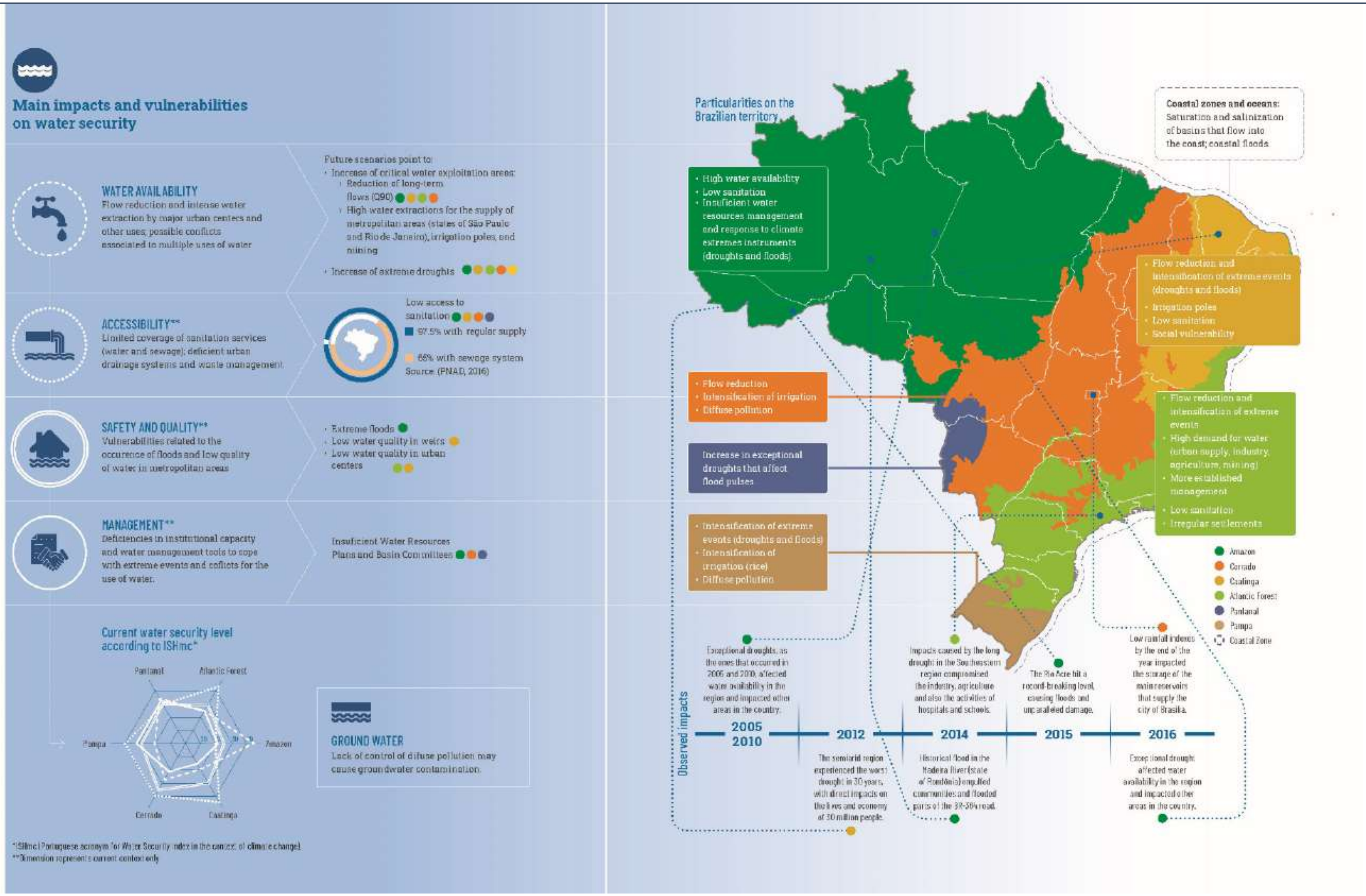
| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2$e) | PFCs (Gg $CO_2$e) | $SF_6$ (Gg $CO_2$e) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.D.1.d.ix | Other annual crops | - | - | 1.95 | - | - | - | - | - | - |
| 3.D.1.e | Mineralization of N associated with loss of C in soil | - | - | 4.18 | - | - | - | - | - | - |
| 3.D.1.f | Organic Soil Management | - | - | 6.40 | - | - | - | - | - | - |
| 3.D.2 | Indirect $N_2O$ Emissions | - | - | 113.79 | - | - | - | - | - | - |
| 3.D.2.a | Atmospheric Deposition | - | - | 42.87 | - | - | - | - | - | - |
| 3.D.2.a.i | Synthetic Fertilizers | - | - | 14.36 | - | - | - | - | - | - |
| 3.D.2.a.ii | Organic Fertilizers | - | - | 3.20 | - | - | - | - | - | - |
| 3.D.2.a.iii | Animal manure applied to soils | - | - | 25.31 | - | - | - | - | - | - |
| 3.D.2.a.iii.1 | Cattle | - | - | 23.43 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.a | Beef Cattle | - | - | 18.87 | - | - | - | - | - | - |
| 3.D.2.a.iii.1.b | Dairy Cattle | - | - | 4.56 | - | - | - | - | - | - |
| 3.D.2.a.iii.2 | Swine | - | - | 0.15 | - | - | - | - | - | - |
| 3.D.2.a.iii.3 | Other Animals | - | - | 1.72 | - | - | - | - | - | - |
| 3.D.2.b | Nitrogen leaching and run-off | - | - | 70.92 | - | - | - | - | - | - |
| 3.D.2.b.i | Synthetic Fertilizers | - | - | 15.44 | - | - | - | - | - | - |
