VOLUME III

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

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FEDERATIVE REPUBLIC OF BRAZIL

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MINISTER OF SCIENCE, TECHNOLOGY AND INNOVATION

CELSO PANSERA

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EMÍLIA MARIA SILVA RIBEIRO CURI

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JAILSON BITTENCOURT DE ANDRADE

GENERAL COORDINATOR OF GLOBAL CLIMATE CHANGE

MÁRCIO ROJAS DA CRUZ

MCTI TECHNICAL TEAM

DIRECTOR OF THE THIRD NATIONAL COMMUNICATION
MÁRCIO ROJAS DA CRUZ

COORDINATOR OF THE THIRD NATIONAL COMMUNICATION
MARCELA CRISTINA ROSAS ABOIM RAPOSO

TECHNICAL COORDINATOR OF THE THIRD BRAZILIAN INVENTORY OF ANTHROPOGENIC EMISSIONS BY SOURCES AND REMOVALS BY SINKS OF GREENHOUSE GASES
EDUARDO DELGADO ASSAD

TECHNICAL COORDINATOR OF THE CLIMATE MODELS AND CLIMATE VULNERABILITIES AND ADAPTATION ON KEY-SECTOR STUDIES
JOSE ANTONIO MARENGO ORSINI

SUPERVISORS OF THE THIRD NATIONAL COMMUNICATION
BRENO SIMONINI TEIXEIRA
DANIELLY GODIVA SANTANA MOLLETA
MAURO MEIRELLES DE OLIVEIRA SANTOS

TECHNICAL ANALYSTS OF THE THIRD NATIONAL COMMUNICATION
CINTIA MARA MIRANDA DIAS
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TECHNICAL TEAM
ANDRÉA NASCIMENTO DE ARAÚJO
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RICARDO VIEIRA ARAUJO
SANDERSON ALBERTO MEDEIROS LEITÃO
SONIA REGINA MUDROVITSCH DE BITTENCOURT
SUSANNA ERICA BUSCH
VICTOR BERNARDES

ASSISTANT OF THE THIRD NATIONAL COMMUNICATION
MARIA DO SOCORRO DA SILVA LIMA

ADMINISTRATIVE TEAM
ANA CAROLINA PINHEIRO DA SILVA
ANDRÉA ROBERTA DOS SANTOS CAMPOS
RICARDO MORÃO ALVES DA COSTA

TRANSLATION
MARIANE ARANTES ROCHA DE OLIVEIRA

MINISTRY OF SCIENCE, TECHNOLOGY AND INNOVATION

ESPLANADA DOS MINISTÉRIOS, BLOCO E

PHONE: +55 (61) 2033-7923

WEB: http://www.mcti.gov.br

CEP: 70.067-900 – Brasília – DF

B823t Brazil. Ministry of Science, Technology and Innovation. Secretariat of Policies and Programs of Research and Development. General Coordination of Global Climate Change.

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TECHNICAL COORDINATORS OF THE THIRD INVENTORY

Emilio Lèbre La Rovere and Carolina Burle Schmidt Dubeux – *Energy sector*

João Wagner Silva Alves – *Waste sector*

Mauro Meirelles de Oliveira Santos – *Industrial Processes sector*

Mercedes Maria da Cunha Bustamante – *Land Use, Land-Use Change and Forestry sector*

Renato de Aragão Ribeiro Rodrigues – *Agriculture sector*

AUTHORS

Adriana dos Santos Siqueira Scolastrici

Alberto Arruda Villela

Alexandre Berndt

Alexandre Rodrigues Filizola

Amanda Prudêncio Lemes

Amaro Olímpio Pereira Jr.

Ana Paula Contador Packer

Ana Paula Dutra de Aguiar

Anderson do Nascimento Dias

Bruna Cordeiro

Bruno Arantes Caldeira da Silva

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Cimelio Bayer

Claudia do Valle Costa

Cristiano Viana Serra Villa

Daniel Oberling

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Fernando Luiz Zancan

Flora da Silva Ramos Vieira Martins

Gustavo Abreu Malaguti

Iracema Alves Manoel Degaspari

Isabella da Fonseca Zicarelli

Jean Pierre Henry Balbaud Ometto

Julia Zanin Shimbo

Larissa Albino da Silva Santos

Laura Alexandra Romero

Leandro Fagundes

Leandro Sannomiya Sakamoto

Leonardo da Silva Ribeiro

Luan Santos

Luciane Garavaglia

Luiza Di Beo Oliveira

Magda Aparecida de Lima

Marcelo Buzzatti

Márcio Zanuz

Marcos Corrêa Neves

Maria Conceição Peres Young Pessoa

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Patricia Turano de Carvalho

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Pedro Valle de Carvalho e Oliveira

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Roberta Zecchini Cantinho

Roberto de Aguiar Peixoto

Rodrigo Pacheco Ribas

Sonia Maria Manso Vieira

Talita Armborst

Thauan Santos

Thiago de Roure Bandeira de Mello

Tiago Zschornack

Viviane A. Alves Vilela

Walkyria Bueno Scivittaro

William Wills

COLLABORATORS

Ademir Fontana
Ademir Rodrigo F. V. B. de Lima Amaro
Alessandra Fidelis
Aline Rocha Silva
Alison Leme dos Santos
Ana Catarine Franzini de Souza
Ana Paula Dalla Corte
Anderson Dias Silveira
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Rafael Notarangeli Favaro
Rafaela Carlota Forastiero
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Rangel Feijó de Almeida
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Sabrina de Oliveira Pereira
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Segundo Urquiaga
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Tainara Melo Siqueira
Talita Assis
Tatiana Almeida de Souza
Tatiana Amaral de Almeida Oliveira

Tayane Pereira Muts Guedes

Thiago Crestani Martins

Tiago Diniz Althoff

Valério de Patta Pillar

Vanildes Oliveira Ribeiro

Vitoria Inocencio Sobrinho

Wagner Júlio Noronha Lima

INSTITUTIONS INVOLVED – VOLUME III

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

Beneficent Association of the state of Santa Catarina Coal Industry (*Associação Beneficente da Indústria Carbonífera de Santa Catarina* – SATC)

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

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

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

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

Clean Coal Technology Center (*Centro Tecnológico de Carvão Limpo* – CTCL)

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

National Steel Company (*Companhia Siderúrgica Nacional* – CSN)

National Department of Mineral Production of the districts of Rio Grande do Sul and Santa Catarina (*Departamento Nacional de Produção Mineral* – DNPM *dos distritos do Rio Grande do Sul e Santa Catarina*)

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

Mining companies of the states of Rio Grande do Sul, Santa Catarina and Paraná

Foundation for Space Science, Technology and Applications (*Fundação de Ciência, Aplicações e Tecnologia Espaciais* – FUNCATE)

Brazil Steel Institute and associates (*Instituto Aço Brasil* – IABr *e suas associadas*)

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

Rice Institute of the State of Rio Grande do Sul (*Instituto Rio Grandense do Arroz*)

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

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

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

P&D Business Consultants Ltd. (*P&D Consultoria Empresarial Ltda.*)

Petrobras

Brazilian Research Network on Global Climate Change (*Rede Brasileira de Pesquisas sobre Mudanças Climáticas Globais – Rede CLIMA*)

Rima Industrial S.A.

Brazilian Coal Industry Extraction Union (*Sindicato da Indústria de Extração de Carvão do Estado de Santa Catarina* – SIECESC)

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

University of Brasília (*Universidade de Brasília* – UnB)

Júlio de Mesquita Filho São Paulo State University - Faculty of Engineering, Guaratinguetá Campus (*Universidade Estadual Paulista "Júlio de Mesquita Filho"* – UNESP *(Faculdade de Engenharia de Guaratinguetá*)

Federal University of Rio de Janeiro (*Universidade Federal do Rio de Janeiro* – UFRJ)

Federal University of Rio Grande do Sul (*Universidade Federal do Rio Grande do Sul* – UFRGS)

White Martins

SYMBOLS, ACRONYMS AND ABBREVIATIONS

% – percentage

°C – Celsius degrees

A – Rivers and lakes

Aa – Alluvial Open Humid Forest

Ab – Lowland Open Humid Forest

ABETRE – Brazilian Association of Solid Waste Treatment Companies *(Associação Brasileira de Empresas de Tratamento de Resíduos)*

ABIA – Brazilian Food Industry Association (*Associação Brasileira das Indústrias da Alimentação*)

ABIC – Brazilian Coffee Industry Association (*Associação Brasileira da Indústria de Café*)

ABIP – Brazilian Bakery and Confectionery Industry Association (*Associação Brasileira da Indústria de Panificação e Confeitaria*)

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

ABNT – Brazilian Association of Technical Standards *(Associação Brasileira de Normas Técnicas)*

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

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

ABRELPE – Brazilian Association of Public Cleaning and Special Wastes Companies (*Associação Brasileira de Empresas de Limpeza Pública e Resíduos Especiais*)

ABS – acrylonitrile butadiene styrene

ABS/PA – acrylonitrile butadiene styrene/polyamide

Ac – Agricultural area

AC – State of Acre

Am – Open Montane Humid Forest

AM – State of Amazonas

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

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

Ap – Planted pasture

AP – state of Amapá

AR4 – IPCC Fourth Assessment Report

AR5 – IPCC Fifth Assessment Report

As – Open Submontane Humid Forest

BA – state of Bahia

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

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

BNF – Biological Nitrogen Fixation

BOD - Biochemical Oxygen Demand

bpd – barrels per day

BT – total biomass

C – carbon

C_2F_6 – hexafluorethane

Ca –Alluvial Deciduous Seasonal Forest

$Ca(OH)_2$ – calcium hydroxide

CaC_2 – calcium carbide

$CaCO_3$– limestone

CaO – calcium oxide

Cb – Lowland Deciduous Seasonal Forest

CBH – circumference at breast height

CDM – Clean Development Mechanism

CE – state of Ceará

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

CF_4 – tetrafluoromethane

CFCs – chlorofluorocarbons

CH_4 – methane

CKD – Cement Kiln Dust

cm – centimeter

Cm – Montane Deciduous Seasonal Forest

CO – carbon monoxide

CO_2 – carbon dioxide

CO_2e – carbon dioxide equivalent

COD – Chemical Oxygen Demand

Cogen – Brazilian Cogeneration Association (*Associação da Indústria de Cogeração de Energia*)

CONAB – National Supply Company *(Companhia Nacional de Abastecimento)*

COP – Conference of the Parties

CORINAIR – Core Inventory Air Emissions

Cs – Submontane Deciduous Seasonal Forest

CS – Forests with selective logging

CSI – Cement Sustainability Initiative

Da – Alluvial Dense Humid Forest

Db – Lowland Dense Humid Forest

DBH – diameter at breast height

DEGRAD – Forest Degradation Mapping System in the Brazilian Amazon *(Mapeamento da Degradação Florestal na Amazônia Brasileira)*

DETEX – Detection of Selective Logging *(Projeto de Mapeamento de Ocorrências de Exploração Seletiva de Madeira)*

DF – Federal District

Dl – High-Montane Dense Humid Forest

Dm – Montane Dense Humid Forest

DNPM – National Department of Mineral Production *(Departamento Nacional de Produção Mineral)*

DPA – Brazil's Political-Administrative Division *(Divisão Político-Administrativa do Brasil)*

Ds – Submontane Dense Humid Forest

E&P – Exploitation and Production

Ea – Wooded Steppe

EF – emission factor

Eg – Woody-Grass Steppe

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

Ep – Park Steppe

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

Fa – Alluvial Semi Deciduous Seasonal Forest

FAO – Food and Agriculture Organization of the United Nations

Fb – Lowland Semi Deciduous Seasonal Forest

FM – Managed Forest

Fm – Montane Semi Deciduous Seasonal Forest

FNM – Unmanaged Forest

FRA – Global Forest Resources Assessment

Fs – Submontane Semi Deciduous Seasonal Forest

FSec – Secondary Forest

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

g – gram

Gg – gigagram

GHG – greenhouse gases

GM – Managed Grasslands

GNM – Unmanaged Grasslands

GO – state of Goiás

GSec – Secondary Grasslands

GTP – Global Temperature Potential

GWP – Global Warming Potential

ha – hectares

HDPE – high-density polyethylene

HCFCs – hydrochlorofluorocarbons

HFCs – hydrofluorocarbons

HGU – Hydrogen Generation Unit

HNO_3 – nitric acid

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

IDW – Inverse Distance Weighting

IL – Indigenous Lands

inhab – inhabitant

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

IPCC – Intergovernmental Panel on Climate Change

kcal – kilocalorie

kg – kilogram

km^2 – square kilometer

L – liter

La – Wooded Campinarana Arborized

Lb – Shrubby Campinarana

Ld – Forested Campinarana

LDPE – low-density polyethylene

Lg – Woody-Grass Campinarana

LLDPE – linear low-density polyethylene

LNG – liquefied natural gas

LULUCF – Land Use, Land-Use Change and Forestry

m^2 – square meter

m^3 – cubic meter

MA – state of Maranhão

Ma –Alluvial Mixed Humid Forest

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

MDIs – Metered Dose Inhalers

MG – state of Minas Gerais

$MgCO_3$ – dolomite

Ml – Montane Mixed High Humid Forest

MLME – Linear Spectral Mixing Model

mm – millimeter

Mm – Montane Mixed Humid Forest

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

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

MS – state of Mato Grosso do Sul

Ms – Submontane Mixed High Humid Forest

Mt – megatonne

MT – state of Mato Grosso

MVC - monomeric vinyl chloride

N – nitrogen

N_2O – nitrous oxide

NA – not applicable

Na_2CO_3 – neutral sodium carbonate

NASA – National Aeronautics and Space Administration

NBR – acrylonitrile-butadiene rubber

NE – Not Estimated area

Nex – nitrogen excreted

NH_3 – ammonia

NMVOC – Non-methane volatile organic compounds

NO – Nitric oxide

NO_2 – nitrogen dioxide

NO_x – nitrogen oxides

O_3 – ozone

ODS – ozone-depleting substances

OX – oxidation factor

Pa – Fluvial and/or lacustre Influenced Vegetation

PA – Protected Areas *(Unidades de Conservação)*

PA – state of Pará

PB – state of Paraíba

PE – state of Pernambuco

Pf – Pioneer formation Fluviomarine Influenced (mangrove)

PFCs – perfluorocarbons

PI – state of Piauí

Pm – Pioneer formation Marine Influenced (sand banks)

PMDBBS – Satellite Monitoring of Deforestation in *Brazilian Biomes* Project (*Projeto de Monitoramento do Desmatamento dos Biomas Brasileiros*)

PNSB – National Survey of Basic Sanitation Study *(Pesquisas Nacionais de Saneamento Básico)*

pot – potential emissions

PPBio – Research Program for Biodiversity *(Programa de Pesquisa em Biodiversidade)*

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

PROBIO – Conservation and Sustainable Use of Biological Diversity Project *(Projeto de Conservação e Utilização Sustentável da Diversidade Biológica)*

PRODES – Project for Estimating Gross Deforestation of the Brazilian Amazon *(Projeto de Monitoramento de Desflorestamento na Amazôniaon Legal)*

PVC – polyvinyl chloride

RAINFOR – Amazon Network of Forestry Inventories *(Rede Amazônica de Inventários Florestais)*

RAL – Mining Annual Report *(Relatório Anual de Lavra)*

RCU – Retarded Coking Unit

Ref – Reforestation

Res – Reservoirs

RF – radiative forcing

Rl – High Montane Vegetational Refuge

Rm – Montane Refuge

RO – state of Rondônia

ROM – run-of-mine

RPPN – Private Reserve of Natural Heritage *(Reservas Particulares de Preservação Natural)*

RR – state of Roraima

Rs – Submontane Refuge

S – Urban area

Sa – Wooded Savanna

SAR – IPCC Second Assessment Report

SBR – styrene-butadiene rubber

Sd – Forested Savanna

SD – standard deviation

SE – state of Sergipe

SF_6 – sulfur hexafluoride

Sg – Woody-grass savanna

SIG – Geographic Information System *(Sistema de Informação Geográfica)*

SINDIPAN – Bakery and Confectionery Industry Union *(Sindicato da Indústria de Panificação e Confeitaria)*

SNC – Second National Communication

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

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

SNUC – National System of Protected Areas *(Sistema Nacional de Unidades de Conservação)*

Sp – Park Savanna

SP – state of São Paulo

t – tonne

Ta – Wooded Steppe Savanna

TAR – IPCC Third Assessment Report

Td – Forested Steppe Savanna

TEAM – Tropical Ecology Assessment and Monitoring

Tg – Woody Grass Steppe Savanna

Tier – approach

TJ – terajoule

TM – thematic mapping

TNC – Third National Communication

TO – state of Tocantins

toe – tonne of oil equivalent

Tp – Park Steppe Savanna

UFCC – Fluid Catalytic Cracking Unit

UFPE – Federal University of Pernambuco

UFRPE – Federal Rural University of Pernambuco

UNESCO – United Nations Educational, Scientific and Cultural Organization

UNFCCC – United Nations Framework Convention on Climate Change

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

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

VS – volatile solids

WBCSD – World Business Council for Sustainable Development

ZAPE – agro-ecological zoning of the State of Pernambuco

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INTRODUCTION

One of Brazil's main requirements as a signatory of the United Nations Framework Convention on Climate Change – hereinafter referred to as Convention – is the preparation and regular updating of the National Inventory of Anthropogenic Emissions by Sources and Removals by Sinks of Greenhouse Gases Not Controlled by the Montreal Protocol – hereinafter referred to as Inventory.

The preparation of this Inventory is in accordance with the Guidelines for the Elaboration of the National Communications of the Parties Not Included in the Annex I to the Convention, established in Decision 17/CP.8 of the Eighth Conference of the Parties to the Convention, held in Delhi, India, in October/November 2002.

This Inventory covers the period between 1990 to 2010. In relation to the period 1990 - 2005, this Inventory updates the information presented in the previous Inventory (BRASIL, 2010).

The following documents, prepared by the Intergovernmental Panel on Climate Change (IPCC), were used as basic technical guidance: "Revised 1996 IPCC Guidelines for National Greenhouse Inventories" – Guidelines 1996; "Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories" – Good Practice Guidance 2000; and "Good Practice Guidance for Land Use, Land-Use Change and Forestry" – Good Practice Guidance 2003. Some of the estimates have already taken into account the information published in "2006 IPCC Guidelines for National Greenhouse Gas Inventories" (Guidelines 2006).

1.1. GREENHOUSE GASES

Climate on Earth is governed by the constant stream of solar energy that passes through the atmosphere in the form of visible light. The Earth returns part of this energy in the form of infrared radiation. Greenhouse gases (GHG) are those present in the Earth's atmosphere that can block part of the infrared radiation. Many of them, such as water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3), exist naturally in the atmosphere and are essential for the maintenance of life on Earth. Without them the planet's temperature would be 30°C colder.

As a result of the anthropogenic activities in the biosphere, concentration levels of some gases, such as CO_2, CH_4, and N_2O, have been increasing in the atmosphere. In addition, the emission of other greenhouse gases, chemical compounds produced by men only, such as chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), hydrochlorofluorocarbons (HCFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6), started to occur.

As determined by the Convention, the Inventory should include only the anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol. Therefore, CFC and HCFC gases, which destroy the ozone layer and are already controlled by the Montreal Protocol, are not considered, although being greenhouse gases.

The greenhouse gases whose anthropogenic emissions and removals have been estimated in this Inventory are CO_2, CH_4, N_2O, HFCs, PFCs and SF_6. Some other gases, such as carbon monoxide (CO), nitrogen oxides (NO_x) and other non-methane volatile organic compounds (NMVOCs), which are not direct greenhouse gases, influence the chemical reactions that occur in the atmosphere. Information about the anthropogenic emissions of these gases is also included in this Inventory when available.

1.2. SECTORS COVERED

Different activity sectors produce anthropogenic emissions of greenhouse gases. The present Inventory is organized according to the structure suggested by the IPCC, covering the following sectors: Energy; Industrial Processes; Solvent and Other Product Use; Agriculture; Land Use, Land-Use Change and Forestry and Waste Treatment.

Removals of greenhouse gases occur in the Land Use, Land-Use Change and Forestry Sector as a result of management of protected areas, reforestation, abandonment of managed land and increase in soil carbon stocks.

1.2.1. Energy Sector

In this sector, all anthropogenic emissions from energy production, transformation and consumption are estimated. They include emissions resulting from fuel combustion as well as fugitive emissions in the chain of production, transformation, distribution and consumption.

1.2.1.1. Fuel Combustion

The energy sector includes emissions of CO_2 from the oxidation of carbon contained in fossil fuels when they are burnt, either for the generation of other forms of energy, such as electricity, or for end use consumption. Emissions of other greenhouse gases during the combustion process (CH_4, N_2O, CO, NOx, and NMVOC) are also taken into account.

CO_2 emissions in the case of biomass fuels (firewood, charcoal, litter, bleach, alcohol and bagasse) have been informed, but not accounted for in the total emissions of the energy sector. Renewable source fuels do not generate net CO_2 emissions and the emissions associated with the non-renewable ones are included in the Land Use, Land-Use Change and Forestry sector.

As in the case of biomass fuels, CO_2 emissions from fuel combustion supplied in the country for international air and sea transportation (bunker fuels) are informed in accordance with decision 17/CP.8, but are not accounted for in the total emissions of the Energy sector.

Due to the basic information available, emissions are presented according to the structure defined in the National Energy Balance (BEN), which is similar, but not identical, to the structure suggested by the IPCC.

1.2.1.2. Fugitive emissions

The Energy sector also includes greenhouse gas emissions from coal mining and processing, and also from the extraction, transportation, and processing of oil and natural gas.

Emissions associated with coal mining include CH_4 emissions from open-pit and underground mines, as well as CO_2 emissions by spontaneous combustion in waste piles of charcoal.

Emissions associated with oil and natural gas include fugitive emissions of CH_4 during their extraction (venting), during transport and distribution in ducts and vessels, and during its processing in refineries. CO_2, CH_4, and N_2O emissions by non-useful combustion (flaring) on extraction platforms of petroleum and natural gas and refineries are also considered. The use of oil and natural gas, or their byproducts, to provide power for internal use in energy production and transport is considered as combustion and is, therefore, treated in the fuel burning section.

CO_2 emissions during flaring operations are included as fugitive emissions, even though they formally result from combustion, as they are associated with a loss and not with the useful consumption of fuel.

1.2.2. Industrial Processes Sector

This sector entails estimates of anthropogenic emissions resulting from production processes in industries, including the non-energy consumption of fuels as raw material, but excluding fuel burning for power generation, which is reported in the Energy Sector.

The subsectors of mineral products, metallurgical industry, chemical industry and other non-energy uses of fuels were considered, besides the production and use of HFCs, PFCs and SF_6.

1.2.2.1. Mineral products

This subsector includes emissions resulting from the production of cement, lime, other uses of limestone and dolomite with calcination, and the use of sodium carbonate (soda ash).

Cement production generates CO_2 emissions by the calcination of limestone ($CaCO_3$) during the production of clinker. In the lime production process, limestone and dolomite ($CaCO_3$•$MgCO_3$) are calcined, which also produces CO_2. In the glass industry, in the steel industry and in the production of magnesium CO_2 emissions also occur by the calcination of limestone and dolomite. The production of neutral sodium carbonate (soda ash) in Brazil is not a source of CO_2 emissions due to the production process used here, and only the use of this substance generates CO_2 emissions.

1.2.2.2. Chemical industry

Among the inventoried emissions in this subsector, emissions of CO_2 resulting from the production of ammonia, the emissions of N_2O and NO_x emissions from production of nitric acid, and emissions of N_2O, CO, and and NO_x resulting from the production of adipic acid are worth mentioning.

During production of other chemicals, there can also be greenhouse gas emissions, especially NMVOC emissions from the petrochemical industry.

For this edition, the Solvent and Other Products Use Sector was included here, with approach only through the non-energy use of lighting kerosene, hydrous alcohol, solvents and other non-energy petroleum products by different sectors of the chemical industry.

1.2.2.3. Metallurgical industry

This subsector covers the steel and ferroalloy industries, where there are emissions in the process of ore reduction, and also the production of non-ferrous metals, including aluminum and magnesium. Relevant emissions of CO_2, CH_4, N_2O, CO, NO_x, NMVOC, PFCs and SF_6 to each sector were estimated.

In the steel and ferroalloy industries, GHG is emitted when carbon contained in the reducing agent combines with the oxygen in the metal oxides. These reducing agents, such as coal coke, are also used as fuel for energy generation. Emissions associated with both processes are reported in this sector. Other emissions from the steel industry are reported in the Energy Sector (coal coke production and power production) and in the Mineral Production Sector (lime production, use of limestone and dolomite). The same principle adopted for fuel separation used as a reducer for the steel industry was used for the ferroalloy and non-ferrous subsectors, except for aluminum and magnesium, which used different estimate methodologies.

In the aluminum industry, CO_2 emissions occur during the electrolysis process, when the oxygen of the aluminum oxide reacts with the carbon of the anode. During the same process, if the level of aluminum oxide in the production tank becomes too low, there can be a rapid increase in voltage (anodic effect). In this case, the fluoride contained in the electrolytic solution reacts with the carbon of the anode, producing perfluorocarbons (CF_4 and C_2F_6), which are greenhouse gases of long residence time in the atmosphere. In the production of magnesium, there are emissions of SF_6 used as cover gas to prevent its oxidation.

Other industries

The Pulp and Paper subsector generates emissions during the chemical treatment to which wood pulp is submitted in the production process. Such emissions depend on the type of raw material used and the quality of the product that is to be obtained.

In Brazil, eucalyptus is the major source of cellulose, with the predominance of the sulphate process, during which CO, NOx, and NMVOC emissions occur. Such emissions have been estimated in this Inventory.

In the Food and Beverage subsector, NMVOC emissions occur during many transformation processes of primary products, such as the production of sugar, animal feed, and beer. Emissions were estimated based on national production data, with the use of default emission factors.

1.2.2.4. Production and use of HFCs and SF_6

HFCs gases were developed in the 1980s and 1990s as alternatives to CFCs and HCFCs. The use of these gases is being phased out because they deplete the ozone layer. HFCs are greenhouse gases that do not contain chlorine and, therefore, do not affect the ozone layer.

During the production and use of HFCs there may be fugitive emissions. During the production process of HCFC-22 there may be the secondary production of HFC-23 and their consequent emission.

SF_6, another greenhouse gas produced only anthropogenically, has excellent characteristics for use in electrical equipment of high capacity and performance. Brazil is not a producer of this gas. Thus, the reported emissions of SF_6 are due only to leakages during the use of equipment installed in the country.

1.2.3. Agriculture Sector

Agriculture and livestock are economic activities of great importance in Brazil. Because of the vast extent of agricultural and grazing lands, the country also occupies a prominent place in this sector's world production.

Many are the processes that result in greenhouse gas emissions, which are described below.

1.2.3.1. Enteric fermentation

Enteric fermentation, which is part of the digestive process of ruminant herbivores, is one of the major sources of CH_4 emissions in the country. The intensity of this process depends on several factors, such as the category of animal, animal feed, the intensity of their physical activity, and different management practices. Among the various categories of animals, cattle are the most important in terms of emissions, and the world's second largest category.

1.2.3.2. Manure Management

Manure management systems may generate CH_4 and N_2O emissions. Anaerobic decomposition produces CH_4, especially when animal wastes are stored in liquid form.

1.2.3.3. Rice cultivation

When grown in flooded fields or floodplains, rice is an important source of CH_4 emissions. This occurs due to the anaerobic decomposition of the organic matter present in the water. In Brazil, however, most of the rice is produced in non-flooded areas, thus reducing the importance of the subsector in the total emissions of CH_4.

1.2.3.4. Crop residue burning

The imperfect practice of burning crop residues, carried out directly in the field, produces CH_4, N_2O, NO_x, CO, and NMVOC emissions. The CO_2 emitted is not considered as net emissions as the same amount is necessarily absorbed, through photosynthesis, during plant growth.

In Brazil, crop residue burning occurs mainly in the sugar cane crops.

1.2.3.5. N_2O emissions from agricultural soils

N_2O emissions from agricultural soils result from the use of nitrogen fertilizers, both synthetic and of animal origin, and from manure deposition in pasture. The latter is not considered an important fertilizer application because it is not intentional. However, it is the most important process in Brazil because of the predominance of extensive livestock production. Crop residues left in the field are also sources of N_2O emissions.

Also in this sector is the cultivation of organic soils, which increases the mineralization of organic matter and releases N_2O.

1.2.4. Land Use, Land-Use Change and Forestry Sector

This sector comprises estimates of emissions and removals of greenhouse gases associated with the increase or decrease of carbon in aboveground and belowground biomass by replacing a particular type of land use by another, as, for example, conversion of forest land to agricultural land or livestock production, or the replacement of cropland with reforestation.

By extension, as recommended by the Good Practice Guidance LULUCF 2003, emissions and removals by land-use are estimated for the use of land not subject to change, growth or loss under the same type of use (for example, growth of secondary vegetation or even of primary vegetation in managed areas).

Estimates should consider all carbon compartments: aboveground living biomass; belowground living biomass (roots); litter (branches and dead leaves); dead wood (either standing or lying on the ground); and soil carbon. In addition, in this sector, emissions from the application of limestone in agricultural soils have also been accounted for.

CO_2 is the predominant gas in this sector, but there are also emissions of other greenhouse gases such as CH_4 and N_2O due to imperfect field burning of wood and conversion of forest land to other uses.

CH_4 emissions from reservoirs (dams, hydroelectric power plants, weirs, etc.) also occur, but they have not been estimated in this inventory because there is no agreed methodology by the IPCC in its calculation due to the difficulty in identifying the human-induced parcel of such emissions.

1.2.5. Waste Sector

1.2.5.1. Solid Waste Disposal

Disposal of solid waste creates anaerobic conditions that generate CH_4. The emission potential for CH_4 increases depending on the control conditions in landfills and the depth of the dumps. Waste incineration, an activity greatly reduced in Brazil, generates emissions of several greenhouse gases (like all forms of combustion), mainly of CO_2.

1.2.5.2. Wastewater Treatment

Wastewater with a high degree of organic content has a great potential for CH_4 emissions, especially domestic and commercial sewage, effluents from the food and beverage industry, and from the pulp and paper industry. The other industries also contribute to these emissions, but to a smaller degree.

In the case of the domestic sewage, because of the nitrogen content in food, N_2O emissions also occur.

CHAPTER II

SUMMARY OF ANTHROPOGENIC EMISSIONS BY SOURCES AND REMOVALS BY SINKS OF GREENHOUSE GASES

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In 2010, net anthropogenic greenhouse gas emissions were estimated at 739,671 Gg CO_2; 16,688.2 Gg CH_4; 560.49 Gg N_2O; 0.0767 Gg CF_4, 0.0059 Gg C_2F_6, 0.0087 Gg SF_6, 2.7196 Gg HFC-134a, 0.1059 Gg HFC-32, 0.5012 Gg HFC-125 and 0.4671 Gg HFC-143a. Between 2005 and 2010, total CO_2, CH_4, and N_2O emissions decreased by 66%, 9% and 8%, respectively. Greenhouse gas emissions with indirect effect were also assessed. In 2010, such emissions were estimated at 3,429.4 Gg NO_x; 35,050.4 Gg CO; and 6,387.2 Gg NMVOC.

2.1. CARBON DIOXIDE EMISSIONS

CO_2 emissions result from various activities. Generally, the main source of emissions is the use of fossil fuels for energy generation. Other important emission sources are the industrial processes of cement, lime, soda ash, ammonia, and aluminum production, as well as waste incineration.

Historically, in Brazil, the largest share of estimated CO_2 net emissions comes from land-use change, particularly the conversion of forest land to agricultural land and livestock production. However, a significant reduction in the emissions from this sector has been observed in recent years, which has contributed to the increased participation of the Energy Sector in total CO_2 emissions in 2010. It is also worth mentioning the large share of renewable energy in the Brazilian energy mix, due to of hydroelectric power generation, use of ethanol in transportation and sugar cane bagasse and charcoal in industry. Table 2.1 and Figures 2.2 and 2.3 summarize CO_2 net emissions, per sector.

The Energy sector comprises emissions from fossil fuel combustion and fugitive emissions. Fugitive emissions include flaring of gas in platforms and refineries, and the spontaneous combustion of coal in deposits and waste piles. In 2010, CO_2 emissions from the energy sector accounted for 47.0% of total CO_2 emissions, having increased by 19.7% in relation to 2005 emissions. The transport subsector alone represented 48.9% of CO_2 emissions in the Energy sector, and 22.8% of total CO_2 emissions in 2010.

Emissions from industrial processes accounted for 10.9% of total emissions in 2010, with the production of iron and steel accounting for the largest share (47.5%). From 2005 to 2010, emissions from industrial processes ranged by 18.8%.

The Land Use, Land-Use Change and Forestry Sector was responsible for the greatest share of CO_2 emissions, and by all CO_2 removals, which have included management of protected areas, regeneration of abandoned areas, and change in soil carbon stock, with net emissions of the sector responding for 42.0% of total CO_2 net emissions in 2010. Conversion of forest land to other uses, particularly agricultural land, made up to almost the total emissions of CO_2 in the sector, being the small portion remaining due to the application of limestone to agricultural soils.

The Waste Sector contributed minimally to CO_2 emissions because of waste incineration containing non-renewable carbon.

TABLE 2.1

CO_2 net emissions

SECTOR	1990	1995	2000	2005	2010	SHARE 2010	VARIATION 2005-2010
	Gg					%	
Energy	169,985	209,124	267,646	290,621	347,974	47.0%	19.7%
Fossil Fuels Combustion	162,431	201,610	256,909	276,744	332,760	45.0%	20.2%
Energy Subsector	21,271	25,281	40,484	47,343	58,857	8.0%	24.3%
Industrial Subsector	35,559	43,068	59,008	60,019	68,306	9.2%	13.8%
Steel Industry	4,436	5,387	4,657	5,526	5,642	0.8%	2.1%
Chemical Industry	8,606	10,057	13,942	14,624	13,847	1.9%	-5.3%
Other Industries	22,517	27,623	40,409	39,869	48,817	6.6%	22.4%
Transport Subsector	79,338	100,457	121,748	135,182	168,364	22.8%	24.5%
Air Transport	4,232	4,732	6,206	6,316	9,751	1.3%	54.4%
Road Transport	70,094	90,916	111,337	123,519	151,481	20.5%	22.6%
Other Means of Transportation	5,012	4,809	4,205	5,347	7,132	1.0%	33.4%
Residential Subsector	13,842	15,942	17,179	15,591	17,249	2.3%	10.6%
Agricultural Subsector	9,846	13,222	14,152	14,964	17,346	2.3%	15.9%
Other Sectors	2,576	3,640	4,338	3,645	2,638	0.4%	-27.6%
Fugitive Emissions	7,554	7,514	10,737	13,877	15,214	2.1%	9.6%
Coal Mining	1,353	920	1,291	1,381	1,846	0.2%	33.7%
Extraction and Transportation of Oil and Natural Gas	6,201	6,594	9,446	12,496	13,368	1.8%	7.0%
Industrial Processes	43,551	54,643	65,991	68,016	80,786	10.9%	18.8%
Cement Production	11,062	11,528	16,047	14,349	21,288	2.9%	48.4%
Lime Production	3,688	4,104	5,008	5,356	5,950	0.8%	11.1%
Ammonia Production	1,683	1,785	1,663	1,922	1,739	0.2%	-9.5%
Iron and Steel Production	21,601	30,130	35,552	37,509	38,360	5.2%	2.3%

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SECTOR	1990	1995	2000	2005	2010	SHARE 2010	VARIATION 2005-2010
	Gg					%	
Ferroalloy Production	116	215	545	932	1,195	0.2%	28.2%
Production of Non-Ferrous Metals except Aluminum	897	1,762	1,606	1,855	4,332	0.6%	133.5%
Aluminum Production	1,574	1,965	2,116	2,472	2,543	0.3%	2.9%
Other industries	2,930	3,154	3,454	3,621	5,379	0.7%	48.6%
Land Use, Land-Use Change and Forestry	756,970	1,837,508	1,197,175	1,797,842	310,736	42.0%	-82.7%
Land-Use Change	751,867	1,832,113	1,188,458	1,790,368	300,312	40.6%	-83.2%
Amazon Biome	437,574	1,459,071	815,416	1,128,545	162,888	22.0%	-85.6%
Cerrado Biome	241,511	212,958	212,958	282,275	58,755	7.9%	-79.2%
Other Biomes	72,782	160,084	160,084	379,548	78,669	10.6%	-79.3%
Application of lime in soils	5,103	5,395	8,717	7,474	10,424	1.4%	39.5%
Waste	19	78	95	128	175	0.0%	36.7%
TOTAL	**970,525**	**2,101,353**	**1,530,907**	**2,156,607**	**739,671**	**100.0%**	**-65.7%**

1 Gg = one thousand tons

FIGURE 2.1

Share in CO_2 net emissions (2005)

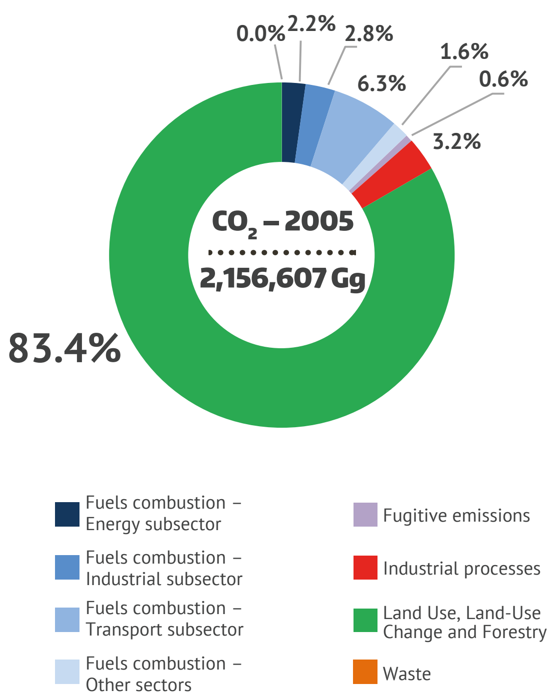


FIGURE 2.2

Share in CO_2 net emissions (2010)

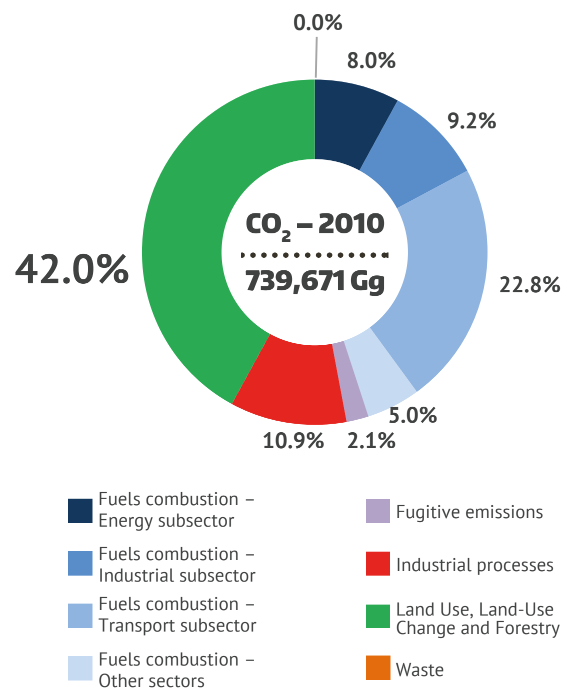
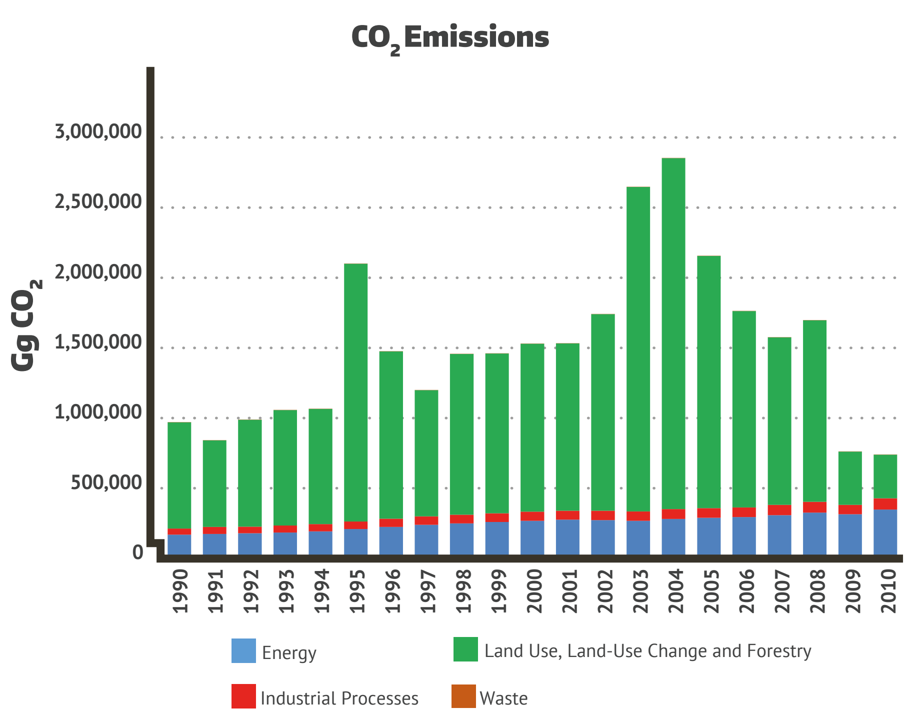


FIGURE 2.3

Evolution of CO_2 net emissions by sector



2.2. METHANE EMISSIONS

CH_4 emissions result from many activities, including landfills, wastewater treatment, oil and natural gas processing systems, agricultural activities, coal mining, fossil fuel and biomass combustion, conversion of forest land to other uses and some industrial processes.

In Brazil, the Agriculture Sector is the most significant contributor to CH_4 emissions (74.4% in 2010), where the main emission source is enteric fermentation (eructation) of ruminants, almost all of which from the cattle herd, the world's second largest cattle herd. In 2010, CH_4 emissions associated with enteric fermentation were estimated at 11,158 Gg, 89.9% of total CH_4 emissions in the Agriculture sector. Manure management, irrigated rice cultivation, and field burning of agricultural crops corresponded to remaining emissions.

In the Energy sector, CH_4 emissions occur as a result of imperfect combustion of fuels and also because of CH_4 leakage during the processes of natural gas production and transportation, and coal mining. CH_4 emissions from the energy sector represented, in 2010, 3,8% of total CH_4 emissions, having increased by 8.1% in relation to 2005 emissions.

In the Industrial Processes sector, CH_4 emissions occur during petrochemical production, but have little participation in Brazilian emissions.

Emissions in the Waste Sector represented 14.8% of total CH_4 emissions in 2010, while solid waste disposal was responsible for 53,9% of this sector. In the 2005-2010 period, CH_4 emissions from the Waste Sector increased by 19,4%.

In the Land Use, Land-Use Change and Forestry sector, CH_4 emissions are caused by biomass burning in deforestation areas. Such emissions represented 6.8% of total CH_4 emissions in 2010.

TABLE 2.2
CH_4 Emissions

SECTOR	1990	1995	2000	2005	2010	SHARE 2010	VARIATION 2005-2010
	Gg					%	
Energy	545.8	473.6	511.8	684.8	629.1	3.8%	-8.1%
Fuel combustion	455.3	388.1	392.8	478.6	448.2	2.7%	-6.4%
Energy subsector	25.5	23.1	20.7	29.2	34.5	0.2%	18.2%
Industry subsector	15.7	18.1	19.9	28.4	34.4	0.2%	21.1%
Iron and Steel industry	0.2	0.2	0.2	0.2	0.3	0.0%	50.0%
Other industries	15.5	17.9	19.7	28.2	34.1	0.2%	20.9%
Transport subsector	72.6	85.8	75.6	74.4	66.9	0.4%	-10.1%
Residential subsector	318.4	243.7	261.5	327.6	290.1	1.7%	-11.4%
Other sectors	23.1	17.4	15.1	19.0	22.3	0.1%	17.4%

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SECTOR	1990	1995	2000	2005	2010	SHARE 2010	VARIATION 2005-2010
	Gg					%	
Fugitive emissions	90.5	85.5	119.0	206.2	180.9	1.1%	-12.3%
Coal mining	49.7	41.1	43.3	49.1	39.2	0.2%	-20.2%
Oil and Natural Gas Production and Transport	40.8	44.4	75.7	157.1	141.7	0.8%	-9.8%
Industrial processes	47.1	41.2	43.7	54.9	45.3	0.3%	-17.5%
Chemical industry	5.2	6.6	9.0	9.4	11.8	0.1%	25.5%
Production of metals	41.9	34.6	34.7	45.5	33.5	0.2%	-26.4%
Agriculture	9,185.6	10,058.2	10,382.3	12,357.7	12,415.6	74.4%	0.5%
Enteric fermentation	8,223.9	8,957.1	9,349.5	11,213.8	11,158.0	66.9%	-0.5%
Cattle	7,808.9	8,534.3	9,005.8	10,855.7	10,798.4	64.7%	-0.5%
Dairy cattle	1,197.7	1,297.1	1,177.9	1,371.4	1,424.0	8.5%	3.8%
Beef cattle	6,611.2	7,237.2	7,827.9	9,484.3	9,374.4	56.2%	-1.2%
Other animals	415.0	422.8	343.7	358.1	359.6	2.2%	0.4%
Manure Management	421.6	471.6	479.7	543.9	608.1	3.6%	11.8%
Cattle	191.2	208.7	215.9	254.0	258.7	1.6%	1.9%
Dairy cattle	35.9	38.5	34.1	39.7	44.0	0.3%	10.8%
Beef cattle	155.3	170.2	181.8	214.3	214.7	1.3%	0.2%
Pigs	159.5	173.7	166.5	178.7	214.9	1.3%	20.3%
Poultry	48.4	66.3	78.1	91.5	115.3	0.7%	26.0%
Other animals	22.5	22.9	19.2	19.7	19.2	0.1%	-2.5%
Rice cultivation	433.6	510.8	448.1	463.7	464.2	2.8%	0.1%
Crop residues burning	106.5	118.7	105.0	136.3	185.3	1.1%	36.0%
Land Use, Land-Use Change and Forestry	1,041.5	2,895.7	2,048.8	3,237.9	1,135.5	6.8%	-64.9%
Waste	1,173.7	1,418.7	1,754.2	2,062.0	2,462.7	14.8%	19.4%
Solid waste	824.4	965.3	1,149.4	1,237.1	1,327.0	8.0%	7.3%
Effluents	349.3	453.4	604.8	824.9	1,135.7	6.8%	37.7%
Industrial	82.6	149.1	233.1	388.3	622.9	3.7%	60.4%
Domestic	266.7	304.3	371.7	436.6	512.8	3.1%	17.5%
TOTAL	**11,993.7**	**14,887.4**	**14,740.8**	**18,397.3**	**16,688.2**	**100.0%**	**-9.3%**

FIGURE 2.4
Share of CH_4 emissions (2005)

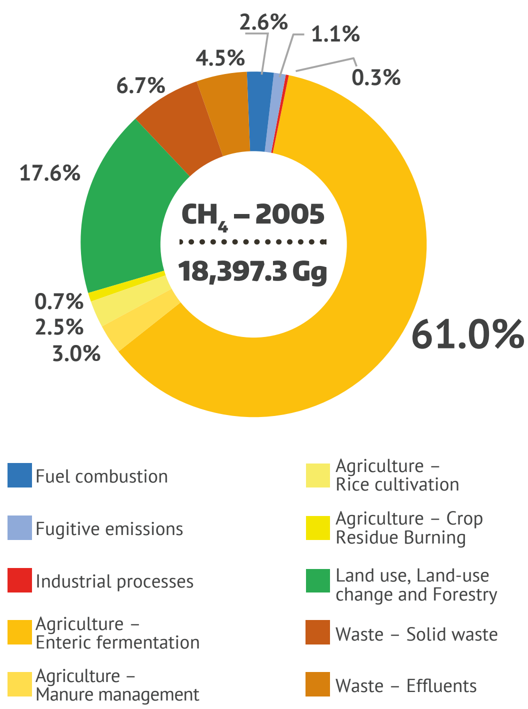


FIGURE 2.5
Share of CH_4 emissions (2010)

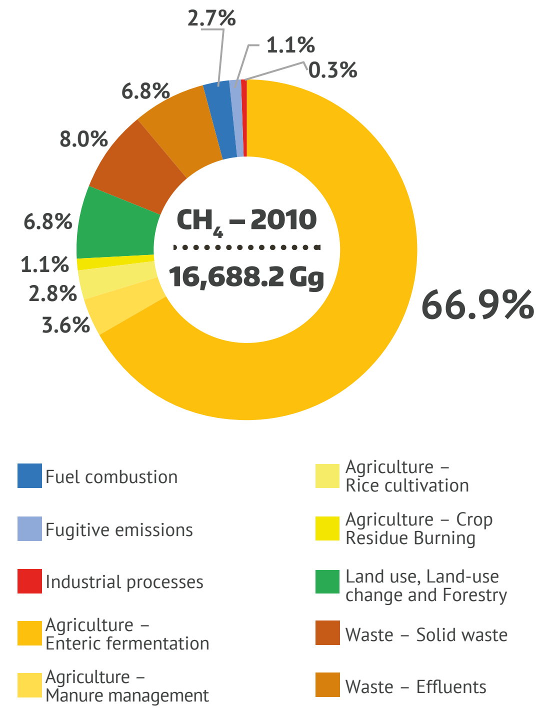
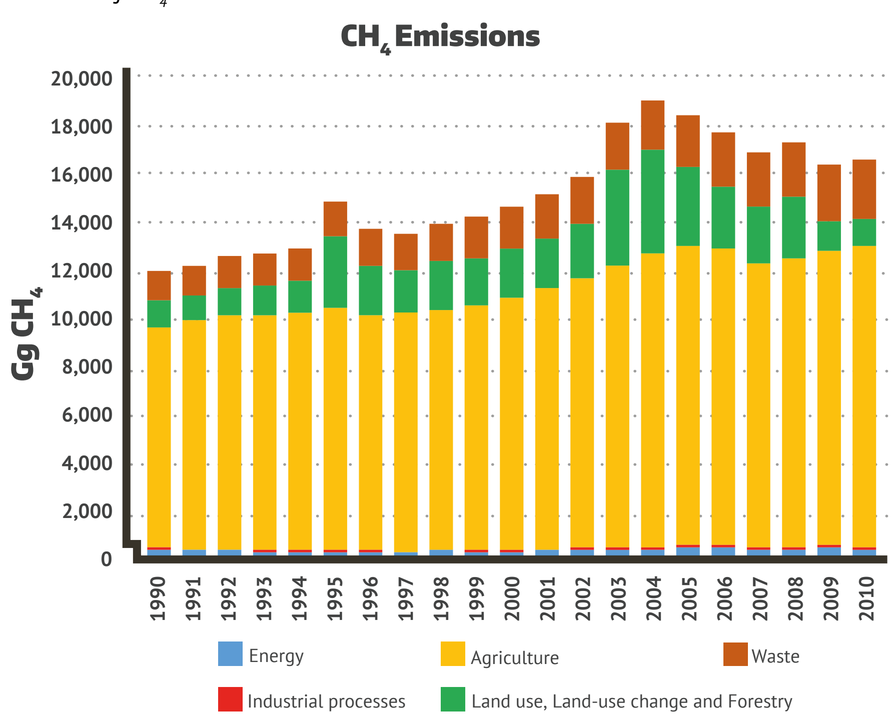


FIGURE 2.6
Evolution of CH_4 emissions



2.3. NITROUS OXIDE EMISSIONS

N_2O emissions result from various activities, including agricultural practices, industrial processes, biomass and fossil fuel combustion and conversion of forest land to other uses.

In Brazil, N_2O emissions occur predominantly in the Agriculture Sector (84.2% in 2010), mainly from manure deposition in pasture. N_2O emissions in the Sector grew by 10.0% between 2005 and 2010. Direct emissions of agricultural soils account for 59.8% (36.1%, if taken into consideration only emissions of animals on pastures) in the Agriculture Sector, in 2010; indirect emissions respond for 36.0%, followed by emissions from animal manure (3.1%) and crop residues burning (0.9%).

N_2O emissions in the Energy Sector represented only 5.7% of total N_2O emissions in 2010, basically due to imperfect fuel burning.

In the Industrial Processes sector, N_2O emissions occur during the production of nitric and adipic acid – which is very much reduced in both cases due to CDM projects aimed at reducing emissions, implemented as at 2007 – and also in metal production; however, they represent, jointly, only 0.4% of total N_2O emissions in 2010.

In the Land-use Change and Forestry Sector, N_2O emissions occur mainly by biomass burning in deforestation areas. These emissions accounted for 8.4% of total N_2O emissions in 2010.

In the Waste sector, N_2O emissions basically occur due to the presence of nitrogen in the protein for human consumption, which ends up being released into the ground or into water bodies. Their contribution to total N_2O emissions was 1.3% in 2010. A much smaller share comes from waste incineration.

TABLE 2.3
N_2O Emissions

SECTOR	1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005-2010
	Gg					%	
Energy	14.08	15.03	18.99	24.96	31.97	5.7%	28.1%
Fuel combustion	14.02	14.97	18.88	24.75	31.76	5.7%	28.3%
Industrial Subsector	2.54	2.97	3.34	4.43	5.73	1.0%	29.3%
Transport Subsector	3.75	5.14	8.67	11.46	16.47	2.9%	43.7%
Other Sectors	7.73	6.86	6.87	8.86	9.56	1.7%	7.9%
Fugitive Emissions	0.06	0.06	0.11	0.21	0.21	0.0%	0.0%
Industrial Processes	11.83	18.57	21.14	24.27	2.15	0.4%	-91.1%
Chemical Industry	10.69	17.45	19.94	22.83	0.93	0.2%	-95.9%
Nitric Acid Production	1.81	2.05	2.09	2.24	0.80	0.1%	-64.3%
Adipic Acid Production	8.63	15.08	17.51	20.29	0.13	0.0%	-99.4%
Other Productions	0.25	0.32	0.34	0.30	0.00	0,0%	-100,0%
Production of Metals	1.14	1.12	1.20	1.44	1.22	0.2%	-15.3%
Agriculture	303.54	340.16	355.93	428.97	472.08	84.2%	10.0%
Manure management	10.03	11.49	11.49	12.82	14.83	2.6%	15.7%
Cattle	2.90	3.07	2.98	3.29	3.46	0.6%	5.2%
Pigs	2.43	2.54	2.06	2.17	2.35	0.4%	8.3%
Poultry	4.40	5.58	6.20	7.11	8.78	1.6%	23.5%
Other Animals	0.30	0.30	0.25	0.25	0.24	0.0%	-4.0%
Agricultural Soils	290.75	325.59	341.72	412.62	452.45	80.7%	9.7%
Direct Emissions	184.07	205.28	213.85	257.09	282.31	50.4%	9.8%
Animals on Pasture	129.73	140.20	140.12	167.45	170.24	30.4%	1.7%
Synthetic Fertilizers	9.81	14.27	21.28	27.51	35.74	6.4%	29.9%
Animals Manure + Vinasse	14.90	16.40	15.88	17.81	21.33	3.8%	19.8%
Crop Residues	15.32	19.80	21.66	29.11	39.49	7.0%	35.7%
Organic Soils	14.31	14.61	14.91	15.21	15.51	2.8%	2.0%
Indirect Emissions	106.68	120.31	127.87	155.53	170.14	30.4%	9.4%
Crop Residues Burning	2.76	3.08	2.72	3.53	4.80	0.9%	36.0%
Land Use, Land-Use Change and Forestry	42.56	106.98	81.96	125.25	47.08	8.4%	-62.4%
Waste (Domestic Effluent)	4.32	4.83	5.68	6.61	7.21	1.3%	9.1%
TOTAL	**376.33**	**485.57**	**483.70**	**610.06**	**560.49**	**100.0%**	**-8.1%**

FIGURE 2.7
Share of N_2O emissions (2005)

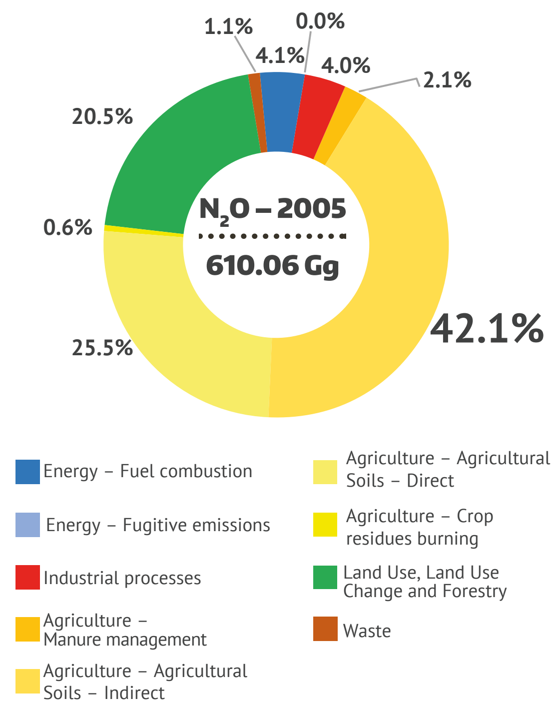


FIGURE 2.8
Share of N_2O emissions (2010)

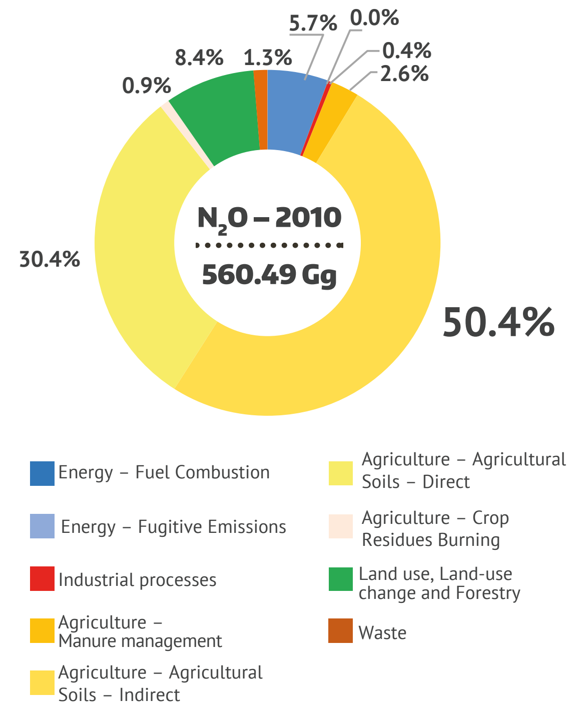
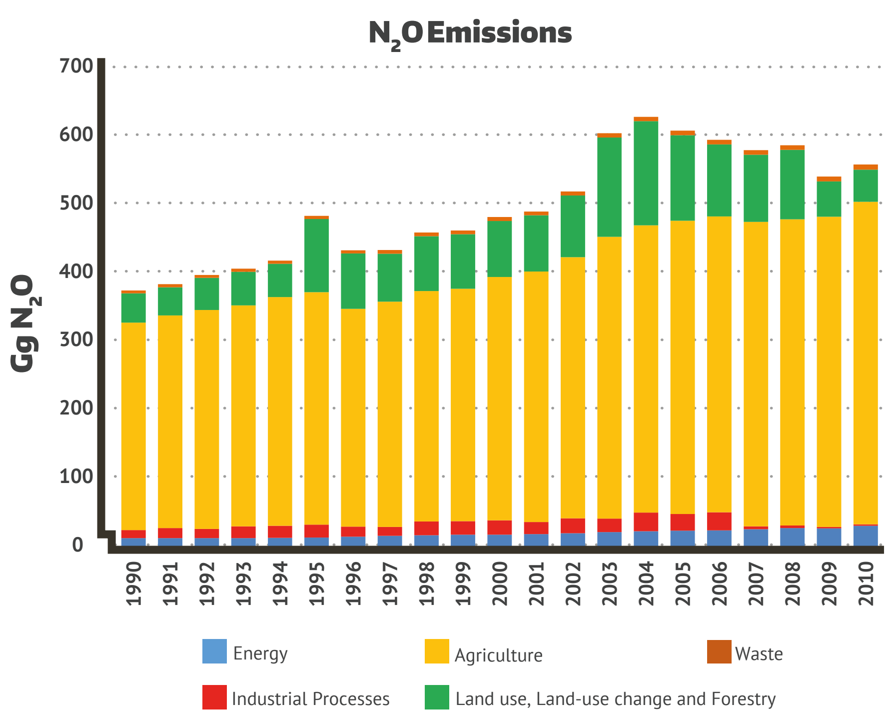


FIGURE 2.9
Evolution of N_2O emissions per sector



2.4. HYDROFLUOROCARBONS, PERFLUOROCARBONS AND SULFUR HEXAFLUORIDE EMISSIONS

HFCs, PFCs and SF_6 gases do not originally exist in nature, being synthesized only by human activities.

Brazil does not produce HFCs. Imports of a little over 7 thousand tons of HFC-134a have been recorded since 2010 for use mainly in the air-conditioning and refrigeration subsector, with total fugitive emissions estimated at 2,719.6 t HFC-134a that year. Imports of other gases within the same group totaled a little over one thousand tons in 2010.

PFCs (CF_4 and C_2F_6) emissions occur during the manufacturing process of aluminum and result from the anodic effect that takes place when the amount of aluminum oxide decreases in the electrolytic process pots. PFCs emissions were estimated at 76.7 t CF_4 and 5.9 t C_2F_6 in 2010, indicating a reduction of 38.1% and 43.3% in relation to 2005, respectively.

SF_6 is used as an insulator in large-sized electrical equipment. Emissions of this gas result from leakages from equipment, especially during maintenance or when equipment is discarded. Historically, this gas had also been used in the production process of magnesium to prevent metal oxidation in its liquid phase, but this stopped in 2010 due to a CDM project aimed at replacing this gas with SO_2. SF_6 emissions were estimated at 8.7 tons in 2010. Table 2.4 summarizes HFCs, PFCs and SF_6 emissions.

TABLE 2.4

HFCs, PFCs and SF_6 Emissions

GAS	ACTIVITY	1990	1995	2000	2005	2010	VARIATION 2005-2010
		Gg					%
HFC-23	HCFC-22 production	0.1202	0.1530	0.0000	0.0000	0.0000	NA
HFC-32	Potential emissions	0.0000	0.0000	0.0000	0.0000	0.1059	NA
HFC-125	Potential emissions	0.0000	0.0000	0.0071	0.1249	0.5012	301.2%
HFC-134a	Actual emissions by use	0.0004	0.0028	0.4988	1.2279	2.7196	121.5%
HFC-143a	Potential emissions	0.0000	0.0000	0.0075	0.0929	0.4671	403.0%
HFC-152a	Potential emissions	0.0000	0.0000	0.0001	0.1748	0.0000	-100.0%
CF_4	Aluminum production	0.3022	0.3060	0.1465	0.1239	0.0767	-38.1%
C_2F_6	Aluminum production	0.0263	0.0264	0.0117	0.0104	0.0059	-43.3%
SF_6	Magnesium production	0.0058	0.0101	0.0103	0.0191	0.0000	-100.0%
	Electrical equipment	0.0042	0.0041	0.0050	0.0061	0.0087	42.6%
	Total SF_6	0.0100	0.0142	0.0153	0.0252	0.0087	-65.5%

2.5. INDIRECT GREENHOUSE GASES

Various gases influence the chemical reactions that occur in the troposphere and thus play an indirect role in increasing the radiative effect. Such gases include CO, NO_x and NMVOC. Emissions of these gases result mostly from human activities.

The majority of CO and NO_x emissions result from imperfect combustion either of fuels in the Energy Sector or waste in the Agriculture Sector or biomass in deforestation areas in the Land-Use Change and Forestry Sector. A small portion of CO emissions results from production processes, basically of aluminum; in relation to NO_x, the remaining emissions also occur in the Industrial Processes sector as a result of the production of nitric acid and aluminum. CO emissions decreased by 49,7% between 2005 and 2010 and NO_x emissions dropped by 15.7% in the same period, mainly because of the decrease in the deforestation rate in Brazil.

Most NMVOC emissions result from the production and use of solvent (74.4% in 2010), but also from imperfect fuel combustion (14.1% in 2010) or industrial processes (11.5% in 2010).

Tables 2.5, 2.6 and 2.7 present CO, NO_x and NMVOC emissions, respectively.

TABLE 2.5
CO Emissions

SECTOR	1990	1995	2000	2005	2010	SHARE 2010	VARIATION 2005-2010
	Gg					%	
Energy	9,592.6	9,636.3	8,181.0	8,194.7	7,695.9	22.0%	-6.1%
Fossil Fuel Combustion	9,592.6	9,636.3	8,181.0	8,194.7	7,695.9	22.0%	-6.1%
Energy Subsector	1,398.0	1,208.5	1,104.3	1,528.1	1,617.9	4.6%	5.9%
Industrial Subsector	758.1	815.1	1,036.8	1,283.5	1,710.3	4.9%	33.3%
Steel Industry	2.5	3.2	8.2	11.4	11.4	0.0%	0.0%
Food and Beverage	182.3	175.8	187.5	204.8	260.9	0.7%	27.4%
Other Industries	573.3	636.1	841.1	1,067.3	1,438.0	4.1%	34.7%
Transport Subsector	5,902.9	6,419.3	4,776.2	3,807.3	2,933.7	8.4%	-22.9%
Road Transportation	5,856.4	6,373.4	4,724.6	3,761.8	2,875.0	8.2%	-23.6%
Other Transports	46.5	45.9	51.6	45.5	58.7	0.2%	29.0%
Residential Subsector	1,443.2	1,098.7	1,172.3	1,468.4	1,306.7	3.7%	-11.0%
Other Sectors	90.4	94.7	91.4	107.4	127.3	0.4%	18.5%
Industrial Processes	900.8	778.0	790.5	1,022.4	809.6	2.3%	-20.8%
Iron and Steel Production	775.0	656.2	676.1	867.3	633.2	1.8%	-27.0%
Ferroalloys Production	60.8	64.2	72.5	96.7	96.7	0.3%	0.0%
Non-Ferrous Metals Production	44.4	27.6	3.7	4.6	4.9	0.0%	6.5%
Other Productions	20.6	30.0	38.2	53.8	74.8	0.2%	39.0%
Agriculture	3,627.6	4,045.8	3,576.4	4,644.4	6,313.5	18.0%	35.9%
Cotton crop waste burning	128.4	0.0	0.0	0.0	0.0	0.0%	NA
Sugarcane burning	3,499.2	4,045.8	3,576.4	4,644.4	6,313.5	18.0%	35.9%
Land Use, Land-Use Change and Forestry	18,429.4	48,855.6	35,879.9	55,810.0	20,231.4	57.7%	-63.7%
TOTAL	**32,550.4**	**63,315.7**	**48,427.8**	**69,671.5**	**35,050.4**	**100.0%**	**-49.7%**

TABLE 2.6
NO_x Emissions

SECTOR	1990	1995	2000	2005	2010	SHARE 2010	VARIATION 2005-2010
	Gg					%	
Energy	1,639.8	1,977.5	2,273.3	2,346.4	2,567.1	74.9%	9.4%
Fossil Fuel Combustion	1,639.8	1,977.5	2,273.3	2,346.4	2,567.1	74.9%	9.4%
Energy Subsector	214.9	266.6	395.0	479.8	577.5	16.8%	20.4%
Industrial Subsector	134.8	169.9	222.7	242.9	286.6	8.4%	18.0%
Steel Industry	10.4	12.3	11.1	12.1	12.0	0.3%	-0.8%
Other Industries	124.4	157.6	211.6	230.8	274.6	8.0%	19.0%
Transport Subsector	1,138.8	1,352.6	1,457.4	1,414.0	1,459.7	42.6%	3.2%
Road Transportation	1021.6	1,237.5	1,355.3	1,287.4	1,290.6	37.6%	0.2%
Other Transports	117.2	115.1	102.1	126.6	169.1	4.9%	33.6%
Residential Subsector	29.2	26.3	28.5	31.3	30.6	0.9%	-2.2%
Other Sectors	122.1	162.1	169.7	178.4	212.7	6.2%	19.2%
Industrial Processes	42.1	53.2	94.9	125.2	100.8	2.9%	-19.5%
Production of metals	36.0	44.5	84.0	110.1	80.1	2.3%	-27.2%
Other productions	6.1	8.7	10.9	15.1	20.7	0.6%	37.1%
Agriculture	98.6	109.9	97.2	126.2	171.6	5.0%	36.0%
Cotton crop waste burning	3.5	0.0	0.0	0.0	0.0	0.0%	NA
Sugarcane burning	95.1	109.9	97.2	126.2	171.6	5.0%	36.0%
Land Use, Land-Use Change and Forestry	526.7	1,196.0	993.8	1,470.3	589.9	17.2%	-59.9%
TOTAL	**2,307.2**	**3,336.6**	**3,459.2**	**4,068.1**	**3,429.4**	**100.0%**	**-15.7%**

TABLE 2.7
NMVOC Emissions

SECTOR	1990	1995	2000	2005	2010	SHARE 2010	VARIATION 2005-2010
	Gg					%	
Energy	1,167.5	1,104.8	987.4	1,061.5	900.5	14.1%	-15.2%
Fossil Fuel Combustion	1,167.5	1,104.8	987.4	1,061.5	900.5	14.1%	-15.2%
Energy Subsector	337.4	271.6	249.5	328.9	251.6	3.9%	-23.5%
Industrial Subsector	31.2	31.2	41.7	48.6	67.3	1.1%	38.5%
Iron and Steel Industry	1.1	1.3	1.2	1.4	1.6	0.0%	14.3%
Food and Beverage	9.2	9.2	9.7	11.1	14.5	0.2%	30.6%
Other Industries	20.9	20.7	30.8	36.1	51.2	0.8%	41.8%
Transport Subsector	541.5	596.2	481.5	417.4	331.3	5.2%	-20.6%
Road Transportation	534.9	589.9	475.3	410.4	322.0	5.0%	-21.5%
Other Transports	6.6	6.3	6.2	7.0	9.3	0.1%	32.9%
Residential Subsector	216.5	164.9	175.9	220.3	196.1	3.1%	-11.0%
Other Sectors	40.9	40.9	38.8	46.3	54.2	0.8%	17.1%
Industrial Processes	345.0	426.2	532.8	616.6	736.8	11.5%	19.5%
Chemical Industry	26.6	31.4	43.0	49.1	61.2	1.0%	NA
Metal Production	24.3	22.0	23.3	29.1	23.0	0.4%	-21.0%
Paper and pulp	13.3	19.2	24.6	34.8	48.5	0.8%	39.4%
Food production	110.5	179.7	252.8	338.8	407.2	6.4%	20.2%
Beverage production	170.3	173.9	189.1	164.8	196.9	3.1%	19.5%
Solvent Use	2,338.9	2,286.9	3,154.0	2,982.2	4,749.9	74.4%	59.3%
TOTAL	**3,851.4**	**3,817.9**	**4,674.2**	**4,660.3**	**6,387.2**	**100.0%**	**37.1%**

Greenhouse Gases Emissions in CO_2e

In this Inventory, a decision was made to continue reporting the anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol simply in units of mass for each greenhouse gas. However, the results of the inventory using different CO_2 equivalent conversion metrics for the conversion of emissions of the various greenhouse gases are described in a box, just for information purposes. According to COP Decision 17/CP.8, which regulates how developing countries should report their emissions, the inventory must be expressed in natural units. If the Party wants to report its emissions in equivalents of carbon dioxide (CO_2e), it should use the global warming potentials (GWP) provided by the IPCC in its Second Assessment Report (SAR) for a time horizon of 100 years. This option was not adopted by Brazil in its Initial Inventory (BRASIL, 2004), but was commented upon in the Second Inventory (BRASIL, 2010).

GWP is based on the relative importance of greenhouse gases in relation to carbon dioxide in the production of a quantity of energy (per unit area) several years after an emission impulse. This metric is characterized by the integration of the radiative forcing (RF) of an emission pulse of a certain substance in a given time horizon. Since the IPCC Third Assessment Report (TAR) (IPCC, 2001), it has been concluded that RF is a useful tool to give a first-order estimate on the global relation between climate impacts and different mechanisms of climate change (RAMASWAMY, et al., 2001), and the value of the radiative forcing can be used to estimate the overall balance on the change in average surface temperature because of different agents involved in the system.

Although the use of GWP-SAR is suggested for inventories of non Annex I Parties, regular evaluation reports of the IPCC present new values for GWP of gases. As of the IPCC Fifth Assessment Report (AR5) (IPCC, 2014), the most recent publication on the subject, we can see for the first time the values for the Global Temperature Potential (GTP), which Brazil also considers important. According to the IPCC, GTP is characterized as being an endpoint metric based on temperature change, i.e., it is correlated to change in the average temperature of global surface in a given future time horizon in response to an emission impulse.

According to the IPCC (2014) "the most appropriate metric and time horizon will depend on which aspects of climate change are considered to be more important to a particular use. No metric is able to accurately compare all the consequences of different emissions, and all of them have constrainsts and uncertainties"[1]. IPCC also argues that the Global Temperature Potential (GTP) metric is more suitable for political decisions based on targets, while the GWP is not directly related to a temperature limit such as the 2°C target[2]. In light of this, the GTP metric is more consistent as a contribution to contain a global temperature increase below 2°C against pre-industrial levels.

The Third Inventory presents the results using three sets of weighting values: the GWP-SAR, determined by Decision 17/CP.8, the GWP-AR5, with cutting-edge science, and GTP-AR5, an old claiming of Brazil. Table I presents previous GWP values according to SAR (IPCC, 1995) and GTP and actual GWP values according to AR5 (IPCC, 2014).

1 *IPCC, 2013: Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. SPM D.2 p.15.*

2 *See: Myhre, G., D. Shindell, F.-M. Bréon, W. Collins, J. Fuglestvedt, J. Huang, D. Koch, J.-F. Lamarque, D. Lee, B. Mendoza, T. Nakajima, A. Robock, G. Stephens, T. Takemura and H. Zhang, 2013: Anthropogenic and Natural Radiative Forcing. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. pp. 710-720. See also: Stocker, T.F., D. Qin, G.-K. Plattner, L.V. Alexander, S.K. Allen, N.L. Bindoff, F.-M. Bréon, J.A. Church, U. Cubasch, S. Emori, P. Forster, P. Friedlingstein, N. Gillett, J.M. Gregory, D.L. Hartmann, E. Jansen, B. Kirtman, R. Knutti, K. Krishna Kumar, P. Lemke, J. Marotzke, V. Masson-Delmotte, G.A. Meehl, I.I. Mokhov, S. Piao, V. Ramaswamy, D. Randall, M. Rhein, M. Rojas, C. Sabine, D. Shindell, L.D. Talley, D.G. Vaughan and S.-P. Xie, 2013: Technical Summary. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. pp. 58-59.*

TABLE I

GWP (100 years) and GTP (100 years) factors

GAS	GWP 100 YEARS SAR-1995	GWP 100 YEARS AR5-2014	GTP 100 YEARS AR5-2014
CO_2	1	1	1
CH_4	21	28	4
$CH_{4\ fóssil}$	21	30	6
N_2O	310	265	234
HFC-23	11,700	12,400	12,700
HFC-32	650	677	94
HFC-125	2,800	3,170	967
HFC-134a	1,300	1,300	201
HFC-143a	3,800	4,800	2,500
HFC-152	140	16	2
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

FIGURE I

Evolution of CO_2e emissions by different metrics, 1990 to 2010

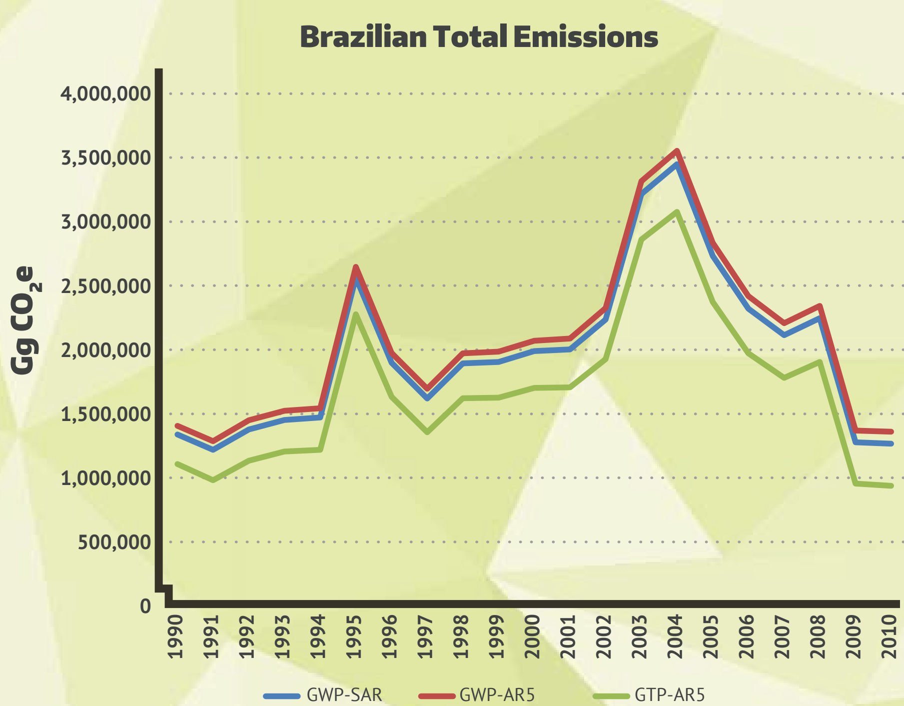


TABLE II

Anthropogenic emissions by sources and removals by sinks of greenhouse gases in CO_2e using GTP and GWP metrics, by sectors

GWP-SAR	CO_2e (Gg)				
	1990	1995	2000	2005	2010
ENERGY	185,808	223,727	284,273	312,747	371,086
INDUSTRIAL PROCESSES	52,059	65,625	75,581	80,517	89,947
AGRICULTURE	286,998	316,671	328,367	392,491	407,067
LAND USE, LAND-USE CHANGE AND FORESTRY	792,038	1,931,478	1,265,606	1,904,666	349,173
WASTE	26,006	31,370	38,693	45,476	54,127
TOTAL	1,342,909	2,568,872	1,992,520	2,735,898	1,271,399

GWP-AR5	CO_2e (Gg)				
	1990	1995	2000	2005	2010
ENERGY	189,319	226,707	287,395	316,985	374,554
INDUSTRIAL PROCESSES	52,038	65,283	75,000	79,972	90,866
AGRICULTURE	337,636	371,773	385,027	459,692	472,734
LAND USE, LAND-USE CHANGE AND FORESTRY	797,413	1,946,934	1,276,260	1,921,694	355,002
WASTE	34,027	41,084	50,717	59,613	71,041
TOTAL	1,410,434	2,651,780	2,074,399	2,837,956	1,364,197

GTP-AR5	CO_2e (Gg)				
	1990	1995	2000	2005	2010
ENERGY	175,786	214,877	274,522	299,773	358,464
INDUSTRIAL PROCESSES	51,110	64,324	73,021	76,380	84,644
AGRICULTURE	107,774	119,828	124,817	149,809	160,125
LAND USE, LAND-USE CHANGE AND FORESTRY	771,096	1,874,123	1,224,546	1,840,104	326,293
WASTE	5,725	6,883	8,440	9,921	11,713
TOTAL	1,111,490	2,280,035	1,705,347	2,375,987	941,239

FIGURE II

CO_2e emissions by sector in 2010, using different metrics. (A) GWP SAR, (B) GWP AR5 and (C) GTP AR5

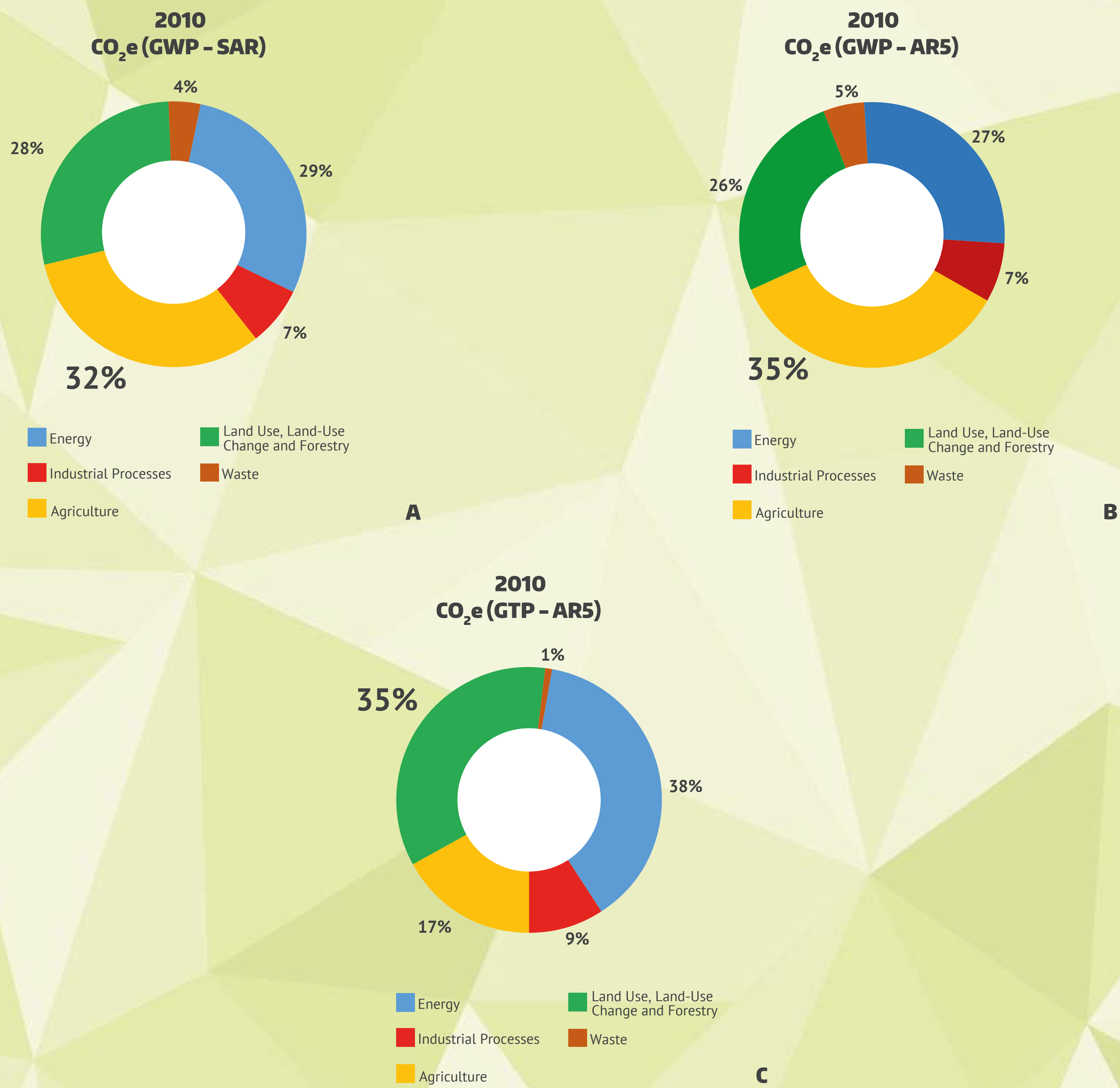
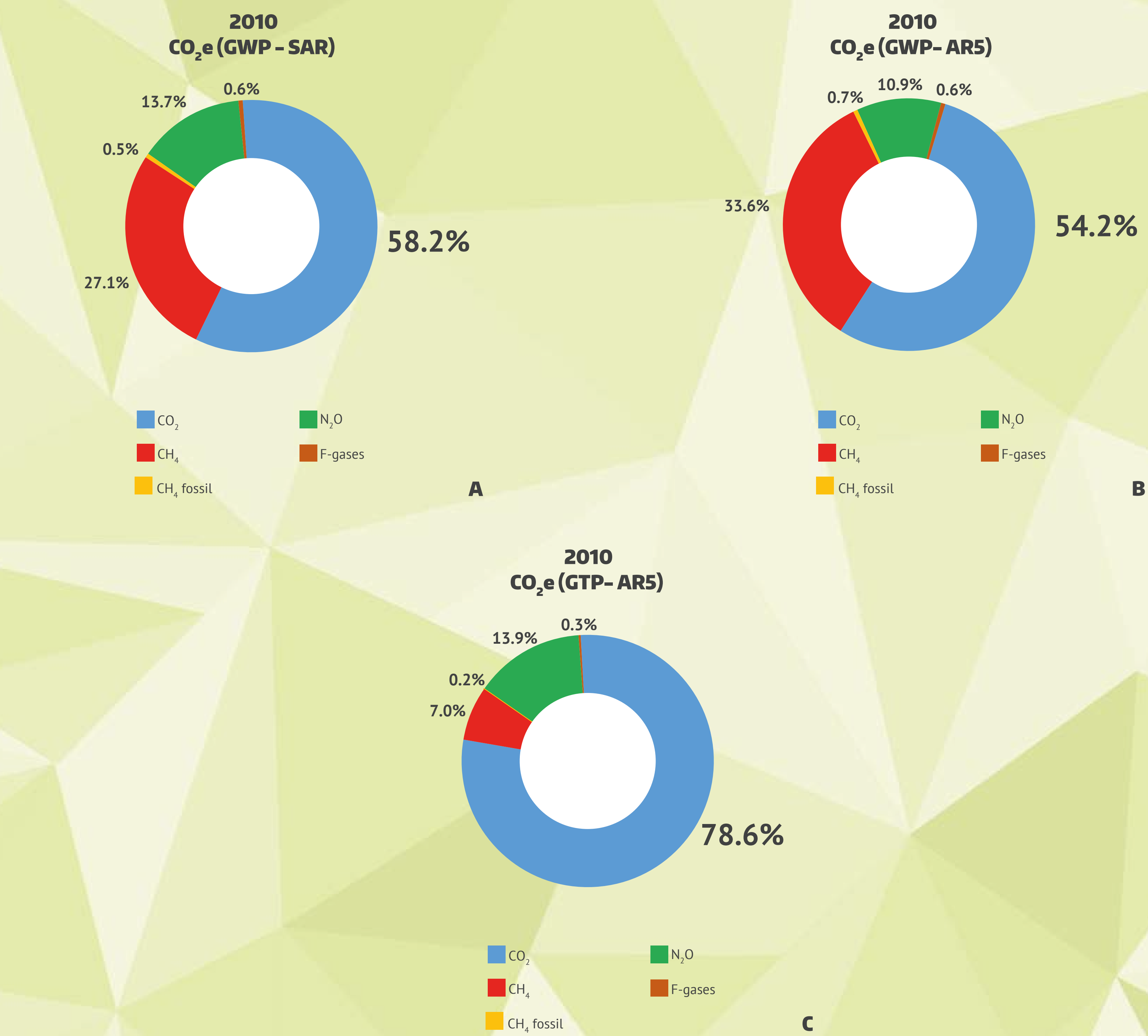


FIGURE III

CO_2e emissions by gas in 2010, using different metrics. (A) GWP SAR, (B) GWP AR5 and (C) GTP AR5



CHAPTER III

ANTHROPOGENIC EMISSIONS BY SOURCES AND REMOVALS BY SINKS OF GREENHOUSE GASES BY SECTOR

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ANTHROPOGENIC EMISSIONS BY SOURCES AND REMOVALS BY SINKS OF GREENHOUSE GASES BY SECTOR

3.1. ENERGY

3.1.1. Characteristics of the Brazilian Energy Mix

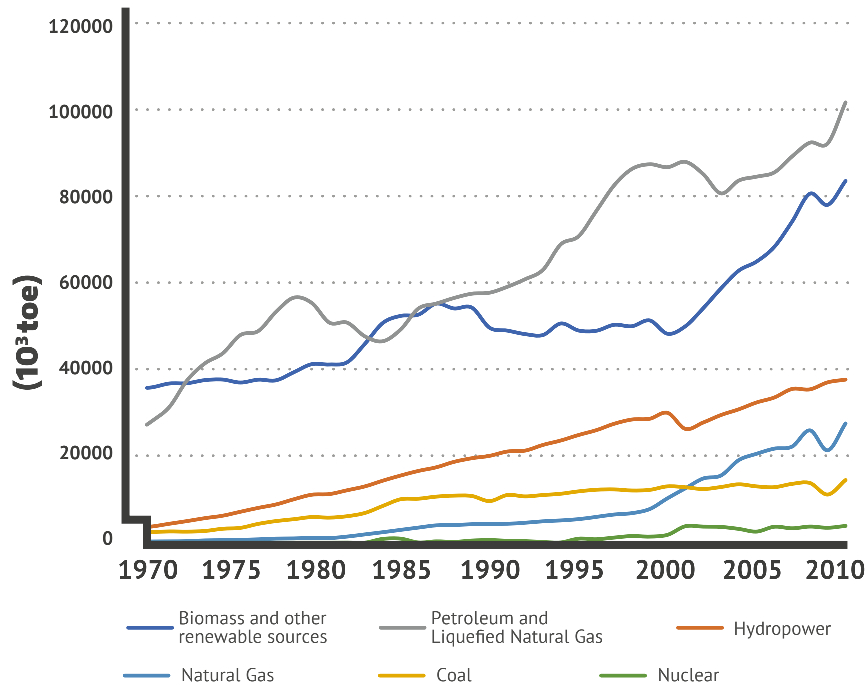
The Brazilian energy mix is characterized by the high share of renewable energy sources, partly due to the country's current state of development and the shortage of fossil energy resources until the 1970s. Strong dependence on imported crude oil made the country vulnerable to oil shocks. This vulnerability, coupled with land availability, resulted in some commercial uses of biomass, mainly ethanol in road transport and charcoal in the steel sector, placing Brazil as one of the most relevant countries in terms of the use of fossil fuel source alternatives.