| 3.D.2.b.ii | Organic Fertilizers | - | - | 4.14 | - | - | - | - | - | - |
| 3.D.2.b.iii | Animal manure applied to soils | - | - | 28.47 | - | - | - | - | - | - |
| 3.D.2.b.iii.1 | Cattle | - | - | 26.36 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.b | Swine | - | - | 0.17 | - | - | - | - | - | - |
| 3.D.2.b.iii.1.c | Other Animals | - | - | 1.94 | - | - | - | - | - | - |
| 3.D.2.b.iv | Crop Residues | - | - | 21.94 | - | - | - | - | - | - |
| 3.D.2.b.iv.1 | Soybean | - | - | 6.24 | - | - | - | - | - | - |
| 3.D.2.b.iv.2 | Maize | - | - | 2.92 | - | - | - | - | - | - |
| 3.D.2.b.iv.3 | Sugar cane | - | - | 3.51 | - | - | - | - | - | - |
| 3.D.2.b.iv.4 | Rice | - | - | 0.41 | - | - | - | - | - | - |
| 3.D.2.b.iv.5 | Bean | - | - | 0.24 | - | - | - | - | - | - |
| 3.D.2.b.iv.6 | Manioc | - | - | 0.19 | - | - | - | - | - | - |
| 3.D.2.b.iv.7 | Wheat | - | - | 0.23 | - | - | - | - | - | - |
| 3.D.2.b.iv.8 | Pasture | - | - | 7.75 | - | - | - | - | - | - |
| 3.D.2.b.iv.9 | Other annual crops | - | - | 0.43 | - | - | - | - | - | - |
| 3.D.2.b.v | Mineralization of N associated with loss of C in soil | - | - | 0.94 | - | - | - | - | - | - |
| **3.E** | **Prescribed Burning of Savannas** | NE | NE | NE | - | - | - | NE | NE | NE |
| **3.F** | **Field burning of agricultural residues** | - | 11.5 | 0.86 | - | - | - | 498 | 18 | - |