In order to understand Brazilian policy regarding fossil fuels, the behavior of fuel demand and greenhouse gas emissions, it is necessary to consider oil price variation in real terms over the years. The first two oil crisis occurred in 1973 and 1979, the latter having serious impacts for Brazil's economy, which at the time was heavily dependent on commodities exports in general, and on oil imports. In 1986, there was what was called a "countershock", when the average price of oil per barrel dropped significantly. A third crisis (or a structural change in price) began in 2005 and has been contributing to the leverage of the domestic oil industry.

With respect to gross domestic supply, Figure 3.1 shows the effect of price shocks in 1979 and in the beginning of 2000s, reducing the oil demand in the immediate following years and increasing the demand for biomass. There is also the increase in oil demand after the "countershock" in 1986. The decrease in oil demand after 2000 is closely linked to the entry of Bolivia's natural gas in the market. However, we clearly notice a return of the demand for biomass. With respect to the structural change in the oil price as of 2005, even with the increase in price levels, there was a strong growth in the demand for energy, especially supplied by the growth in natural gas and biomass supply.

FIGURE 3.1

Gross Domestic Supply, by source (thousand toe)



Source: BRASIL (2013).

In 2010, primary fossil sources accounted for some 54% of domestic gross supply of energy. Out of those, oil and oil by-products were responsible for the most significant contribution, followed by natural gas. From 1990 to 2010 there was an increase in fossil fuel consumption of almost 100%, from 72,207 to 143,831 thousand toe[3]. There is a significant increase in the consumption of natural gas in the indicated period.

The evolution of final energy consumption can be observed in Table 3.1, which presents values for each period of five-year consumption in thousand toe per energy source as of 1990. An increase in energy consumption can be observed in the period from 1990 to 2010, covered by the Inventory, from some 123 to 228 thousand toe. In 2010, as in 1990, diesel oil stood out and contributed with 18.2% of total energy consumption in the country. It is worth highlighting that that only figures for energy consumption as fuel together with bunker values have emissions estimated in this report. Other values (consumption as a reducer, raw materials and products for non-energy use) are represented in the chapter on Industrial Processes and Product Use.

3 *Tonne of oil equivalent.*

TABLE 3.1
Final energy consumption by source

SOURCE	1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005/ 2010
	(10^3 toe)					(%)	
Diesel Oil	20,851	25,468	30,903	34,277	41,481	18.2%	21.0%
Natural Gas (dry)	1,536	3,028	5,992	14,670	19,048	8.3%	29.8%
Motor Gasoline	7,279	10,823	13,205	13,595	17,525	7.7%	28.9%
LPG	5,476	6,426	7,836	7,121	7,701	3.4%	8.1%
Fuel Oil	10,128	11,823	11,573	7,270	6,068	2.7%	-16.5%
Petroleum Coke	41	155	2,564	2,761	4,514	2.0%	63.5%
Refinary Gas	1,572	1,979	2,841	3,749	3,979	1.7%	6.1%
Natural Gas (humid)	740	249	1,292	2,016	3,382	1.5%	67.8%
Jet fuel	1,366	1,534	2,016	2,069	3,205	1.4%	54.9%
Other Energy Oil Products	957	1,440	2,179	2,133	2,219	1.0%	4.0%
Sub-bituminous Coal	1,166	1,058	1,706	1,323	1,852	0.8%	39.9%
Coke Oven Gas	1,324	1,489	1,415	1,467	1,738	0.8%	18.4%
Lignite	696	831	884	792	455	0.2%	-42.6%
Coking Coal	92	394	720	803	439	0.2%	-45.4%
Other renewable primary sources	25	22	65	141	119	0.1%	-15.8%
Coal Tar	143	210	100	50	106	0.0%	113.0%
Coal coke	99	0	1	122	104	0.0%	-15.1%
Aviation Gasoline	48	48	58	42	53	0.0%	26.5%
Other Bituminous Coal	0	0	0	0	12	0.0%	-
Lighting Kerosene	188	101	56	25	7	0.0%	-71.9%
Steam Coal	0	0	0	0	0	0.0%	-
Naphtha	0	30	4	0	0	0.0%	-
Gasworks Gas (Rio de Janeiro)	148	103	86	0	0	0.0%	-
Gasworks Gas (São Paulo))	132	17	0	0	0	0.0%	-
Subtotal Fossil	**54,008**	**67,228**	**85,495**	**94,428**	**114,006**	**49.9%**	**20.7%**
Bagasse	11,666	14,875	14,122	22,675	34,146	14.9%	50.6%
Firewood	28,548	23,271	23,067	28,420	25,997	11.4%	-8.5%

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SOURCE	1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005/ 2010
	(10^3 toe)					(%)	
Hydrated Alcohol	5,208	5,072	2,776	2,885	8,251	3.6%	186.0%
Black Liquor	1,315	2,112	2,895	4,252	6,052	2.6%	42.3%
Anhydrous Alcohol	650	1,801	3,046	4,079	3,790	1.7%	-7.1%
Biodiesel	0	0	0	0	2,033	0.9%	-
Other primary (biomass)	382	470	570	849	1,165	0.5%	37.3%
Charcoal	1,156	826	718	866	723	0.3%	-16.6%
Other primary (biogas)	0	0	0	0	5	0.0%	-
Subtotal biomass	**48,926**	**48,427**	**47,195**	**64,025**	**82,162**	**36.0%**	**28.3%**
Final consumption as reducing agent (emissions in Industrial Processes sector)							
Coal Coke	5,036	6,811	6,508	6,298	7,413	3.2%	17.7%
Charcoal	4,983	4,091	4,098	5,382	3,950	1.7%	-26.6%
Coking Coal	0	297	1,843	2,490	2,385	1.0%	-4.2%
Petroleum Coke	350	491	755	1,059	819	0.4%	-22.7%
Other Bituminous Coal	0	0	0	0	0	0.0%	-
Final consumption as raw material (emissions in Industrial Processes sector)							
Naphtha	4,969	5,957	8,094	7,277	7,601	3.3%	4.4%
Natural Gas (Humid and Dry)	896	841	731	747	1,453	0.6%	94.4%
Hydrated Alcohol	459	548	515	284	438	0.2%	54.1%
Anhydrous Alcohol	32	64	122	74	149	0.1%	102.4%
Coal Tar	109	67	142	160	143	0.1%	-10.9%
Refinary Gas	246	291	172	156	98	0.0%	-36.9%
Kerosene	81	34	51	19	11	0.0%	-41.3%
Final consumption of non-energy products							
Other Non-Energy Oil Products	1,080	856	1,480	1,179	3,435	1.5%	191.4%
Bitumen (Asphalt)	1,283	1,244	1,742	1,461	2,793	1.2%	91.2%
Lubricants	698	674	821	856	1,106	0.5%	29.3%
Solvent	219	276	424	1,005	462	0.2%	-54.0%

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SOURCE	1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005/ 2010
	(10^3 toe)					(%)	
Total							
Subtotal (Fuel)	**102,934**	**115,655**	**132,689**	**158,452**	**196,168**	**85.9%**	**23.8%**
Subtotal (Reducing agent)	**10,369**	**11,690**	**13,203**	**15,229**	**14,567**	**6.4%**	**-4.3%**
Subtotal (Raw material)	**6,793**	**7,802**	**9,828**	**8,718**	**9,893**	**4.3%**	**13.5%**
Subtotal (Non-energy products)	**3,279**	**3,051**	**4,467**	**4,500**	**7,797**	**3.4%**	**73.3%**
Total final consumption	**123,375**	**138,199**	**160,188**	**186,899**	**228,424**	**100%**	**22.2%**
Final Consumption as bunker							
Fuel Oil	396	1,106	2,182	2,537	3,228	54.7%	27.3%
Jet Fuel + Bunker Gasoline	1,458	1,510	1,545	1,573	1,932	32.7%	22.9%
Bunker Diesel Oil	141	181	626	593	743	12.6%	25.3%
Total bunker	**1,995**	**2,798**	**4,353**	**4,702**	**5,903**	**100.0%**	**25.6%**

Source: BRASIL (2013).

A sectoral breakdown shows higher energy consumption in the industrial and transport subsectors. The industrial subsector increased its share in total energy consumption between 1990 and 2010, jumping from 22.7% to 27.2%, below the transport subsector, which went from 31% to 35.4%, with an increase of 34% in energy consumption from 2005 to 2010, against 23.8% for fuels in industry, as shown in Table 3.2.

The evolution of final energy consumption by subsector is shown in Figure 3.2 for the period from 1990 to 2010.

TABLE 3.2

Final energy consumption, by subsector

SUBSECTOR AND USE	1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005/ 2010
	(10^3 toe)					(%)	
Energy	**27,379**	**26,855**	**30,092**	**40,322**	**49,370**	**25.2%**	**22.4%**
Consumption of Energy Sector	11,421	12,096	11,948	16,479	21,956	11.2%	33.2%
Thermoelectric Plants	3,173	4,663	8,857	11,670	18,777	9.6%	60.9%
Charcoal Plants	12,785	10,096	9,288	12,173	8,637	4.4%	-29.0%
Industrial	**23,406**	**28,757**	**35,251**	**43,090**	**53,344**	**27.2%**	**23.8%**
Transport	**31,924**	**39,991**	**46,033**	**51,872**	**69,521**	**35.4%**	**34.0%**

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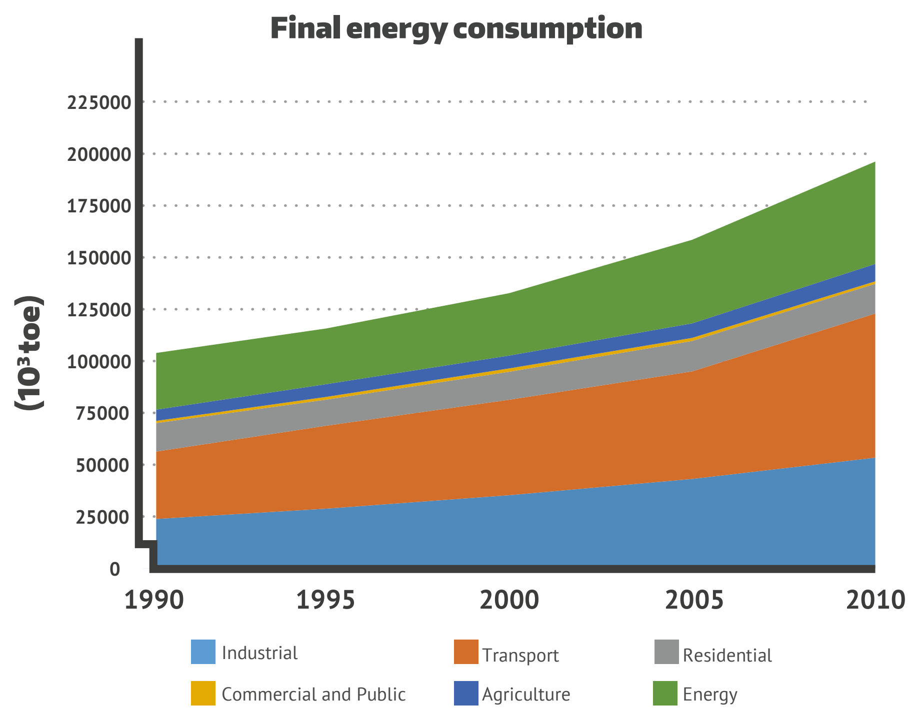
SUBSECTOR AND USE	1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005/ 2010
	(10^3 toe)					(%)	
Residential	13,821	12,575	13,497	14,672	14,342	7.3%	-2.3%
Commercial and Public	1,050	1,327	1,615	1,488	1,191	0.6%	-20.0%
Agriculture	5,354	6,150	6,202	7,009	8,400	4.3%	19.8%
Final energy consumption	102,934	115,655	132,689	158,452	196,168	100.0%	23.8%

FIGURE 3.2
Final energy consumption, by subsector



The next section presents greenhouse gas emissions estimates due to production, transformation, transport and consumption and is divided into two subsections: fuel combustion and fugitive emissions.

3.1.2. Fuel Combustion Emissions

The combustion process essentially generates CO_2 from oxidation of the carbon contained in fuels, thus releasing energy. However, this process is imperfect, and as a consequence, it also produces CH_4, CO and NMVOC. N_2O and NO_x are also generated as a secondary effect.

3.1.2.1. CO_2 emissions from fuel combustion

Brazil's CO_2 emissions from fuel combustion were estimated using two IPCC methodologies (IPCC, 1997): the reference or top-down approach, in which CO_2 emissions are calculated from fuel supply; and the sectoral or bottom-up approach, in which CO_2 emissions are calculated from each sector's final energy consumption. Only CO_2 emissions from fossil fuels are considered in this chapter, and accounted for in the national total. Emissions resulting from biomass fuel combustion are considered null by the IPCC as they derive from photosynthesis. They are presented here for information purposes only, as shown in Table 3.3.

Emissions from non-renewable biomass consumption are covered in another specific methodological module – Land-Use Change and Forestry (IPCC, 2006).

Emission estimates are based on production and consumption data by energy source obtained from the Brazilian Energy Balance (BEN) (BRASIL, 2013), previously published by the Ministry of Mines and Energy (MME) and in recent years published by the Energy Research Company (EPE), under the MME.

The three editions of the Useful Energy Balance (BEU) (BRASIL, 2006) available in Brazil (1983, 1993 and 2003) were used specifically for the sector-wide approach, aimed at breaking down fuel consumption into final destinations. BEU provides the framework for the allocation of each energy sector in terms of final energy by type of use for the several sectors, as well as respective efficiencies. Among the available destinations, the following are relevant for emissions: Driving Force, Heat, Direct Heating, Cooling, Lighting, Electrochemistry and Others.

The main source of data for of emission factors used were the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) and EMEP/EEA 2013 Air Pollutant Emission Inventory Guidebook 2013 (EMEP/EEA, 2013). In some cases specific emission factors have been developed and adopted in order to assess emissions of different gases.

Top-down

The top-down approach is a simple procedure, where emissions from fuel combustion are calculated from aggregate data on the fuel supply in a given economy. For such purpose, it uses the concept of apparent consumption, which is added up to primary fuel production, primary and secondary fuel imports, then subtracted from primary and secondary fuel exports, bunkers and stock variation (which may be positive or negative).

Non-energy fuel emissions are accounted for by the new Guidelines (IPCC, 2006) in Industrial Processes and Product Use. They refer to raw materials of the chemical industry (part of the supply of naphtha, refinery gas, natural gas, lighting kerosene, anhydrous and hydrous ethanol and tar), iron and steel fittings industry (part of coke supply from coal, and oil and bituminous, coking and charcoal), and non-energy use products (full supply of lubricants, asphalt, and other non-energy oil and solvent products) among others.

In the top-down approach, energy sources are separated by physical state of the primary product, fundamentally corresponding to oil, oil by-products, and natural gas liquids (liquids), coal and coal by-products (solids) and dry natural gas (gaseous). Table 3.3 presents the results of CO_2 emissions estimated by the top-down approach for 1990, 1995, 2000, 2005 and 2010, and Figure 3.3 presents the share of biomass and fossil fuels.

TABLE 3.3

CO_2 Emissions (top-down approach)

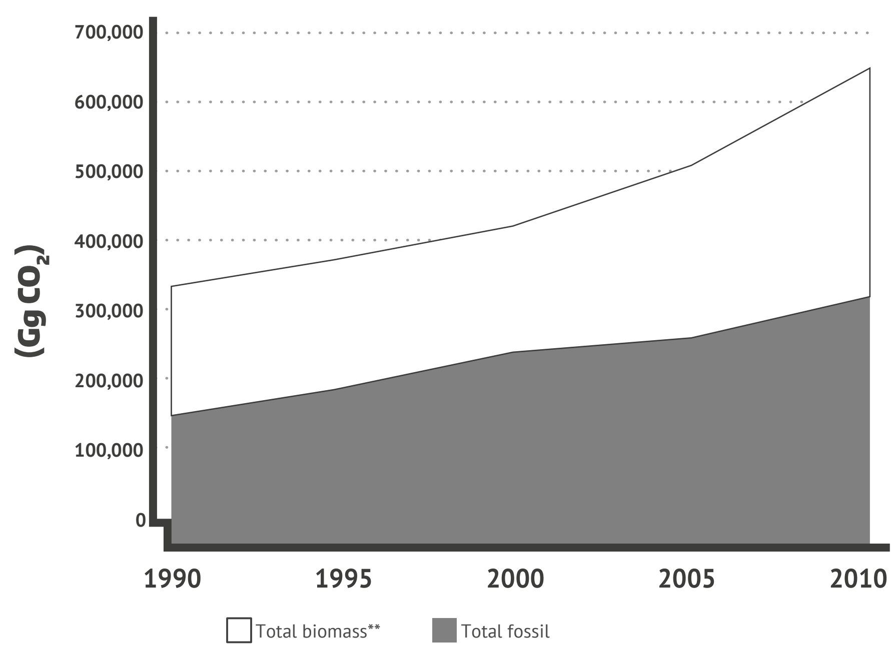
SECTOR	1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005-2010
	($Gg\ CO_2$)					%	
Oil and oil by-products	152,710	188,248	228,195	226,595	270,659	79.6%	19.4%
Coal and coal by-products	15,345	16,469	17,724	16,579	14,982	4.4%	-9.6%
Natural gas	6,089	8,305	17,909	39,739	53,711	15.8%	35.2%
Other Primary Fossil Sources*	151	133	392	845	711	0.2%	-15.8%
Total fossil	**174,294**	**213,155**	**264,219**	**283,758**	**340,062**	**100%**	**19.8%**
Solid Biomass	148,351	144,097	140,335	194,348	239,732	76.8%	23.4%
Liquid Biomass	27,976	33,180	31,862	41,150	72,242	23.2%	75.6%
Gaseous Biomass	0	0	0	0	10	0.0%	NA
Total biomass**	**176,327**	**177,277**	**172,197**	**235,498**	**311,985**	**100%**	**32.5%**

** Includes primary sources with different physical states.*

*** CO_2 emissions from use of biomass as a fuel are presented for information purposes only and should not be covered in this Inventory.*

FIGURE 3.3

CO_2 emissions calculated according to the top-down approach



Total CO_2 emissions from fossil fuel combustion grew from 174,294 Gg CO_2, in 1990, to 340,062 Gg CO_2, in 2010, representing a 95% growth in the period. However, fossil fuel production recorded an increase from 38,744 to 125,188 thousand toe, a 223, 1% growth; imports, in turn, grew by 54.6%.

A significant increase in emissions from natural gas consumption (gaseous fossil) is noticed, which increases its total emissions shares by almost five times. Liquid fossil fuels had their share reduced from 87.6% to 79.6% between 1990 and 2010.

As already explained above, the approach used for inventories provides that CO_2 emissions from fuel combustion resulting from biomass should be informed, but not considered in the total emissions from the energy sector in the country.

Bottom-up

The sectoral, or bottom-up, approach allows the identification of where and how emissions occur, favoring the establishment of mitigation measures. This approach also addresses emissions of other greenhouse gases emissions whose behavior is important.

The estimation of emissions based on the bottom-up approach considers the various destinations of fuel use. Besides CO_2, emissions of non-CO_2 gases are estimated, namely: CO, CH_4, N_2O, NO_x, and NMVOC.

CO_2 emissions depend on fuel carbon content, and can be estimated at a high level of aggregation with reasonable accuracy such as that proposed in the top-down approach. However, for non-CO_2 gases it is necessary to work with additional information on end-use, equipment technology, operating conditions, etc., and therefore it is necessary to use a more disaggregated approach. Nevertheless, under the IPCC methodology (IPCC, 1997) it is recommended that CO_2 emissions are also estimated using a more disaggregated level of information, which allows for a comparison between the two approaches, as will be addressed further ahead. In this sense, CO_2 emissions from fuel combustion were estimated for the various sectors of the economy.

The determination of final consumption of fuels by sector demanded an adjustment of the available database. The said adjustment was needed regarding the fuels as well as the activity sectors. In relation to emissions, each country's peculiarities are reflected in the difference of carbon content of the fuels used and/or the characteristics of use and transformation equipment. Taking into account that in fuel combustion emission factors for non-CO_2 gases depend on the technology used, an attempt was made to develop appropriate emission factors for Brazil by identifying the equipment used by the various sectors.

Table 3.4 shows fossil fuel emissions for the 1990 to 2010 period. CO_2 emissions in 2010 were estimated at 332,760 Gg, growing by 20.2% from 2005 to 2010. In 2010, diesel oil was the fossil fuel energy responsible for higher shares of CO_2 emissions, accounting for 38.7% of emissions for the year. Motor gasoline and dry natural gas are also relevant for emissions and had similar shares in 2010 (15.3% and 13.4%, respectively). It is noteworthy that diesel oil and motor gasoline maintained stable shares over the period, but dry natural gas increased considerably (in 1990 it was only 2.2%).

TABLE 3.4
CO_2 emissions by fuel

SOURCE	1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005-2010
	(Gg CO_2)					(%)	
Motor Gasoline	21,119	31,403	38,313	39,446	50,848	15.3%	28.9%
Aviation Gasoline	142	141	170	123	155	0.0%	26.0%
Lighting Kerosene	567	304	168	74	21	0.0%	-71.6%
Jet Fuel	4,090	4,591	6,036	6,193	9,596	2.9%	54.9%
Diesel Oil	64,691	79,013	95,874	106,342	128,693	38.7%	21.0%
Fuel Oil	32,821	38,312	37,504	23,560	19,663	5.9%	-16.5%
LPG	14,466	16,978	20,702	18,814	20,345	6.1%	8.1%
Petroleum Coke	167	634	10,467	11,271	18,426	5.5%	63.5%
Lignite	2,945	3,516	3,737	3,350	1,924	0.6%	-42.6%
Sub-bituminous Coal	4,693	4,257	6,865	5,324	7,450	2.2%	39.9%
Other Bituminous Coal	-	-	-	-	48	0.0%	-
Coking Coal	363	1,560	2,851	3,181	1,738	0.5%	-45.4%
Coal Tar	482	711	338	168	359	0.1%	113.7%
Coal Coke	442	-	3	547	464	0.1%	-15.2%
Natural Gas (Humid)	1,738	585	3,034	4,735	7,944	2.4%	67.8%
Natural Gas (Dry)	3,607	7,112	14,074	34,456	44,740	13.4%	29.8%
Refinery Gas	3,791	4,772	6,852	9,042	9,596	2.9%	6.1%
Other Energy Oil Products	2,938	4,420	6,686	6,546	6,809	2.0%	4.0%
Gasworks Gas – Rio de Janeiro	400	266	201	-	-	0.0%	-
Gasworks Gas – São Paulo	356	43	-	-	-	0.0%	-
Coke Oven Gas	2,462	2,767	2,630	2,728	3,230	1.0%	18.4%
Naphtha	-	92	12	-	-	0.0%	-
Other Primary Fossil Sources*	151	133	392	845	711	0.2%	-15.9%
Total domestic emissions	**162,431**	**201,610**	**256,909**	**276,744**	**332,760**	**100%**	**20.2%**

**Includes primary sources in different physical states.*

CO_2 emissions from biomass as fuel are shown in Table 3.5 only for information purposes and should not be considered in this Inventory. Only non-CO_2 emissions from the combustion of these fuels will be considered. CO_2 emissions from biomass consumption are addressed in another specific methodological module – Land Use, Land-Use Change and Forestry (IPCC, 2003), where the balance between carbon emitted by removed biomass and carbon absorbed during the growth of new plants is determined.

TABLE 3.5
CO_2 emissions from biomass use

SOURCE	1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005-2010
	(Gg CO_2)					(%)	
Firewood	87,580	72,062	72,910	88,327	85,939	28.3%	-2.7%
Charcoal	5,157	3,682	3,204	3,862	3,223	1.1%	-16.5%
Bagasse	48,842	62,280	59,126	94,936	142,964	47.2%	50.6%
Other Primary (biogas)	-	-	-	-	19	0.0%	-
Other Primary (biomass)	1,599	1,967	2,385	3,555	4,880	1.6%	37.3%
Black Liquor	5,249	8,426	11,552	16,965	24,148	8.0%	42.3%
Anhydrous Alcohol	1,928	5,338	9,031	12,090	11,234	3.7%	-7.1%
Hydrated Alcohol	15,438	15,036	8,229	8,551	24,458	8.1%	186.0%
Biodiesel	-	-	-	-	6,306	2.1%	-
Total	**165,793**	**168,791**	**166,437**	**228,286**	**303,171**	**100.0%**	**32.8%**

Figure 3.4 shows emissions calculated in accordance with the bottom-up approach for fossil fuels and biomass.

FIGURE 3.4
CO_2 emissions (bottom-up approach)

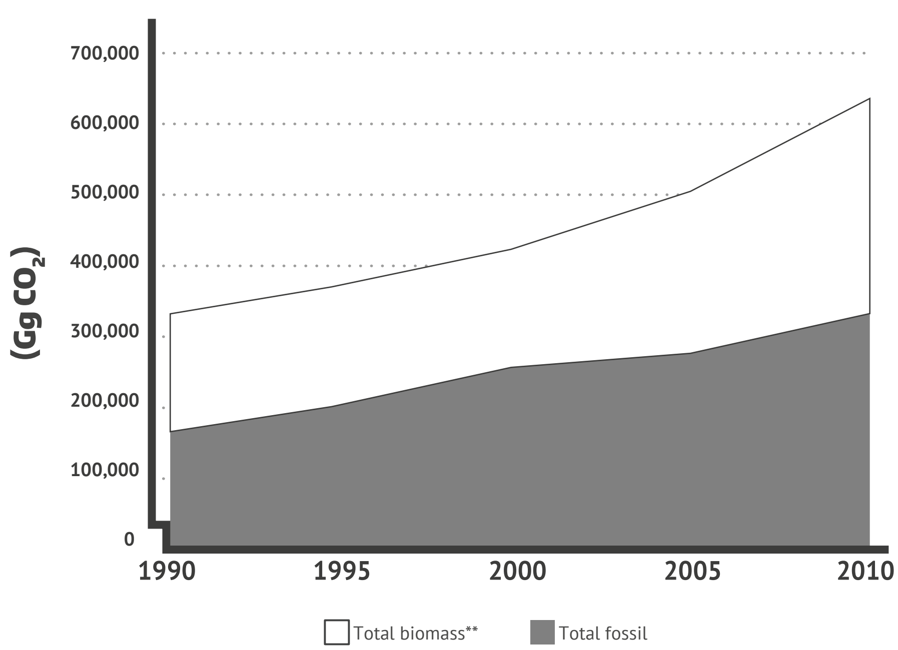


Table 3.6 shows CO_2 emissions by subsector for fossil fuels. The transport subsector was the largest source of emissions in 2010, accounting for 50.6% of CO_2 emissions. Road transport corresponds to 45.5% of total emissions

that year and to 90% of all transport emissions. An increase by 24.5% in the CO_2 emissions share is observed in this subsector between 2005 and 2010.

TABLE 3.6

CO_2 emissions of fuel by subsector

EMISSIONS BY SUBSECTOR	1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005-2010
	(Gg CO_2)					(%)	
Energy subsector	21,271	25,282	40,483	47,344	58,857	17.7%	24.3%
Public Service Power Plants	6,194	9,016	19,075	20,911	26,592	8.0%	27.2%
Self-Producers Power Plants	2,275	3,159	5,141	5,474	9,445	2.8%	72.5%
Charcoal Plants*	0	0	0	0	0	0.0%	-
Energy consumption	12,802	13,106	16,268	20,958	22,820	6.9%	8.9%
Residential	13,842	15,942	17,179	15,591	17,249	5.2%	10.6%
Commercial	2,073	1,565	2,216	1,903	1,446	0.4%	-24.0%
Public	503	2,075	2,122	1,742	1,192	0.4%	-31.6%
Agriculture	9,846	13,222	14,152	14,964	17,346	5.2%	15.9%
Transport	79,337	100,457	121,748	135,182	168,364	50.6%	24.5%
Road Transportation	70,094	90,916	111,337	123,519	151,481	45.5%	22.6%
Railways	1,592	1,332	1,247	1,748	2,717	0.8%	55.4%
Civil Aviation	4,232	4,732	6,206	6,316	9,751	2.9%	54.4%
Navigation	3,420	3,477	2,958	3,599	4,415	1.3%	22.7%
Industrial	35,559	43,068	59,008	60,019	68,305	20.5%	13.8%
Cement	5,790	6,073	10,512	8,951	14,259	4.3%	59.3%
Iron and Steel	4,373	5,387	4,620	5,297	5,540	1.7%	4.6%
Ferroalloys	63	1	37	229	102	0.0%	-55.5%
Mining and Pelleting	2,412	3,263	5,666	7,230	7,289	2.2%	0.8%
Non-Ferrous Metals	1,357	1,868	3,709	4,916	5,476	1.6%	11.4%
Chemical	8,606	10,057	13,942	14,624	13,847	4.2%	-5.3%
Food and Beverages	3,239	4,074	4,476	3,755	3,965	1.2%	5.6%
Textiles	1,600	1,328	1,268	1,159	1,015	0.3%	-12.4%
Pulp and Paper	2,464	3,384	4,320	3,840	3,632	1.1%	-5.4%
Ceramic	1,692	2,691	3,382	3,805	4,888	1.5%	28.5%
Other industries	3,962	4,942	7,076	6,213	8,293	2.5%	33.5%
Total	**162,431**	**201,610**	**256,909**	**276,744**	**332,760**	**100%**	**20.2%**

* *CO_2 emissions from Charcoal Plants are from biomass.*

The industrial subsector was the source of 20.5% emissions from the Energy sector, with cement and chemicals standing out, each of those responsible for approximately 4%. Noteworthy is the increase in emissions of the cement sector, with a variation of 59.3% and the reduction of emissions of the ferroalloy sector, with a variation of -55.5% from 2005 to 2010.

In the industrial subsector, in relation to Mining and Pelletizing, Iron and Steel, Ferroalloys and Non-Ferrous Minerals, it is worth mentioning that part of their emissions are accounted for in Industrial Processes and Product Use and refer to the use of energy as reducers, according to the IPCC Guidelines (IPCC, 1997 and 2006).

Among the subsectors with a minor share of total emissions, public and commercial were the ones with the lowest contribution from 2005 to 2010.

Table 3.7 presents a comparison between CO_2 emission estimates obtained from the two methods. Some variation is expected between the two results, since they use different levels of aggregation and hypotheses that may sometimes only apply to one of the approaches. The fact that bottom-up approach uses a broader scope of variables also contributes to this difference.

In accordance with IPCC (1997), this difference can be considered reasonable if it is within a 2% range (negative or positive). If the result extrapolates this limit, justifications must be submitted.

As shown in Table 3.7, the results from the top-down approach are consistently higher than those obtained through the bottom-up approach. Estimates through the top-down approach do not account for energy losses in processing and distribution, which leads to different estimates for the bottom-up approach. Besides, statistic adjustments in the BEN contribute to the difference in results between the two approaches.

TABLE 3.7

CO_2 emissions from fossil fuel combustion estimated by top-down and bottom-up approaches

SECTOR	1990	1995	2000	2005	2010
	(Gg CO_2)				
Top-Down (A)	174,294	213,155	264,219	283,758	340,062
Bottom-Up (B)	162,431	201,610	256,909	276,744	332,760
Difference (%) ((A-B)/B)	7.3%	5.7%	2.8%	2.5%	2.2%

The BEN used to include information on bunker fuels for aviation (fuel supplied to air transport companies for international transportation) in the export account (fuel exported as good), but it began to present the information in a separate format since 1998. In this case, the National Civil Aviation Agency (ANAC) provided the information used, as it separates bunker fuels data from exports since 1990. Furthermore, greater details in the distinction made between national and international transportation grants more soundness to data submitted and ensures the adequacy of the methodology to IPCC guidelines. In the case of civil aviation, therefore, more precise export and bunker fuels data, obtained, respectively, from the National Agency of Petroleum, Natural Gas and Biofuels (ANP) and ANAC were used.

Table 3.8 shows the CO_2 emissions from bunker fuels for 1990, 1995, 2000, 2005 and 2010.

TABLE 3.8
CO_2 emissions from bunker fuels

SOURCE	1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005-2010
	(Gg CO_2)					(%)	
Aviation							
Jet fuel + Aviation Gasoline	4,366	4,520	4,626	4,707	5,784	31.2%	22.9%
Marine							
Diesel oil	437	562	1,942	1,839	2,304	12.4%	25.3%
Bunker fuel oil	1,283	3,585	7,071	8,220	10,462	56.4%	27.3%
Total bunker	**6,086**	**8,667**	**13,639**	**14,766**	**18,550**	**100%**	**25.6%**

3.1.2.2. Emissions of other greenhouse gases from fuel combustion

Other greenhouse gases that have been estimated are: CH_4, N_2O, CO, NO_x and NMVOC. These gases are broadly treated as "non-CO_2" gases and their emissions have been estimated for all fuels, including those derived from biomass.

Non-CO_2 gas emissions do not depend only on the type of fuel used, but also on the combustion technology, operation conditions, equipment maintenance conditions, age, etc. Therefore, for applying the bottom-up approach, the end uses of the energy sources, as well as the characteristics of the equipment used, must be known. Thus, the most precise calculation of non-CO_2 emissions gases requires more disaggregated data and detailed methodology (Tier 2 and Tier 3). However, since this information is not always available, a simplified method has been developed (Tier 1) to evaluate those emissions, using only information on energy consumption by sector. Tier 2-detailed method, which uses emission factors for equipment classes and fuels by subsector (IPCC, 1997), was applied in most end uses of fuels. Tier 1 has been used in some cases when there was no available data, technology or equivalent fuel (IPCC, 1997). For gasoline and ethanol consumed in the road transport mode, specific emission factors for the national light vehicle fleet were used, which can be classified as a Tier 3 method, calculated from data obtained at Cetesb (CETESB, 2011a; 2011b; 2013).

In the case of non-CO_2 gases, fossil fuels and biomass emissions must be included in the aggregation of the inventory, unlike the case of CO_2. It should be noted that, because of the bottom-up modeling of the road transport carried out by Tier 3 separately, non-CO_2 emissions from this sector result from the mixture of gasoline with anhydrous alcohol, estimated jointly, as used in the national fleets.

Table 3.9 shows emissions of other greenhouse gases by fuels combustion for 1990, 1995, 2000, 2005 and 2010.

TABLE 3.9
Emissions from other greenhouse gases from fuel combustion

GAS	1990	1995	2000	2005	2010	VARIATION 2005-2010
	(Gg)					(%)
CH_4	455.3	388.1	392.8	478.6	448.2	-6.4%
N_2O	14.02	14.97	18.88	24.75	31.76	28.3%
CO	9,592.6	9,636.3	8,181.0	8,194.7	7,695.9	-6.1%
NO_x	1,639.8	1,977.5	2,273.3	2,346.4	2,567.1	9.4%
NMVOC	1,167.5	1,104.8	987.4	1,061.5	900.5	-15.2%
BUNKER FUELS EMISSIONS						
CH_4	0.0	0.0	0.1	0.1	0.2	25.3%
N_2O	0.13	0.16	0.20	0.21	0.27	24.4%
CO	0.9	0.9	0.9	1.2	1.1	-6.0%
NO_x	1.6	2.1	3.2	3.4	4.3	27.0%
NMVOC	2.9	7.3	14.9	16.9	21.4	26.8%

A more detailed analysis of the above results is found in the following items. Tables with emissions by fuel and sector for the 1990 to 2010 period are presented for each gas. Each table also shows the percentage distribution in 2010 and the corresponding growth rate for the 2005 to 2010 period.

Methane

In 2010 448.2 Gg CH_4 were emitted from fuel combustion. Emissions showed a reduction of 6.4% in the 2005 to 2010 period.

Table 3.10 shows biomass fuel is the main source of CH_4 (84.2% in 2010). Firewood was the main fuel in terms of CH_4 emissions (71.8%), followed by motor gasoline (11.2%) and by bagasse (9.6%). Among these fuels, firewood and motor gasoline showed reduction of CH_4 emissions by 10.4% and 18.1%, respectively, from 2005 to 2010.

TABLE 3.10
CH_4 emissions by fuel

EMISSION BY FUEL	1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005-2010
FOSSIL	(Gg CH_4)					(%)	
Motor Gasoline	65.0	77.8	67.3	61.4	50.3	11.2%	-18.1%
Aviation Gasoline	0.0	0.0	0.0	0.0	0.0	0.0%	-
Lighting Kerosene	0.1	0.0	0.0	0.0	0.0	0.0%	-
Jet Fuel	0.0	0.0	0.0	0.0	0.0	0.0%	-
Diesel Oil	4.8	5.5	6.5	7.0	8.8	2.0%	25.7%
Fuel Oil	1.2	1.4	1.3	1.0	0.8	0.2%	-20.0%
LPG	0.3	0.3	0.4	0.3	0.3	0.1%	0.0%
Petroleum Coke	0.0	0.0	0.3	0.3	0.6	0.1%	100.0%
Lignite	0.1	0.1	0.0	0.0	0.0	0.0%	-
Sub-bituminous Coal	0.1	0.1	0.1	0.1	0.2	0.0%	100.0%
Other Bituminous Coal	0.0	0.0	0.0	0.0	0.0	0.0%	-
Coking Coal	0.0	0.1	0.2	0.3	0.1	0.0%	-66.7%
Coal Tar	0.0	0.1	0.0	0.0	0.0	0.0%	-
Coal Coke	0.0	0.0	0.0	0.1	0.0	0.0%	-100.0%
Natural Gas (Humid)	0.0	0.0	0.1	0.2	0.4	0.1%	100.0%
Natural Gas (Dry)	0.1	0.4	1.9	7.9	8.6	1.9%	8.9%
Refinery Gas	0.1	0.1	0.1	0.2	0.2	0.0%	0.0%
Other Energy Oil Products	0.1	0.1	0.3	0.3	0.3	0.1%	0.0%
Gasworks gas	0.0	0.0	0.0	0.0	0.0	0.0%	-
Coke Oven Gas	0.1	0.1	0.1	0.1	0.1	0.0%	0.0%
Other Primary Fossil Sources	0.0	0.0	0.0	0.0	0.0	0.0%	-
Total Fossil	**72.0**	**86.1**	**78.6**	**79.2**	**70.7**	**15.8%**	**-10.7%**
BIOMASS	**1990**	**1995**	**2000**	**2005**	**2010**	**SHARE IN 2010**	**VAR. 2005-2010**
	(Gg CH_4)					(%)	
Firewood	353.1	271.4	286.7	359.1	321.8	71.8%	-10.4%
Charcoal	11.9	8.5	7.5	9.1	7.7	1.7%	-15.4%
Bagasse	14.7	18.7	17.7	28.5	42.9	9.6%	50.5%
Other Primary (biogas)	0.0	0.0	0.0	0.0	0.0	0.0%	-
Other Primary (biomass)	0.5	0.6	0.7	1.0	1.5	0.3%	50.0%
Black Liquor	0.1	0.2	0.3	0.5	0.6	0.1%	20.0%
Anhydrous Alcohol	0.0	0.0	0.0	0.0	0.0	0.0%	-
Hydrated Alcohol	3.0	2.6	1.3	1.2	3.0	0.7%	150.0%
Total Biomass	**383.3**	**302.0**	**314.2**	**399.4**	**377.5**	**84.2%**	**-5.5%**
Total	**455.3**	**388.1**	**392.8**	**478.6**	**448.2**	**100%**	**-6.4%**

In terms of sectoral emissions in 2010 (Table 3.11), the residential subsector was the main source of CH_4 emissions (64.7%) especially because of firewood combustion. Then there is the transport subsector, highlighted by road transport (14.8%). During the period from 2005 to 2010 there was significant growth in some subsectors such as: public service power plants, self-producers and energy sector (50%, 136% and 56.6% respectively).

TABLE 3.11

CH_4 emissions by subsector

EMISSIONS BY SUBSECTOR		1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005-2010
		(Gg CH_4)					(%)	
Broad Energy subsector	Public Service Power Plants	0.1	0.2	0.4	0.8	1.2	0.3%	50.0%
	Self-Producers Power Plants	0.6	0.9	1.3	2.5	5.9	1.3%	136.0%
	Charcoal Plants	16.1	12.7	11.7	15.3	10.8	2.4%	-29.4%
	Energy Sector	8.7	9.3	7.3	10.6	16.6	3.7%	56.6%
Industry	Cement	3.1	2.6	2.3	2.4	1.2	0.3%	-50.0%
	Iron and Steel	0.2	0.2	0.1	0.1	0.2	0.0%	100.0%
	Ferroalloys	0.0	0.0	0.1	0.1	0.1	0.0%	0.0%
	Mining and Pelleting	0.4	0.2	0.3	0.4	0.3	0.1%	-25.0%
	Non-Ferrous Metals	0.1	0.1	0.1	0.2	0.2	0.0%	0.0%
	Chemical	0.8	0.8	1.3	2.4	2.5	0.6%	4.2%
	Food and Beverages	6.8	10.1	11.1	17.7	23.2	5.2%	31.1%
	Textiles	0.2	0.1	0.1	0.1	0.1	0.0%	0.0%
	Pulp and Paper	1.0	1.2	1.5	1.8	2.5	0.6%	38.9%
	Ceramics	2.2	2.0	2.2	2.3	3.0	0.7%	30.4%
	Others	0.9	0.8	0.8	0.9	1.1	0.2%	22.2%
	Subtotal	**15.7**	**18.1**	**19.9**	**28.4**	**34.4**	7.7%	21.1%
Transport	Road Transportation	72.2	85.4	75.2	74.0	66.3	14.8%	-10.4%
	Railways	0.1	0.1	0.1	0.1	0.2	0.0%	100.0%
	Civil Aviation	0.0	0.0	0.0	0.0	0.0	0.0%	-
	Navigation	0.3	0.3	0.3	0.3	0.4	0.1%	33.3%
	Subtotal	**72.6**	**85.8**	**75.6**	**74.4**	**66.9**	14.9%	-10.1%
Other subsectors	Residential	318.4	243.7	261.5	327.6	290.1	64.7%	-11.4%
	Commercial	3.7	3.5	3.1	3.1	3.8	0.8%	22.6%
	Public	0.1	0.1	0.0	0.0	0.0	0.0%	-
	Agriculture	19.3	13.8	12.0	15.9	18.5	4.1%	16.4%
	Total	**455.3**	**388.1**	**392.8**	**478.6**	**448.2**	**100%**	**-6.4%**

When comparing tables of emission results by fuel (Table 3.10) and by subsector (Table 3.11), the evaluation of emissions by technology shows direct heating was responsible for 73.5% of CH_4 emissions in 2010.

Nitrous Oxide

In 2010 31.76 Gg of N_2O were emitted from fuel combustion. Emissions growth rates were of 28.3% between 2005 and 2010.

TABLE 3.12
N_2O emission by fuel

EMISSIONS BY FUEL	1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005-2010
FOSSIL	(Gg N_2O)					(%)	
Motor Gasoline	0.67	1.79	4.78	6.45	9.42	29.7%	46.0%
Aviation Gasoline	0.00	0.00	0.00	0.00	0.00	0.0%	-
Lighting Kerosene	0.00	0.00	0.00	0.00	0.00	0.0%	-
Jet Fuel	0.11	0.12	0.16	0.17	0.26	0.8%	52.9%
Diesel Oil	3.28	3.66	4.15	4.68	6.12	19.3%	30.8%
Fuel Oil	0.23	0.26	0.24	0.18	0.17	0.5%	-5.6%
LPG	0.23	0.29	0.38	0.36	0.40	1.3%	11.1%
Petroleum Coke	0.00	0.00	0.06	0.07	0.11	0.3%	57.1%
Lignite	0.03	0.03	0.03	0.03	0.02	0.1%	-33.3%
Sub-bituminous Coal	0.06	0.04	0.06	0.05	0.07	0.2%	40.0%
Other Bituminous Coal	0.00	0.00	0.00	0.00	0.00	0.0%	-
Coking Coal	0.00	0.02	0.04	0.05	0.02	0.1%	-60.0%
Coal Tar	0.01	0.01	0.01	0.00	0.01	0.0%	-
Coal Coke	0.01	0.00	0.00	0.01	0.01	0.0%	0.0%
Natural Gas (Humid)	0.01	0.00	0.02	0.03	0.08	0.3%	166.7%
Natural Gas (Dry)	0.02	0.07	0.24	1.07	1.22	3.8%	14.0%
Refinery Gas	0.04	0.04	0.09	0.13	0.14	0.4%	7.7%
Other Energy Oil Products	0.02	0.03	0.05	0.05	0.05	0.2%	0.0%
Gasworks gas	0.01	0.00	0.00	0.00	0.00	0.0%	-
Coke Oven Gas	0.02	0.02	0.02	0.02	0.02	0.1%	0.0%
Other Primary Fossil Sources	0.00	0.00	0.00	0.00	0.00	0.0%	-
Total Fossil	4.75	6.38	10.33	13.35	18.12	57.1%	35.7%
BIOMASS	1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005-2010
	(Gg N_2O)					(%)	
Firewood	6.97	5.71	5.78	7.01	6.58	20.7%	-6.1%
Charcoal	0.12	0.09	0.07	0.09	0.06	0.2%	-33.3%
Bagasse	1.95	2.49	2.37	3.80	5.72	18.0%	50.5%
Other Primary (biogas)	0.00	0.00	0.00	0.00	0.00	0.0%	-
Other Primary (biomass)	0.06	0.08	0.09	0.14	0.20	0.6%	42.9%
Black Liquor	0.09	0.15	0.20	0.29	0.41	1.3%	41.4%
Anhydrous Alcohol	0.00	0.00	0.00	0.00	0.00	-	-
Hydrated Alcohol	0.08	0.07	0.04	0.07	0.67	2.1%	857.1%
Total Biomass	9.27	8.59	8.55	11.40	13.64	42.9%	19.6%
Total	**14.02**	**14.97**	**18.88**	**24.75**	**31.76**	**100.0%**	**28.3%**

Table 3.12 shows that fossil fuels are the main sources of N_2O (57.1% in 2010), having presented growth by 35.7% in emissions in the 2005 to 2010 period. N_2O emissions demonstrate the role of gasoline in fossil fuel emissions. N_2O emissions from gasoline consumption accounted for 29.7% of total emissions in 2010, having grown by 46% between 2005 and 2010.

As for emissions from biomass, firewood and bagasse are the main sources of N_2O emissions (20.7% and 18%, respectively). Despite the low turnout, it is necessary to stress the growth of hydrous ethanol from 2005 to 2010 (857.1%).

TABLE 3.13

N_2O emissions by subsector

EMISSIONS BY SUBSECTOR		1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005-2010
		(Gg N_2O)					(%)	
Broad Energy subsector	Public Service Power Plants	0.05	0.07	0.14	0.23	0.32	1.0%	39.1%
	Self-Producers Power Plants	0.12	0.16	0.24	0.41	0.93	2.9%	126.8%
	Charcoal Plants	2.14	1.69	1.56	2.04	1.45	4.6%	-28.9%
	Energy Sector	1.22	1.30	1.06	1.52	2.32	7.3%	52.6%
Industry	Cement	0.12	0.11	0.12	0.11	0.13	0.4%	18.2%
	Iron and Steel	0.02	0.03	0.02	0.02	0.02	0.1%	0.0%
	Ferroalloys	0.00	0.00	0.01	0.02	0.02	0.1%	0.0%
	Mining and Pelleting	0.03	0.03	0.06	0.07	0.07	0.2%	0.0%
	Non-Ferrous Metals	0.02	0.02	0.02	0.02	0.03	0.1%	50.0%
	Chemical	0.12	0.11	0.13	0.18	0.18	0.6%	0.0%
	Food and Beverages	1.31	1.70	1.84	2.69	3.52	11.1%	30.9%
	Textiles	0.05	0.04	0.04	0.04	0.04	0.1%	0.0%
	Pulp and Paper	0.39	0.49	0.60	0.75	1.03	3.2%	37.3%
	Ceramics	0.29	0.27	0.31	0.31	0.41	1.3%	32.3%
	Others	0.19	0.17	0.19	0.22	0.28	0.9%	27.3%
	Subtotal	**2.54**	**2.97**	**3.34**	**4.43**	**5.73**	**18.0%**	**29.3%**

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EMISSIONS BY SUBSECTOR		1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005-2010
		(Gg N_2O)					(%)	
Transport	Road Transportation	2.94	4.41	7.94	10.53	14.98	47.2%	42.3%
	Railways	0.61	0.51	0.48	0.67	1.10	3.5%	64.2%
	Civil Aviation	0.11	0.13	0.17	0.17	0.27	0.9%	58.8%
	Navigation	0.09	0.09	0.08	0.09	0.12	0.4%	33.3%
	Subtotal	**3.75**	**5.14**	**8.67**	**11.46**	**16.47**	**51.9%**	**43.7%**
Other subsectors	Residential	3.29	2.62	2.85	3.48	3.15	9.9%	-9.5%
	Commercial	0.05	0.03	0.04	0.04	0.04	0.1%	0.0%
	Public	0.00	0.01	0.02	0.02	0.02	0.1%	0.0%
	Agriculture	0.86	0.98	0.96	1.12	1.33	4.2%	18.8%
Total		**14.02**	**14.97**	**18.88**	**24.75**	**31.76**	**100.0%**	**28.3%**

In terms of subsectoral emissions (Table 3.13), the transport subsector was the main source of N_2O emissions in 2010 (51.9%), with road transport accounting for 47.2%. Most subsectors had some growth in the 2005–2010 period, except for Charcoal Plants, with a reduction of 28.9%.

When analyzed by technology, N_2O emissions are more important in driving force.

Carbon Monoxide

Carbon monoxide emissions occur due to imperfect combustion in equipment. In many cases, its emission also reveals inefficiency in the use of fuels. Carbon monoxide is a chemical compound harmful to health, being an environmental problem in large urban conglomerates.

In 2010, fuels combustion emitted 7,695.9 Gg CO, showing a reduction of 6.1% in the 2005–2010 period. Table 3.14 shows that the biomass fuels were the main sources of CO emissions (62.3% in 2010). There is a predominance of the emissions deriving from the consumption of firewood, which accounts for 33.9% of the CO total emissions in 2010. In the case of fossil fuels, it should be noted that oil by-products (gasoline and diesel oil) and natural gas (to a lesser extent) are the main fuels responsible for CO emissions. Motor gasoline and diesel oil together are responsible for 89% of the CO emissions from fossil fuels in 2010.

TABLE 3.14
CO emissions by fuel

EMISSIONS BY FUEL	1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005-2010
FOSSIL	(Gg CO)					(%)	
Motor Gasoline	4,527.9	5,174.8	3,967.7	3,116.1	2,278.6	29.6%	-26.9%
Aviation Gasoline	30.4	30.2	36.4	26.3	33.3	0.4%	26.6%
Lighting Kerosene	0.5	0.3	0.1	0.1	0.0	0.0%	-100.0%
Jet Fuel	2.6	2.9	3.9	4.4	5.2	0.1%	18.2%
Diesel Oil	178.1	216.6	257.2	275.8	310.3	4.0%	12.5%
Fuel Oil	13.8	17.5	18.9	20.0	16.1	0.2%	-19.5%
LPG	2.8	3.7	5.7	4.6	5.0	0.1%	8.7%
Petroleum Coke	0.9	5.5	99.2	107.6	175.9	2.3%	63.5%
Lignite	1.2	1.1	0.7	0.5	0.4	0.0%	-20.0%
Sub-bituminous Coal	4.1	2.5	1.6	1.4	2.6	0.0%	85.7%
Other Bituminous Coal	0.0	0.0	0.0	0.0	0.1	0.0%	-
Coking Coal	0.0	0.1	0.2	0.3	0.1	0.0%	-66.7%
Coal Tar	0.3	0.5	0.2	0.1	0.3	0.0%	200.0%
Coal Coke	3.8	0.0	0.0	4.8	4.0	0.1%	-16.7%
Natural Gas (Humid)	1.8	0.7	3.0	6.1	8.6	0.1%	41.0%
Natural Gas (Dry)	2.9	6.1	14.2	37.9	46.2	0.6%	21.9%
Refinery Gas	3.0	4.2	4.6	4.9	5.3	0.1%	8.2%
Other Energy Oil Products	1.8	2.7	5.7	5.6	5.9	0.1%	5.4%
Gasworks gas	0.3	0.1	0.1	0.0	0.0	0.0%	-
Coke Oven Gas	1.9	2.2	1.9	1.9	2.3	0.0%	21.1%
Other Primary Fossil Sources	0.1	0.1	0.1	0.0	0.0	0.0%	-
Total Fossil	**4,778.2**	**5,471.8**	**4,421.4**	**3,618.4**	**2,900.2**	**37.7%**	**-19.8%**
BIOMASS	**1990**	**1995**	**2000**	**2005**	**2010**	**SHARE IN 2010**	**VARIATION 2005-2010**
	(Gg CO)					(%)	
Firewood	2,910.5	2,332.0	2,367.6	2,924.3	2,605.2	33.9%	-10.9%
Charcoal	183.9	128.9	110.6	134.5	103.5	1.3%	-23.0%
Bagasse	328.2	366.0	314.0	496.7	892.4	11.6%	79.7%
Other Primary (biogas)	0.0	0.0	0.0	0.0	0.0	0.0%	-
Other Primary (biomass)	9.1	12.8	17.0	28.3	29.9	0.4%	5.7%
Black Liquor	182.4	281.8	384.6	560.2	789.7	10.3%	41.0%
Anhydrous Alcohol	0.0	0.0	0.0	0.0	0.0	0.0%	-
Hydrated Alcohol	1,200.3	1,043.0	565.8	432.3	375.0	4.9%	-13.3%
Total Biomass	**4,814.4**	**4,164.5**	**3,759.6**	**4,576.3**	**4,795.7**	**62.3%**	**4.8%**
Total	**9,592.6**	**9,636.3**	**8,181.0**	**8,194.7**	**7,695.9**	**100.0%**	**-6.1%**

In terms of subsectoral emissions (Table 3.15), emissions from the transport subsector predominate, being the main source of CO emissions in 2010 (38.1%), of which the road subsector stands out, with 37.4%. Nevertheless, it must be emphasized that transport subsector showed a reduction of 22.9% in the emissions from 2005 to 2010, while the industrial subsector, responsible for 22.2% of the CO total emissions, showed an increase by 33.3%.

TABLE 3.15

CO emissions by subsector

EMISSIONS BY SUBSECTOR		1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005-2010
		(Gg CO)					(%)	
Broad Energy subsector	Public Service Power Plants	3.1	5.4	9.1	15.2	19.7	0.3%	29.6%
	Self-Producers Power Plants	30.0	42.2	63.0	126.8	303.0	3.9%	139.0%
	Charcoal Plants	1,070.6	845.4	777.7	1,019.3	723.2	9.4%	-29.0%
	Energy Sector	294.3	315.5	254.5	366.8	572.0	7.4%	55.9%
Industry	Cement	63.8	51.4	114.2	118.6	140.3	1.8%	18.3%
	Iron and Steel	2.5	3.2	3.2	3.7	3.7	0.0%	0.0%
	Ferroalloys	0.0	0.0	5.0	7.7	7.7	0.1%	0.0%
	Mining and Pelleting	10.4	1.3	7.1	17.0	25.5	0.3%	50.0%
	Non-Ferrous Metals	3.5	4.0	1.1	1.6	2.1	0.0%	31.3%
	Chemical	29.5	25.1	20.4	21.5	22.5	0.3%	4.7%
	Food and Beverages	182.3	175.8	187.5	204.8	260.9	3.4%	27.4%
	Textiles	13.9	9.1	7.3	8.5	8.3	0.1%	-2.4%
	Pulp and Paper	254.4	369.1	483.5	673.1	938.9	12.2%	39.5%
	Ceramics	134.9	121.3	140.8	149.0	202.1	2.6%	35.6%
	Others	62.9	54.8	66.7	78.0	98.3	1.3%	26.0%
	Subtotal	**758.1**	**815.1**	**1,036.8**	**1,283.5**	**1,710.3**	**22.2%**	**33.3%**
Transport	Road Transportation	5,856.4	6,373.4	4,724.6	3,761.8	2,875.0	37.4%	-23.6%
	Railways	5.4	4.5	4.3	6.0	9.7	0.1%	61.7%
	Civil Aviation	33.0	33.1	40.3	31.0	38.5	0.5%	24.2%
	Navigation	8.1	8.3	7.0	8.5	10.5	0.1%	23.5%
	Subtotal	**5,902.9**	**6,419.3**	**4,776.2**	**3,807.3**	**2,933.7**	**38.1%**	**-22.9%**
Other subsectors	Residential	1,443.2	1,098.7	1,172.3	1,468.4	1,306.7	17.0%	-11.0%
	Commercial	4.5	3.9	3.9	3.9	4.6	0.1%	17.9%
	Public	0.4	0.9	0.6	0.5	0.2	0.0%	-60.0%
	Agriculture	85.5	89.9	86.9	103.0	122.5	1.6%	18.9%
Total		**9,592.6**	**9,636.3**	**8,181.0**	**8,194.7**	**7,695.9**	**100%**	**-6.1%**

When analyzing the emissions per technology, a concentration of the driving force emissions, consistent with the large share of the transport subsector in the emissions of this gas, is observed.

Nitrogen Oxides

NO_x emissions, which are indirect related greenhouse gases, are also an important pollution factor and may cause a series of negative impacts on health, also contributing to acid rain.

Unlike what has been previously analyzed in terms of emission behavior for other non-CO_2 gases reported so far, NO_x emissions are more directly related to fossil fuels as they involve high burning temperatures (90.3% share of total emissions in 2010). Oil by-products (the emissions of diesel oil contribute with 59.4% to the total emissions) and natural gas (9.4% participation) cause most emissions.

In 2010 2,567.1 Gg NO_x were emitted from fuel combustion. The emissions growth rate was 9.4% during the 2005-2010 period.

TABLE 3.16
NO_x emissions, by fuel

EMISSIONS BY FUEL	1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005-2010
FOSSIL	($Gg\ NO_X$)					(%)	
Motor Gasoline	186.4	264.4	234.8	194.3	161.1	6.3%	-17.1%
Aviation Gasoline	0.6	0.6	0.7	0.5	0.7	0.0%	40.0%
Lighting Kerosene	1.6	0.8	0.5	0.2	0.1	0.0%	-50.0%
Jet Fuel	3.5	4.0	5.4	5.5	8.6	0.3%	56.4%
Diesel Oil	930.6	1,126.3	1,351.4	1,365.7	1,523.6	59.4%	11.6%
Fuel Oil	133.4	153.0	146.0	140.4	130.1	5.1%	-7.3%
LPG	14.6	19.9	32.2	26.2	28.1	1.1%	7.3%
Petroleum Coke	0.6	1.4	18.9	20.0	32.7	1.3%	63.5%
Lignite	21.9	27.2	31.1	28.2	15.7	0.6%	-44.3%
Sub-bituminous Coal	22.6	26.1	53.7	40.9	52.5	2.0%	28.4%
Other Bituminous Coal	0.0	0.0	0.0	0.0	0.2	0.0%	-
Coking Coal	0.6	3.3	6.0	6.6	2.3	0.1%	-65.2%
Coal Tar	2.6	4.1	1.8	0.9	2.1	0.1%	133.3%
Coal Coke	0.7	0.0	0.0	0.9	0.8	0.0%	-11.1%
Natural Gas (Humid)	20.4	10.0	26.3	72.1	84.5	3.3%	17.2%
Natural Gas (Dry)	14.8	32.5	80.2	122.3	155.7	6.1%	27.3%
Refinery Gas	37.8	53.8	59.1	63.4	64.4	2.5%	1.6%

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EMISSIONS BY FUEL	1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005-2010
FOSSIL	($Gg\ NO_X$)					(%)	
Other Energy Oil Products	13.8	21.4	44.4	43.7	45.6	1.8%	4.3%
Gasworks gas	0.7	0.3	0.3	0.0	0.0	-	-
Coke Oven Gas	11.8	14.1	10.4	9.2	8.3	0.3%	-9.8%
Other Primary Fossil Sources	0.6	0.4	0.6	0.9	1.0	0.0%	11.1%
Total Fossil	**1,419.6**	**1,763.6**	**2,103.8**	**2,141.9**	**2,318.1**	**90.3%**	**8.2%**
BIOMASS	**1990**	**1995**	**2000**	**2005**	**2010**	**SHARE IN 2010**	**VARIATION 2005-2010**
	($Gg\ NO_X$)					(%)	
Firewood	51.0	43.6	45.1	52.4	58.0	2.3%	10.7%
Charcoal	4.3	3.1	2.6	3.2	2.5	0.1%	-21.9%
Bagasse	44.7	55.9	51.9	82.5	123.8	4.8%	50.1%
Other Primary (biogas)	0.0	0.0	0.0	0.0	0.0	0.000%	-
Other Primary (biomass)	1.5	1.7	2.0	3.0	4.4	0.2%	46.7%
Black Liquor	5.9	9.6	13.2	19.4	27.7	1.1%	42.8%
Anhydrous Alcohol	0.0	0.0	0.0	0.0	0.0	-	-
Hydrated Alcohol	112.8	100.0	54.7	44.0	32.6	1.3%	-25.9%
Total Biomass	**220.2**	**213.9**	**169.5**	**204.5**	**249.0**	**9.7%**	**21.8%**
Total	**1,639.8**	**1,977.5**	**2,273.3**	**2,346.4**	**2,567.1**	**100.0%**	**9.4%**

Table 3.16 confirms that the main sources of NO_x emissions are fossil fuels, with growth rate during the 2005-2010 period (8.2%). In terms of subsectoral emissions in 2010 (Table 3.17), the transport subsector was the major source of NO_x emissions (56.9%), out of which 50.3% refer to road transport, followed by energy (14.5%) and industrial (11.2%) subsectors. The subsectors that contributed the most to emissions showed increasing growth rates during the 2005-2010 period: transport (3.2%), industry (18%) and energy (22%).

TABLE 3.17

NO_x emissions, by subsector

EMISSIONS BY SUBSECTOR		1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005-2010
		(Gg NO_x)					(%)	
Broad Energy subsector	Public Service Power Plants	52.2	79.1	136.4	143.5	155.2	6.0%	8.2%
	Self-Producers Power Plants	11.2	15.0	28.6	29.2	48.8	1.9%	67.1%
	Charcoal Plants	2.7	2.1	1.9	2.5	1.8	0.1%	-28.0%
	Energy Sector	148.8	170.4	228.1	304.6	371.7	14.5%	22.0%
Industry	Cement	15.8	14.7	20.9	17.8	27.7	1.1%	55.6%
	Iron and Steel	10.3	12.3	10.8	11.2	11.4	0.4%	1.8%
	Ferroalloys	0.1	0.0	0.3	0.9	0.6	0.02%	-33.3%
	Mining and Pelleting	6.7	9.9	15.7	20.3	21.1	0.8%	3.9%
	Non-Ferrous Metals	2.7	4.4	7.3	8.4	9.7	0.4%	15.5%
	Chemical	27.3	36.5	59.4	61.3	58.3	2.3%	-4.9%
	Food and Beverages	30.2	40.6	44.6	61.2	81.0	3.2%	32.4%
	Textiles	3.7	2.8	2.5	2.0	1.8	0.1%	-10.0%
	Pulp and Paper	14.3	19.2	23.8	28.0	35.7	1.4%	27.5%
	Ceramics	10.6	13.8	17.5	15.2	19.0	0.7%	25.0%
	Others	13.1	15.7	19.9	16.6	20.3	0.8%	22.3%
	Subtotal	**134.8**	**169.9**	**222.7**	**242.9**	**286.6**	**11.2%**	**18.0%**
Transport	Road Transportation	1,021.6	1,237.5	1,355.3	1,287.4	1,290.6	50.3%	0.2%
	Railways	26.3	22.2	20.9	29.2	47.7	1.9%	63.4%
	Civil Aviation	4.1	4.6	6.1	6.0	9.3	0.4%	55.0%
	Navigation	86.8	88.3	75.1	91.4	112.1	4.4%	22.6%
	Subtotal	**1,138.8**	**1,352.6**	**1,457.4**	**1,414.0**	**1,459.7**	**56.9%**	**3.2%**
Other subsectors	Residential	29.2	26.3	28.5	31.3	30.6	1.2%	-2.2%
	Commercial	4.1	4.1	5.3	3.5	2.6	0.1%	-25.7%
	Public	2.3	6.8	4.7	3.1	1.2	0.05%	-61.3%
	Agriculture	115.7	151.2	159.7	171.8	208.9	8.1%	21.6%
Total		**1,639.8**	**1,977.5**	**2,273.3**	**2,346.4**	**2,567.1**	**100%**	**9.4%**

In relation to the technologies adopted, there is a predominance of driving force emissions, which account for 71.6% of emissions in 2010, also compatible with the role of the transport subsector regarding NO_x emissions.

Non-Methane Volatile Organic Compounds

Non-methane volatile organic compounds (NMVOC) emissions are quantified in Table 3.18, which indicates a reduction by 15.2% in total emissions during the 2005-2010 period. In 2010, 900.5 Gg NMVOC were emitted from fuel combustion.

TABLE 3.18
NMVOC emissions by fuel

EMISSIONS BY FUEL	1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005-2010
FOSSIL	(Gg NMVOC)					(%)	
Motor Gasoline	373.8	431.7	351.2	300.7	230.2	25.6%	-23.4%
Aviation Gasoline	0.6	0.6	0.7	0.5	0.7	0.1%	40.0%
Lighting Kerosene	0.1	0.0	0.0	0.0	0.0	0.0%	-
Jet Fuel	0.6	0.7	1.0	0.8	0.5	0.1%	-37.5%
Diesel Oil	60.9	74.5	88.7	88.5	91.1	10.1%	2.9%
Fuel Oil	3.6	4.1	3.7	3.2	3.4	0.4%	6.2%
LPG	0.8	0.7	1.2	1.3	1.2	0.1%	-7.7%
Petroleum Coke	0.1	0.5	9.5	10.3	16.8	1.9%	63.1%
Lignite	0.1	0.1	0.1	0.0	0.0	0.0%	-
Sub-bituminous Coal	0.5	0.3	0.2	0.1	0.3	0.0%	200.0%
Other Bituminous Coal	0.0	0.0	0.0	0.0	0.0	0.0%	-
Coking Coal	0.0	0.0	0.0	0.0	0.0	0.0%	-
Coal Tar	0.1	0.2	0.1	0.0	0.1	0.0%	-
Coal Coke	0.4	0.0	0.0	0.5	0.4	0.0%	-20.0%
Natural Gas (Humid)	0.1	0.1	0.2	0.4	0.5	0.1%	25.0%
Natural Gas (Dry)	0.2	0.4	1.0	2.4	3.0	0.3%	25.0%
Refinery Gas	0.3	0.4	0.6	0.8	0.8	0.1%	0.0%
Other Energy Oil Products	0.7	1.0	2.1	2.1	2.2	0.2%	4.8%
Gasworks gas	0.1	0.0	0.0	0.0	0.0	0.0%	-
Coke Oven Gas	0.9	1.1	1.0	1.1	1.3	0.1%	18.2%
Other Primary Fossil Sources	0.0	0.0	0.0	0.0	0.0	0.0%	-
Total Fossil	443.9	516.4	461.3	412.7	352.5	**39.1%**	**-14.6%**

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BIOMASS	1990	1995	2000	2005	2010	SHARE IN 2010	VAR. 2005-2010
	(Gg NMVOC)					(%)	
Firewood	567.9	448.6	437.2	559.0	455.7	50.6%	-18.5%
Charcoal	18.8	13.1	12.1	15.1	14.4	1.6%	-4.6%
Bagasse	16.7	18.1	14.5	21.8	33.8	3.8%	55.0%
Other Primary (biogas)	0.0	0.0	0.0	0.0	0.0	0.0%	-
Other Primary (biomass)	4.8	5.5	6.1	8.6	14.2	1.6%	65.1%
Black Liquor	0.2	0.3	0.3	0.5	0.7	0.1%	40.0%
Anhydrous Alcohol	0.0	0.0	0.0	0.0	0.0	0.0%	-
Hydrated Alcohol	115.2	102.8	55.9	43.8	29.2	3.2%	-33.3%
Total Biomass	**723.6**	**588.4**	**526.1**	**648.8**	**548.0**	**60.9%**	**-15.5%**
Total	**1,167.5**	**1,104.8**	**987.4**	**1,061.5**	**900.5**	**100.0%**	**-15.2%**

Table 3.18 shows that emissions from the use of biomass sources prevail (60.9%), despite the reduction by 15.5% during the 2005-2010 period. The main driver of biomass fuels to NMVOC emissions is firewood, accounting for 50.6% of total emissions in 2010. Fossil fuels emissions decreased by 14.6% during the same period. In 2010, gasoline emissions were dominant, accounting for 25.6% of total emissions, whereas diesel oil accounted for 10.1% of the emissions. During the 2005-2010 period, there is a reduction in the NMVOC emissions due to the decrease in the consumption of gasoline from 300.7 to 230.2 Gg despite an increase from 88.5 to 91.1 Gg in the case of diesel oil.

In terms of subsectoral emissions, in 2010 (Table 3.19), the transport sector was the major source of NMVOC emissions due to road transportation (35.8%), followed by charcoal plants (24.1%) and the housing subsector (21.8%). There was a reduction in the emissions during the 2005-2010 period for charcoal plants (29%), road transportation (21.5%) and the housing subsector (11%).

TABLE 3.19

NMVOC emissions by subsector

EMISSIONS BY SUBSECTOR		1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005-2010
		(Gg NMVOC)					(%)	
Broad Energy subsector	Public Service Power Plants	0.8	1.4	2.1	3.0	3.5	0.4%	16.7%
	Self-Producers Power Plants	0.4	0.6	1.2	1.5	2.4	0.3%	60.0%
	Charcoal plants	321.2	253.6	233.3	305.8	217.0	24.1%	-29.0%
	Energy Sector	15.0	16.0	12.9	18.6	28.7	3.2%	54.3%
Industry	Cement	2.3	1.8	8.3	9.2	14.6	1.6%	58.7%
	Iron and Steel	1.1	1.3	1.1	1.2	1.4	0.2%	16.7%
	Ferroalloys	0.0	0.0	0.1	0.2	0.2	0.0%	0.0%
	Mining and Pelleting	0.7	0.3	0.8	1.8	2.7	0.3%	50.0%
	Non-Ferrous Metals	0.2	0.2	0.1	0.2	0.2	0.0%	0.0%
	Chemical	2.5	2.9	3.3	3.4	3.4	0.4%	0.0%
	Food and Beverages	9.2	9.2	9.7	11.1	14.5	1.6%	30.6%
	Textiles	0.7	0.4	0.4	0.4	0.4	0.0%	0.0%
	Pulp and Paper	7.9	9.0	10.2	12.7	18.5	2.1%	45.7%
	Ceramics	4.1	3.7	4.2	4.5	6.4	0.7%	42.2%
	Others	2.5	2.4	3.5	3.9	5.0	0.6%	28.2%
	Subtotal	**31.2**	**31.2**	**41.7**	**48.6**	**67.3**	**7.5%**	**38.5%**
Transport	Road Transportation	534.9	589.9	475.3	410.4	322.0	35.8%	-21.5%
	Railways	2.3	2.0	1.9	2.6	4.2	0.5%	61.5%
	Civil Aviation	1.3	1.3	1.7	1.3	1.2	0.1%	-7.7%
	Navigation	3.0	3.0	2.6	3.1	3.9	0.4%	25.8%
	Subtotal	**541.5**	**596.2**	**481.5**	**417.4**	**331.3**	**36.8%**	**-20.6%**

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EMISSIONS BY SUBSECTOR		1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005-2010
		(Gg NMVOC)					(%)	
Other subsectors	Residential	216.5	164.9	175.9	220.3	196.1	21.8%	-11.0%
	Commercial	2.8	2.4	2.5	2.4	2.7	0.3%	12.5%
	Public	0.3	0.8	0.8	0.6	0.4	0.0%	-33.3%
	Agriculture	37.8	37.7	35.5	43.3	51.1	5.7%	18.0%
Total		**1,167.5**	**1,104.8**	**987.4**	**1,061.5**	**900.5**	**100%**	**-15.2%**

NMVOC emissions per subsector convey the predominance of the transport subsector, due to road traffic, which accounts for 35.8%, followed by charcoal plants, which contribute with 24.1%, and the housing subsector, which was the source for 21.8% of the total emissions in 2010.

The use in direct heating stands out with 51.3% of the emissions in 2010, followed by driving force with a 30.2% share in the total emissions of NMVOCs in 2010.

3.1.3. Fugitive Emissions

3.1.3.1. Fugitive emissions from coal mining

This section presents estimates for greenhouse gas emissions from the coal mining industry, in mining and processing operations, for the 1990-2010 period. The estimates include the fugitive emissions of CH_4 of open pit and underground mines and the post-mining activities. In addition to these, CO_2 emissions from the spontaneous combustion of waste piles are also estimated. Brazil did not report any cases in the period between 1990 and 2010 involving the recovery of gases and thermal conversion in coal mining companies. Therefore this category was disregarded for the application of the IPCC methodology (1996).

Coal is formed from the burial and decomposition of vegetable matter. As they undergo burial and compaction processes in deposition basins, these materials gradually increase their carbon content. External factors, such as pressure, temperature and exposure time determine the characteristics of the coal, including the degree of carbonification of these fuels.

Coal production in Brazil takes place in the three southern states in the country: Rio Grande do Sul, Santa Catarina and Paraná, where the main coal reserves are located. Rio Grande do Sul is the state with the largest geological reserves, followed by Santa Catarina and Paraná. Brazilian coal quality varies from south to north, reducing ash content and increase calorific value and sulfur content, demanding environmental control due to SO_x emissions (sulfur oxides – SO_2 and SO_3).

CH_4 production is inherent to the coal formation process, being released to the atmosphere in the mining process. The amount of CH_4 released during the mining process is a primary function of the coal classification, of the depth it is located, of its gas content and of the mining method. CO_2 emissions may also occur as a result of coal burning in waste deposits and piles.

Brazil produces two types of coal: energetic coal, also called steam coal, for industrial application in steam and energy production; and metallurgical coal, for industrial application in steel mills. A significant increase can be observed in steam coal production from 1990 to 2010. Metallurgical coal, on the other hand, has been entirely imported since 2010.

Brazil's dependence on imported coking coal rose from 79% in 2005 to 82% in 2010, mainly on account of the metallurgical coal, and in the 1980s the steel industry started replacing the national metallurgical coal by the imported coal.

The total production of run-of-mine (ROM) coal in Brazil is shown in Table 3.20. There was a small reduction in terms of production compared to 2005. In 2010, 53.6% of coal production was from underground mines and 46.4% from surface mines. Data used for developing this survey and applying the IPCC methodology were obtained from official sources from national government entities, specifically the National Department of Mineral Production (DNPM), under the Ministry of Mines and Energy (MME). These publications ceased in 2000, motivating a review of the database and the consultation of the Annual Mining Report (RAL) informed by the sector to the DNPM.

ROM coal production data were obtained from Annual Carbon Industry Information/DNPM, detailed per mine. However, there is no detailed data by mine for 1997 for the states of Rio Grande do Sul and Paraná and for 2000 there is no data for any state. DNPM's Brazilian Mineral Yearbook provides ROM coal production by state for 1996 to 2000 and for the processed products from 1996 to 2010. As of 2005, along with DNPM (extracted directly from RAL) in the states of Rio Grande do Sul, Santa Catarina and Paraná, considering the years from 2006 to 2012 as base years.

The share of coal and its by-products in the primary energy supply in Brazil dropped from 6.8% in 1990 to 6.4% in 2005, and then to 5.4% in 2010. Coal's share in the supply of primary energy exceeds national production due to imports by several sectors.

TABLE 3.20
Run-of-mine coal production (ROM)

RUN-OF-MINE COAL (ROM)	1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005-2010
	PRODUCTION (t)					(%)	
Open-pit mines							
Rio Grande do Sul	3,577,545	3,587,888	5,950,038	4,250,367	4,523,071	46.4%	6.4%
Santa Catarina	21,970	453,236	383,873	131,720	0	0,0%	-100.0%
Paraná	0	0	0	0	0	0,0%	-
Total open-pit mines	**3,599,515**	**4,041,124**	**6,333,911**	**4,382,087**	**4,523,071**	**46.4%**	**3.2%**

continues on the next page

RUN-OF-MINE COAL (ROM)	1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005-2010
	PRODUCTION (t)					(%)	
Underground mines							
Rio Grande do Sul	213,527	86,931	53,058	0	0	0.0%	-
Santa Catarina	6,231,261	5,163,126	5,571,109	6,300,417	4,933,730	50.6%	-21.7%
Paraná	239,313	254,172	108,225	287,573	293,328	3.0%	2.0%
Total underground mines	**6,684,101**	**5,504,229**	**5,732,392**	**6,587,990**	**5,227,058**	**53.6%**	**-20.7%**
Total Brazil	**10,283,616**	**9,545,353**	**12,066,303**	**10,970,077**	**9,750,129**	**100%**	**-11.1%**

Methane Emissions

Methane content in coal is related to factors like rank (degree of carbonification of the original vegetable matter), depth of the layer and physical-chemical properties, among others. However, there are relevant geological factors that affect the dynamic balance of methane found in the coal layer.

In the same way as presented in the Second Inventory, despite the initial effort of studies for the search of emission factors that could better reflect the reality of Brazil's coal mining and handling, for this publication the approach adopted was the 1996 Tier 1 Guidelines minimum emission factors, not only for post-mining, but, coherently, for the mining as well. The adopted approach aimed at safeguarding the reliability of calculated values, considering that the experimental part pointed to divergences between the behavior conceptually foreseen for methane emissions and the results achieved in the sampled mines. For open-pit mines, the minimum null value for post-mining was discarded and an arbitrated value was used so measured emissions would not be disregarded. The factors adopted in this Inventory are shown in Table 3.21.

TABLE 3.21
Emission factors for CH_4 of fugitive emissions of coal production

EMISSION FACTORS FOR CH_4 FUGITIVE EMISSION FROM COAL	LOW EMISSION LEVEL	
	MINING	POST-MINING
	(M^3 CH_4/t COAL)	
Underground mines	10	0.9
Open-pit mines	0.3	0.05

Total CH_4 emissions are shown in Table 3.22. Underground mines accounted for 89.26% of total CH_4 emissions, open-air mines accounted for 2.3% and emissions from post-mining activities represented 8.4% of the total.

TABLE 3.22
CH_4 emissions from coal mines

COAL MINING AND POST-MINING EMISSION	1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005-2010
	(Gg CH_4)					(%)	
Open-pit mining							
Rio Grande do Sul	0.7	0.7	1.2	0.9	0.9	2.3%	6.4%
Santa Catarina	0.0	0.1	0.1	0.0	0.0	0.0%	-100.0%
Paraná	0.0	0.0	0.0	0.0	0.0	0.0%	-
Total	**0.7**	**0.8**	**1.3**	**0.9**	**0.9**	**2.3%**	**3.2%**
Underground mining							
Rio Grande do Sul	1.4	0.6	0.4	0.0	0.0	0.0%	-
Santa Catarina	41.7	34.6	37.3	42.2	33.1	84.3%	-21.7%
Paraná	1.6	1.7	0.7	1.9	2.0	5.0%	2.0%
Total	**44.8**	**36.9**	**38.4**	**44.1**	**35.0**	**89.3%**	**-20.7%**
Post-mining							
Rio Grande do Sul	0.2	0.2	0.2	0.1	0.2	0.4%	6.4%
Santa Catarina	3.8	3.1	3.4	3.8	3.0	7.6%	-21.8%
Paraná	0.1	0.2	0.1	0.2	0.2	0.5%	2.0%
Total	**4.2**	**3.5**	**3.7**	**4.1**	**3.3**	**8.4%**	**-19.8%**
Total Brazil	**49.7**	**41.1**	**43.3**	**49.1**	**39.2**	**100%**	**-20.2%**

Carbon Dioxide Emissions

Carbon present in coal can be converted into CO_2 emissions from inadvertent combustion in storage and in waste, as well as in final consumption. This Inventory considers all extracted ROM coal processed, resulting in washed (energetic) coal and waste. In order to assess CO_2 emissions resulting from inadvertent combustion in waste piles, the quantity of waste was estimated using company records, mass balances and average carbon content in ROM coal and in processed products. In this evaluation, ROM coal was considered a product that does not remain as extracted from the mine, being immediately processed or sold.

A limiting factor for estimating CO_2 emissions is the absence of knowledge of run-of-mine and washed coal storage time, nor of the waste piles. For this survey, only those mines that produce made to order coal or that have a guaranteed consumer market (and therefore do not administer coal stocks) were considered. It was also considered that all carbon present in ROM coal was transferred to processed products and to waste, with the process losses being accounted for in the waste. Since in Santa Catarina, waste was reprocessed, carbon percentages were estimated and the carbon thus calculated was added to the carbon in the run-of-mine coal for mass balance. For calculating CO_2 emissions, a 50% oxidation factor was used for waste.

Estimates of CO_2 emissions from coal deposits and waste piles can be observed in Table 3.23 separately, and by producer states.