| **3.G** | **Liming** | 15,844 | - | - | - | - | - | - | - | - |
| **3.H** | **Urea application** | 3,888 | - | - | - | - | - | - | - | - |
| **3.I** | **Other** | NO | - | - | - | - | - | - | - | - |
| **4** | **Land Use, Land-Use Change and Forestry (LULUCF)** | **365,404** | **1,037.2** | **32.81** | - | - | - | **16,346** | **298** | - |
| **4.A** | **Forest Land** | -349,535 | 55.6 | 1.76 | - | - | - | 877 | 16 | - |
| 4.A.1 | Forest Land remaining Forest Land | -312,255 | 53.5 | 1.57 | - | - | - | 819 | 13 | - |
| 4.A.2 | Land converted to Forest Land | -37,281 | 2.1 | 0.19 | - | - | - | 59 | 4 | - |
| **4.B** | **Cropland** | 129,819 | 97.1 | 3.68 | - | - | - | 1,658 | 42 | - |
| 4.B.1 | Cropland remaining Cropland | - | - | - | - | - | - | - | - | - |
| 4.B.2 | Land converted to Cropland | 129,819 | 97.1 | 3.68 | - | - | - | 1,658 | 42 | - |
| **4.C** | **Grassland** | 614,001 | 862.1 | 26.69 | - | - | - | 13,464 | 234 | - |
| 4.C.1 | Grassland remaining Grassland | -4,481 | 21.5 | 1.96 | - | - | - | 607 | 36 | - |
| 4.C.2 | Land converted to Grassland | 618,482 | 840.6 | 24.72 | - | - | - | 12,856 | 198 | - |
| **4.D** | **Wetlands** | 8,308 | 9.4 | 0.29 | - | - | - | 147 | 3 | - |
| 4.D.1 | Wetland remaining Wetland | - | - | - | - | - | - | - | - | - |