TABLE 3.23

CO_2 emissions from coal mines and waste piles

CALCULATING CO_2 EMISSIONS FROM WASTE PILES	1990	1995	2000	2005	2010	VARIATION 2005-2010
Carbon in Run-of-Mine coal (t)						
Rio Grande do Sul	890,966	892,079	1,437,521	903,529	1,008,459	11.6%
Santa Catarina	1,438,429	1,331,633	1,390,053	1,628,249	1,377,788	-15.4%
Paraná	58,870	57,791	24,892	66,142	64,532	-2.4%
Brasil	**2,388,265**	**2,281,503**	**2,852,467**	**2,597,920**	**2,450,779**	-5.7%
Carbon in products (t)						
Rio Grande do Sul	785,152	849,515	1,110,514	935,733	545,806	-41.7%
Santa Catarina	812,407	872,812	1,013,524	910,669	859,948	-5.6%
Paraná	52,684	57,181	24,167	30,429	38,043	25.0%
Brasil	**1,650,244**	**1,779,508**	**2,148,205**	**1,876,831**	**1,443,796**	-23.1%
Carbon in waste piles (t)						
Rio Grande do Sul	105,814	42,564	327,008	0	462,653	-
Santa Catarina	626,022	458,821	376,529	717,580	517,841	-27.8%
Paraná	6,186	610	725	35,712	26,490	-25.8%
Brasil	**738,022**	**501,995**	**704,262**	**753,292**	**1,006,983**	33.7%
Emissions (Gg CO_2)	**1,353**	**920**	**1,291**	**1,381**	**1,846**	**33.7%**

3.1.3.2. Fugitive emissions from oil and natural gas activities

This category includes emissions from production, processing, transportation and use of oil and natural gas and from combustion not related to production. Therefore, anthropogenic emissions of CO_2, CH_4 and N_2O are estimated due to oil and natural gas activities. Fugitive emission sources are considered for: Exploration and Production (E&P), Refining and Transportation. In addition to the emissions concerning Petrobras, the estimates of emissions from other companies that carry out activities in the oil and gas industry in Brazil are also presented, for the first time, between 2003 and 2010, calculated based on an extrapolation of data from the production and the processing as well as the application of Petrobras' implicit annual emission factors.

Emissions associated with oil and natural gas include fugitive emissions of CH_4 during oil and natural gas production (venting), during transportation and distribution in pipelines and ships and during processing at refineries. CO_2 emissions from non-useful combustion (flaring) at oil and natural gas production platforms and refining units are also considered. The following processes and equipment were considered:

>> Exploration and Production (E&P): Torch (flare), Gas ventilation, methane flash tanks, glycol dehydration process, CO_2 removal process from gas (MEA/ DEA), running pigs in lines, fugitives from line components (flanges, connectors, valves, pump and compressor seals, drains and others), drilling activities, oil spill in trenches, depressurization and clearing of tanks and vessels;

>> Refining: UFCC Regenerator, Hydrogen Generation Units (HGU), fugitives from line components (flanges, connectors, valves, pump and compressor seals, drains and others), torch (flare), gas vent, glycol dehydration and pig passages in lines and;

>> Transport: line decompression, fugitives from line components (flanges, connectors, valves, pump and compressor seals, drains and others), pipeline, gas vent, torch (flare), methane flash in tanks and pig passage in lines.

The use of oil and natural gas, or their by-products, for domestic use in the production of energy and transport is considered as combustion and, therefore, discussed in another Energy sector section.

Data from condensed oil and liquid natural gas (LNG) production were used to calculate fugitive emissions in the Exploration and Production (E&P) area and for the estimates of the emissions from the refining area, data on the volume of load processed in refineries were used. The national data on the production of oil, condensate and liquid natural gas (LNG) were obtained by Petrobras for the years between 1990 and 2000, and by ANP, for the years 2000 to 2010. Table 3.24 displays the data for the years 1990, 1995, 2000, 2005 and 2010.

TABLE 3.24

Production of Condensed Oil and Liquid Natural Gas

PRODUCTION	1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005-2010
	(BPD*)					(%)	
Condensed Oil	631,256	693,024	1,234,592	1,633,574	2,054,668	96.1%	25.8%
LNG	22,372	23,137	35,931	79,297	82,749	3.9%	4.4%
Total	**653,628**	**716,161**	**1,270,523**	**1,712,871**	**2,137,417**	**100%**	**24.8%**

* *bpd- barrels per day*

The processed load in refineries was obtained from ANP website for the period between 2000 a 2010. For 1990 and 1999, the processed load volume was obtained from BEN. Data for 1990, 1995, 2000, 2005 and 2010 can be seen in Table 3.25.

TABLE 3.25

Volume of oil processed by Brazilian refineries

VOLUME OF OIL PROCESSED BY BRAZILIAN REFINERIES	1990	1995	2000	2005	2010	VARIATION 2005-2010
	(BPD*)					(%)
	1,175,310	1,236,720	1,619,328	1,740,720	1,813,257	4.2%

** bpd- barrels per day*

The Inventory of fugitive emissions from the oil and gas sectors includes the three Tiers, depending on the period considered, on the greenhouse gas and on the typology of the emission source. Table 3.26 shows the estimated emissions.

TABLE 3.26

Oil and Natural Gas fugitive emissions

GAS	1990	1995	2000	2005	2010	VARIATION 2005-2010
	(Gg)					(%)
CO_2	6,201	6,594	9,446	12,496	13,368	7.0%
CH_4	40.8	44.4	75.7	157.1	141.7	-9.8%
N_2O	0.06	0.06	0.11	0.21	0.21	0.0%

With regard to CH_4 emissions, a larger share of the E&P area in the total emissions of the subsector is noticed, although decreasing from 89.9% in 2005 to 87.2% in 2010. In the case of the N_2O fugitive emissions, there is also a larger involvement of E&P, representing 95.7% in 2010. CO_2 emissions are those related to the activities of *flaring*. As a consequence of the relative increment in production, an increase by 7% in total CO_2 emissions was observed in the 2005 to 2010 period.

Condensed oil production reveals a growth of 25.8% from 2005 to 2010, whereas NGL grew 4.4%. Despite this increase, on account of the emission factors applied, it was observed that, as regards the activities of E&P, only the fugitive emissions of CO_2 increased by 4.4%, while those of CH_4 and N_2 reduced by 12.4% and 0.1%, respectively, in the period between 2005 and 2010.

CO_2 and CH_4 emissions relating to refining activities rose during the 2005 to 2010 range. In terms of production, there is an increase of 4.2% in the volume of load processed in the Brazilian refineries. Fugitive emissions from the Refining area increased by 9.6% for CO_2 and 10% for CH_4, and decreased by 14.1% for N_2O.

3.2. INDUSTRIAL PROCESSES

Some industries generate greenhouse gases as a by-product of their production processes. In addition to these emissions, the industrial sector is also responsible for a share of the CO_2 emissions by fossil fuels combustion for power generation. The latter are allocated in the Energy sector.

The main industrial processes that generate CO_2 emissions in Brazil are iron and steel production, cement production, lime production, aluminum production and ammonia production. Iron and steel production is the largest source of CH_4 emissions due to the use of charcoal by the pig iron industries. N_2O emissions occur mainly in the production processes of adipic and nitric acid, and also in the production of iron and steel. During the production of iron and steel, iron-alloys and aluminum, there are emissions of CO and PFCs (CF_4 and C_2F_6). Pulp and paper production is the main NO_x generator. The food and beverage subsector is responsible for most NMVOC emissions by industrial processes. HFC emissions occur during their use in the refrigeration sector and during production of HCFC-22.

3.2.1. Mineral Products

3.2.1.1. Cement Production

In 2011, Brazil ranked 6th in cement production in the world, according to information of the 2012 Annual Report of the National Cement Industry Union (SNIC, 2012) and production took place in several states. In 2012 the cement industrial park was composed of 83 plants, 53 of which were integrated plants (out of which 46 associated with the SNIC and 7 not) with oven for the production of cement clinker, and the other 30 were only mills (22 were associated with the SNIC and 8 were not), which use the ready-made clinker.

Globally, approximately 90% of CO_2 emissions from cement manufacturing occur during clinker production, both for the calcination/decarbonation of raw material, or for the fuel combustion in furnaces. The remaining emissions derive from the transportation of raw materials and for the electricity consumption at the factory. The emissions reported in the Industrial Processes sector are only for calcination/ decarbonation of raw materials.

Clinker is obtained from the calcination of limestone ($CaCO_3$), a process that generates CO_2 emissions. Table 3.27 presents a summary of the data for the 1990 to 2010 period.

TABLE 3.27
Cement and clinker production

PRODUCT	1990	1995	2000	2005	2010	VAR. 2005/ 2010
	(10^3 t)					(%)
Cement	25,848	28,256	39,901	38,706	59,117	52.7%
Clinker	20,161	21,071	29,227	26,307	39,119	48.7%

Source: National Cement Industries Union – SNIC (2012).

The national cement industry has a tradition of using cement with additions, making use of by-products from other activities (such as slag and thermoelectric ash) and alternative raw materials. These additions have been ongoing for over 50 years in the country, a practice that only recently has been adopted worldwide and which, in addition to diversifying the applications and specific characteristics of the cement, leads to less CO_2 emissions, both by decreasing the production of clinker and by reducing the use of fossil fuels. The growing use, for a long time, of additions to cement in Brazil has represented one of the most effective measures for the control and the reduction of CO_2 emissions from the industry.

For this reason the Brazilian cement industry is committed to obtaining every detailed information necessary for the application of the sectoral methodology of the Cement Sustainability Initiative (CSI), an initiative of the largest world cement groups linked to the World Business Council for Sustainable Development (WBCSD), aiming at developing a series of environmental actions, among which are the control and the monitoring of GHG emissions. This information is consistent with the Tier 3 approach of the 2006 IPCC Guidelines for National Inventories of Greenhouse Gases (IPCC, 2006), which considers the composition of raw materials (carbonates) used, corrects the emissions by the MgO content and includes other specific parameters such as the correction of cement kiln dust (CKD), which is regarded as a system loss, and the carbon of the organic matter contained in raw materials. The CO_2 emissions were calculated using the default recommended by the CSI methodology and, whenever there were no available data, the EF of 0.536 t CO_2 /t clinker was used, considering the organic carbon contained in the raw material. The results are summarized in Table 3.28.

TABLE 3.28

CO_2 emissions from limestone decarbonation in cement production

EMISSIONS SOURCE	1990	1995	2000	2005	2010	VAR. 2005/ 2010
	(Gg CO_2)					(%)
Cement production	11,062	11,528	16,047	14,349	21,288	48.4%

3.2.1.2. Lime production

In 2010, Brazil was responsible for 2.5% of the global lime production, and was the fourth largest producer, after China, United States and India, in this order.

The term lime is used in Brazilian literature and in Brazilian Association of Technical Standards (ABNT) to designate the product made of calcium oxide (CaO) and calcium and magnesium oxide (CaO.MgO), resulting from the calcination of limestone, magnesium and dolomite limestone. Lime is classified in accordance with the total percentage of calcium oxide. Thus, when referring to a type of lime, reference is actually made to a range of products with different amounts of CaO and CaO.MgO.

Lime is formed by heating limestone for decomposition of carbonates, a process called calcination or decarbonation. It is carried out at high temperatures in a rotary oven, followed by CO_2 emissions. Hydrated lime is obtained from quicklime by adding water. Dolomite ($CaCO_3.MgCO_3$) can also be processed at high temperatures to obtain dolomite lime (and CO_2 emissions). Lime is a product with several applications, among which metallurgy, civil construction, pulp and paper industry, water and effluent treatment, pH control and soil stabilization stand out.

Table 3.29 presents the production of quicklime and hydrated lime ($Ca(OH)_2$ or $Ca(OH)_2 \cdot Mg(OH)_2$), for some years in the period 1990-2010.

TABLE 3.29
Lime production in Brazil

PRODUCT	1990	1995	2000	2005	2010	VAR. 2005/ 2010
	PRODUCTION (10^3 t)					(%)
Quicklime – associated with ABPC	1,335	1,444	1,595	2,189	4.677	26.1%
Quicklime – non-associated with ABPC	646	546	1,491	1.521		
Quicklime – captive production	1,048	1,427	1,546	1,392	995	-28.5%
Total quicklime	**3,029**	**3,417**	**4,632**	**5,102**	**5,672**	**11.2%**
Hydrated lime – associated with ABPC	978	1,273	1,244	1,165	2,089	10.8%
Hydrated lime – non-associated with ABPC	893	754	682	720		
Total Hydrated lime	**1,871**	**2,027**	**1,926**	**1,885**	**2,089**	**10.8%**
Total	**4,900**	**5,444**	**6,558**	**6,987**	**7,761**	**11.1%**

Source: Brazilian Association of Lime Producers (ABPC).

Similar to the cement and lime production processes, there are others where limestone and dolomite are submitted to high temperatures and where CO_2 is released, at the same time in which the produced lime undergoes several other reactions. This item encompasses the processes that involve limestone and dolomite calcination, besides those related to cement and lime production. For other uses, the steel industry, the production of glass and the production of magnesium have been analyzed. CO_2 emissions from lime production and those tied to other uses of limestone and dolomite are shown in Table 3.30.

TABLE 3.30
CO_2 emissions from lime production and other uses for limestone and dolomite

CO_2 EMISSIONS	1990	1995	2000	2005	2010	VAR. 2005/ 2010
	(Gg CO_2)					(%)
Lime production	3,688	4,104	5,008	5,356	5,950	11.1%
Other uses of limestone and dolomite	1,630	1,728	1,756	1,815	3,060	68.6%

3.2.1.3. Production and consumption of soda ash

Soda ash (neutral sodium carbonate – Na_2CO_3) is used as feedstock in many industries, including glass, soap and detergent manufacturing, pulp and paper production and water treatment.

Four different processes can be commercially used to produce soda ash. Three are referred to as natural processes and use trona as a basic input. The fourth, the Solvay process, is classified as a synthetic process. The natural processes are the only ones that produce CO_2 emissions. Brazilian production, discontinued in 2002, used the synthetic process, and thus no net emissions were produced.

CO_2 emissions occur when soda ash is consumed in industry. Consumption is calculated based on data on production, imports and exports of soda ash in Brazil, shown in Table 3.31.

TABLE 3.31
Production, imports, exports and consumption of soda ash

PRODUCT	1990	1995	2000	2005	2010	VAR. 2005/ 2010
	(t)					(%)
Production	195,893	203,950	190,616	-	-	NA
Imports	242,788	392,071	393,845	597,888	954,675	59.7%
Exports	-	2	4	2	47	2230.0%
Consumption	**438,681**	**596,019**	**584,457**	**597,886**	**954,629**	**59.7%**

Source: Brazilian Association of Chemical Industry (ABIQUIM).

For the estimates of CO_2 emissions, it is assumed that one carbon mol is released for each mol of soda ash consumed. Hence the 0.415 t CO_2 / t Na_2CO_3 emission factor was used. Estimated CO_2 emissions are shown in Table 3.32.

TABLE 3.32
CO_2 emission from soda ash consumption

USE OF SODA ASH	1990	1995	2000	2005	2010	VAR. 2005/ 2010
	(Gg CO_2)					(%)
CO_2 emissions	182	247	243	248	396	59.7%

3.2.2. Chemical Industry

Several production processes in the national chemical industry cause greenhouse gas emissions – CO_2, CH_4 and N_2O – as well as indirect greenhouse gas emissions – CO, NO_x and NMVOC. These emissions deriving from the chemical sector in Brazil are associated with the production of ammonia, nitric acid, adipic acid, caprolactam, calcium carbide calcium, petrochemicals (methanol, ethylene, dichloroethane and vinyl chloride, ethylene oxide and acrylonitrile), carbon black and petroleum coke. In addition, other chemicals such as ABS resins, phthalic anhydride, styrene butadiene rubber (SBR), styrene, ethylbenzene, formaldehyde, polyvinyl chloride (PVC), polystyrene, polyethylene (HDPE), polyethylene (LDPE), polyethylene (LLDPE), polypropylene and propylene produce indirect emissions of volatile organic compounds such as SO_2, NO_x, NMVOC and CO. The production of titanium oxide was not assessed, because the technological route used in Brazil does not emit GHG.

With the advance in biofuel production technologies, the national chemistry industry has begun to replace fossil fuels, used as raw materials in its production processes, with renewable fuels. This action aims at reducing greenhouse gas emissions in the process. Additionally, new N_2O control technologies have been adopted, mainly for adipic acid production, which were responsible for most of this sort of greenhouse gas emissions.

Direct greenhouse gases were estimated based on 2006 Guidelines (IPCC, 2006) and indirect greenhouse gases based on 1996 Guidelines (IPCC, 1997).

3.2.2.1. Ammonia production

Ammonia is one of the basic chemical products, produced in large quantities, used as a source of nitrogen. It is a raw material for manufacturing urea, the main nitrogenized fertilizer, and for producing nitric acid, an intermediate element in the production of ammonium nitrate fertilizer or explosive.

Ammonia production requires a source of hydrogen and another of nitrogen. The atmosphere is the nitrogen source. Hydrogen can be obtained from different raw materials, such as: asphalt residue, residual refining gas, natural gas, petrochemical naphtha and ethanol.

CO_2 is generated as a by-product of ammonia production, and is released into the atmosphere. When there is integration with an urea or methanol plant, part of this CO_2 is used as a raw material to produce those products. Alternatively, CO_2 can also be recovered for use as a refrigerant fluid, in liquid carbonation and as an inert gas. In all such cases, however, CO_2 is short-lived and thus not deducted from ammonia production emissions.

Until 2005, the emissions from the production of ammonia were estimated on the basis of the measurement of fuels used as raw materials in the process, as per the 2006 Guidelines, without the due discount of the share of CO_2 intended for the production of urea in integrated plants as oriented in the 2006 Guidelines. After this, considering the raw materials used in Brazil and their respective FEs, an average value was obtained for the national emission factor of 1.46 t CO_2 /t of ammonia, which was applied to all years of the 1990 to 2010 period.

Ammonia production is presented in Table 3.33, and the corresponding CO_2 emissions are displayed in Table 3.34.

3.2.2.2. Nitric acid production

Nitric acid (HNO_3) is an inorganic compound mainly used for manufacturing synthetic fertilizers. It is the most important compound not only as a feedstock in adipic acid production, but also as an intermediate element in concentrated nitric acid production, as a nitration agent in organic compounds or as an input for the production of explosives.

The traditional and commercially available production process for nitric acid involves the catalytic oxidation of ammonia with air and the subsequent reactions of oxidation with water, through the Ostwald process, generating N_2O as a by-product. Furthermore, NO_x emissions other than those from combustion may occur.

In production units in Brazil, which comprise low pressure and medium pressure and vacuum plants, there are abatement technologies for NO and NO_2 emissions (nitric oxide, nitrogen dioxide, generically called NO_x), in accordance with the standards established by environmental control entities.

From late 2006, CDM project activities began to be developed in Brazil, involving the installation of secondary catalyzers for N_2O destruction. After July 2007, with the implementation of a CDM project in medium-pressure plant, this plant's measured emission factor was reduced from 6.01 kg N_2O/t HNO_3 to 0.52 kg N_2O/t HNO_3.

N_2O emissions were estimated using different methods, depending on the plant. For those plants that conducted CDM project activities, it was possible to apply the most accurate method (Tier 3), with direct measurements of emissions, which result in specific emission factors for each plant. For the others, the simplified method was used, applying default emission factors from 2006 Guidelines.

For NO_X emissions, the country's specific emission factor was applied, 1.75 kg NO_X /t nitric acid, in accordance with ABIQUIM, as a result of the emission controls for these gases in the country.

Nitric acid production is shown in Table 3.33 and the corresponding N_2O and NO_X emissions in Table 3.34.

3.2.2.3. Adipic acid production

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

The only adipic acid plant in Brazil uses the two-stage production technology. The first involves cyclohexane oxidation for the cyclohexanone/cyclohexanol mixture. The second stage involves the cyclohexanol oxidation process using nitric acid. In this latter stage, N_2O is released. Adipic acid production also emits CO and NO_x.

An N_2O abatement project at this factory was registered at the CDM Executive Board in the end of 2005, with effective destruction of N_2O from 2007. A dedicated installation was constructed for high temperature conversion of nitrous oxide into nitrogen, as part of the N_2O thermal decomposition process.

The measured N_2O emission factor was of 0.270 t N_2O/t adipic acid, applied from 1990 to 2006. After implementation of the CDM project in 2007, there was a significant emission reduction, and the implicit emission factor, also obtained by measurements, ranged from 0.00640 t N_2O/t adipic acid to 0.00155 t N_2O/t adipic acid.

Indirect greenhouse gases were estimated with national emission factors as a result of the control of emissions of these gases in the country. CO emissions were estimated with a factor of 16 kg CO/t adipic acid. below the 1996 Guidelines default, 34.4 kg CO/t adipic acid. For NO_x emissions, the emission factor of 5 kg NO_x /t adipic acid, below the default of 8.1 kg NO_x /t adipic acid from the 1996 Guidelines, was applied.

Adipic acid production is shown in Table 3.33 and the corresponding N_2O, CO and NO_x emissions in Table 3.34.

3.2.2.4. Caprolactam production

The primary industrial use of caprolactam is as a monomer in the production of nylon-6. This chemical is also used for manufacturing plastics, bristles, films, covers, carpets, synthetic leather, plasticizers, and automotive paints. It is biodegradable and allows for a removal rate up to 94% for the chemical demand for oxygen in activated sludge systems.

Brazilian production of caprolactam stems from the hydrogenation of benzene to cyclohexane, oxidation of cyclohexanol and cyclohexanone with nitric acid, a step in which N_2O is generated, followed by the dehydrogenation of the cyclohexanol produced and subsequent reaction with sulfate.

N_2O emissions were based on plant measurements adopting the resulting average value of 6 kg N_2O/t caprolactam was adopted.

Caprolactam production is shown in Table 3.33 and the corresponding N_2O emissions in Table 3.34.

3.2.2.5. Calcium carbide production and use

Calcium carbide (CaC_2) is produced from the calcination of limestone and the subsequent reduction of lime with petroleum coke or charcoal. These two types of reducing agents are used in Brazil. Emissions related to lime production are reported in the specific lime item. From the reaction of calcium carbide production, only those emissions related to the use of petroleum coke, a fossil fuel, are considered.

Around 67% of the carbon contained in petroleum coke is retained in the final product (CaC_2). Later use of calcium carbide in the steel industry and in the production of acetylene leads to more CO_2 emissions.

CO_2 emissions associated with the production of calcium carbide (CaC_2) were based on petroleum coke consumption data, using the default emission factor of 1.7 t CO_2 / t consumed coke. The emission factor 1.10 t CO_2/ t CaC_2 consumed was used for consumption, disregarding the emissions that occur after product exportation, which accounts for about 15% of national production.

The calcium carbide production data are confidential. However, the corresponding emissions are shown in Table 3.34.

TABLE 3.33
Ammonia, nitric acid, adipic acid, and caprolactam production

CHEMICAL PRODUCT	1990	1995	2000	2005	2010	VAR. 2005/ 2010
	(t)					(%)
Ammonia	1,152,563	1,222,348	1,139,109	1,316,154	1,191,042	-9.5%
Nitric Acid	295,824	332,842	336,025	363,422	360,083	-0.9%
Adipic Acid	31,951	55,864	64,862	75,147	86,286	14.8%
Caprolactam	42,059	52,608	56,005	49,655	-	-100.0%

Source: ABIQUIM.

TABLE 3.34

Greenhouse gas emissions from ammonia, calcium carbide, nitric acid, adipic acid, and caprolactam production

GAS	CHEMICAL PRODUCT	1990	1995	2000	2005	2010	VAR. 2005/ 2010
		(Gg)					(%)
CO_2	Ammonia	1,683	1,785	1,663	1,922	1,739	-9.5%
	Calcium Carbide	0	4	51	35	42	20.0%
N_2O	Nitric Acid	1.81	2.05	2.09	2.24	0.80	-64.3%
	Adipic Acid	8.63	15.08	17.51	20.29	0.13	-99.4%
	Caprolactam	0.25	0.32	0.34	0.30	0.00	-100.0%
CO	Adipic Acid	0.5	0.9	1.0	1.2	1.4	16.7%
NO_x	Nitric Acid	0.5	0.6	0.6	0.6	0.6	0.0%
	Adipic Acid	0.2	0.3	0.3	0.4	0.4	0.0%

3.2.2.6. Petrochemical and carbon black production

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

Methanol

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

Methanol production technologies need hydrogen, CO and CO_2. In Brazil, the process consists of low and high-pressure synthesis and the raw materials are CH_4 and CO_2.

Natural gas fed in the synthesis reactor uses primary reformation as the process for hydrogen and CO generation. CO_2 as a raw material is obtained by partially recycling the gas produced in the CO conversion phase. Alternatively, CO_2 can be obtained as a by-product from another production process, as in ammonia production, for example.

The main greenhouse gases emitted are: CO_2 and CH_4, with estimated emissions with default factors of 0.267 t CO_2 / t methanol, and 2.3 kg CH_4 / t methanol.

Ethylene

Ethylene is the most produced primary hydrocarbon in the country and one of the most important products in the petrochemical industry value chain. It is used in the plastic production process including high and low density polyethylenes and polyvinyl chloride, and is also used as a raw material in the manufacturing of vinyl chloride, ethylene oxide, ethylbenzene and dichloroethylene.

Ethylene is universally produced through the cracking of petrochemical raw materials. Ethylene production also generates propylene, butadiene and aromatic compounds as secondary substances. The traditional naphtha cracking process is the technological route used in Brazil. However, in 2004, natural gas was introduced for the first time as a raw material in the pyrolysis process.

The main gases emitted are CO_2 and CH_4, in addition to NMVOC. By 2005, the emissions of CO_2 were estimated with the default emission factor of 1.73 kg CO_2/t ethylene, corrected by a factor of 1.1 to account for the mix of production line of the steam cracker process, which includes, in addition to ethylene, propylene, butadiene, aromatic hydrocarbons and other chemicals. For CH_4, default factors of 3 kg CH_4/t ethylene were also used. As of 2006, with the start-up of the plant that uses natural gas, the factors had to be calculated from the specific measurements of the plants' consumption of fossil raw materials. For carbon dioxide, the EFs from 2006 onwards began to be 1.74 kg CO_2/t ethylene, while for methane it was 3.54 kg CH_4 /t of ethylene between 2006 and 2009 and 3.25 kg of CH_4 /t of ethylene from 2010.

For indirect greenhouse gases, the default emission factor of the 1996 Guidelines, of 1.4 kg NMVOC/t ethylene, was used.

Dichloroethane and vinyl chloride (MVC)

Dichloroethane (1.2 dichloroethane) was one of the first chlorinated hydrocarbons, synthesized in 1795, as a light-colored oily, with a sweet chloroform scent. It is used as an intermediate in the production of vinyl chloride – MVC, solvents, polychlorinated hydrocarbons, ethylene glycol and others. It is also used as a solvent for greases, oils and fats, industrial cleaning, additive for fuels and in solvent formulations. It is also much used in the extraction of natural products like steroids, vitamin A, caffeine and nicotine. MVC is applied as an intermediate in the production of polyvinyl chloride, broadly used in electrical materials and wires manufacturing, civil construction materials, tubes, connections and packaging.

Production of MVC and dichloroethane in Brazil uses direct chlorination and ethylene oxichlorination technological route, using hydrogen chloride generated in dichloroethane cracking. MVC and dichloroethane production plant can operate as a "balanced process" between the two products. Since the process does not reach 100% conversion of ethylene, a small percentage of raw material is not converted. Thus, exhaust gases are treated to eliminate the chlorinated compounds formed in secondary reactions. Non-reacted ethylene is converted into CO_2 and the chlorinated compounds undergo a catalytic reduction process. Hence, clean gases are sent into the atmosphere in compliance with environmental control entity demands.

The main greenhouse gases are CO_2 and CH_4, as well as NMVOC, with estimated emissions with default factors of 0.294 t CO_2 / t vinyl chloride, 0.0226 kg CH_4 / t vinyl chloride and 8.5 kg NMVOC / t vinyl chloride and 2.2 kg NMVOC / t dichloroethane, as per the 1996 Guidelines. The calculations are valid for the integrated production of two chemicals.

Ethylene oxide

The main use of ethylene oxide, or ethylene, in the world is in the production of ethylene glycol, commonly known for its use as automotive refrigerant and anti-freeze. This chemical product is also used in the production of polyester polymers, as an intermediate in the production of ethers, higher alcohols and amines. In Brazil, it is mainly used to produce glycols. Additionally, ethylene oxide is broadly used in the sterilization of medical supplies such as bandages, sutures and surgical instruments.

It can be produced through two technological routes. The first begins with the reaction of chlorine on ethylene in the presence of water, followed by the dehydrochlorination of the ethylene chlorihydrin that forms. The second one uses the direct oxidation of ethylene from the air. The latter is the process adopted in ethylene oxide production in Brazil.

The main gases emitted are CO_2 and CH_4. CO_2 emissions were estimated by the total carbon mass balance of raw materials used, resulting in the factor of 0.52 t CO_2 / t ethylene oxide; for CH_4, the default factor used was 1.79 kg CH_4 / t ethylene oxide.

Acrylonitrile

Acrylonitrile is used to manufacture acrylic fibers, organic syntheses, fumigants, surfactants and dyes. The most known compounds that use it are NBR rubber, ABS resin and the ABS/PA mixture. The main gases emitted in its production in Brazil are CO_2 and CH_4, as well as NMVOC. CO_2 emissions were estimated from the total carbon mass balance from raw materials used, resulting in the factor of 0.2325 t CO_2 / t acrylonitrile; for the others, the default factors used were 0.18 kg CH_4 / t acrylonitrile and 1 kg NMVOC / t acrylonitrile.

Calcined Petroleum Coke

After petroleum coke, so-called "green petroleum coke", has been produced in the refinery, this product can go through another process, in a chemical industry, for purification meant to increase its carbon content, originating the so-called calcined petroleum coke.

The green petroleum coke is a solid product, obtained from the cracking of heavy residual oils in waste conversion units called Delayed Coking Units. In these places occurs the destruction of petroleum distillation waste, especially vacuum waste, aiming at obtaining clear by-products. Calcined petroleum coke is produced in a thermal process, which enables the drastic reduction of volatile matter content present in the green petroleum coke. Calcined petroleum coke is used in mixtures with pitch in the production of anodes for the aluminum industry, graphite electrodes and in the titanium oxide industry.

The emissions related to the use and/or the consumption of both the green and the calcined coke, either domestically produced or imported, are estimated in other sectors of the inventory (production of metals, Fossil Fuels Combustion). In the industrial chemical sector the emissions of methane (CH_4), the main gas emitted from coke calcining, are taking into account by calculating the default factor of 0.5 kg CH_4/t coke produced.

Carbon black

The main use of carbon black is as an additive in rubber for tires manufacturing. Another important use is as a pigment in paints manufacturing. In Brazil, carbon black's principal raw material is aromatic residue associated with heavy fuel oil (naphthenic), and natural gas or fuel oil as a secondary raw material.

CO_2 and CH_4 are the major gases emitted. The total carbon mass balance of raw materials used estimated CO_2 emissions. The emission factor calculated up to 2003 is of 1.989 t CO_2 / t carbon black. As of 2004, due to the start-up of a plant with lower emissions, the emission factor was recalculated to 1.618 t CO_2 / t carbon black. In the emissions of CH_4, the Tier 1 method was used, with the default emission factor of 0.06 kg CH_4 / t carbon black. For the indirect greenhouse gases, the estimates of the Initial Inventory were kept, when only emissions of NO_x were considered, with the emission factor of 0.14 kg NO_x / t carbon black, determined in the Second Inventory by the authors and by ABIQUIM.

Production data for petrochemicals and carbon black are shown in Table 3.35 and the corresponding emissions are provided in Table 3.37.

TABLE 3.35
Petrochemical and carbon black production

CHEMICAL PRODUCT	1990	1995	2000	2005	2010	VAR. 2005/2010
	(t)					(%)
Methanol	168,557	205,134	211,584	240,360	205,999	-14.3%
Ethylene	1,499,714	1,881,078	2,633,818	2,699,831	3,276,627	21.4%
Vinyl Chloride	480,415	388,905	424,732	609,207	724,927	19.0%
Ethylene oxide	127,221	161,326	256,035	297,183	280,953	-5.5%
Acrylonitrile	78,000	79,825	87,361	76,780	94,501	23.1%
Calcined Petroleum Coque	226,204	318,073	265,707	300,829	485,058	61.2%
Carbon black	178,395	200,554	229,860	280,140	400,060	42.8%

3.2.2.7. Phosphoric Acid

Phosphoric acid is mainly used to produce phosphate fertilizers, the most representative being monoammonium phosphate, diammonium phosphate, simple superphosphate and triple superphosphate.

The raw materials used in the production of phosphoric acid include sulfuric acid and phosphate rock. The latter contains inorganic carbon to a lesser or greater degree in the form of calcium carbonate ($CaCO_3$), which is an integral part of the mineral. The carbonate contained in the rock reacts with the sulfuric acid and produces agricultural gypsum and CO_2 as by-products.

CO_2 emissions were based on the quantity of carbon in the phosphate concentrate, estimated at 0.6%. The use of phosphate concentrate is shown in Table 3.36 and the corresponding CO_2 emissions in Table 3.37.

TABLE 3.36

Quantity of phosphate rock consumed in primary phosphoric acid production

CHEMICAL PRODUCT	1990	1995	2000	2005	2010	VARIATION 2005/ 2010
	(t)					(%)
Phosphate concentrate	2,817,000	3,888,000	4,725,106	5,631,000	5,071,682	-9.9%

TABLE 3.37

Greenhouse gas emissions from petrochemical, carbon black and phosphoric acid production

GAS	CHEMICAL PRODUCT	1990	1995	2000	2005	2010	VARIATION 2005/ 2010
		(Gg)					(%)
CO_2	Methanol	45	55	56	64	56	-12.5%
	Ethylene	3	4	5	5	6	20.0%
	Vinyl chloride	141	114	125	179	213	19.0%
	Ethylene oxide	66	84	133	155	146	-5.8%
	Acrylonitrile	18	19	20	18	22	22.2%
	Carbon black	355	399	457	453	647	42.8%
	Phosphoric acid	62	86	104	124	112	-9.7%
CH_4	Methanol	0.4	0.5	0.5	0.6	0.5	-16.7%
	Ethylene	4.5	5.6	7.9	8.1	10.6	30.9%
	Vinyl chloride	0.0	0.0	0.0	0.0	0.0	NA
	Ethylene oxide	0.2	0.3	0.5	0.5	0.5	0.0%
	Acrylonitrile	0.0	0.0	0.0	0.0	0.0	NA
	Calcined Petroleum Coque	0.1	0.2	0.1	0.2	0.2	0.0%
	Carbon black	0.0	0.0	0.0	0.0	0.0	NA
NO_x	Carbon black	0.0	0.0	0.0	0.0	0.1	NA
NMVOC	Ethylene	2.1	2.6	3.7	3.8	4.6	21.1%
	Vinyl chloride	4.1	3.3	3.6	3.9	6.2	59.0%
	Acrylonitrile	0.1	0.1	0.1	0.1	0.1	0.0%

3.2.2.8. Production of other chemicals

For the chemical products in this section, with production presented in Table 3.38, indirect greenhouse gas emissions were calculated using the default emission factors shown in Table 3.39. In general, they are default factors from the 1996 Guidelines, but some were derived from technologies suggested by the Core Inventory Air Emissions (CORINAIR) (phthalic anhydride, polyvinyl chloride – PVC and polystyrene) or determined by the authors and by ABIQUIM (styrene butadiene rubber – SBR).

TABLE 3.38
Activity data for other chemical products

CHEMICAL PRODUCT	1990	1995	2000	2005	2010	VARIATION 2005/ 2010
	(t)					(%)
ABS	27,000	33,000	33,000	33,000	33,000	0.0%
Phthalic Anhydride	65,645	74,778	87,595	84,579	94,368	11.6%
Styrene butadiene rubber (SBR)	184,692	221,191	236,627	212,205	231,435	9.1%
Dichloroethane	538,183	494,361	541,335	581,366	578,200	-0.5%
Styrene	306,217	272,858	406,225	405,205	440,016	8.6%
Ethylbenzene	441,007	407,453	436,577	395,024	430,384	9.0%
Formaldehyde	177,391	276,426	357,262	508,680	490,614	-3.6%
PVC – Polyvinyl Chloride	504,330	581,332	648,199	640,319	724,927	13.2%
Polystyrene	134,332	168,615	175,575	317,434	390,234	22.9%
HDPE Polyethylene	322,219	494,547	891,050	812,160	1,092,409	34.5%
LDPE Polyethylene	626,028	594,985	646,832	681,686	916,913	34.5%
LLDPE Polyethylene*	0	149,753	333,756	442,274	594,888	34.5%
Polypropylene	303,841	558,252	847,639	1,212,200	1,586,213	30.9%
Propylene	793,544	1,076,832	1,409,375	1,731,428	2,191,597	26.6%

* *The production of LLDPE polyethylene began in Brazil in 1993.*

TABLE 3.39
NMVOC emission factors for other chemical products

CHEMICAL PRODUCT	EMISSION FACTOR (kg NMVOC / t PROD)
ABS	27.2
Phthalic Anhydride	1.3
Styrene butadiene rubber (SBR)	5.8

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CHEMICAL PRODUCT	EMISSION FACTOR (kg NMVOC / t PROD)
Dichloroethane	2.2
Styrene	18
Ethylbenzene	2
Formaldehyde	5
PVC – Polyvinyl Chloride	1.5
Polystyrene	3.3
HDPE Polyethylene	6.4
LDPE Polyethylene	3
LLDPE Polyethylene	2
Polypropylene	12
Propylene	1.4

Correspondent NMVOC emissions are presented in Table 3.40.

TABLE 3.40
NMVOC emissions from the production of other chemical products

CHEMICAL PRODUCT	1990	1995	2000	2005	2010	VARIATION 2005/ 2010
	(t NMVOC)					(%)
ABS	0.7	0.9	0.9	0.9	0.9	0.0%
Phthalic Anhydride	0.1	0.1	0.1	0.1	0.1	11.6%
Styrene butadiene rubber (SBR)*	1.1	1.3	1.4	1.2	1.3	9.1%
Dichloroethane	1.2	1.1	1.2	1.3	1.3	-0.5%
Styrene	5.5	4.9	7.3	7.3	7.9	8.6%
Ethylbenzene	0.9	0.8	0.9	0.8	0.9	9.0%
Formaldehyde	0.9	1.4	1.8	2.5	2.5	-3.6%
PVC – Polyvinyl Chloride	0.8	0.9	1.0	1.0	1.1	13.2%
Polystyrene	0.4	0.6	0.6	1.0	1.3	22.9%
HDPE Polyethylene	2.1	3.2	5.7	5.2	7.0	34.5%
LDPE Polyethylene	1.9	1.8	1.9	2.0	2.8	34.5%
LLDPE Polyethylene*	0.0	0.3	0.7	0.9	1.2	34.5%

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CHEMICAL PRODUCT	1990	1995	2000	2005	2010	VARIATION 2005/ 2010
	(t NMVOC)					(%)
Polypropylene	3.6	6.7	10.2	14.5	19.0	30.9%
Propylene	1.1	1.5	2.0	2.4	3.1	26.6%
Total	**20.3**	**25.4**	**35.6**	**41.3**	**50.3**	**21.8%**

**The production of this polyethylene began in Brazil in 1993.*

3.2.3. Metal Production

3.2.3.1. Iron and Steel Production

In 2010, the Brazilian production of pig iron was of 30.8 Mt, a 23% growth when compared to the previous year. The production of integrated plants was 25.8 Mt, while independent producers (pig iron market) produced 5.06 Mt. Hence, independent producers accounted for only 16.4% of the total production. The steel produced in the same year reached 32.9 million tons, the highest production in Latin America and 2.2% of the world production, which totaled 1,498.9 million tons (BRASIL, 2011).

Up to 75% of CO_2 emissions from steel manufacturing occur during the production of pig iron in the blast furnace, i.e., in the reduction step of the iron ore. The remaining percentage results from the transportation of raw materials, the generation of electric power and heat. The emissions in this sector include only the production process, excluding power generation and transportation.

In Brazil, the production of pig iron and steel by integrated/semi-integrated plants uses petroleum coke, steam coal of calorific value greater than or equal to 5,900 kcal/kg, metallurgical coal and coal coke as the main reducing fuels. The production of pig iron by independent plants uses charcoal. The production of the plants is summarized in Table 3.41.

TABLE 3.41
Pig Iron and Steel production of integrated and semi-integrated plants

PRODUCTION	1990	1995	2000	2005	2010	VARIATION 2005/2010
	(10^3 t)					(%)
Steel	20,814	24,975	28,658	31,650	32,948	4.1%
Pig Iron (independent plants)	5,121	4,919	5,916	9,774	5,061	-48.2%

CO_2 emissions have been estimated based on the consumption of fuels used as direct heating, informed by the National Energy Balance (BEN) and the Useful Energy Balance (BEU) reported in Table 3.42 with the objective of avoiding double counting with the energy sector. For the calculation of CO_2, the carbon contained in the steel was discounted. Emissions of other direct and indirect greenhouse gases were also estimated. The result is summarized in Table 3.47.

TABLE 3.42
Consumption of fuels used in Iron and Steel production of integrated and semi-integrated plants

FUEL	1990	1995	2000	2005	2010	VARIATION 2005/ 2010
Petroleum Coke (10^3 m^3)	0	16	277	487	45	-90.8%
Steam Coal (10^3 t)	0	0	0	0	3,104	NA
Metallurgical Coal (10^3 t)	0	363	2,227	3,208	0	-100.0%
Coal Coke (10^3 t)	7,157	9,576	9,298	8,792	10,367	17.9%
Charcoal (10^3 t)	6,760	5,517	5,668	7,436	5,220	-29.8%

3.2.3.2. Ferroalloy production

Ferroalloy is a term used to describe concentrated alloys of iron and one or more metals, such as silicon, manganese, chrome, molybdenum, vanadium and tungsten. These alloys are used to deoxidize and alter the physical properties of steel. Ferroalloy factories produce concentrated compounds that are sent to steel plants to be incorporated to diverse steel alloys. Ferroalloy production involves the metallurgical reduction process, which results in CO_2 emissions.

In the production of ferroalloys, the ore is melted with the coke and slag under high temperatures. During ferroalloy fusion, the reduction reaction occurs at high temperatures. Carbon captures the oxygen from metallic oxides to form CO_2, while the minerals are reduced to basic melted metals. Consequently, those metals present combine with each other in the solution.

In Brazil, the production of ferroalloys predominantly uses charcoal. Other fuels (petroleum coke, metallurgical coal and coal coke) have been increasingly used since 1998. The methodology for the calculation of CO_2 emissions and non-CO_2 gases was the same as the one used for iron and steel. In the case of ferroalloys, 100% of the fuel consumption presented in BEN is considered as application in direct heating by BEU. Furthermore, in the absence of further information and as recommended in the 2000 Good Practice Guidance (IPCC, 2000), the carbon contained in iron-alloys was not considered.

National production data are shown in Table 3.43 and fuel consumption in Table 3.44. Emissions are summed up in Table 3.47.

TABLE 3.43
Brazilian ferroalloy production

	1990	1995	2000	2005	2010	VARIATION 2005/ 2010
	(t)					(%)
Ferroalloy	807,663	756,625	736,672	1,171,583	924,749	-21.1%

Source: Statistical Yearbook Brazilian Metallurgical Industry– MME.

TABLE 3.44
Consumption of fuel used in ferroalloy production

FUEL	1990	1995	2000	2005	2010	VARIATION 2005/ 2010 (%)
Petroleum Coke (10^3 m^3)	0	0	102	140	192	37.7%
Metallurgical Coal (10^3 t)	0	19	49	0	0	NA
Coal Coke (10^3 t)	37	51	8	134	156	16.6%
Charcoal (10^3 t)	560	590	666	883	880	-0.3%

3.2.3.3. Aluminum production

Primary aluminum is obtained through bauxite mining, mineral found on the Earth's crust. In 2012, the world's bauxite reserves totaled 28 billion tons, and Brazil holds 9.3% of this total, approximately 95% of the metallurgical bauxite and 5% of the refractory one. The most expressive Brazilian reserves (95%) are located in the Northern region (state of Pará), which has as main dealers the companies Alcoa Aluminio S.A., Norsk Hydro Brasil Ltda., Mineração Rio do Norte S.A. and Votorantim Metais – Companhia Brasileira de Aluminio. Primary aluminum is produced through an electrolytic reduction process. The reduction occurs in a carbon container that acts like a cathode and which contains the electrolytic solution. The carbon anode is partially submerged in the solution and consumed during the process.

The electrolysis of aluminum oxide produces melted aluminum, which deposits on the cathode, and oxygen, which deposits on the anode and reacts with the carbon, producing CO_2 emissions. Some quantity of CO_2 is also produced when the anode reacts with other sources of oxygen (like air). Other gases emitted in the production of primary aluminum are perfluorocarbons or PFCs, greenhouse gases that have a very long atmospheric life. The PFCs emitted by the aluminum industry occasionally occur during the process of electrolytic reduction in events called anodic effects. These effects are unwanted due to also implying a loss of efficiency of the process and increased energy consumption. Traditionally, the industry measures their occurrence in terms of frequency and duration. The quantity of PFCs emitted by an aluminum reduction plant is a direct proportion of the frequency and the duration of the anode effects.

The primary aluminum production process can use two main types of technology, Soderberg and Prebaked Anode. The distinction between these technologies is related to the type of anode used. Brazilian aluminum production by type of technology is shown in Table 3.45.

TABLE 3.45

Aluminum production by type of technology

TECHNOLOGY	1990	1995	2000	2005	2010	VARIATION 2005/ 2010
	(t ALUMINUM)					(%)
Soderberg	369,803	390,171	438,744	573,261	649,383	13.3%
Prebaked Anode	551,070	798,289	830,840	924,494	884,320	-4.3%
Total	**920,873**	**1,188,460**	**1,269,584**	**1,497,755**	**1,533,703**	**2.4%**

Source: Producing companies.

During the drafting of the Second National Inventory, the companies made a great effort to report their emissions as accurately as possible, with developments in relation to the Initial Inventory. Each plant employed the best approach (Tier) possible for the calculation of the emissions from their processes, in accordance with Table 3.46. Due to the lack of specific information of each plant, as of 2008, the 2007 implicit emission factors have been used.

TABLE 3.46

Approaches applied for CO_2 and PFCs emissions estimates per plant for the period 1990-2007

TECHNOLOGICAL ROUTE		PLANT	CO_2	PFCS
TYPE	SUBDIVISION			
Soderberg	VSS and HSS	Novelis (BA)	Tier 2	Tier 2
	HSS	Novelis (MG)	Tier 2	Tier 2
	VSS	Alcoa (MG)	Tier 2	Tier 3
	VSS	CBA (SP)	Tier 3	Tier 3
Prebaked Anode	CWPB	Albras (PA)	Tier 1	Tier 1 (1990-1996)
				Tier 3 (1997-2007)
	CWPB	Alumar (MA)	Tier 3	Tier 2
	CWPB	Valesul (RJ)	Tier 2	Tier 1

GHG emissions related to the use of fuels in the production of aluminum are listed in Table 3.47 and CF_4 and C_2F_6 emissions are shown in Table 3.48.

3.2.3.4. Magnesium production

SF_6 is used as a coverage gas to avoid oxidation of melted magnesium during production and casting of metal magnesium products, and it normally leaks into the atmosphere. SF_6 is considered a non-reactive gas and ideally adapts to this type of protection, as "coverage" for molten magnesium (thus the term "coverage gas"). So, gas consumption is used to estimate emissions. Table 3.48 presents SF_6 emissions in this subsector.

3.2.3.5. Summary of the estimates of the direct and indirect Greenhouse Gas emissions from the production of metals

TABLE 3.47
GHG direct and indirect emissions from metal production

GAS	FUEL TYPE	PRODUCTION	1990	1995	2000	2005	2010	VARIATION 2005/2010
			Gg					%
CO_2	Fossil fuels	Pig-iron and steel	21,601	30,130	35,552	37,509	38,360	2.3
		Ferroalloys	116	215	545	932	1,195	28.2
		Aluminum	1,574	1,965	2,116	2,472	2,543	2.9
		Other non-ferrous metals	897	1,762	1,606	1,855	4,332	133.6
		Total fossil	**24,188**	**34,073**	**39,818**	**42,768**	**46,430**	**8.6**
	*Biomass**	*Pig-iron and steel*	*18,758*	*15,200*	*15,490*	*20,026*	*14,321*	*-28.5*
		Ferroalloys	*1,616*	*1,703*	*1,922*	*2,547*	*2,539*	*-0.3*
		Aluminum	-	-	-	-	-	*NA*
		Other non-ferrous metals	*1,137*	*652*	*26*	*35*	*42*	*17.7*
		Total biomass*	***21,511***	***17,555***	***17,437***	***22,609***	***16,902***	***-25,2***

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GAS	FUEL TYPE	PRODUCTION	1990	1995	2000	2005	2010	VARIATION 2005/2010
			Gg					%
CH_4	All	Pig-iron and steel	36.8	30.1	31.0	40.6	28.6	-29.5
		Ferroalloys	3.0	3.2	3.6	4.8	4.8	-0.3
		Other non-ferrous metals	2.1	1.3	0.1	0.1	0.1	11.8
		Total	**42.0**	**34.6**	**34.7**	**45.5**	**33.5**	**-26.4**
N_2O		Pig-iron and steel	1.02	1.00	1.09	1.31	1.08	-17.8
		Ferroalloys	0.06	0.07	0.08	0.10	0.11	1.7
		Non-ferrous metals	0.06	0.05	0.03	0.03	0.03	-11.3
		Total	**1.14**	**1.11**	**1.19**	**1.44**	**1.21**	**-16.2**
CO		Pig-iron and steel	775.0	656.2	676.1	867.3	633.2	-27.0
		Ferroalloys	60.8	64.2	72.5	96.7	96.7	0.0
		Non-ferrous metals	44.4	27.6	3.7	4.6	4.9	6.4
		Total	**880.2**	**747.9**	**752.3**	**968.7**	**734.8**	**-24.1**
NO_x		Pig-iron and steel	25.5	30.8	66.4	90.8	60.1	-33.7
		Ferroalloys	1.6	2.0	4.6	5.2	6.2	19.7
		Non-ferrous metals	8.9	11.7	13.0	14.1	13.8	-2.5
		Total	**36.0**	**44.5**	**84.0**	**110.1**	**80.1**	**-27.2**
NMVOC		Pig-iron and steel	21.6	19.6	21.1	26.3	20.2	-22.9
		Ferroalloys	1.5	1.6	1.9	2.5	2.5	0.5
		Non-ferrous metals	1.2	0.8	0.3	0.3	0.3	-18.6
		Total	**24.3**	**22.0**	**23.2**	**29.1**	**23.0**	**-20.9**

**For information purposes only. These emissions are included in the Reference Report 'Land Use, Land Use Change and Forestry'.*

TABLE 3.48
Emissions from the metal production process not related to the use of fuel

PRODUCTION	GAS	1990	1995	2000	2005	2010	VARIATION 2005/ 2010
		(Gg)					(%)
Aluminum	CF_4	0.3022	0.3060	0.1465	0.1239	0.0767	-38.1%
	C_2F_6	0.0263	0.0264	0.0117	0.0104	0.0059	-43.3%
Magnesium	SF_6	0.0058	0.0101	0.0103	0.0191	-	-100.0%

3.2.4. Other Industries

3.2.4.1. Pulp and Paper Industry

The Pulp and Paper sector is comprised of 62 companies and state agencies of products originating in the cultivation of planted trees. This industry has 2.4 million hectares of own forestations, especially the *Eucalyptus* and *Pinus* species, for the production of pulp and paper.

Preparation of pulp paste for papers and other purposes consists of separating the fibers from the other wood components, especially lignin, which gives firmness to the wood. Some types of wood, such as pine and araucaria, have long fibers (3 to 5 mm), whereas eucalyptus has shorter and thinner fibers (0.8 to 1.2 mm). Those from the first group are called conifers or softwood, whereas those from the second group are called leafy or hardwood.

There are many and varied preparation processes for pulp paste, from the purely mechanical to the chemical, in which wood is treated with chemical products, pressure and heat (temperatures greater than 150ºC) to dissolve the lignin. The use of chemical products in the process generates greenhouse gas emissions.

Pulp and paper paste production have three main phases: pulping, bleaching and paper production. The type of pulping and the quantity of bleaching used depend on the nature of the raw material and the desired quality of the final product. Kraft pulping is the most widely used process.

In Brazil, the most used process is a variation of Kraft, called Sulfate. It uses the same chemical products, although employing higher doses of sodium sulfate and caustic soda, and it is cooked longer and at higher temperatures. It is considered the most appropriate for obtaining chemical pastes from eucalyptus. There are CO, NOx and NMVOC emissions during the process.

Table 3.49 presents a summary of Brazilian production of pulp paste, highlighting the sulfate process, which generates indirect greenhouse gases.

TABLE 3.49
Brazilian pulp paste production

TYPE OF PULP / CHEMICAL PROCESS	1990	1994	2000	2005	2010	VAR. 2005/ 2010
	(t)					(%)
Chemical and Semi-Chemical Pulp	3,914,688	5,376,271	6,961,470	9,852,462	13,733,000	39.4%
Sulfate*	3,593,547	5,127,981	6,639,971	9,397,450	13,098,775	39.4%
Other Processes	321,141	248,290	321,499	455,012	634,225	39.4%
High Performance Pastes	436,455	452,599	501,796	499,651	431,000	-13.7%
Total	**4,351,143**	**5,828,870**	**7,463,266**	**10,352,113**	**14,164,000**	**36.8%**

Source: Ibá – Brazilian Tree Industry.

**For the sulfate process, the same share as in 1994 was considered for the subsequent years.*

In this Inventory, emission factors from IPCC guidelines for the Kraft process were used for the Sulfate process, responsible for most of the production, since information about emissions for the other processes was not available. Sectoral greenhouse gas emissions are shown in Table 3.50.

TABLE 3.50
Emissions from pulp production in Brazil

GAS	1990	1994	2000	2005	2010	VAR. 2005/ 2010
	(Gg)					(%)
CO	20.1	29.1	37.2	52.6	73.4	39.5%
NOx	5.4	7.8	10.0	14.1	19.6	39.0%
NMVOC	13.3	19.2	24.6	34.8	48.5	39.4%

3.2.4.2. Food and Beverage

NMVOC emissions can occur in the industrial processing of foods and production of beverages. The IPCC presents emissions factors for some subsectors. Without additional information, these factors were adopted in this Inventory. In Table 3.51 Brazilian production of foods for which emissions have been associated is shown for 1990 – 2010.

TABLE 3.51
Brazilian food production

PRODUCT	1990	1995	2000	2005	2010	VARIATION 2005/ 2010
	(1,000 t)					(%)
Meat, fish and poultry	5,837	6,367	7,038	16,556	21,419	29.4%
Sugar	7,214	12,652	19,388	26,685	32,956	23.5%
Margarines and solid fats for cooking	453	485	602	759	820	8.1%
Cakes, biscuits and breakfast cereals	459	690	729	829	879	6.0%
Breads	2,885	4,341	4,585	5,218	5,532	6.0%
Animal feed	8,258	10,610	12,935	16,225	17,137	5.6%
Roasted coffee	584	685	890	1,134	1,354	19.4%

Source: ABIA; UNICA; SINDIPAN; ABIP; IBGE; ABIC.

In the production of alcoholic beverages, there are NMVOC emissions during cereal and fruit fermentation. IPCC default emission factors were also used to estimate these emissions. In Table 3.52 Brazilian beverage production is presented for the years of 1990 – 2010.

TABLE 3.52
Brazilian production of beverages

PRODUCT	1990	1995	2000	2005	2010	VARIATION 2005/2010
	(1,000 L)					(%)
Wine	308,954	251,059	319,161	378,272	376,520	-0.5%
Beer	3,749,150	8,037,262	9,023,303	9,865,939	12,947,054	31.2%
Distilled beverages	1,125,000	1,139,503	1,237,610	1,073,583	1,280,761	19.3%

Source: UVIBRA; ABIA; ABRABE; IBGE.

The emissions of food and beverages subsector are provided, for the 1990 to 2010 period, in Table 3.53.

TABLE 3.53
NMVOC emission from food and beverage production

SECTOR	1990	1995	2000	2005	2010	VARIATION 2005/ 2010
	(Gg NMVOC)					(%)
Food industry	110.5	179.7	252.8	338.8	407.2	20.2%
Beverage industry	170.3	173.9	189.1	164.8	196.9	19.5%
Total	**280.8**	**353.6**	**441.9**	**503.6**	**604.1**	**20.0%**

3.2.5. Emissions related to hydrofluorocarbon production

There was no production of HFCs and SF_6 in Brazil from 1990 to 2010, only emissions of HFC-23, generated as a by-product from the production of HCFC-22, which ceased in 1999. Emissions of HFC-23 by this means are shown in Table 3.54.

TABLE 3.54
Potential HFC-23 emissions due to HCFC-22 production

GAS	1990	1995	2000	2005	2010	VARIATION 2005/ 2010
	(Gg)					(%)
HFC-23	0.1202	0.1530	-	-	-	NA

3.2.6. Emissions related to hydrofluorocarbon consumption

HFCs were introduced as alternatives to substances depleting the ozone layer (ODS) and are used mainly in the refrigeration and air-conditioning sector, but also in the aerosols, solvents, foam and in fire extinguishers and protection of explosions. These chemicals are emitted instantly or slowly through leaks that occur over time. The HFCs are mainly applied for:

- >> Refrigeration and air conditioning, including the sub-categories of domestic refrigeration, commercial refrigeration, refrigerated transport, industrial refrigeration, air-conditioning and stationary and mobile air-conditioning;
- >> Foam blowing agents;
- >> Aerosols, including inhalers;
- >> Solvent and cleaning agents;
- >> Other uses.

The main emissions from this sector are related to the use of HFCs in refrigeration and air conditioning. The HFC-134a is the most used HFC refrigerant fluid in this sector. Other refrigerants, such as R-404A, R-410A, R-407C and others, are well-determined mixtures from different HFCs and are used in the maintenance of equipment. Such mixtures began to be used subsequently to HFC-134a, still in an incipient way.

The actual emissions of HFC-134a through the Tier 2a methodology were estimated, which considers emissions in the assembly, operation and scrapping stages. The other gases - HFC-32, HFC-125, HFC-143a and HFC-152 - will be accounted for their potential emissions by the Tier 1b methodology, which takes the national production (non-existent), the import and export of HFCs, either directly as fluids or within imported and exported equipment, into account.

The charges of HFC-134a considered in products in the refrigeration and air-conditioning sector are presented in Table 3.55, and emissions are reported in Table 3.56.

TABLE 3.55

HFC-134a charges considered for the refrigeration and air conditioning sector

HFC-134a CHARGES		1990	1995	2000	2005	2010	VARIATION 2005/ 2010
		(kg)					(%)
Household refrigeration	National production	0	0	619,950	802,902	1,184,911	47.6%
	Installed base	129	4,292	1,375,380	4,310,995	9,294,490	115.6%
Commercial refrigeration	National production	0	0	120,530	166,749	207,088	24.2%
	Installed base	0	0	682,814	1,195,646	2,042,121	70.8%
Automobiles	National production	0	0	426,601	867,337	1,344,039	55.0%
	Installed base	0	0	1,200,611	3,070,895	7,309,553	138.0%

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HFC-134a CHARGES		1990	1995	2000	2005	2010	VARIATION 2005/ 2010
		(kg)					(%)
Buses	National production	0	0	34,360	32,110	59,405	85.0%
	Installed base	0	0	153,115	324,870	577,810	77.9%
Refrigerated trucks	National production	0	0	978	912	1,689	85.2%
	Installed base	0	0	4,356	9,240	16,434	77.9%
Chillers	National production	0	25,490	61,404	53,193	71,400	34.2%
	Installed base	0	25,490	260,467	525,361	852,016	62.2%
Water fountains	National production	0	0	20,202	17,024	19,424	14.1%
	Installed base	0	0	45,734	127,618	190,343	49.2%
Total charge	National production	0	25,490	1,284,026	1,940,226	2,887,956	48.8%
	Installed base	129	29,782	3,722,478	9,564,625	20,282,767	112.1%

TABLE 3.56

Real HFC-134a emission in the refrigeration and air conditioning sector

HFC-134a	1990	1995	2000	2005	2010	VARIATION 2005/ 2010
	(Gg)					(%)
Emissions in the assembly		0.0003	0.0089	0.0129	0.0186	44.4%
Emissions in the operation		0.0025	0.4862	1.1971	2.5912	116.5%
Emissions in the scrapping (automobiles and light commercial vehicles)		0.0000	0.0037	0.0179	0.0573	220.5%
Real emissions	**0.0004***	**0.0028**	**0.4988**	**1.2279**	**2.6671**	**117.2%**

* *Estimated as half of imports in this year.*

Emissions of HFC-134a are also reported in the manufacturing of foam in only one company in São Paulo. The company reported having consumed about 50 ton/year from 2006 to 2011 in the production of rigid foams, closed cell. The emissions of this use are reported in Table 3.57.

TABLE 3.57
HFC-134a emission estimates in foams production

YEAR	USE IN THE ASSEMBLY	LEAK IN THE ASSEMBLY	ANNUAL LEAK	TOTAL LEAK
		10%	4.50%	HFC-134a
	(Gg)			
2006	0.050	0.005	0.0011	**0.0061**
2007	0.050	0.005	0.0034	**0.0084**
2008	0.050	0.005	0.0056	**0.0106**
2009	0.050	0.005	0.0079	**0.0129**
2010	0.050	0.005	0.0101	**0.0151**

Another source of emissions of the HFC-134a refrigerant fluid is in the use of medicinal Metered Dose Inhalers aerosols (MDIs). This use only began in 2006 and the emissions are reported in Table 3.58.

TABLE 3.58
HFC-134a emission estimates in aerosol use

YEAR	HFC-134a EMISSIONS
	(Gg)
2006	**0.0123**
2007	**0.0193**
2008	**0.0128**
2009	**0.0169**
2010	**0.0205**

Table 3.59 shows HFC-134a emissions in the refrigeration and air-conditioning, foam and aerosols sectors.

TABLE 3.59
Real HFC-134a emissions

HFC-134a EMISSIONS	1990	1995	2000	2005	2010	VARIATION 2005/ 2010
	(Gg)					(%)
Refrigeration and air-conditioning	0.0004	0.0028	0.4988	1.2279	2.6671	117.2%
Foams	-	-	-	-	0.0151	NA
Aerosols	-	-	-	-	0.0374	NA
Total emissions	**0.0004**	**0.0028**	**0.4988**	**1.2279**	**2.7196**	**121.5%**

For the other refrigerants (HFC-32, HFC-125, HFC-143a and HFC-152a), the imports and exports were identified whenever relevant. Table 3.60 shows the potential emissions of HFCs.

TABLE 3.60
HFCs potential emissions

GAS	1990	1995	2000	2005	2010	VARIATION 2005/ 2010
	(Gg)					(%)
HFC-32	-	-	-	-	0.1059	NA
HFC-125	-	-	0.0071	0.1249	0.5012	301.3%
HFC-143a	-	-	0.0075	0.0929	0.4671	402.8%
HFC-152a	-	-	0.0001	0.1748	-	-100.0%

3.2.7. Emissions related to the consumption of sulfur hexafluoride

Due to its excellent properties as an inert, non-toxic, high dielectric rigidity insulation and non-flammable, thermally stable and self-regenerating refrigerant, SF_6 permitted the development of high capacity and performance electrical equipment, which are also compact, light and safe. Among the electrical equipment developed as a result of SF_6, circuit breakers and shielded substations stand out using 10% of the physical space of the equivalent conventional substations.

In Brazil, there is no production of SF_6, but emissions occur due to gas leaks at SF_6 insulated and shielded substations.

The actual emissions of SF_6 were informed by the studies carried out by MCTI for the Second Inventory, involving the use of electrical power equipment and in the production of magnesium. At that time, the installed park of equipment using SF_6 was evaluated up to 2008. The extrapolation of this capacity up to 2010 took into account the average growth during the ten previous years, considering an annual emission factor of 2% of the installed capacity. For the production of magnesium, the use of SF_6 was reported in the metal manufacture sector.

Table 3.61 below shows the first results in terms of installed capacity of SF_6 in equipment, and an estimate of annual leakage based on default factor, according to the 2000 Good Practice Guidance, at the amount of 2% per year.

TABLE 3.61
Installed capacity in terms of SF_6 in equipment and estimates of annual leaks

DESCRIPTION	1990	1995	2000	2005	2010	VARIATION 2005/ 2010 (%)
Installed capacity (t SF_6)	208.85	205.47	248.31	306.32	436.32	42.4%
SF_6 emissions (Gg)	0.0042	0.0041	0.0050	0.0061	0.0087	42.6%

3.3. SOLVENT AND OTHER PRODUCT USE SECTOR

This sector has been completely modified in relation to the earlier inventories. Like in the Iron and Steel sub-sector, compatibility with the National Energy Balance (BEN), was sought. Data on the use of solvents and other products were taken from the same source and no longer from uncertain emission factors and activity data based on other countries. Emissions of NMVOCs concerning the non-energy use informed at BEN, apart from the Chemical Industry use, were counted in this sector. Thus, Lighting Kerosene, Hydrated Alcohol, Solvents, Other Non-Energy of Petroleum were recorded. In addition, NMVOC emissions were recorded on account of the use of asphalt for paving, on the basis of the 1997 IPCC emission factor.

The 1996 Guidelines indicate that, for a certain percentage of each fuel, the carbon will be stored in products in a more or less permanent form, being necessary to estimate CO_2 emissions for the others. Based on this methodology, emissions relating to the use of lubricants were considered as if 80% would be stored, according to the 2006 Guidelines (to consider 20% emitted in two strokes engines, in which the lubricant is burned with the fuel). Lighting kerosene, hydrated alcohol, solvents and other non-energy of petroleum, in turn, will be 100% emitted as NMVOC.

For the calculation of CO_2 emissions from the use of lubricants, factors of 0.891 m^3 / toe, 41.868 10^3 toe / TJ and, finally, the emission factor of 20 t C/TJ were used. For NMVOC, default factors of 790 kg/m^3 of lighting kerosene, 809 kg/m^3 of hydrated alcohol, 740 kg/m^3 of solvents and 873 kg/m^3 of other petroleum energy were used.

It should be noted that these emissions fully include those calculated for the Second Inventory in the Solvent and Other Products sector. The consumption of non-energy lubricants (CO_2 emissions) and lighting kerosene, hydrated alcohol, solvent and other non-energy petroleum products (emissions of NMVOC) informed by BEN are presented in Table 3.61. CO_2 emissions related to the consumption of lubricants and NMVOC from the use of lighting kerosene, hydrated alcohol, solvent and other non-energy petroleum products are shown in Table 3.63.

TABLE 3.62

Date on activity and non-energy consumption informed by The Brazilian Energy Balance (BEN)

CONSUMPTION	1990	1995	2000	2005	2010	VAR.2005/ 2010
	10^3 m^3					(%)
Lubricants	783	757	921	960	1,242	29.3%
Lighting Kerosene	0	0	0	29	9	-68.6%
Hydrated Alcohol	855	1,021	960	530	0	-100.0%
Solvents	281	354	543	1,287	592	-54.0%
Other Non-Energy Oil Products	1,213	962	1,663	1,324	3,948	198.1%
Pavement asphalt	1,143	1,079	1,575	1,269	2,578	103.2%

TABLE 3.63
CO_2 and NMVOC emissions by lubricants, solvents and other products use

GASES	FUEL	1990	1995	2000	2005	2010	VAR.2005/2010
		(Gg)					(%)
CO_2	Lubricants	**428**	**414**	**504**	**525**	**679**	29.3%
NMVOC	Lighting Kerosene	0	0	0	23	7	-68.6%
	Hydrated Alcohol	692	826	776	429	0	-100.0%
	Solvents	208	262	402	953	438	-54.0%
	Other Non-Energy Oil Products	1,059	840	1,452	1,156	3,447	198.1%
	Pavement asphalt	380	359	524	422	858	103.2%
	Total	**2,339**	**2,287**	**3,154**	**2,982**	**4,750**	**59.3%**

3.4. AGRICULTURE

Agriculture, which includes livestock, is an economic activity of great importance in Brazil. Due to its large extension of agricultural and grazing lands, the country is one of the largest producers of this sector in the world.

Agriculture and livestock activities generate greenhouse gas emissions that occur through several processes. Enteric fermentation in ruminants is one of the most important sources of CH_4 emissions in the country (64.4% in 2010). Manure management systems cause CH_4 and N_2O emissions from livestocks.

Flooded rice crops, which are one of the main sources of CH_4 in the world, are not a very expressive emissions source in Brazil, because a major portion of the rice is produced in non-flooded areas. Imperfect crop residue burning produces CH_4 and N_2O emissions, besides NO_x, CO and NMVOC. In Brazil, waste burning is applied in the sugarcane and cotton crops.

N_2O emissions in agricultural soils occur mainly from the animal manure in pastureland and also from soil fertilization practices, which include the use of synthetic nitrogen fertilizers and animal waste management. The use of organic soils for farming also generates N_2O emissions.

3.4.1. Livestock

There are several processes in the cattle activity that cause greenhouse gas emissions. The production of CH_4 is part of the normal digestive process in ruminant herbivores (enteric fermentation); animal waste management produces CH_4 and N_2O emissions; the use of animal manure as a fertilizer and deposition of grazing animal wastes also produce N_2O in the soil.

Livestock, in particular ruminant herbivores, constitute an important source of methane emissions. The categories of animals considered by the 1996 Guidelines include: ruminant animals (dairy cattle, beef cattle, buffalo, sheep and goats) and non-ruminant animals (horses, mules, donkeys and swine). Poultry is only included in the estimate of emissions from animal waste management.

In 2010, there was an estimated 284 million heads of national cattle herd, not including poultry, which accounted for another 1.2 billion, as per Table 3.64.

TABLE 3.64
Population of the different herds

ANIMALS CATEGORIES	1990	1995	2000	2005	2010	VAR. 2005/ 2010
	(10³ HEAD)					(%)
Beef cattle	128,306	140,649	151,991	186,531	186,616	0.0%
Dairy cattle	19,167	20,579	17,885	20,626	22,925	11.1%
Swine	33,687	36,062	31,562	34,064	38,957	14.4%
Sheep	20,049	18,336	14,785	15,588	17,381	11.5%
Goats	11,901	11,272	9,347	10,307	9,313	-9.6%
Horses	6,161	6,394	5,832	5,787	5,514	-4.7%
Asses	1,343	1,344	1,242	1,192	1,002	-15.9%
Mules	2,034	1,990	1,348	1,389	1,277	-8.0%
Buffaloes	1,398	1,642	1,103	1,174	1,185	0.9%
Hens	174,714	188,367	183,495	186,573	210,761	13.0%
Roosters, Chicks and broilers	372,066	541,164	659,246	812,468	1,028,151	26.5%
Quails	2,464	2,939	5,775	6,838	12,992	90.0%

Source: IBGE.

In 2010, 94.8% of total methane emissions from Brazilian livestock were attributed to enteric fermentation, as per Table 3.65. Still considering 2010, the categories of cattle contributed with 96.8% of methane emissions from enteric fermentation and 93.9% of total methane emissions from livestock.

TABLE 3.65
Methane emissions from livestock

SOURCE	1990	1995	2000	2005	2010	SHARE IN 2010	VAR. 2005/ 2010
	(Gg CH_4)					(%)	
Enteric fermentation	8,223.9	8,957.1	9,349.5	11,213.8	11,158.0	94.8%	-0.5%
Manure management	421.6	471.6	479.7	543.9	608.1	5.2%	11.8%
Total	**8,645.5**	**9,428.7**	**9,829.2**	**11,757.7**	**11,766.1**	**100%**	**0.1%**

Detailed estimates of emissions from enteric fermentation and animal waste management are presented below. N_2O emissions from manure addition to the soil, whether intentional or by grazing livestock, are treated with other types of fertilizers in item 3.4.4. (Direct emissions of N_2O by agricultural soils).

3.4.1.1. Enteric fermentation

The production of CH_4 is part of the normal digestive process of ruminant animals. It occurs in much smaller quantities in other herbivores. The contribution of non-ruminant animals to global methane emissions is considered insignificant, representing only about 5.2% of total methane emissions from domestic and wild animals.

Emission intensity depends on the type of animal, the type and amount of food, the degree of digestibility and the intensity of the animal's physical activity, as a result of the diverse raising practices.

The estimate of emission factors is based on recognition of these parameters, which will allow for the evaluation of emissions. In Brazil, due to its large territorial extension and wide dispersion of activity, with a diversity of practices and food types provided to the animals, these parameters vary greatly.

Unfortunately, studies in this area are insufficient in the country. However, with the contribution of Brazilian specialists, emission factors that could be straightforwardly applied to raising characteristics and regional differences were obtained for cattle. The values obtained proved to be consistently higher than the IPCC Guidelines default values (1997).

In accordance with diet characteristics, methane gas emissions were estimated to vary between 4% and 12% of gross ingested food energy, with the average considered to be 8%. As the production of methane varies with the quantity and quality of food ingested, different types and conditions for livestock production systems result in different percentages of methane emissions. Food consumption is related to animal size, environmental conditions, growth rate and production (milk, meat, wool and gestation). Generally, the greater this consumption, the greater the CH_4 emission and the better quality of the diet, the lower this emission will be per unit of ingested food.

Furthermore, it is necessary to consider that ruminants experience seasonal differences in food supply, considering climatic conditions that alter pasture quality, which also differs in accordance with soil type. Thus, it is possible to observe a seasonal pattern of weight gain in the wet season (hot) and weight loss in the dry season (cold), which occurs in individuals over 3.5 years of age.

For dairy farming, production systems are observed with different degrees of specialization, from subsistence properties – without techniques and daily production of less than 10 liters, to highly specialized producers - with daily production above 50 thousand liters. It is estimated that only 2.3% of dairy properties are specialized and that these are responsible for approximately 44% of total milk production in the country. On the other hand, 90% of the producers considered small are responsible for only 20% of total production. There is also an intermediate group in terms of property specialization that corresponds to 7.7% of producers and that are responsible for 36% of production.

Zootechnical features were set for 1990-1995, 1996-2001 and 2002-2006, according to the peculiarities of the country's herds. Among these periods, there was a variation in digestibility and pregnancy data for the Southeast, South and Central-West regions. Based on these parameters, methane emission factors were estimated for enteric fermentation in livestock. For females in beef cattle and for dairy cattle, estimations also take into account the production of milk, which is assumed to be the same in both cases and is available by state and year, resulting in different emission factors for all years in each state.

For other animals, IPCC default emission factors were used due to the absence of consistent national data, increasing the degree of uncertainty of the estimates.

In Table 3.66 estimates are provided for methane emissions, resulting from enteric fermentation, in accordance with animal category. Among the types of animals, non-dairy cattle was the major contributor for these emissions.

TABLE 3.66
CH_4 emissions from enteric fermentation

TYPE OF ANIMAL	1990	1995	2000	2005	2010	SHARE IN 2010	VAR. 2005/ 2010
	(Gg CH_4)					(%)	
Bovines	7,809.9	8,534.3	9,005.8	10,855.7	10,798.4	96.8%	-0.5%
Dairy cattle	1,197.7	1,297.1	1,777.9	1,371.4	1,424.0	12.8%	3.8%
Beef cattle	6,611.2	7,237.2	7,827.9	9,484.3	9,374.4	84.0%	-1.2%
Other animals	415.0	422.8	343.7	358.1	359.6	3.2%	0.4%
Total	**8,223.9**	**8,957.1**	**9,349.5**	**11,213.8**	**11,158.0**	**100%**	**-0.5%**

3.4.1.2. Manure management

The main source of methane emissions is related to animal wastes treated under anaerobic conditions. This occurs due to methanogenic bacteria activity in anaerobic conditions producing important quantities of CH_4. This process is favored when dejects are stored in liquid form.

Due to the characteristics of extensive cattle raising in Brazil, anaerobic treatment lagoons constitute a small fraction of the management systems. Even for confined cattle, a restricted number of manure treatment facilities can be observed. Animal wastes deposited in pasture dries and decomposes in the field, so that minimum quantities of CH_4 emissions are expected from this source. The use of manure as fertilizer is not expressive in the country. It is estimated as no more than 20% in the cases of beef and dairy cattle and swine, and approximately 80% in the case of poultry.

CH_4 emissions were estimated using the methodologies recommended by the IPCC. Detailed methodology that takes into account national feeding parameters, digestibility and management systems, obtained with the collaboration of Brazilian specialists, was used for cattle and swine.

The manure composition is determined by the animal's diet so that the greater the energy content and digestibility of the food, the greater the capacity for CH_4 production. Cattle fed a high quality diet produces a highly biodegradable manure with greater potential for methane generation, whereas cattle fed a more fibrous diet will produce a less biodegradable deject, containing more complex organic material, such as cellulose, hemicellulose and lignin. The latter would be more closely associated with cattle raised on pastures in tropical conditions. The higher emissions of methane from animal waste are associated with animals raised under intensive management.

According to researchers, the existing swine manure treatment and storage systems in southern Brazil consist of manure storage systems. The objective is to apply them to the soil and valorize them as agricultural fertilizer for corn and other crops. At present, the two swine manure storage systems most used are known as bio manure piles and conventional manure piles. There were few biodigesters installed in the country until 1996, but due to new technologies that emerged within the scope of the CDM, there was an increase in the adoption of this equipment.

Depending on the system used, management of animals manure can also produce, during its processing, emissions of N_2O that are described among the emissions from agricultural soils. The estimated emissions of N_2O were made using the methodology recommended by the IPCC, taking into consideration the involvement of the various systems used for each type of animal. In the absence of information on emission factors specific to Brazil, the IPCC default values were used.

Information on the size of the herd (small and medium-sized properties, below 300 animals; and large properties, above 300 animals) was also used as the basis for the calculation of the estimates. The largest emissions of methane from animal waste are associated with animals bred under intensive management. The potential of animal waste to produce CH_4 can be expressed in terms of CH_4 generated per kg of volatile solids (VS) of residual material. CH_4 emissions estimates per management of animals manure can be seen in Table 3.67.

TABLE 3.67

CH_4 emissions from animal manure management

TYPE OF ANIMAL	1990	1995	2000	2005	2010	SHARE IN 2010	VAR. 2005/ 2010
	(Gg CH_4)					(%)	
Bovines	191.2	208.7	215.9	254	258.7	42.5%	1.9%
Dairy cattle	35.9	38.5	34.1	39.7	44	7.2%	10.8%
Beef cattle	155.3	170.2	181.8	214.3	214.7	35.3%	0.2%
Swine	159.5	173.7	166.5	178.7	214.9	35.3%	20.3%
Poultry	48.4	66.3	78.1	91.5	115.3	19.0%	26.0%
Other Animals	22.5	22.9	19.2	19.7	19.2	3.2%	-2.5%
Total	**421.6**	**471.6**	**479.7**	**543.9**	**608.1**	**100%**	**11.8%**

3.4.2. Rice Cultivation

Rice can be cultivated under different systems, in accordance with arrangements for the water supply: (a) upland or highlands rice – depends solely on the amount of rainfall for development, and the areas of cultivation are not subject to flooding; (b) rice cultivated in areas favored by irrigation without the formation of a water depth; (c) rice grown in conditions of wet meadows – areas subject to flooding from the ground, although with no irrigation control; and d) rice irrigated by flood – produced under irrigation controlled with water depth for considerable periods of time throughout the crop cycle (IPCC, 2006). The anaerobic decomposition of organic matter in irrigated or flooded rice grasslands is an important source of CH_4. This process does not occur, however, when rice is grown in highlands (upland rice).

In Brazil, the production of rice is developed under irrigated and dryland farming, which responded in the 2009/2010 harvest, respectively, for 51% and 49% of the cultivated area (EMBRAPA, 2014). The methane emissions associated with the cultivation of rice is only related to the crops irrigated by flooding or established in wet lowland. The cultivation of rice irrigated by flood is a relevant activity in accounting for methane emissions from the livestock sector, particularly for the Southern region, where more than a million hectares are cultivated annually, contributing with around 72% of the national production of the cereal in 2010 (CONAB, 2010).

In 1990, Brazil presented a harvested area of 1,258,445 ha of irrigated rice, 85.6% of which under continuous flooding, 1.5% under intermittent flooding and 12.9% in lowland. In 1995, this proportion was 89.9%, 0.9% and 9.2%, for those categories, respectively. In 2005, the harvested area of irrigated rice in the country was estimated at 1,428,192 ha, 96.8% using continuous flooding and 3.2% in wet meadows. In the year 2010, only two categories of cultivation were also recorded: irrigated rice by continuous flooding, accounting for 97.4% of the area (1,376,501 ha) and wet lowland, representing 2.6% of the area (37,262 ha) (EMBRAPA, 2013). In the harvest (2009/2010), rice contributed with approximately 7.7% (11.236 million tons) of the total grains harvested in the country (147.091 million tonnes) (CONAB, 2010).

The total area sown to rice under irrigation or flood plains can be seen in Table 3.68.

TABLE 3.68
Harvested area of rice

HARVESTED AREA	1990	1995	2000	2005	2010	SHARE IN 2010	VAR. 2005/2010
	(10^3 ha)					(%)	
Continuous flooded	1,077.10	1,359.50	1,262.20	1,382.50	1,376.50	97.4%	-0.4%
Intermittent flooded (Single aeration)	19.5	13	0	0	0	0.0%	NA
Rainfed – flood prone	161.9	139.7	59.3	45.7	37.3	2.6%	-18.4%
Irrigated Rice Total	**1,258.40**	**1,512.20**	**1,321.50**	**1,428.20**	**1,413.80**	**100%**	**-1.0%**

Source: EMBRAPA (2013).

Studies conducted in different countries have shown the influence of several factors on CH_4 emissions in flooded rice fields. These factors include temperature, solar radiation, types of fertilizer, types of cultivars, and types of soil. Brazil still does not have experimental data that allow defining specific emission factors under different regional and climatic conditions. For this reason, IPCC default factors have been used.

Estimates for CH_4 emissions from rice crop can be seen in Table 3.69. Emission reductions observed between 1995 and 2010 were due to a reduction in harvested area during the period. In 2010, emissions from rice cultivation in continuous flooded fields represented 98.1%, and in lowlands, they accounted for 1.9% of total emissions. Table 3.70 shows the contribution of each region of the country to methane emissions from rice cultivation.

TABLE 3.69

CH_4 emissions per rice cultivation regime

PLANTING REGIME	1990	1995	2000	2005	2010	SHARE IN 2010	VAR. 2005/ 2010
	($Gg\ CH_4$)					(%)	
Continuous regime	393.6	476.4	433.9	452.7	455.3	98.1%	0.6%
Intermittent regime	1.2	0.8	0	0	0	0	NA
Rainfed – flood prone	38.9	33.5	14.2	11.0	8.9	1.9%	-18.5%
Total	**433.6**	**510.8**	**448.1**	**463.7**	**464.2**	**100%**	**0.1%**

TABLE 3.70

CH_4 emissions per rice cultivation region

REGION	1990	1995	2000	2005	2010	SHARE IN 2010	VAR. 2005/ 2010
	($Gg\ CH_4$)					(%)	
North	8.8	22.2	16.8	23.3	23.6	5.1%	1.1%
Northeart	16.3	18.9	15.4	16.2	14	3.0%	-13.7%
Southeast	67.2	53.8	26.6	20	11.8	2.5%	-41.1%
South	320.2	402.2	376.9	387.8	404.3	87.1%	4.3%
Central-West	21	13.7	12.4	16.3	10.5	2.3%	-35.6%
Total	**433.6**	**510.8**	**448.1**	**463.7**	**464.2**	**100%**	**0.1%**

3.4.3. Crop Residue Burning

In Brazil, crop residue burning still occurs, mainly in the sugarcane crop, despite the progressive increase in mechanized harvesting in recent years. However, for the cotton crop, the burning practice ceased being common in the beginning of the 1990s.

Although the burning of residues releases a large quantity of CO_2, these emissions are not considered in the Inventory, because the same amount of CO_2 is necessarily absorbed during plant growth through photosynthesis. However, during the combustion process, other non- CO_2 gases are produced. Emission rates for these gases depend on the type of biomass and burning conditions. In the combustion with flame phase, N_2O and NO_X gases are generated; and CO and CH_4 gases are formed under burning conditions with a predominance of smoke.

3.4.3.1. Sugarcane

Sugarcane presents high photosynthetic efficiency, with optimal growth within the 20 to 35 °C temperature range. Therefore, its growing expanded to very diversified types of soil in the national territory. It is also highly tolerant to acidity and alkalinity. Sugarcane has great importance in the national economy, mainly due to sugar production.

The sugarcane burning practice during pre-harvest was broadly used in the country by 2005, with the objective of improving manual cutting performance, avoiding problems with poisonous animals, common in plantations, and facilitating land preparation for new planting. After 2006, a significant increase in the share of harvesting without burning was observed, reaching 34% of the total harvest area in 2007.

More than 55% of the sugarcane crop area in the state of São Paulo is currently being harvested without burning (AGUIAR et al., 2010), and this state is responsible for more than 60% of Brazilian production (UNICA, 2010[4]).

Preliminary data on sugarcane production area, from a survey conducted by CONAB with 355 plants in the country, for the 2007 harvest, indicate that mechanical harvesting was used in only 4% of the state of Pernambuco, the second largest sugarcane producer, and only 3% in the state of Alagoas. For years prior to 2006, due to the lack of reliable data and indications as to the gradual proportions of mechanization, it was assumed that the entire sugarcane producing area in these states was subject to burning.

In 2010, the Southeast region contributed the most to emissions, accounting for 55.2% of total average emissions in the period, followed by the Central-West, which contributed with 20.6%. The North contributed with only 0.4%. The increase in CH_4 emissions from 2005 to 2010 can be explained by the increase in harvested sugarcane area and the increase in average crop yield, reflecting greater biomass subject to burning. During this period, there was a 153.8% increase in burnt area in the Central-West region, which contributed with 14.9% of the country's harvested area in 2010.

4 Perspectivas da Expansão da Produção *(Persperctives of Production Expansion). Prepared by: UNICA, Copersucar and Cogen. Not published.*

The average annual harvest area for sugarcane, its production and average yield can be observed in Table 3.71.