| 4.D.2 | Land converted to Wetland | 8,308 | 9.4 | 0.29 | - | - | - | 147 | 3 | - |
| **4.E** | **Settlements** | 4,984 | 2.7 | 0.09 | - | - | - | 43 | 1 | - |
| 4.E.1 | Settlements remaining Settlements | - | - | - | - | - | - | - | - | - |
| 4.E.2 | Land converted to Settlements | 4,984 | 2.7 | 0.09 | - | - | - | 43 | 1 | - |
| **4.F** | **Other Land** | 8,600 | 10.3 | 0.31 | - | - | - | 158 | 3 | - |
| 4.F.1 | Other Land remaining Other Land | - | - | - | - | - | - | - | - | - |

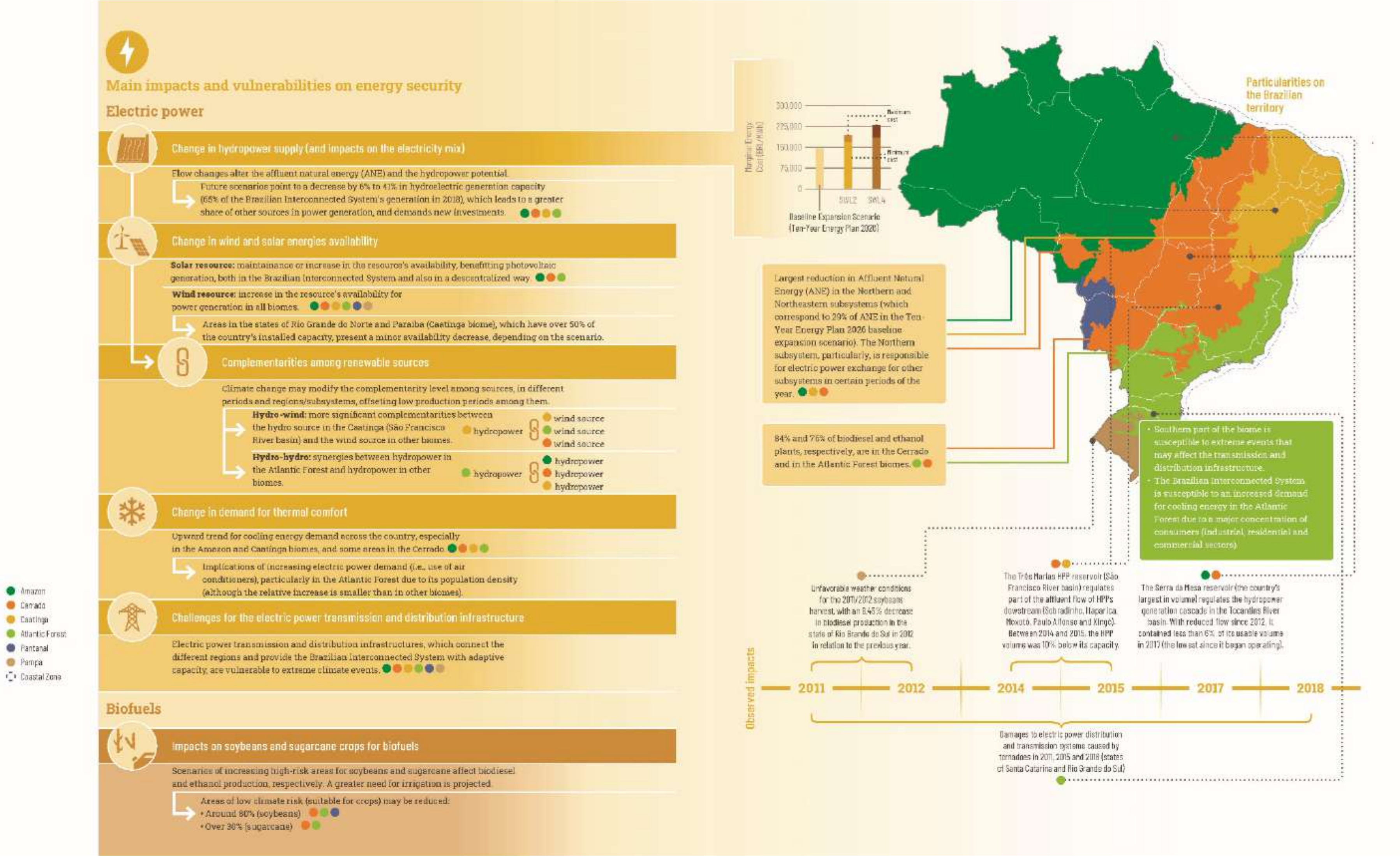
| | | $CO_2$ (Gg) [net emissions] | $CH_4$ (Gg) | $N_2O$ (Gg) | HFCs (Gg $CO_2e$) | PFCs (Gg $CO_2e$) | $SF_6$ (Gg $CO_2e$) | CO (Gg) | $NO_x$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 4.F.2 | Land converted to Other Land | 8,600 | 10.3 | 0.31 | - | - | - | 158 | 3 | - |
| **4.G** | **Harvested Wood Products** | -50,772 | - | - | - | - | - | - | - | - |
| **5** | **Waste** | **504** | **2,988.7** | **8.67** | **-** | **-** | **-** | **-** | **-** | **-** |
| **5.A** | **Solid Waste Disposal** | - | 1,857.2 | - | - | - | - | - | - | - |
| 5.A.1 | Managed Waste Disposal Sites | - | 874.8 | - | - | - | - | - | - | - |
| 5.A.3 | Uncategorized Waste Disposal Sites | - | 982.4 | - | - | - | - | - | - | - |
| **5.B** | **Biological Treatment of Solid Waste** | - | 1.4 | 0.09 | - | - | - | - | - | - |
| **5.C** | **Incineration and Open Burning of Waste** | 504 | 23.4 | 0.35 | - | - | - | - | - | - |
| **5.D** | **Wastewater Treatment and Discharge** | - | 1,106.7 | 8.24 | - | - | - | - | - | - |
| 5.D.1 | Domestic Wastewater Treatment and Discharge | - | 897.3 | 8.24 | - | - | - | - | - | - |
| 5.D.2 | Industrial Wastewater Treatment and Discharge | - | 209.4 | - | - | - | - | - | - | - |
| **5.E** | **Other** | - | - | - | - | - | - | - | - | - |
| | **Memo items** | | | | | | | | | |
| | **International bunkers** | 17,666 | 10.9 | 11.13 | - | - | - | 12 | 13 | 11 |
| 1.A.3.a.i | Aviation | 6,727 | 0.0 | 0.19 | - | - | - | 1 | 2 | 0 |
| 1.A.3.d.i | Navigation | 10,939 | 10.9 | 10.94 | - | - | - | 11 | 11 | 11 |
| | **$CO_2$ emissions from biomass** | 320,192 | | | | | | | | |

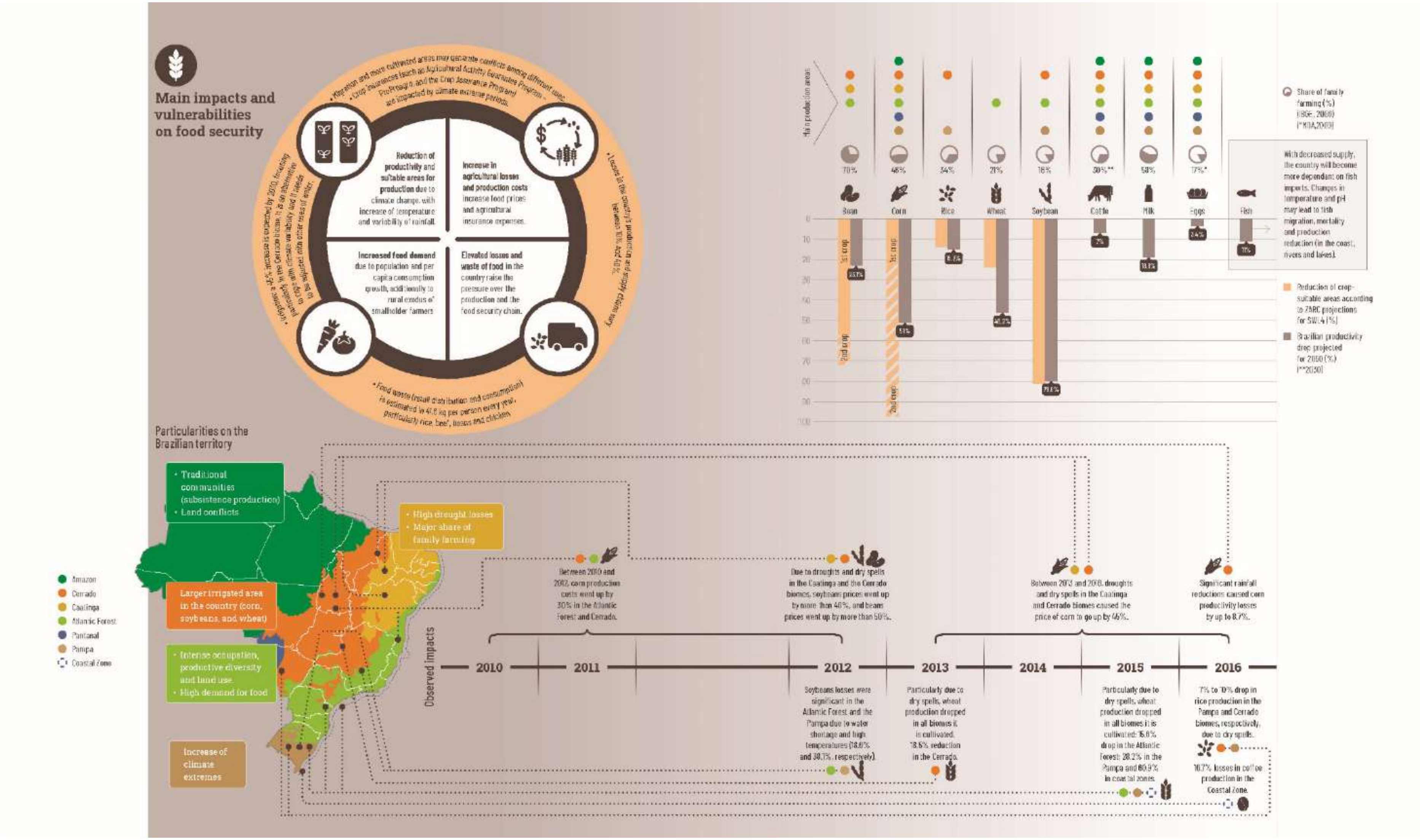
Notation Keys: NO — not occurring; NE — not estimated; NA — not applicable (cells in grey)

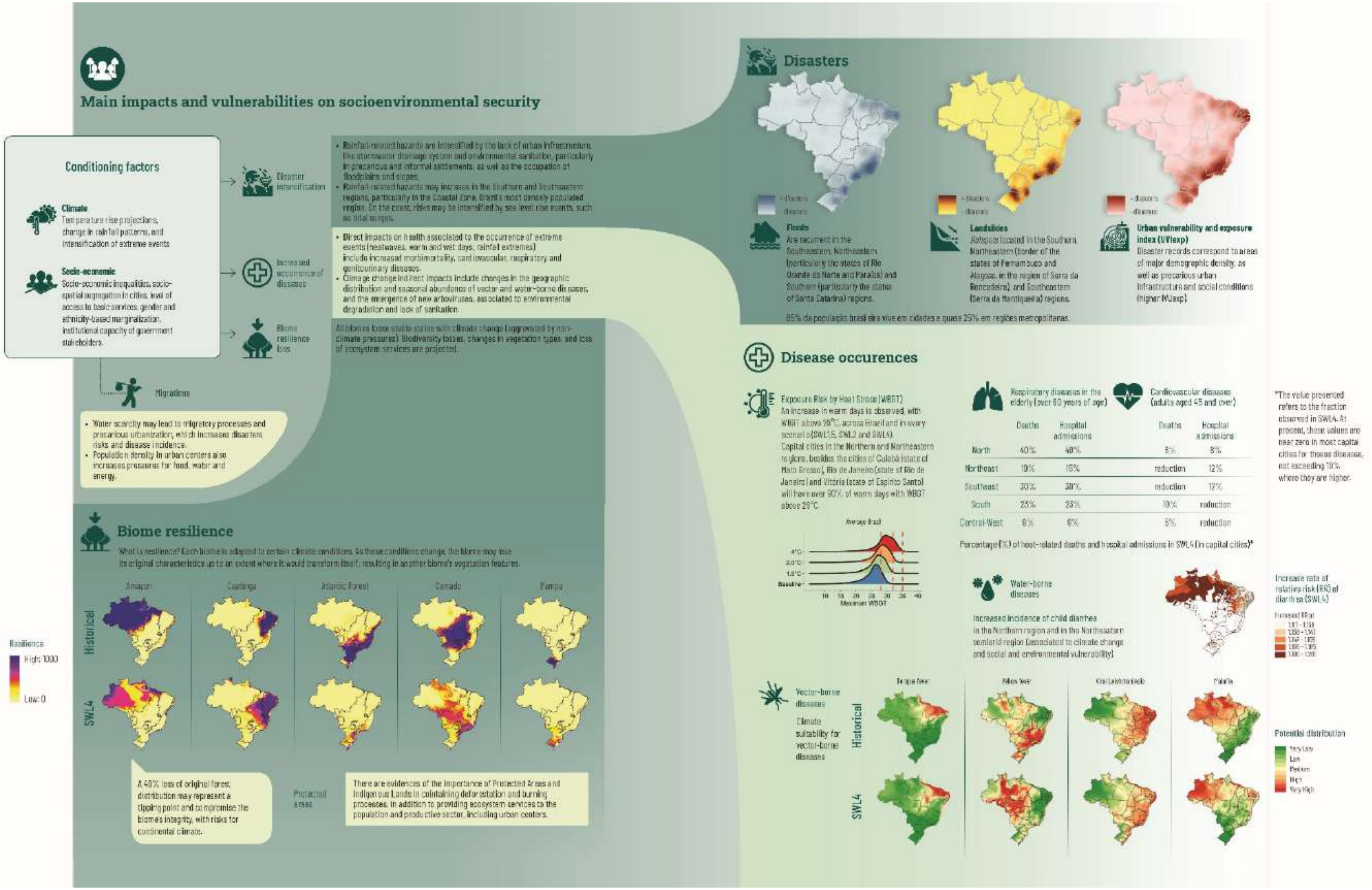
# APPENDIX

## APPENDIX II – MAIN IMPACTS AND VULNERABILITIES ON WATER, ENERGY, FOOD AND SOCIALENVIRONMENTAL SECURITIES



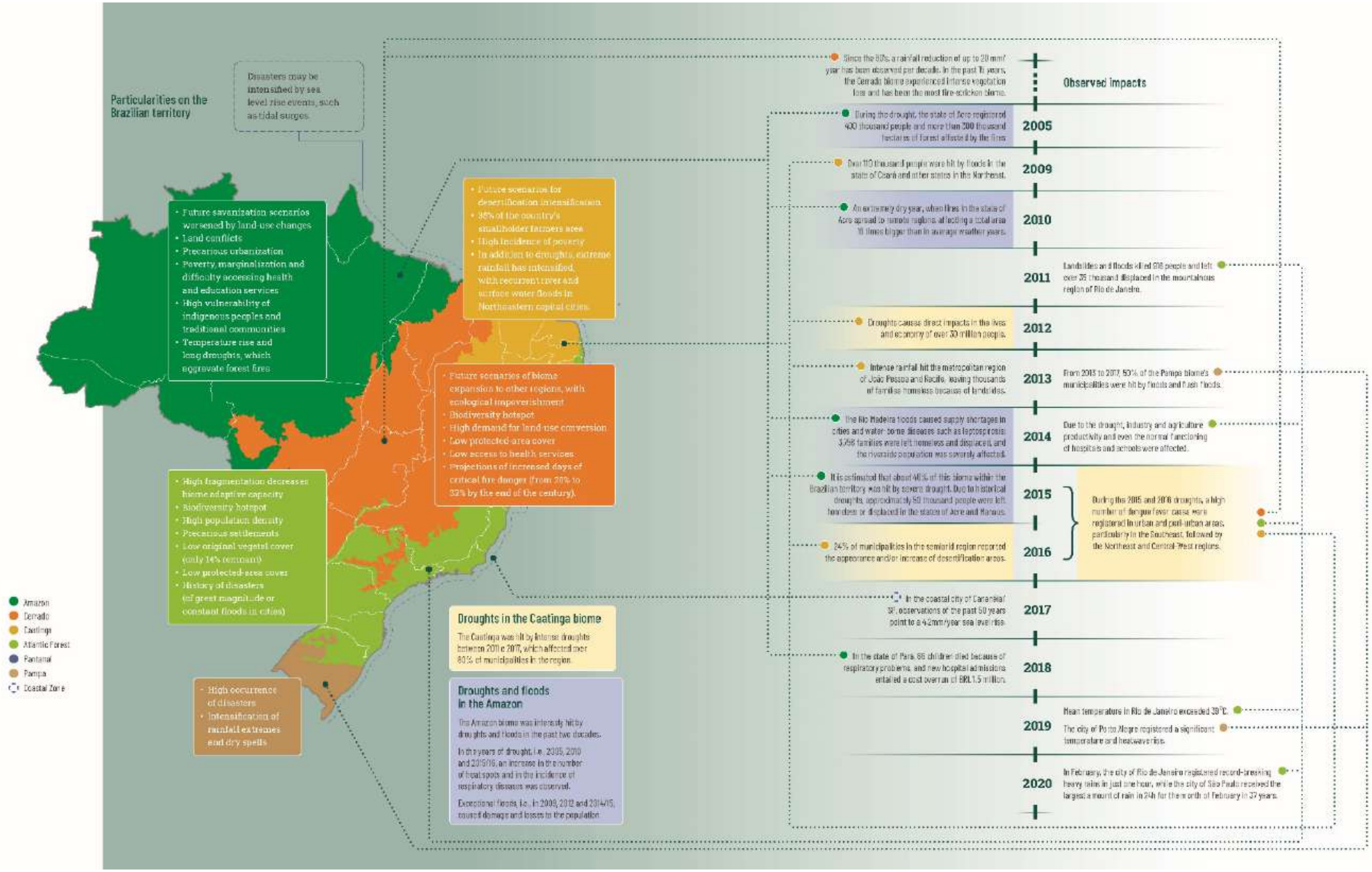

Main impacts and vulnerabilities on energy security
Electric power
Change in hydropower supply (and impacts on the electricity mix)
Flow changes alter the affluent natural energy (ANE) and the hydropower potential.