TABLE 3.71
Harvested area, production and average yield for sugarcane crop

YEAR	HARVESTED AREA	PRODUCTION	AVERAGE YIELD
	(ha)	(t)	(t/ha)
1990	4,287,625	262,674,150	61
1991	4,210,954	260,887,893	62
1992	4,202,604	271,474,875	65
1993	3,863,702	244,531,308	63
1994	4,345,260	292,101,835	67
1995	4,559,062	303,699,497	67
1996	4,750,296	317,016,081	67
1997	4,814,084	331,612,687	69
1998	4,985,624	345,254,972	69
1999	4,898,844	333,847,720	68
2000	4,804,511	326,121,011	68
2001	4,957,897	344,292,922	69
2002	5,100,405	364,389,416	71
2003	5,371,020	396,012,158	74
2004	5,631,741	415,205,835	74
2005	5,805,518	422,956,646	73
2006	6,144,286	457,245,516	74
2007	7,143,906	549,707,314	77
2008	8,113,213	645,300,182	79
2009	8,933,825	691,606,147	77
2010	9,195,843	717,462,101	78

Table 3.72 shows estimated values for gas emissions from burning sugarcane. A 36% increase in gas emissions from burning sugarcane waste in the country was observed from 2005 to 2010, although the sugarcane-harvested area had grown 58%.

TABLE 3.72
Emissions for sugarcane burning

GAS	1990	1995	2000	2005	2010	VAR. 2005/ 2010
	(Gg)					(%)
CH_4	102.7	118.7	105.0	136.3	185.3	36.0%
N_2O	2.66	3.08	2.72	3.53	4.80	36.0%
CO	3,499.2	4,045.8	3,576.4	4,644.4	6,313.5	35.9%
NO_x	95.1	109.9	97.2	126.2	171.6	36.0%

3.4.3.2. Herbaceous cotton

Cotton crops are broken down into two categories, which are the herbaceous cotton and the arboreal cotton, the latter characterized by being a perennial crop where waste is not burned. For this Inventory, based on information obtained after consulting cotton production chain agents and current legislation, the practice of burning was re-evaluated as a method for eradicating and eliminating crop residues for the period after 1990. According to specialists, the common practice has been to grub and harrow crop residues, incorporating the waste to the soil, in consonance with the non-obligatory burning in current legislation. Chemical treatment is most used in cases of sprouting. It was thus assumed that there was a transition period between the obligatory and non-obligatory burning of cotton crop wastes in the beginning of the 1990s, as well as the eradication mechanisms of crop residues in the field. A gradual drop from 50% to 0% was considered from 1990 to 1995, as a fraction of the areas still practicing burning. After this period, it was assumed that cotton waste burning no longer existed in the country.

TABLE 3.73
Emissions from cotton crop waste burning

GAS	1990	1995	2000	2005	2010	VAR. 2005/ 2010
	(Gg)					(%)
CH_4	3.8	-	-	-	-	-
N_2O	0.10	-	-	-	-	-
CO	128.4	-	-	-	-	-
NO_x	3.5	-	-	-	-	-

3.4.4. N_2O emissions from agricultural soils

Use of nitrogen fertilizers is pointed out as the main reason for the global increase in N_2O emissions by agricultural soils. However, in Brazil, the main source of emissions is manure from grazing animals. N_2O emissions also occur from applying animal manure as fertilizer, from the nitrogen found in agricultural waste and from the atmospheric deposition of NO_x and NH_3.

N_2O emissions from agricultural lands were subdivided into three categories, as per 1996 Guidelines:

- >> N_2O emissions from grazing animal manure;
- >> other direct sources of N_2O emissions, including the use of synthetic fertilizers, nitrogen from manure used as fertilizer, the biological nitrogen fixation and crop residues; and
- >> indirect sources of N_2O emissions from the nitrogen used in agriculture, which include the volatilization and subsequent atmospheric deposition of NO_x and NH_3 from fertilizer applications, and leaching and runoff of nitrogen from fertilizers.

Estimates of N_2O emissions from agricultural soils in Brazil are shown in Table 3.74. In 2010, total emissions were estimated at 452.45 Gg N_2O, the highest share coming from direct emissions, in which grazing animal waste is the main cause.

From 2005 to 2010, the different source of N_2O emissions maintained the same order of importance as to their contribution towards total N_2O emissions from agricultural soils. The deposition of animal excrement in pastures remained as the most important source. Indirect emissions represented 37.6% of the total in 2010.

It is important to underscore that recent results from studies on N_2O emissions from national agriculture do not confirm that biological nitrogen fixation is a relevant process for N_2O emissions, an understanding in line with the 2006 Guidelines, in which this source of emissions is absent. Therefore, biological fixation of nitrogen was not considered as a source of emissions in this Inventory.

TABLE 3.74
N_2O emissions per agricultural soil

SOURCE	1990	1995	2000	2005	2010	SHARE IN 2010	VAR. 2005/ 2010
	(Gg N_2O)					(%)	
Direct emissions	184.07	205.28	213.85	257.09	282.31	62.4%	9.8%
Grazing animals	129.73	140.2	140.12	167.45	170.24	37.6%	1.7%
Bovine	107.99	118.49	122.04	148.83	152	33.6%	2.1%
Others	21.74	21.71	18.08	18.62	18.24	4.0%	-2.0%
Synthetic fertilizers	9.81	14.27	21.28	27.51	35.74	7.9%	29.9%
Application of fertilizer	14.9	16.4	15.88	17.81	21.33	4.7%	19.8%
Bovine	4.74	5.03	4.87	5.46	5.77	1.3%	5.7%
Others + Vinasse	10.16	11.37	11.01	12.35	15.56	3.4%	26.0%

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SOURCE	1990	1995	2000	2005	2010	SHARE IN 2010	VAR. 2005/ 2010
	($Gg\ N_2O$)					(%)	
Crop residues	15.32	19.8	21.66	29.11	39.49	8.7%	35.7%
Soy bean	4.85	6.26	8	12.47	16.75	3.7%	34.3%
Sugarcane	1.03	1.2	1.82	2.35	5.47	1.2%	132.8%
Beans	0.77	1.02	1.06	1.05	1.09	0.2%	3.8%
Rice	0.85	1.29	1.28	1.52	1.29	0.3%	-15.1%
Corn	3.48	5.91	5.27	5.72	9.02	2.0%	57.7%
Manioc	2.66	2.78	2.52	2.83	2.73	0.6%	-3.5%
Others	1.68	1.34	1.71	3.17	3.14	0.7%	-0.9%
Organic Soils	14.31	14.61	14.91	15.21	15.51	3.4%	2.0%
Indirect emissions	106.68	120.31	127.87	155.53	170.14	37.6%	9.4%
Atmospheric deposition	22.31	25.18	26.53	32.69	35.65	7.9%	9.1%
Synthetic fertilizers	2.44	3.56	4.94	7.08	9.13	2.0%	29.0%
Animal fertilizer	19.87	21.62	21.59	25.61	26.52	5.9%	3.6%
Bovine	15.58	17.06	17.49	21.21	21.71	4.8%	2.4%
Others	4.29	4.56	4.1	4.4	4.81	1.1%	9.3%
Leaching	84.37	95.13	101.34	122.84	134.49	29.7%	9.5%
Synthetic Fertilizers	9.18	13.37	19.66	25.95	33.65	7.4%	29.7%
Animal Fertilizer	75.19	81.76	81.68	96.89	100.84	22.3%	4.1%
Bovine	58.44	63.96	65.59	79.53	81.41	18.0%	2.4%
Others	16.75	17.8	16.09	17.36	19.43	4.3%	11.9%
Total	**290.75**	**325.59**	**341.72**	**412.62**	**452.45**	**100%**	**9.7%**

3.4.4.1. N_2O emissions due to grazing animals

Waste deposited on soils by animals during grazing is the most important source of N_2O emissions by agricultural soils in Brazil due to the large herd and the fact that extensive raising is the predominant cattle practice in the country. The production systems are also characterized by large territorial extension, with pasture management conducted continuously.

In Brazil, between 2005 and 2010, total nitrogen directly excreted in pastures increased by 1.8%, and it is possible to observe this evolution from data in Table 3.75. N_2O emissions from grazing animals represented 37.6% of emissions of this gas from agricultural soils, in 2010, with cattle as the main contributor of these emissions.

N_2O emissions were estimated using IPCC default emission factors for the nitrogen content in animal wastes and for the N_2O emission factor for the quantity of nitrogen deposited. Among the Brazilian regions, in 2010, the Central-West had the largest number of heads of beef cattle, corresponding to 34.6% of the Brazilian herd. Table 3.75 shows that the Central-West region offers the highest contribution in quantity of nitrogen from animal manure directly applied to pasture.

Beef cattle production in the beginning of the 2000s was characterized by a migration from the Southeast to the Central-West and North regions. This explains the increase in the quantity of nitrogen applied directly to the soil in the latter.

TABLE 3.75

Nitrogen amount in animal manure applied directly to pasture

SYSTEM		1990	1995	2000	2005	2010	SHARE IN 2010	VAR. 2005/ 2010
		(t NEx*)					(%)	
Grazing animals	North	514,405	697,323	826,639	1,358,545	1,366,162	19.4%	0.6%
	Northeast	1,157,440	1,050,992	1,004,210	1,162,718	1,233,083	17.5%	6.1%
	Southeast	1,262,937	1,303,752	1,227,253	1,281,403	1,279,669	18.2%	-0.1%
	South	872,450	908,321	843,641	877,841	895,889	12.7%	2.1%
	Central-West	1,465,912	1,757,240	1,851,101	2,226,094	2,253,743	32.1%	1.2%
	Total	**5,273,143**	**5,717,627**	**5,752,843**	**6,906,602**	**7,028,545**	**100%**	**1.8%**

** Excreted nitrogen*

3.4.4.2. N_2O emissions by other direct sources

Use of synthetic fertilizer

The most important nitrogen fertilizers used in Brazil are urea, ammonia, anhydrous ammonium nitrate and ammonium sulfate. Total consumption of synthetic nitrogen fertilizers in Brazil in 2010 was 2.854 million tonnes of nitrogen content, 29.7% more than consumption in 2005 according to Table 3.76. Part of this nitrogen is incorporated to plants and soil, part is volatized as NO_x and NH_3 and part is released as N_2O. Due to the absence of specific studies on emission factors for Brazil's management and climate conditions, IPCC default emission factors have been used.

The share of the Southeast region in the total consumption of nitrogen fertilizers in the country increased by 10.7% between 2005 and 2010, and accounted for the largest share of consumption in the country in 2010, with 37.9% of the total. The direct emissions of N_2O by the use of synthetic fertilizers accounted for 7.9% of the emissions of N_2O from agricultural land in 2010, as shown in Table 3.74.

TABLE 3.76

Amount of fertilizer in the form of nitrogen delivered to the end consumer in Brazil from 1990 to 2010

REGION	1990	1995	2000	2005	2010	SHARE IN 2010	VAR. 2005/ 2010
	(t N)					(%)	
North	1,273	4,941	13,731	22,692	33,113	1.2%	45.9%
Northeast	80,013	119,902	147,286	197,012	280,905	9.8%	42.6%
Southeast	402,060	563,642	721,382	977,190	1,081,888	37.9%	10.7%
South	231,403	327,147	499,749	631,653	882,822	30.9%	39.8%
Central-West	64,566	119,013	286,047	372,857	576,091	20.2%	54.5%
Brazil	**779,315**	**1,134,645**	**1,668,195**	**2,201,404**	**2,854,819**	**100%**	**29.7%**

Use of manure as fertilizer

The emissions of nitrous oxide (N_2O) estimated in this section are related to the N_2O produced during the storage and treatment of animal waste, before being applied to the soil as a fertilizer. The term manure or waste is used here collectively for both liquid and solid wastes produced by livestock. The emission of N_2O from waste during storage and treatment depends on the nitrogen and carbon contained therein, the duration of storage and the type of treatment. The term “management system” is used for all types of storage and handling of manure.

The amount of nitrogen excreted by animals that does not occur directly in the pasture is assumed as being applied to the soil as fertilizer.

According to the practices used in each region, it is considered that the managed manure, using the systems of anaerobic lagoon, solid storage, dry lot, pasture, manure and biodigester, are applied in the grassland as fertilizer. As for the N_2O emission factors, the IPCC default values were adopted. The direct emissions of N_2O by the use of animal manure as fertilizer accounted for 4.7% of the emissions of N_2O from agricultural land in 2010, as shown in Table 3.74.

Except for the category of swine and poultry, a large part of manure is deposited directly in the pastures. In the case of animals whose manure is “not managed”, that is, animals from pasture and paddock, manure are not stored or processed, but deposited directly in the grassland.

TABLE 3.77

Nitrogen amount in animal manure applied on soils (except grazing)

REGION	1990	1995	2000	2005	2010	SHARE IN 2010	VAR. 2005/ 2010
	(t NEx)					(%)	
North	71,207	87,270	61,546	64,687	59,001	4.2%	-8.8%
Northeast	207,200	197,977	171,135	181,051	177,911	12.6%	-1.7%
Southeast	299,922	319,268	313,788	336,297	376,677	26.8%	12.0%
South	349,212	415,349	432,639	485,119	586,326	41.7%	20.9%
Central-West	123,310	140,701	138,503	176,124	207,686	14.8%	17.9%
Brazil	**1,050,851**	**1,160,565**	**1,117,611**	**1,243,278**	**1,407,600**	**100%**	**13.2%**

The quantities of nitrogen in manure used for fertilizers that directly generate emissions of N_2O are estimated at 80% of the total, with the remaining 20% corresponding to losses by volatilization of NH_3 and NO_x, which will generate indirect emissions of N_2O.

Table 3.78 shows emissions from manure management systems in Brazil, not including those deposited directly in pastures, indicating that emissions of N_2O from the management systems of animal waste are predominant in the South region of the country.

TABLE 3.78

Summary of N_2O emissions by animal manure management in Brazil

REGIÃO	1990	1995	2000	2005	2010	SHARE IN 2010	VAR. 2005/ 2010
	(Gg N_2O)					(%)	
North	0,73	0,91	0,66	0,67	0,62	4,2%	-6,6%
Northeast	2,36	2,36	2,13	2,27	2,34	15,7%	3,1%
Southeast	2,95	3,3	3,47	3,79	4,37	29,5%	15,4%
South	2,98	3,73	3,94	4,45	5,52	37,2%	24,2%
Central-West	1,01	1,2	1,29	1,65	1,98	13,4%	20,5%
Total	**10,03**	**11,49**	**11,49**	**12,82**	**14,84**	**100%**	**15,8%**

Biological nitrogen fixation

The reduction process of atmospheric N_2O to combined forms of ammonium-N using living organisms is called biological nitrogen fixation. In Brazil, the practice of inoculation with specific bacteria for N_2 fixation is routinely used only in the soybean crop, and there is no other available information about its application in other crops.

In relation to N_2O emissions resulting from the biological nitrogen fixation (BNF) process using legumes, as shown in 1996 Guidelines, Rochette and Janzen (2005) demonstrated that there are no data in literature to confirm the existence of any relation between the two processes, thus BNF is no longer considered a source of N_2O in 2006 Guidelines. The confirmation that the soy bean crop does not imply N_2O emissions due to BNF associated with the culture was achieved by Cardoso et al. (2008) by failing to find any difference between N_2O emissions measured in soil planted with a nodulating variety and another non-nodulating variety (unable to benefit from BNF). In the South of Brazil, Jantalia et al. (2008) did not record N_2O emissions either during soybean crop growth that could suggest BNF as a relevant source of this gas.

Thus, for this Inventory, BNF was removed as a source of N_2O, as described in the 2006 Guidelines methodology, corroborated by national studies.

Crop residues

Nitrogen contained in crop residues and incorporated into the soil is also a source of N_2O emissions. In order to estimate these emissions, annual productions and the amount of dry matter per crop were used. The main crops considered were sugarcane, corn, soybean, rice, beans, and cassava.

Considering the quantity of nitrogen contained in the waste of each main crop, as well as other annual crops, there has been a 35.7% increase in the amount of nitrogen between 2005 and 2010 that returns to the agricultural soil (Table 3.79), with soy bean standing out as the main contributor.

TABLE 3.79
Nitrogen amount in residue left on agricultural soils by crop

CROP	1990	1995	2000	2005	2010	SHARE IN 2010	VARIATION 2005/ 2010
	(t N)					(%)	
Soy bean	308,484	398,168	508,834	793,496	1,065,957	42.4%	34.3%
Sugarcane	65,863	76,150	115,631	149,598	347,858	13.8%	132.5%
Beans	49,241	64,925	67,352	66,588	69,613	2.8%	4.5%
Rice	54,232	82,040	81,372	96,413	82,113	3.3%	-14.8%
Corn	221,385	376,103	335,182	364,139	574,150	22.8%	57.7%
Manioc	169,233	176,893	160,341	180,017	173,721	6.9%	-3.5%
Others	107,201	85,489	108,978	201,545	199,954	8.0%	-0.8%
Total	**975,639**	**1,259,767**	**1,377,690**	**1,851,798**	**2,513,365**	**100%**	**35.7%**

Due to lack of reliable data related to residues from permanent crops (coffee, coconut, oranges, among others), the quantity of nitrogen that returns as waste from these crops was not calculated. The parameters used for temporary crops (fraction of dry matter from the harvested product) would not serve as reference for perennial crop waste, since residues from these cultures do not return to agricultural soils.

For annual crops, a bibliographical study was conducted to estimate dry matter fraction of the product and the nitrogen fraction of the aerial part of the plant. Due to the lack of better information, IPCC default emission factors were used for nitrogen content in residues and for the portion of waste that remains in the field. Direct N_2O emissions from the use of harvest waste represented 8.7% of N_2O emissions from agricultural soil in 2010, as per Table 3.74, and the six main crops accounted for 92% of emissions for all crops.

High organic content soils

It is necessary to estimate the managed area for emissions of N_2O through the management of organic soils, which is multiplied by the emission factor (EF). For this Inventory, the area of organic soil was raised in accordance with the IPCC definition (2006), which complies with the WRB system (FAO/UNESCO), taking into account the following criteria:

1 thickness of 10 cm or more. Horizon with <20cm must be 12% or more of organic carbon when mixed up to 20cm of depth;

2 the saturation of the soil with water must occur for a few days only, and the soil must have more than 20% carbon (weight) or more than 35% organic matter;

3 If the soil is subject to episodes of saturation with water and has (1) at least 12% carbon in the case of not having clay; (2) at least 18% carbon if it has 60% or more of clay; or (3) intermediate proportion of carbon for intermediate proportion of clay.

The soil survey was based on the map of Brazilian soils developed by Embrapa (scale 1:5,000,000). Map units were designed for each state, with the location of Histosols and Melanin Gleysols, whose descriptions meet the specification for organic soils.

The components 1, 2 and 3 were considered (COMP1, COMP2 and COMP3), which represent the level of importance of the soil class in the occurrence of associations of soils observed in the map unit. For each component, the share of each soil class was established in the mapping units (MU), in which a 3 component MU stands for component 1 (50%), component 2 (30%), component 3 (20%) and/or, in the case of 2 components, component 1 (60%), component 2 (40%), according to the criteria established for the composition of MU in soil surveys. The areas of organic soils total 1,598,267.46 ha (15,982.6746 km^2).

For the estimation of management, maps of land use in 1994 and 2002 were applied, which are set out in the report of Land Use, Land-Use Change and Forestry in the Second National Communication. They were considered areas of soils subjected to agricultural use, identified as 'Agricultural Area' (Ac), 'Planted Pasture' (Ap), 'Managed Grassland' (GM) and 'Reforestation' (Ref), to which the identification used in the report of Land Use, Land-Use Change and Forestry was foundational. In 1994, the areas of managed organic soils corresponded to 771,644.79 ha, and in 2002, 797,004,49 ha, which represented an increase of only 3.3% in 8 years, indicating some stability in the area managed. A simplified assumption that the variation was linear between the two years evaluated and that the same model would apply to estimates back to 1990 and projections up to 2010 was taken into account. Thus, the area managed in 1990 accounted for 47.5% of the total area of organic soils in Brazil, and that increased linearly until 2010, reaching 51.5%.

According to the 1996 Guidelines, the cultivation of organic soils in subtropical and tropical regions implies emissions from 8 to 16 kg $N\text{-}N_2O$ ha^{-1} $year^{-1}$. Since the occurrence reports of organic soils are more geared toward the Central-South region, an average value for the emission factor of N_2O (EF) of 12kg $N\text{-}N_2O$ ha^{-1} $year^{-1}$ was adopted.

3.4.4.3. N_2O emissions from indirect sources

Atmospheric deposition of NO_x and NH_3

Part of the nitrogen contained in synthetic fertilizers and in animal manure, used as fertilizers, volatilizes as NO_x and NH_3. This part is discounted from the estimates of emissions from direct sources. However, part of these gases is deposited again on the Earth's surface, and if this deposition occurs on agricultural soils, it can result in additional N_2O emissions. It is impossible to determine where this deposition will occur, and it may even occur in the oceans. Likewise, NO_x and NH_3 stemming from other sources, such as combustion, may deposit on agricultural soils. Therefore, the uncertainty related to this portion of emissions is very large. It was decided to consider total deposition corresponding to the volatilized gases from agricultural soils. IPCC default emission factors were used. N_2O emissions from atmospheric deposition of NO_x and NH_3, in 2010, represented 7.9% of N_2O emissions from agricultural soils, growing 9.1% compared to the value estimated in 2005, as per Table 3.74.

Nitrogen leaching and surface runoff

Part of the nitrogen applied to agricultural soils as synthetic fertilizers or animal manure is subject to leaching and runoff, flowing through rivers into the ocean. These environments also have N_2O emissions, classified as indirect emissions from fertilizer applications. Uncertainty regarding N_2O emission factors by runoff of this nitrogen is very large, and there is no assessment concerning the most appropriate values for Brazil's wide-ranging conditions. IPCC default emission factors were used. In 2010, N_2O emissions due to leaching and runoff nitrogen applied as fertilizer accounted for 29.7% of N_2O emissions from agricultural soils, a growth of 9.5% compared to the estimated value for 1990, as per Table 3.73.

3.5. LAND USE, LAND-USE CHANGE AND FORESTRY

The methodologies adopted for this part of the Inventory are consistent with those in the 2003 Good Practice Guidance (IPCC, 2003), with updates of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006), when relevant. Even if these guides are not mandatory for developing countries, it was decided to use them given the importance of emissions associated with Land use, Land-Use Change and Forestry (LULUCF) mentioned in previous inventories (BRASIL 2004; 2010). In this context, a more detailed approach described in the guides was again applied, which includes the spatially explicit observation of categories of land use and their conversions in the evaluated period.

Emissions and removal estimates based on this methodology require a correct representation of areas and their association with use categories proposed by the IPCC from a proper, consistent, complete, and transparent approach. Thus, in order to reach an in-depth result of this work, the implementation of the inventory involved the search of information in scientific literature and expert support from various regions of the country, both for the mapping of different uses of land and data compilation used for emissions and removals estimates. In addition, to keep the whole process transparent and replicable, all steps are described in detail and their meta-data are made available, when possible.

One of the difficulties associated with this sector is the identification of anthropogenic and non-anthropogenic emissions and removals of greenhouse gases. Similarly to the Second National Inventory, this report applies the concept of managed land proposed by the IPCC (IPCC, 2003; 2006), meaning that all emissions and removals occurred on these lands are considered anthropogenic. On the other hand, emissions and removals occurred on unmanaged lands are considered non-anthropogenic, except for the unmanaged area converted into other categories of land use, as established in the Good Practice Guidance LULUCF (IPCC, 2003) and the 2006 IPCC Guidelines (IPCC, 2006).

In the case of Brazil, Managed Land comprises the entire area contained in Indigenous Lands – according to information provided by the National Indian Foundation (FUNAI), whose processes of demarcation are minimally in the "Delimited" phase – in state and federal protected areas – according to the Ministry of the Environment (MMA) and the National System of Protected Areas (SNUC), Law 9985/2000, except for the Private Reserves of Natural Preservation (RPPN) due to the lack of consistent information about them.

The net anthropogenic emissions (emissions by sources minus removals by sinks) between two points in time are estimated for all carbon stocks as follows: (i) living biomass (above and belowground biomass), (ii) dead organic matter (litter and dead wood), (iii) organic carbon in the soil, as proposed by the IPCC (IPCC, 2003; 2006).

This Inventory presents average annual net emissions for the period between the years 2002 and 2010 for all Brazilian biomes. Exceptionally for the Amazon, estimates are presented for the periods of 2002-2005 and 2005-2010, in order to capture the impact of the implementation of the Action Plan for the Prevention and Control of Deforestation of the Legal Amazon[5] area (PPCDAm), established on 2004.

The activity data for this inventory was foremost based on image analysis of satellites with appropriate spatial resolution (TM-Landsat-5, 30 meters; LISS-III/Resourcesat-1, 23,5 meters). The mapping of land-use categories/subcategories was prepared on a 1:250.000 scale with a minimum mapping unity of 6 hectares. Whenever possible, emission factors were based on national data, and when these data were not available, on default data of the IPCC (IPCC, 2003; 2006). Those data associated with the methodological proposal of the IPCC enabled emission and sink estimates for the studied period, taking into consideration the specificities of Brazilian biomes. It should be noted that more detailed information on methods, data and results presented are found on the Reference Report "Greenhouse Emissions for the Land Use, Land-Use Change and Forestry Sector".

Based on these results, the average net annual emissions for the period 1994 to 2010 were estimated, as described in section 3.5.2.8.

Additionally, CO_2 emissions of resulting from liming – application of limestone on the soil to reduce its acidification – are included in this sector.

5 *Legal Amazon: Area encompassing whole nine states: Acre, Amazonas, Amapá, Maranhão (totally included since May 2008), Mato Grosso, Rondônia, Pará, Roraima and Tocantins, with a total of 5.02 million km^2. It incorporates the whole Amazon biome (4.21 km^2) and parts of the Cerrado and the Pantanal biomes.*

3.5.1. Methodology

3.5.1.1. Land Use, Land-Use Change and Forestry

The identification of areas under different categories of land-use/land-cover using approach 3 (Tier 3) of the Good Practice Guidance LULUCF (IPCC, 2003) was continued in order to assure consistence of estimates of this Third Inventory. All categories and changes occurred between the inventories are spatially identified for all the national territory. This approach requires spatially explicit observations of transitions and, in the Brazilian case, included managed and unmanaged areas. The methodology used to calculate emissions for land-use, land-use change and forestry is detailed in Appendix I.

3.5.1.2. Liming of agricultural soils

Emissions from lime application to soils are calculated based on the amount of lime commercialized in Brazil annually, by state, between 1990-2010, based on the information provided by the Brazilian Association of Agricultural Lime Producers (ABRACAL). Due to the lack of detailed information on the composition of lime sold in the country it is assumed that the lime is composed basically of calcic limestone. The emission factor used to calculate the emissions is 0.44 t CO_2/t $CaCO_3$.

3.5.2. Results

This Third Inventory presents updates of data activity and emission factors for the following reasons: (1) new methodological approach (for example, new carbon content based on plant phytophysiognomy of the Amazon); (2) updated data (for example, on planted forestry); (3) refined classification of land use/coverage. Hence, estimates for the period of 1994-2002 were recalculated in order to assure consistence among periods. It is worth mentioning that the mapping for the year 2002 used in the Second Inventory was based on a mapping commissioned by the Ministry of the Environment (PROBIO I) and was prepared by six distinct institutions, resulting in some inconsistencies when compared to the mapping of 2010. Therefore, the mappings for land use and land cover for 2002 were re-elaborated by the same team, which mapped 2010, assuring greater consistency and accuracy for the classification of land use/cover.

Net anthropogenic CO_2 emissions are presented for each of the six Brazilian biomes.

The following Tables show the areas of each transition between land use and land use cover that have been considered between 1994 and 2002 and between 2002 and 2010 and then net emissions for each transition. Exceptionally for the Amazon, the year of 2005 is also presented because there is a reduced level of deforestation from this year onwards. It is worth noting that the total areas of the biomes presented in the results are not exactly the same presented in Table A1.1 (see Appendix I) due to corrections of topological errors (overlapping and gaps) of the original information plans.

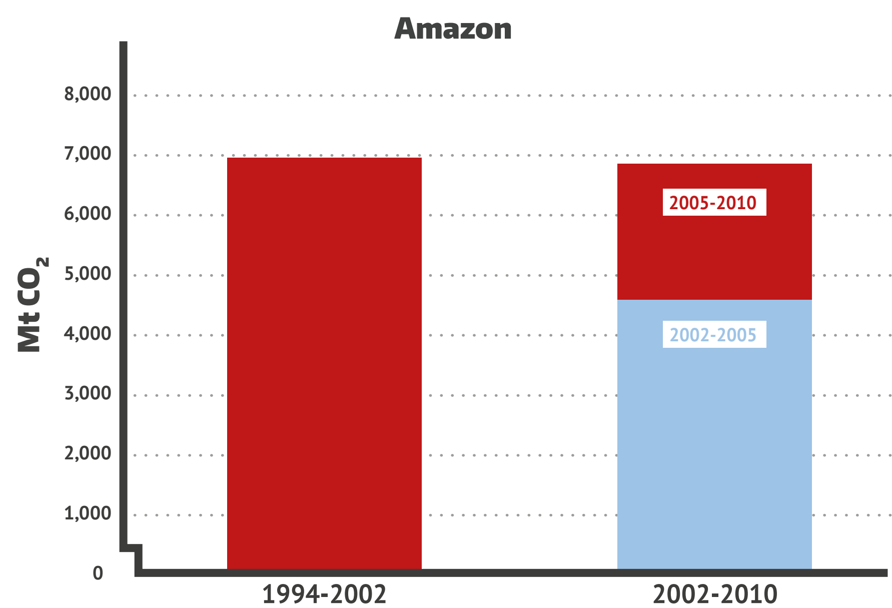
3.5.2.1. Amazon Biome

Tables 3.81 (1994-2002), 3.83 (2002-2005) and 3.85 (2005-2010) present the estimated areas for the land-use categories/subcategories, which are maintained on the same categories/subcategories or were converted into other uses between the initial and final years of the Inventory. Tables 3.80, 3.82 and 3.84 present net CO_2 emissions based on the data of Tables 3.81, 3.83 and 3.85 and emission factors are presented in Appendix I.

There was a decrease in emissions due to land-use change in the Amazon biome over the evaluated periods. Partial net anthropogenic emissions totaled 6,958,430.5 Gg CO_2 in the 1994 to 2012 period. In the 2002 to 2005 period emissions were 4,594,652.8 Gg CO_2 and, from 2005 to 2010 were at 2,262,372.2 Gg CO_2 (Figure 3.5).

FIGURE 3.5

Anthropogenic net emissions of the Amazon biome for the considered periods



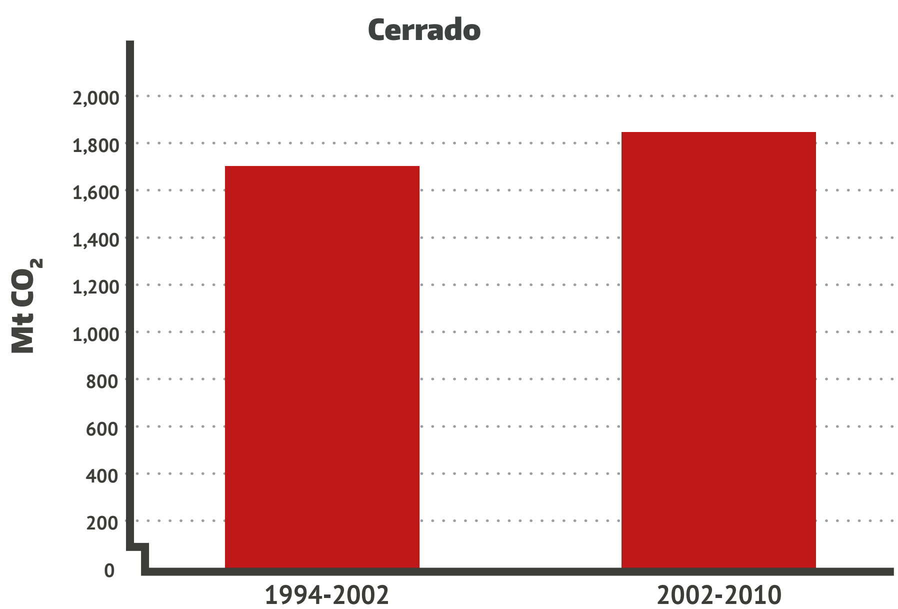
3.5.2.2. Cerrado Biome

Tables 3.87 and 3.89 present estimated areas of each land-use change and land cover transition observed between 1994 and 2002, and between 2002 and 2010 for the Cerrado biome. Tables 3.88 and 3.90 present net anthropogenic CO_2 emission related.

Net anthropogenic CO_2 emissions related to land-use change and land cover in the Cerrado biome totaled 1,703,660.0 Gg CO_2 in the period from 1994 to 2002, increasing to 1,845,024.7 Gg CO_2 between the years 2002 to 2010 (Figure 3.6).

FIGURE 3.6

Anthropogenic net emissions of the Cerrado biome for the considered periods

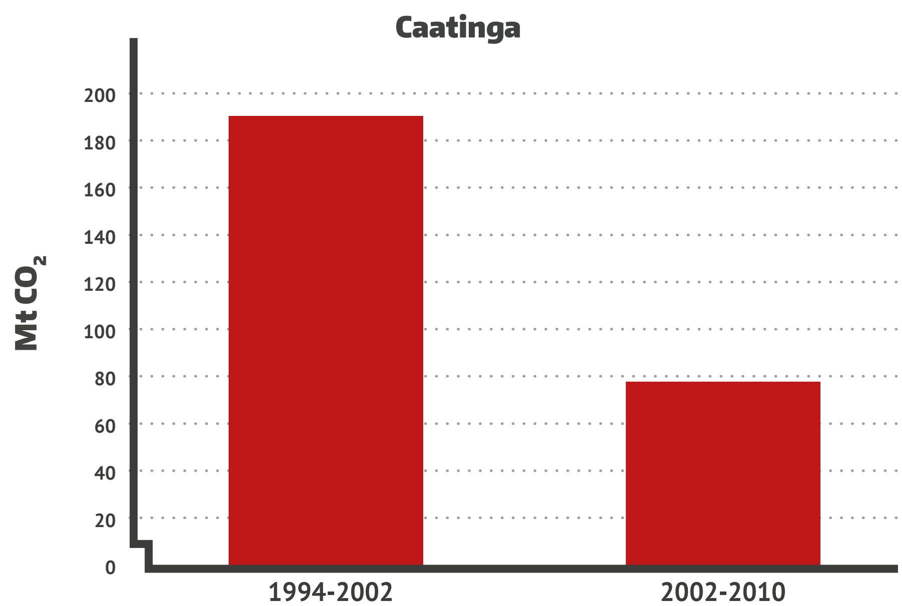


3.5.2.3. Caatinga Biome

Tables 3.91 and 3.93 present the estimated areas of each transition observed between 1994 and 2002, and between 2002 and 2010 for the Caatinga biome. Tables 3.92 and 3.94 show net anthropogenic CO_2 emission related.

Net anthropogenic CO_2 emissions of the Caatinga biome totaled 190,190.9 Gg CO_2 for the period of 1994-2002, reducing to 77,708.0 Gg CO_2 for the period of 2002 to 2010 (Figure 3.7).

FIGURE 3.7
Anthropogenic net emissions of the Caatinga biome for the considered periods



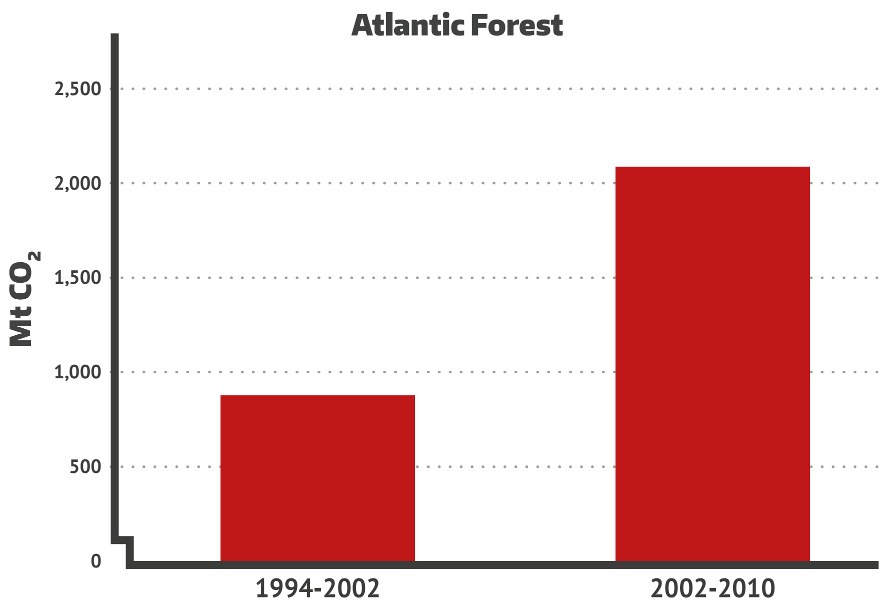
3.5.2.4. Atlantic Forest Biome

Tables 3.95 and 3.97 present the estimated areas of each transition observed between 1994 and 2002, and between 2002 and 2010 for the Atlantic Forest biome. Tables 3.96 and 3.98 show net anthropogenic CO_2 emission related.

Land-use change emissions of the Atlantic Forest biome totaled 888,574.3 Gg CO_2 for the period of 1994-2002, increasing to 2,090,380.7 Gg CO_2 for the period of 2002 to 2010 (Figure 3.8).

FIGURE 3.8

Net anthropogenic emissions of the Atlantic Forest biome for the considered periods



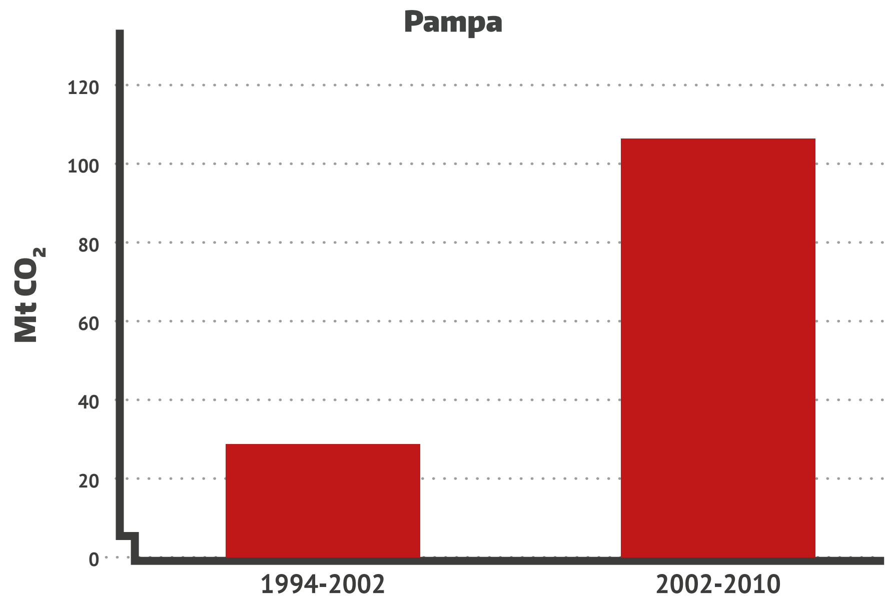
3.5.2.5. Pampa Biome

Tables 3.99 and 3.101 present the estimated areas of each transition observed between 1994 and 2002, and between 2002 and 2010 for the Pampa biome. Tables 3.100 and 3.102 present net anthropogenic CO_2 emissions related.

Net emissions related to land-use change in the Pampa biome totaled 28,787.6 Gg CO_2 in the period from 1994 to 2002, increasing to 106,823.1 Gg CO_2 between the years 2002 to 2010 (Figure 3.9).

FIGURE 3.9

Net anthropogenic emissions of the Pampa biome for the considered periods



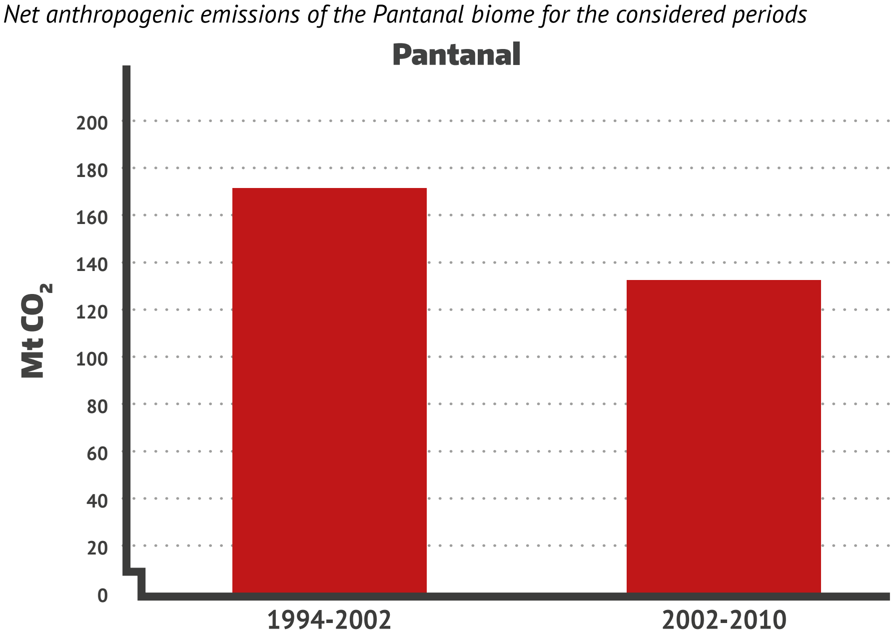
3.5.2.6. Pantanal Biome

Tables 3.103 and 3.105 present the estimated areas of each of the transitions observed between 1994 and 2002, and between 2002 and 2010 for the Pantanal biome. Tables 3.104 and 3.106 show net anthropogenic CO_2 emission related.

CO_2 net emissions related to land-use change in the Pantanal biome totaled 173,116.3 Gg CO_2 in the period from 1994 to 2002, reducing to 133,913.3 Gg CO_2 between the years 2002 to 2010 (Figure 3.10).