Future scenarios point to a decrease by 6% to 41% in hydroelectric generation capacity (65% of the Brazilian Interconnected System's generation in 2018), which leads to a greater share of other sources in power generation, and demands new investments.
Change in wind and solar energies availability
Solar resource: maintainance or increase in the resource's availability, benefitting photovoltaic generation, both in the Brazilian Interconnected System and also in a descentralized way.
Wind resource: increase in the resource's availability for power generation in all biomes.
Areas in the states of Rio Grande do Norte and Paraiba (Caatinga biome), which have over 50% of the country's installed capacity, present a minor availability decrease, depending on the scenario.
Complementarities among renewable sources
Climate change may modify the complementerity level among sources, in different periods and regions/subsystems, offseting low production periods among them.
Hydro-wind: more significant complementarities between the hydro source in the Caatinga (São Francisco River basin) and the wind source in other biomes.
hydropower
wind source
wind source
wind source
Hydro-hydro: synergies between hydropower in the Atlantic Forest and hydropower in other biomes.
hydropower
hydropower
hydropower
hydropower
Change in demand for thermal comfort
Upward trend for cooling energy demand across the country, especially in the Amazon and Caatinga biomes, and some areas in the Cerrado.
Implications of increasing electric power demand (i.e., use of air conditioners), particularly in the Atlantic Forest due to its population density (although the relative increase is smaller than in other biomes).
Challenges for the electric power transmission and distribution infrastructure
Electric power transmission and distribution infrastructures, which connect the different regions and provide the Brazilian Interconnected System with adaptive capacity, are vulnerable to extreme climate events.
Biofuels
Impacts on soybeans and sugarcane crops for biofuels
Scenarios of increasing high-risk areas for soybeans and sugarcane affect biodiesel and ethanol production, respectively. A greater need for irrigation is projected.
Areas of low climate risk (suitable for crops) may be reduced:
• Around 80% (soybeans)
• Over 30% (sugarcane)
Amazon
Cerrado
Caatinga
Atlantic Forest
Pantanal
Pampa
Coastal Zone
300,000
225,000
150,000
75,000
0
Maximum cost
Minimum cost
SWL2
SWL4
Baseline Expansion Scenario (Ten-Year Energy Plan 2026)
Largest reduction in Affluent Natural Energy (ANE) in the Northern and Northeastern subsystems (which correspond to 29% of ANE in the Ten-Year Energy Plan 2026 baseline expansion scenario). The Northern subsystem, particularly, is responsible for electric power exchange for other subsystems in certain periods of the year.
84% and 76% of biodiesel and ethanol plants, respectively, are in the Cerrado and in the Atlantic Forest biomes.
Particularities on the Brazilian territory
• Southern part of the biome is susceptible to extreme events that may affect the transmission and distribution infrastructure.
• The Brazilian Interconnected System is susceptible to an increased demand for cooling energy in the Atlantic Forest due to a major concentration of consumers (industrial, residential and commercial sectors).
Observed impacts
Unfavorable weather conditions for the 2011/2012 soybeans harvest, with an 8.45% decrease in biodiesel production in the state of Rio Grande do Sul in 2012 in relation to the previous year.
The Três Marias HPP reservoir (São Francisco River basin) regulates part of the affluent flow of HPPs dowstream (Sobradinho, Itaparica, Moxotó, Paulo Afonso and Xingó). Between 2014 and 2015, the HPP volume was 10% below its capacity.
The Serra da Mesa reservoir (the country's largest in volume) regulates the hydropower generation cascade in the Tocantins River basin. With reduced flow since 2012, it contained less than 6% of its usable volume in 2017 (the lowest since it began operating).
2011
2012
2014
2015
2017
2018
Damages to electric power distribution and transmission systems caused by tornadoes in 2011, 2015 and 2018 (states of Santa Catarina and Rio Grande do Sul)


Main impacts and vulnerabilities on food security
• Migration and more cultivated areas may generate conflicts among different uses.
• Crop insurances (such as Agricultural Activity Guarantee Program – ProAgro), and the Crop Assurance Program) are impacted by climate extreme periods.
• Losses in the country's production and supply chains vary between 10% and 40%.
• Food waste (retail distribution and consumption) is estimated in 41.6 kg per person every year, particularly rice, beef, beans and chicken.
• Irrigation: a 45% increase is expected by 2030, focusing particularly in the Cerrado biome. It is an alternative to cope with climate variability and it needs to be adjusted with other uses of water.
Reduction of productivity and suitable areas for production due to climate change, with increase of temperature and variability of rainfall.
Increase in agricultural losses and production costs increase food prices and agricultural insurance expenses.
Increased food demand due to population and per capita consumption growth, additionally to rural exodus of smallholder farmers
Elevated losses and waste of food in the country raise the pressure over the production and the food security chain.
Main production areas
70%
46%
34%
21%
16%
30%**
58%
17%*
Bean
Corn
Rice
Wheat
Soybean
Cattle
Milk
Eggs
Fish
1st crop
2nd crop
51%
Share of family farming (%) (IBGE, 2006) (*MDA,2009)
With decreased supply, the country will become more dependant on fish imports. Changes in temperature and pH may lead to fish migration, mortality and production reduction (in the coast, rivers and lakes).
Reduction of crop-suitable areas according to ZARC projections for SWL4 (%)
Brazilian productivity drop projected for 2050 (%) (**2030)
Particularities on the Brazilian territory
• Traditional communities (subsistence production)
• Land conflicts
• High drought losses
• Major share of family farming
Larger irrigated area in the country (corn, soybeans, and wheat)
• Intense occupation, productive diversity and land use
• High demand for food
Increase of climate extremes
Amazon
Cerrado
Caatinga
Atlantic Forest
Pantanal
Pampa
Coastal Zone
Observed impacts
Between 2010 and 2012, corn production costs went up by 30% in the Atlantic Forest and Cerrado.
Due to droughts and dry spells in the Caatinga and the Cerrado biomes, soybeans prices went up by more than 40%, and beans prices went up by more than 50%.
Between 2013 and 2016, droughts and dry spells in the Caatinga and Cerrado biomes caused the price of corn to go up by 46%.
Significant rainfall reductions caused corn productivity losses by up to 8.7%.
2010
2011
2012
2013
2014
2015
2016
Soybeans losses were significant in the Atlantic Forest and the Pampa due to water shortage and high temperatures (18.8% and 38.1%, respectively).
Particularly due to dry spells, wheat production dropped in all biomes it is cultivated. 18.5% reduction in the Cerrado.
Particularly due to dry spells, wheat production dropped in all biomes it is cultivated: 15.6% drop in the Atlantic Forest; 28.2% in the Pampa and 60.9% in coastal zones.
7% to 10% drop in rice production in the Pampa and Cerrado biomes, respectively, due to dry spells.
10.7% losses in coffee production in the Coastal Zone.


Main impacts and vulnerabilities on socioenvironmental security
Conditioning factors
Climate
Temperature rise projections, change in rainfall patterns, and intensification of extreme events
Socio-economic
Socio-economic inequalities, socio-spatial segregation in cities, level of access to basic services, gender and ethnicity-based marginalization. Institutional capacity of government stakeholders.
Disaster intensification
• Rainfall-related hazards are intensified by the lack of urban infrastructure, like stormwater drainage system and environmental sanitation, particularly in precarious and informal settlements, as well as the occupation of floodplains and slopes.
• Rainfall-related hazards may increase in the Southern and Southeastern regions, particularly in the Coastal Zone, Brazil's most densely populated region. On the coast, risks may be intensified by sea level rise events, such as tidal surges.
Increased occurrence of diseases
• Direct impacts on health associated to the occurrence of extreme events (heatwaves, warm and wet days, rainfall extremes) include increased morbimortality, cardiovascular, respiratory and genitourinary diseases.
• Climate change indirect impacts include changes in the geographic distribution and seasonal abundance of vector and water-borne diseases, and the emergence of new arboviruses, associated to environmental degradation and lack of sanitation.
Biome resilience loss
All biomes loose stable states with climate change (aggravated by non-climate pressures). Biodiversity losses, changes in vegetation types, and loss of ecosystem services are projected.
Migrations
• Water scarcity may lead to migratory processes and precarious urbanization, which increases disasters risks and disease incidence.
• Population density in urban centers also increases pressures for food, water and energy.
Biome resilience
What is resilience? Each biome is adapted to certain climate conditions. As these conditions change, the biome may lose its original characteristics up to an extent where it would transform itself, resulting in another biome's vegetation features.
Amazon
Caatinga
Atlantic Forest
Cerrado
Pampa
Historical
SWL4
Resilience
High: 1000
Low: 0
A 40% loss of original forest distribution may represent a tipping point and compromise the biome's integrity, with risks for continental climate.
Protected areas
There are evidences of the importance of Protected Areas and Indigenous Lands in containing deforestation and burning processes, in addition to providing ecosystem services to the population and productive sector, including urban centers.
Disasters
+ disasters
- disasters
Floods
Are recurrent in the Southeastern, Northeastern (particularly the states of Rio Grande do Norte and Paraíba) and Southern (particularly the state of Santa Catarina) regions.
Landslides
Hotspots located in the Southern, Northeastern (border of the states of Pernambuco and Alagoas, in the region of Serra da Borborema) and Southeastern (Serra da Mantiqueira) regions.
Urban vulnerability and exposure index (UVIexp)
Disaster records correspond to areas of major demographic density, as well as precarious urban infrastructure and social conditions (higher UVIexp).
85% da população brasileira vive em cidades e quase 25% em regiões metropolitanas.
Disease occurences
Exposure Risk by Heat Stress (WBGT)
An increase in warm days is observed, with WBGT above 26°C, across Brazil and in every scenario (SWL1.5, SWL2 and SWL4).
Capital cities in the Northern and Northeastern regions, besides the cities of Cuiabá (state of Mato Grosso), Rio de Janeiro (state of Rio de Janeiro) and Vitória (state of Espírito Santo) will have over 90% of warm days with WBGT above 29°C.
Average Brazil
4°C
2.0°C
1.5°C
Baseline
Maximum WBGT
Respiratory diseases in the elderly (over 60 years of age)
Cardiovascular diseases (adults aged 45 and over)

| | Respiratory: Deaths | Respiratory: Hospital admissions | Cardiovascular: Deaths | Cardiovascular: Hospital admissions |
|---|---|---|---|---|
| North | 40% | 40% | 8% | 8% |
| Northeast | 10% | 15% | reduction | 12% |
| Southeast | 30% | 30% | reduction | 12% |
| South | 23% | 23% | 10% | reduction |
| Central-West | 6% | 6% | 5% | reduction |

Percentage (%) of heat-related deaths and hospital admissions in SWL4 (in capital cities)*
*The value presented refers to the fraction observed in SWL4. At present, these values are near zero in most capital cities for theses diseases, not exceeding 10%, where they are higher.
Water-borne diseases
Increased incidence of child diarrhea in the Northern region and in the Northeastern semiarid region (associated to climate change and social and environmental vulnerability)
Increase rate of relative risk (RR) of diarrhea (SWL4)
Vector-borne diseases
Climate suitability for vector-borne diseases
Dengue fever
Yellow fever
Visceral Leishmaniasis
Malaria
Historical
SWL4
Potential distribution
Very Low
Low
Medium
High
Very High



Particularities on the Brazilian territory
Disasters may be intensified by sea level rise events, such as tidal surges.
• Future savanization scenarios worsened by land-use changes
• Land conflicts
• Precarious urbanization
• Poverty, marginalization and difficulty accessing health and education services
• High vulnerability of indigenous peoples and traditional communities
• Temperature rise and long droughts, which aggravate forest fires
• Future scenarios for desertification intensification
• 38% of the country's smallholder farmers area
• High incidence of poverty
• In addition to droughts, extreme rainfall has intensified, with recurrent river and surface water floods in Northeastern capital cities.
• Future scenarios of biome expansion to other regions, with ecological impoverishment
• Biodiversity hotspot
• High demand for land-use conversion
• Low protected-area cover
• Low access to health services
• Projections of increased days of critical fire danger (from 20% to 32% by the end of the century).
• High fragmentation decreases biome adaptive capacity
• Biodiversity hotspot
• High population density
• Precarious settlements
• Low original vegetal cover (only 14% remnant)
• Low protected-area cover
• History of disasters (of great magnitude or constant floods in cities)
• High occurrence of disasters
• Intensification of rainfall extremes and dry spells
Amazon
Cerrado
Caatinga
Atlantic Forest
Pantanal
Pampa
Coastal Zone
Droughts in the Caatinga biome
The Caatinga was hit by intense droughts between 2011 e 2017, which affected over 80% of municipalities in the region.
Droughts and floods in the Amazon
The Amazon biome was intensely hit by droughts and floods in the past two decades.
In the years of drought, i.e. 2005, 2010 and 2015/16, an increase in the number of heat spots and in the incidence of respiratory diseases was observed.
Exceptional floods, i.e., in 2009, 2012 and 2014/15, caused damage and losses to the population.
Observed impacts
Since the 80s, a rainfall reduction of up to 20 mm/year has been observed per decade. In the past 15 years, the Cerrado biome experienced intense vegetation loss and has been the most fire-stricken biome.
2005
During the drought, the state of Acre registered 400 thousand people and more than 200 thousand hectares of forest affected by the fires.
2009
Over 110 thousand people were hit by floods in the state of Ceará and other states in the Northeast.
2010
An extremely dry year, when fires in the state of Acre spread to remote regions, affecting a total area 11 times bigger than in average weather years.
2011
Landslides and floods killed 918 people and left over 35 thousand displaced in the mountainous region of Rio de Janeiro.
2012
Droughts cause direct impacts in the lives and economy of over 30 million people.
2013
Intense rainfall hit the metropolitan region of João Pessoa and Recife, leaving thousands of families homeless because of landslides.
From 2013 to 2017, 53% of the Pampa biome's municipalities were hit by floods and flash floods.
2014
The Rio Madeira floods caused supply shortages in cities and water-borne diseases such as leptospirosis. 3,758 families were left homeless and displaced, and the riverside population was severely affected.
Due to the drought, industry and agriculture productivity and even the normal functioning of hospitals and schools were affected.
2015
It is estimated that about 40% of this biome within the Brazilian territory was hit by severe drought. Due to historical droughts, approximately 50 thousand people were left homeless or displaced in the states of Acre and Manaus.
2016
24% of municipalities in the semiarid region reported the appearance and/or increase of desertification areas.
During the 2015 and 2016 droughts, a high number of dengue fever cases were registered in urban and peri-urban areas, particularly in the Southeast, followed by the Northeast and Central-West regions.
2017
In the coastal city of Cananéia/SP, observations of the past 50 years point to a 4.2mm/year sea level rise.
2018
In the state of Pará, 66 children died because of respiratory problems, and new hospital admissions entailed a cost overrun of BRL 1.5 million.
2019
Mean temperature in Rio de Janeiro exceeded 39°C.
The city of Porto Alegre registered a significant temperature and heatwave rise.
2020
In February, the city of Rio de Janeiro registered record-breaking heavy rains in just one hour, while the city of São Paulo received the largest amount of rain in 24h for the month of February in 37 years.

# FOURTH NATIONAL COMMUNICATION OF BRAZIL TO THE UNFCCC

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