FIGURE 3.10

Net anthropogenic emissions of the Pantanal biome for the considered periods



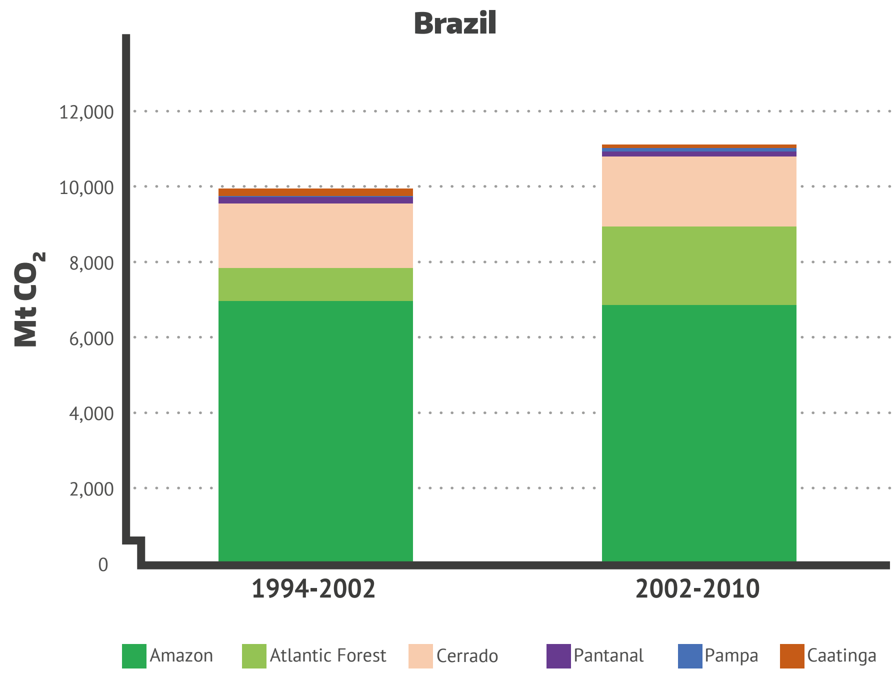
3.5.2.7. Consolidated results

Table 3.107 presents the estimated area of each transition observed between 1994 and 2002 in the country, in relation to the matrix presented in the Second Inventory, but with some amendments. Table 3.108 presents net anthropogenic emissions for the period from 1994 to 2002. Table 3.109 presents the areas of each transition of land use and land cover for all biomes, but for the Amazon biome only one transition was considered, from 2002 to 2010. Net anthropogenic CO_2 emissions for the period from 2002 to 2010 are detailed on Table 3.110, which is not totally compatible with Table 3.109, give that this Table the part in relation to transitions in the Amazon biome involves an analysis of the intermediary situation in 2005.

Figure 3.11 presents partial net anthropogenic CO_2 emissions for the periods from 1994 to 2002, and from 2002 to 2010 for the whole country. Net anthropogenic CO_2 emissions related to land-use change in Brazil totaled 9,942,759.6 Gg CO_2 from 1994 to 2002, and for the period from 2002 to 2010 totaled 11,110,874.8 Gg CO_2. Table 3.80 presents net emissions by biome for such periods.

FIGURE 3.11

Anthropogenic CO_2 emissions related to land-use change and land cover in Brazil for the periods considered in this Inventory



OBS: Net anthropogenic CO_2 emissions related to land-use change and land cover in Brazil in the period between 2002 to 2010 comprise the sum of emissions from 2002-2005 and 2005-2010 for the Amazon biome, and 2002-2010 for the other biomes, according to 3.80.

TABLE 3.80

Net anthropogenic CO_2 emissions by biome in the periods considered in this Inventory

BIOME	Net emissions (Gg CO_2)			
	1994 TO 2002	2002 TO 2010	2002 - 2005	2005 - 2010
Amazon	6,958,430.5	➔	4,594,652.8	2,262,372.2
Cerrado	1,703,660.0	1,845,024.7	-	-
Atlantic Forest	888,574.3	2,090,380.7	-	-
Caatinga	190,190.9	77,708.0	-	-
Pampa	28,787.6	106,823.1	-	-
Pantanal	173,116.3	133,913.3	-	-
Brazil	**9,942,759.6**	**11,110,874.8**	🡐	

TABLE 3.81

Transition areas for land-use and land-cover identified in the Amazon biome for the period from 1994 to 2002 (hectare)

LAND-USE TRANSITION MATRIX IN THE AMAZON BIOME - 1994-2002 (ha)									
LAND USE IN 1994		LAND USE IN 2002							
		FNM	FM	FSEC	REF	CS	GNM	GM	GSEC
1994	FNM	216,613,348.8	39,369,988.0	798,320.7	28,645.9	235,584.8			
	FM		92,803,469.4	34,268.6	0.1	23,704.6			
	FSec			751,094.9	634.8				
	Ref			57.7	295,454.3				
	CS								
	GNM				8,770.9		6,457,476.4	1,480,387.9	17,176.0
	GM							2,695,998.4	218.2
	GSec				104.4				8,383.2
	Ap			1,639,036.8	22,442.2				7,938.9
	Ac			13,560.9	0.1				64.5
	S								
	A	92.4	57.5						
	Res			857.8					
	O			795.3					
	NO	27,608.7	54,620.5	24,757.0	290.1	321.1	37.9	354.7	3.3
	Total 2002	216,641,049.9	132,228,135.4	3,262,749.7	356,342.8	259,610.6	6,457,514.3	4,176,741.0	33,784.0
	% of biome	51.5	31.4	0.8	0.1	0.1	1.5	1.0	0.0

TABLE 3.82

Net CO_2 emissions in the Amazon biome in the period from 1994 to 2002 (Gg)

NET EMISSIONS MATRIX IN THE AMAZON BIOME - 1994-2002 (Gg CO_2)									
LAND USE IN 1994		LAND USE IN 2002							
		FNM	FM	FSEC	REF	CS	GNM	GM	GSEC
1994	FNM		-248,293.4	437,773.1	15,433.3	27,194.6			
	FM		-1,170,561.1	19,882.3	0.1	2,468.4			
	FSec			-109,279.3	80.2				
	Ref			2.7					
	CS								
	GNM				-1,068.1			-11,290.4	822.1
	GM							-41,123.0	9.4
	GSec				-15.7				-127.9
	Ap			-24,715.4	-3,491.7				153.5
	Ac			-815.5	0.0				0.4
	S								
	A								
	Res								
	O			-32.2					
	NO								
	From the situation of 2002		-1,418,854.5	322,815.7	10,938.1	29,663.0		-52,413.4	857.6

	AP	AC	S	A	RES	O	NO	TOTAL 1994	% OF BIOME
	13,901,301.2	399,023.2	17,445.9	117.6	9,307.8	8,196.0	408.9	271,381,689.0	64.5
	605,955.5	4,065.2	2,040.3		245.2	5,150.1	531.6	93,479,430.7	22.2
	612,188.8	4,138.2	1,117.1	8.8	0.6	715.4		1,369,898.6	0.3
	943.7	8.2	0.8			0.0		296,464.8	0.1
								-	-
	236,513.5	9,908.6	5,623.7	24.3		5.7		8,215,886.9	2.0
	6,832.6	142.1	51.5				6.0	2,703,248.7	0.6
	8,690.9	0.0	47.9					17,226.4	0.0
	26,517,358.5	101,130.1	62,596.7	296.0	404.8	1,226.0	1,531.2	28,353,961.2	6.7
	58,815.5	556,189.5	339.3	1.6				628,971.5	0.1
			189,812.3					189,812.3	0.0
	145.8	11.4		12,723,074.4	22,671.0			12,746,052.5	3.0
				14.4	596,680.5			597,552.7	0.1
	10,351.7		5.1	417.1	0.0	45,016.4		56,585.6	0.0
	711,347.7	266.0	3,605.7		96.6	1,802.7	16,005.3	841,117.3	0.2
	42,670,445.4	1,074,882.7	282,686.3	12,723,954.3	629,406.6	62,112.4	18,483.0	420,877,898.3	
	10.1	0.3	0.1	3.0	0.1	0.0	0.0		

	AP	AC	S	A	RES	O	NO	FROM THE SITUATION OF 1994
	7,381,720.2	160,142.2	12,270.3		6,431.0	5,028.9		7,797,700.1
	349,506.9	2,115.5	1,353.8		170.5	3,246.9		-791,816.7
	131,285.6	818.3	385.4		0.1	188.1		23,478.5
	90.1	0.9	0.1			0.0		93.7
	5,742.6	380.1	405.3			0.5		-5,007.9
	127.8	6.1	3.5					-40,976.2
	-25.9	0.0	1.9					-167.6
		1,791.8	3,684.0		24.0	75.6		-22,478.1
	-944.5		16.9					-1,742.7
	-620.4							-652.6
	7,866,882.2	165,254.9	18,121.4		6,625.5	8,539.9		6,958,430.5

TABLE 3.83

Transition areas for land-use and land-cover identified in the Amazon biome for the period from 2002 a 2005 (hectare)

LAND-USE TRANSITION MATRIX IN THE AMAZON BIOME - 2002-2005 (ha)										
LAND USE IN 2002		LAND USE IN 2005								
		FNM	FM	FSEC	REF	CS	GNM	GM	GSEC	
2002	FNM	176,098,546.5	21,512,520.9	39,112.3	29,077.0	1,135,787.5				
	FM		123,129,397.6	1,465.9	278.6	46,548.1				
	FSec			2,862,684.7	648.8	230.4				
	Ref			28,861.1	173,398.6				16,202.3	
	CS			173,148.3		36,157.7				
	GNM				9,819.6		5,676,463.1	277,153.7	66.6	
	GM				0.0			3,915,039.7	104.7	
	GSec								31,344.2	
	Ap			2,965,927.3	42,552.1				90,842.3	
	Ac			39,576.1	7,337.4				2,427.4	
	S									
	A	176,099.1	103,582.2	262.6	2.3	17.0	2,576.9	3,241.3	0.8	
	Res			1,009.2						
	O			12,909.2	1.1				2.9	
	NO	872.2	9,877.7	510.0				5.7		
	Total 2005	**176,275,517.8**	**144,755,378.3**	**6,125,466.7**	**263,115.6**	**1,218,740.8**	**5,679,039.9**	**4,195,440.4**	**140,991.1**	
	% of biome	**41.9**	**34.4**	**1.5**	**0.1**	**0.3**	**1.3**	**1.0**	**0.0**	

TABLE 3.84

Net CO_2 emissions in the Amazon biome in the period from 2002 to 2005 (Gg)

NET EMISSIONS MATRIX IN THE AMAZON BIOME - 2002-2005 (Gg CO_2)										
LAND USE IN 2002		LAND USE IN 2005								
		FNM	FM	FSEC	REF	CS	GNM	GM	GSEC	
2002	FNM		-50,877.1	25,854.3	11,449.0	185,805.6				
	FM		-582,402.1	975.3	198.6	8,037.7				
	FSec			-156,188.1	122.6	15.2				
	Ref			4,242.9					3,426.5	
	CS			-972.5		-254.2				
	GNM				-141.0			-792,7	2.7	
	GM				0.0			-22.394,0	5.5	
	GSec								-179.3	
	Ap			34,721.1	-1,937.7				2,237.6	
	Ac			-255.3	-395.0				42.7	
	S									
	A									
	Res									
	O			-208.9	-0.1				0.0	
	NO									
	From the situation of 2005		**-633,279.2**	**-91,831.2**	**9,296.4**	**193,604.2**		**-23.186,7**	**5,535.8**	

AP	AC	S	A	RES	O	NO	TOTAL 2002	% OF BIOME
8,049,257.0	708,242.3	4,707.7	191,226.1	3,125.7	15,018.6	8,854,428.4	216,641,049.9	51.5
544,559.1	7,273.5	1,661.9	205,304.3	8,908.7	2,175.9	8,280,561.9	132,228,135.4	31.4
358,979.7	11,621.0	1,191.7	3,024.4	615.2	202.4	23,551.4	3,262,749.7	0.8
8,183.5	32,414.0	208.0	10.6		7.9	97,056.8	356,342.8	0.1
25,037.1	23,926.1			0.1		1,341.3	259,610.6	0.1
183,916.8	19,718.8	556.3	6,134.8	214.6	237.8	283,232.2	6,457,514.3	1.5
21,084.3	4,024.8	79.1	2,122.4		1.5	234,284.4	4,176,741.0	1.0
1,687.2	99,4		3.5			649.8	33,784.0	0.0
36,853,444.7	1,366,461.6	64,197.9	32,359.9	8,948.3	17,228.0	1,228,483.3	42,670,445.4	10.1
123,956.6	895,834.8	1,325.0	683.1	74.2		3,668.0	1,074,882.7	0.3
		281,887.1				799.2	282,686.3	0.1
54,588.9	483.9	2,065.8	12,124,397.4	20,385.5	3,730.2	232,520.4	12,723,954.3	3.0
1,136.1	2.8	45.1	5,536.8	621,427.0	34.7	214.9	629,406.6	0.1
8,376.7	10.2	2.2	176.4	92.8	39,180.8	1,360.2	62,112.4	0.0
456.2	11.0	390.8	8.3		6.6	6,344.5	18,483.0	0.0
46,234,663.7	3,070,124.2	358,318.7	12,570,987.8	663,792.0	77,824.6	19,248,496.6	420,877,898.3	
11.0	0.7	0.1	3.0	0.2	0.0	4.6		

AP	AC	S	A	RES	O	NO	FROM THE SITUATION OF 2002
4,378,696.0	288,786.6	2,938.6		1,582.4	9,411.9		4,853,647.3
314,309.2	2,993.6	1,001.5		6,932.3	1,320.0		-246,633.8
80,167.1	1,956.5	321.3		113.8	53.7		-73,437.8
1,344.7	5,023.9	38.7			1.5		14,078.2
6,364.4	7,121.4			0.0			12,259.1
3,788.1	674,7	26.6		10.8	14.6		3,583.9
520.3	35,6	5.2			0.1		-21,827.3
-7.1	0,8						-185.6
	16,825.0	2,563.9		344.2	690.0		55,444.1
-1,160.9		39.6		1.9			-1,727.0
-338.9	-0.3						-548.2
4,783,682.7	323,417.9	6,935.6		8,985.3	11,491.8		4,594,652.8

TABLE 3.85

Transition areas for land-use and land-cover identified in the Amazon biome for the period from 2005 to 2010 (hectare)

LAND-USE TRANSITION MATRIX IN THE AMAZON BIOME - 2005-2010 (ha)									
LAND USE IN 2005		LAND USE IN 2010							
		FNM	FM	FSEC	REF	CS	GNM	GM	GSEC
2005	FNM	126,777,743.1	33,703,629.2	2,493.8	15,446.6	911,685.4			
	FM		136,015,684.2	1,377.7	88.3	74,489.2			
	FSec			4,136,114.4	10,967.2	13,727.6			
	Ref			8,702.7	191,479.3				2,318.1
	CS			956,142.7	150.9	167,526.2			
	GNM				5,280.5		4,223,184.1	659,739.3	
	GM				4.4			3,923,889.4	66.5
	GSec				1,050.9				92,661.3
	Ap			2,501,645.7	51,749.6				68,543.1
	Ac			94,590.1	23,804.2				8,416.5
	S								
	A	73,791.4	62,808.2	1,203.3	0.3	1.7	1,215.0	639.9	13.2
	Res			3,534.4					
	O			5,469.8	2.1				1.1
	NO	3,608,079.5	9,724,891.1	450,335.3	49,626.3	11,239.5	171,624.5	219,735.9	18,527.0
	Total 2010	130,459,613.9	179,507,012.8	8,161,610.1	349,650.5	1,178,669.6	4,396,023.6	4,804,004.5	190,546.9
	% of biome	31.0	42.7	1.9	0.1	0.3	1.0	1.1	0.0

TABLE 3.86

Net CO_2 emissions in the Amazon biome in the period from 2005 to 2010 (Gg)

NET EMISSIONS MATRIX IN THE AMAZON BIOME - 2005-2010 (Gg CO_2)									
LAND USE IN 2005		LAND USE IN 2010							
		FNM	FM	FSEC	REF	CS	GNM	GM	GSEC
2005	FNM		-132,848.5	1,376.4	7,589.5	140,264.4			
	FM		-1.072.257,0	739.6	58.7	12,293.4			
	FSec			-376,110.7	1,950.2	804.7			
	Ref			1,139.3					504.6
	CS			-8,132.6	55.8	-1,179.0			
	GNM				-318.9			-3,144.8	
	GM				-0.2			-37,407.7	3.0
	GSec				-106.8				-883.4
	Ap			2,493.0	-4,899.5				1,544.3
	Ac			-2,892.1	-2,584.7				114.5
	S								
	A								
	Res								
	O			-142.7	-0.3				0.0
	NO								
	From the situatiton of 2010		-1,205,105.4	-381,529.8	1,743.7	152,183.5		-40,552.5	1,283.0

AP	AC	S	A	RES	O	NO	TOTAL 2005	% OF BIOME
150,834.2	5,137,169.9	4,182.2	152,886.3	5,222.9	8,216.4	9,406,007.9	176,275,517.8	41.9
1,935.8	474,344.3	1,175.0	114,849.0	337.3	4,755.0	8,066,342.5	144,755,378.3	34.4
68,676.2	1,651,515.4	2,056.4	7,460.9	599.2	2,590.1	231,759.4	6,125,466.7	1.5
4,589.7	4,527.3	6.4	0.9		30.3	51,460.8	263,115.6	0.1
6,158.0	61,226.7		58.4		439.5	27,038.2	1,218,740.8	0.3
2,952.6	123,101.0	299.5	73,442.4	19.0	291.3	590,730.3	5,679,039.9	1.3
200.3	9,867.0	63.6	37,641.3		0.8	223,707.0	4,195,440.4	1.0
617.3	34,862.0	3.8	70.7	0.3	4.7	11,720.2	140,991.1	0.0
614,976.3	41,356,677.9	20,376.8	22,497.6	1,412.2	4,805.3	1,591,979.3	46,234,663.7	11.0
2,531,507.1	378,473.8	1,125.4	160.0	43.2	97.5	31,906.2	3,070,124.2	0.7
		358,017.9				300.7	358,318.7	0.1
2,302.8	17,068.6	804.4	11,569,987.1	1,502.4	113.6	839,535.9	12,570,987.8	3.0
2.8	838.9	8.2	28,162.8	629,386.4	152.5	1,706.1	663,792.0	0.2
	3,329.7	345.5	39.7	169.3	66,140.4	2,327.1	77,824.6	0.0
40,025.8	688,422.6	4,074.3	174,936.1	555.1	2,564.1	4,083,859.6	19,248,496.6	4.6
3,424,779.0	49,941,425.1	392,539.3	12,182,193.2	639,247.1	90,201.5	25,160,381.4	420,877,898.3	
0.8	11.9	0.1	2.9	0.2	0.0	6.0		

AP	AC	S	A	RES	O	NO	FROM THE SITUATION OF 2005
2,931,806.9	66,600.9	2,764.7		2,709.2	5,765.6		3,026,028.9
280,167.0	915.1	666.8		228.7	2,950.5		-774,237.0
387,201.2	12,004.9	629.4		134.2	727.6		27,341.4
672.0	731.9	1.2			6.2		3,055.2
27,135.9	2,251.0				236.5		20,367.6
2,999.7	93.3	18.4		1.2	18.9		-332.1
280.7	7.4	2.3			0.1		-37,114.6
-115.2	2.6	0.1		0.0	0.2		-1,102.5
	8,465.7	976.3		66.0	234.3		8,880.2
-4,891.2		36.2		1.4	4.3		-10,211.7
-160.2							-303.2
3,625,096.7	91,072.7	5,095.5		3,140.6	9,944.2		2,262,372.2

TABLE 3.87

Transition areas for land-use and land-cover identified in the Cerrado biome for the period from 1994 to 2002 (hectares)

LAND-USE TRANSITION MATRIX IN THE CERRADO BIOME - 1994-2002 (ha)							
LAND USE IN 1994	LAND USE IN 2002						
1994	FNM	FM	FSEC	REF	GNM	GM	GSEC
FNM	70,642,384.5	4,551,742.0		38,516.9			
FM		6,848,585.1		688.3			
FSec							
Ref			16,709.9	1,987,032.6			7,614.9
GNM				14,791.8	32,198,920.5	4,653,399.3	
GM				18.6		2,330,903.1	
GSec							
Ap			857,263.0	79,748.1			407,169.9
Ac			55,084.3	17,617.3			36,496.1
S							
A	436.0	8.4		6.5	402.7	19.2	
Res			826.7	0.5			186.7
O			140.2				70.1
NO	4,572.3			1,962.6	3,938.7		
Total 2002	**70,647,392.8**	**11,400,335.5**	**930,024.1**	**2,140,383.2**	**32,203,261.9**	**6,984,321.6**	**451,537.8**
% of biome	**34.6**	**5.6**	**0.5**	**1.0**	**15.8**	**3.4**	**0.2**

TABLE 3.88

Net CO_2 emissions in the Cerrado biome in the period from 1994 to 2002 (Gg)

NET EMISSIONS MATRIX IN THE CERRADO BIOME - 1994-2002 (Gg CO_2)							
LAND USE IN 1994	LAND USE IN 2002						
1994	FNM	FM	FSEC	REF	GNM	GM	GSEC
FNM		-13,351.8		2,677.0			
FM		-40,178.4		-12.9			
FSec							
Ref			1,647.8				883.5
GNM				-1,446.1		-35,489.9	
GM				-1.7		-35,554.0	
GSec							
Ap			-12,777.7	-12,541.5			7,906.2
Ac			-2,991.6	-2,885.5			233.5
S							
A							
Res							
O			-4.8				-2.3
NO							
From the situation of 2002		**-53,530.1**	**-14,126.2**	**-14,210.9**		**-71,044.0**	**9,020.9**

AP	AC	S	A	RES	O	NO	TOTAL 1994	% OF BIOME
6,524,547.5	1,551,325.4	71,350.7	1,842.2	2,023.1	2,782.5	24,473.2	83,410,988.0	40.9
55,062.9	6,493.9	4,828.1				20.7	6,915,679.1	3.4
							0.0	0.0
109,682.7	57,551.1	115.7			16.1	369.9	2,179,092.9	1.1
2,630,265.6	1,057,043.3	28,812.1	935.3	220.6	955.1	41,118.3	40,626,462.0	19.9
9,931.2	38,454.1	161.1			24.5	242.3	2,379,734.8	1.2
							0.0	0.0
41,221,789.3	1,171,306.1	103,222.0	1,441.5	1,696.4	734.3	106,325.4	43,950,696.0	21.6
1,427,951.3	21,112,273.3	50,255.3	1,482.9	471.4	117.5	9,202.5	22,710,951.7	11.1
		509,101.7					509,101.7	0.2
2,079.6	677.2		658,313.6	557.5		20.8	662,521.4	0.3
427.3	255.9	4.7	451.6	336,271.3			338,424.8	0.2
41.2	198.1	519.8	3.3		107,402.7		108,375.3	0.1
14,665.7	125,657.9	1,296.0				84.5	152,177.8	0.1
51,996,444.2	**25,121,236.4**	**769,667.2**	**664,470.4**	**341,240.2**	**112,032.5**	**181,857.5**	**203,944,205.4**	
25.5	**12.3**	**0.4**	**0.3**	**0.2**	**0.1**	**0.1**		

AP	AC	S	A	RES	O	NO	FROM THE SITUATION OF 1994
1,250,177.1	300,107.4	18,175.7		643.3	1,027.5		1,559,456.3
13,819.6	1,115.8	1,834.1					-23,421.8
10,458.1	6,329.9	17.4			2.5		19,339.1
156,990.8	71,435.2	3,324.7		24.9	107.9		194,947.6
592.6	2,550.1	18.2			2.3		-32,392.5
	19,963.2	5,751.3		74.1	42.5		8,418.0
-19,306.4		2,255.8		19.4	5.6		-22,669.4
-1.8	-8.5						-17.3
1,412,730.1	**401,493.2**	**31,377.1**		**761.7**	**1,188.2**		**1,703,660.0**

TABLE 3.89

Transition areas for land-use and land-cover identified in the Cerrado biome for the period from 2002 - 2010 (hectares)

LAND-USE TRANSITION MATRIX IN THE CERRADO BIOME - 2002-2010 (ha)								
LAND USE IN 2002		LAND USE IN 2010						
		FNM	FM	FSEC	REF	GNM	GM	GSEC
2002	FNM	60,125,463.6	1,156,125.0		177,833.0			
	FM		10,904,881.9		8,598.6			
	FSec			782,955.3	8,038.5			
	Ref			73,466.1	1,588,940.3			14,415.8
	GNM				112,596.1	27,266,009.9	894,201.8	
	GM				1,385.0		6,713,078.7	
	GSec				9,312.2			351,926.5
	Ap			2,670,463.8	594,836.7			1,170,186.3
	Ac			107,370.4	202,384.3			75,085.9
	S							
	A	21,889.0	10,271.2	174.4	43.7	12,858.6	5,310.6	189.1
	Res			751.2	16.3			494.3
	O			420.6	342.3			92.0
	NO	5,052.3		3,276.6	2,955.3	6,304.1	9.2	4,836.4
	Total 2010	60,152,404.8	12,071,278.0	3,638,878.4	2,707,282.1	27,285,172.6	7,612,600.3	1,617,226.2
	% of biome	29.5	5.9	1.8	1.3	13.4	3.7	0.8

TABLE 3.90

Net CO_2 emissions in the Cerrado biome in the period from 2002 to 2010 (in Gg)

NET EMISSIONS MATRIX IN THE CERRADO BIOME - 2002-2010 (Gg CO_2)								
LAND USE IN 2002		LAND USE IN 2010						
		FNM	FM	FSEC	REF	GNM	GM	GSEC
2002	FNM		-3,391.3		10,290.9			
	FM		-63,975.3		378.0			
	FSec			-39,502.7	-636.2			
	Ref			10,177.4				2,283.2
	GNM				-12,591.9		-6,819.8	
	GM				-146.9		-102,396.8	
	GSec				-1,511.7			-5,368.1
	Ap			-39,963.2	-101,049.0			22,657.8
	Ac			-5,870.6	-35,942.9			418.9
	S							
	A							
	Res							
	O			-16.9	-76.7			-3.0
	NO							
	From the situation of 2010		-67,366.6	-75,175.9	-141,286.5		-109,216.6	19,988.8

	AP	AC	S	A	RES	O	NO	TOTAL 2002	% OF BIOME
	6,798,388.7	2,078,315.1	23,798.2	86,093.3	154,258.1	5,807.7	41.310,3	70,647,392.8	34.6
	329,391.6	45,522.4	2,268.5	7,732.9	24,946.5	373.5	76,619.6	11,400,335.5	5.6
	96,092.0	41,105.4	298.3	425.5	883.2	41.4	184.5	930,024.1	0.5
	228,004.3	227,044.7	861.7	333.2	278.6	286.3	6,752.1	2,140,383.2	1.0
	2,973,353.7	759,028.1	10,291.5	36,933.4	118,753.3	3,881.1	28,212.9	32,203,261.9	15.8
	205,470.1	29,668.0	3,162.9	1,552.3	13,979.4	163.7	15,861.5	6,984,321.6	3.4
	63,184.9	26,371.0	143.0	233.2	309.2	53.5	4.3	451,537.8	0.2
	44,618,907.5	2,774,888.5	72,263.9	13,314.5	57,951.2	8,662.2	14,969.7	51,996,444.2	25.5
	2,859,339.7	21,809,340.0	54,969.9	5,443.2	5,704.2	1,009.5	589.3	25,121,236.4	12.3
			769,667.2					769,667.2	0.4
	9,046.7	1,321.2	227.2	536,807.5	65,644.0	196.2	491.1	664,470.4	0.3
	6,721.2	356.2	34.4	6,646.3	326,220.1		0.1	341,240.2	0.2
	2,162.3	3.3	271.9	25.2	93.1	108,621.9		112,032.5	0.1
	145,940.4	12,195.6	1,180.1	83.9			23.5	181,857.5	0.1
	58,336,003.2	27,805,159.6	939,438.8	695,624.4	769,020.9	129,097.0	185,018.9	203,944,205.4	
	28.6	13.6	0.5	0.3	0.4	0.1	0.1		

	AP	AC	S	A	RES	O	NO	FROM THE SITUATION OF 2002
	1,322,750.9	424,891.8	5,854.0		36,096.5	1,338.0		1,797,830.7
	59,941.7	7,909.7	478.7		4,482.3	73.6		9,288.7
	6,975.5	3,788.6	39.5		111.8	8.1		-29,215.4
	31,615.3	34,928.1	170.0		54.8	54.5		79,283.3
	175,453.8	53,483.2	1,180.7		12,253.9	405.0		223,364.8
	12,171.4	2,275.0	380.9		1,802.8	19.8		-85,893.9
	638.3	617.3	8.7		21.4	3.0		-5,591.0
		47,358.3	4,034.6		2,996.3	491.0		-63,474.3
	-41,673.7		2,442.2		228.8	48.1		-80,349.2
	-122.4	-0.1						-219.1
	1,567,750.8	575,251.7	14,589.2		58,048.6	2,441.3		1,845,024.7

TABLE 3.91

Transition areas for land-use and land-cover identified in the Caatinga biome for the period from 1994 to 2002 (hectares)

LAND-USE TRANSITION MATRIX IN THE CAATINGA BIOME - 1994-2002 (ha)								
LAND USE IN 1994		LAND USE IN 2002						
		FNM	FM	FSEC	REF	GNM	GM	GSEC
1994	FNM	46,557,448.0	3,327,990.8		2,102.7			
	FM		557,272.2					
	FSec							
	Ref			223.2	94,538.9			261.1
	GNM				9.2	1,324,856.0	35,357.7	
	GM						137,323.8	
	GSec							
	Ap			647,082.8	3,503.7			15,899.4
	Ac			146,898.7	0.4			2,838.0
	S							
	A	892.3	3.0			498.9		
	Res			185.9				636.9
	O			245.1				
	NO	300,661.2	2,449.6		0.5	606.3		
	Total 2002	46,859,001.5	3,887,715.7	794,635.7	100,155.3	1,325,961.2	172,681.5	19,635.4
	% of biome	56.6	4.7	1.0	0.1	1.6	0.2	0.0

TABLE 3.92

Net CO_2 emissions in the Caatinga biome in the period from 1994 to 2002 (Gg)

NET EMISSIONS MATRIX IN THE CAATINGA BIOME - 1994-2002 (Gg CO_2)								
LAND USE IN 1994		LAND USE IN 2002						
		FNM	FM	FSEC	REF	GNM	GM	GSEC
1994	FNM		-4,881.1		-235.0			
	FM		-1,634.7					
	FSec							
	Ref			25.8				30.1
	GNM				-1.1		-269.7	
	GM						-2,094.6	
	GSec							
	Ap			-17,712.1	-607.5			109.3
	Ac			-8,007.8	-0.1			19.0
	S							
	A							
	Res							
	O			-8.0				
	NO							
	From the situation of 2002		-6,515.7	-25,702.1	-843.6		-2,364.3	158.4

	AP	AC	S	A	RES	O	NO	TOTAL 1994	% OF BIOME
	3,101,858.1	299,205.8	5,173.5	1,625.5	7,266.5	3,854.4	143,817.3	53,450,342.6	64.6
	18,795.0	187.5	0.0				2,912.1	579,166.9	0.7
								0.0	0.0
	1,508.0							96,531.2	0.1
	76,262.1	12,683.5	100.9	1.5	767.6	35.5	1,157.0	1,451,231.1	1.8
	6,243.6						570.2	144,137.6	0.2
								0,0	0.0
	19,853,803.1	41,119.8	9,040.1	1,002.1	800.7	1,586.9	108,741.9	20,682,580.4	25.0
	32,909.6	4,280,154.4	1,374.0	4.3	115.8	861.3	84,210.5	4,549,366.8	5.5
			232,353.4				34.7	232,388.2	0.3
	28.3	56.3		161,286.3	5.9	43.6	96.7	162,911.2	0.2
	36.0			48.5	493,730.0		96.5	494,733.9	0.6
	844.3	1,019.4		0.4		112,438.3		114,547.5	0.1
	376,517.4	99,711.9	168.1	223.7	888.4	130.9	57,309.3	838,667.2	1.0
	23,468,805.3	4,734,138.7	248,210.0	164,192.1	503,574.9	118,950.9	398,946.3	82,796,604.5	
	28.3	5.7	0.3	0.2	0.6	0.1	0.5		

	AP	AC	S	A	RES	O	NO	FROM THE SITUATION OF 1994
	198,375.4	19,546.4	557.3		1.097,8	616.9		215,077.7
	1,438.2	25.7	0.0					-170.7
	167.0							222.8
	2,292.3	599.1	5.6		41.7	2.0		2,669.9
	285.6							-1,809.0
		7.0	306.5		17.7	67.5		-17,811.7
	-8.4		43.5		2.8	27.0		-7,924.0
	-27.3	-28.9						-64.2
	202,522.8	20,149.2	912.9		1,159.9	713.3		190,190.9

TABLE 3.93

Transition areas for land-use and land-cover identified in the Caatinga biome for the period from 2002 to 2010 (hectares)

LAND-USE TRANSITION MATRIX IN THE CAATINGA BIOME - 2002-2010 (ha)								
LAND USE IN 2002		LAND USE IN 2010						
		FNM	FM	FSEC	REF	GNM	GM	GSEC
2002	FNM	39,541,113.7	916,623.0		8,891.7			
	FM		3,549,361.7					
	FSec			670,333.6	241.8			
	Ref			5,270.1	68,833.5			982.2
	GNM				1,276.2	1,176,543.8	22,954.7	
	GM						136,284.4	
	GSec				261.5			13,244.7
	Ap			5,498,797.6	6,297.4			105,087.1
	Ac			591,407.9	973.6			19,190.3
	S							
	A	7,210.2	809.2	34.0	9.0	102.7		2.7
	Res			14,717.9				140.1
	O			5,490.6				
	NO	35,295.0	1,840.0	51,905.9	409.6	117.9		405.5
	Total 2010	39,583,618.9	4,468,633.9	6,837,957.7	87,194.3	1,176,764.4	159,239.1	139,052.8
	% of biome	47.8	5.4	8.3	0.1	1.4	0.2	0.2

TABLE 3.94

Net CO_2 emissions in the Caatinga biome in the period from 2002 to 2010 (Gg)

NET EMISSIONS MATRIX IN THE CAATINGA BIOME - 2002-2010 (Gg CO_2)								
LAND USE IN 2002		LAND USE IN 2010						
		FNM	FM	FSEC	REF	GNM	GM	GSEC
2002	FNM		-1,344.4		-5,880.0			
	FM		-10,411.5					
	FSec			-11,797.9	-174.0			
	Ref			829.0				152.0
	GNM				-875.8		-175.1	
	GM						-2,078.8	
	GSec				-186.9			-202.0
	Ap			-150,422.1	-4,604.6			708.5
	Ac			-32,247.2	-700.0			149.9
	S							
	A							
	Res							
	O			-164.1				
	NO							
	From the situation of 2010		-11,755.8	-193,802.3	-12,421.4		-2,253.9	808.4

AP	AC	S	A	RES	O	NO	TOTAL 2002	% OF BIOME
2,822,718.1	623,748.4	12,925.9	44,000.5	145,799.9	42,255.7	2,700,924.8	46,859,001.5	56.6
94,891.1	44,335.7	896.1	2,959.6	1,801.1	1,818.3	191,652.1	3,887,715.7	4.7
71,653.2	22,972.9	702.9	1,216.8	1,051.9	123.4	26,339.2	794,635.7	1.0
4,653.7	3,178.1	0.5	23.4			17,213.8	100,155.3	0.1
32,537.6	29,980.1	552.0	2,969.7	19,353.9	1,432.1	38,361.2	1,325,961.2	1.6
572.9	2.6		5.7			35,815.9	172,681.5	0.2
4,395.4	973.8			649.5		110.4	19,635.4	0.0
13,852,972.8	500,692.5	42,463.9	27,285.3	76,740.5	5,230.9	3,353,237.3	23,468,805.3	28.3
89,006.1	3,678,061.8	15,832.6	4,739.3	14,371.0	4,954.8	315,601.3	4,734,138.7	5.7
		246,085.4				2,124.6	248,210.0	0.3
4,681.0	1,695.9	148.2	123,789.5	5,950.2	3,857.5	15,901.9	164,192.1	0.2
2,684.5	1,570.5	12.0	3,776.8	472,912.9	1,605.4	6,154.7	503,574.9	0.6
1,647.6	1,783.6	141.3	202.3	1,746.9	106,183.2	1,755.3	118,950.9	0.1
116,722.7	38,393.3	866.8	1,083.4	592.5		151,313.6	398,946.3	0.5
17,099,136.9	4,947,389.1	320,627.6	212,052.2	740,970.4	167,461.3	6,856,505.8	82,796,604.5	
20.7	6.0	0.4	0.3	0.9	0.2	8.3		

AP	AC	S	A	RES	O	NO	FROM THE SITUATION OF 2002
193,654.0	39,510.7	1,989.0		15,863.2	18,965.6		262,758.1
10,616.2	3,212.0	125.2		134.8	771.2		4,448.0
1,934.6	452.0	53.2		44.3	14.4		-9,473.4
698.4	482.2	0.1					2,161.6
925.6	1,357.2	30.9		1,028.4	77.4		2,368.6
27.1	0.1						-2,051.6
9.8	3.2			20,4			-355.5
	78.7	1,400.8		2,388.7	236.2		-150,213.8
-42.2		538.3		442,1	181.2		-31,678.0
-36.4	-55.5						-256.1
207,787.0	45,040.7	4,137.4		19,921.9	20,246.0		77,708.0

TABLE 3.95

Transition areas for land-use and land-cover identified in the Atlantic Forest biome for the period from 1994 to 2002 (hectares)

LAND-USE TRANSITION MATRIX IN THE ATLANTIC FOREST BIOME - 1994-2002 (ha)								
LAND USE IN 1994		LAND USE IN 2002						
		FNM	FM	FSEC	REF	GNM	GM	GSEC
1994	FNM	24,089,624.5	1,564,269.9		69,578.1			
	FM		3,827,963.1		2,970.8			
	FSec							
	Ref			67,412.4	2,652,245.6			3,041.2
	GNM				14,479.6	3,091,758.8	82,370.1	
	GM				289.7		147,781.5	
	GSec							
	Ap			421,838.1	69,690.3			28,781.8
	Ac			283,548.5	23,859.0			14,246.0
	S							
	A	456.5	91.6		13.4	7.6		
	Res			8,770.9				79.6
	O			72.7	9.1			
	NO	152,342.6	3,627.6		7,626.7	6,071.1	5.2	
	Total 2002	24,242,423.6	5,395,952.2	781,642.6	2,840,762.3	3,097,837.5	230,156.8	46,148.6
	% of biome	21.7	4.8	0.7	2.5	2.8	0.2	0.0

TABLE 3.96

Net CO_2 emissions in the Atlantic Forest biome in the period from 1994 to 2002 (Gg)

NET EMISSIONS MATRIX IN THE ATLANTIC FOREST BIOME - 1994-2002 (Gg CO_2)								
LAND USE IN 1994		LAND USE IN 2002						
		FNM	FM	FSEC	REF	GNM	GM	GSEC
1994	FNM		-7,341.6		24,686.0			
	FM		-35,931.8		980.2			
	FSec							
	Ref			2,779.1				349.6
	GNM				-1,638.3		-628.2	
	GM				-26.3		-2,254.2	
	GSec							
	Ap			-6,381.3	-10,743.0			555.1
	Ac			-18,839.6	-3,645.9			35.2
	S							
	A							
	Res							
	O			-2.8	-2.0			
	NO							
	From the situation of 2002		-43,273.5	-22,444.7	9,610.6		-2,882.4	940.0

	AP	AC	S	A	RES	O	NO	TOTAL 1994	% OF BIOME
	1,739,931.7	214,318.0	102,746.4	355.9	132,318.7	1,260.4	322,924.1	28,237,327.7	25.3
	76,734.8	2,261.7	12,526.0	19.1	267.0	55.6	4,002.8	3,926,801.0	3.5
								0,0	0.0
	29,886.5	2,181.3	880.9		36.2	3.9	12,952.8	2,768,640.8	2.5
	355,017.4	54,302.2	3,291.0	16.2	6,461.9	307.9	10,249.7	3,618,254.7	3.2
	633.7	70.1	398.9					149,173.9	0.1
								0,0	0.0
	46,459,350.4	1,529,971.9	174,398.4	902.9	2,302,7	638,4	377,131.1	49,065,005.9	44.0
	1,081,354.0	19,038,989.1	61,739.8	1,357.0	754.4	43.8	217,755.6	20,723,647.2	18.6
			1,314,540.7					1,314,540,7	1.2
	290.7	1,873.2	33.1	515,797.9	193.7	20.3	30.7	518,808.8	0.5
	377.6	398.9			419,071.5		539.8	429,238.3	0.4
	478.3	82.9	842.0	59.9		13,715.9		15,260.8	0.0
	244,089.8	280,870.6	31,835.5	23.3	12,717.5	105.6	49,871.7	789,187.2	0.7
	49,988,145.0	21,125,319.9	1,703,232.7	518,532.3	574,123.6	16,151.8	995,458.1	111,555,887.1	
	44.8	18.9	1.5	0.5	0.5	0.0	0.9		

	AP	AC	S	A	RES	O	NO	FROM THE SITUATION OF 1994
	677,754.6	83,209.8	51,957.1		53,111.4	305.1		883,682.3
	30,877.4	1,062.9	5,597.5		110.3	38.2		2,734.6
	2,865.9	243.7	136.3		5.5	0.6		6,380.7
	14,201.2	3,187.4	318.1		610.0	29.9		16,080.0
	25.9	4.3	37.5					-2,212.9
		27,995.4	10,434.0		109.9	40.5		22,010.5
	-20,544.2		2,903.4		23.7	2.0		-40,065.3
	-27.4	-3.5						-35.7
	705,153.4	115,699.9	71,384.0		53,970.7	416.2		888,574.3

TABLE 3.97

Transition areas for land-use and land-cover identified in the Atlantic Forest biome for the period from 2002 to 2010 (hectares)

LAND-USE TRANSITION MATRIX IN THE ATLANTIC FOREST BIOME - 2002-2010 (ha)								
LAND USE IN 2002		LAND USE IN 2010						
		FNM	FM	FSEC	REF	GNM	GM	GSEC
2002	FNM	17,637,695.9	442,297.5		657,903.9			
	FM		4,536,928.6		85,766.1			
	FSec			663,029.6	31,385.5			
	Ref			318,124.5	1,987,178.8			15,262.9
	GNM				142,662.0	2,247,624.4	48,822.8	
	GM				13,031.1		188,536.6	
	GSec				4,427.2			35,353.2
	Ap			3,678,084.9	1,203,947.7			235,653.9
	Ac			649,397.4	207,300.6			63,169.2
	S							
	A	19,819.6	10,725.1	238.8	523.3	839.7		4.3
	Res			2,347.2	88.0			67.8
	O			165.1	2.1			10.9
	NO	210,784.6	4,647.1	233,107.8	27,577.3	10,366.9		10,240.3
	Total 2010	17,868,300.0	4,994,598.3	5,544,495.3	4,361,793.8	2,258,831.0	237,359.4	359,762.6
	% of biome	16.0	4.5	5.0	3.9	2.0	0.2	0.3

TABLE 3.98

Net CO_2 emissions in the Atlantic Forest biome in the period from 2002 to 2010 (Gg)

NET EMISSIONS MATRIX IN THE ATLANTIC FOREST BIOME - 2002-2010 (Gg CO_2)								
LAND USE IN 2002		LAND USE IN 2010						
		FNM	FM	FSEC	REF	GNM	GM	GSEC
2002	FNM		-2,075.8		226,401.9			
	FM		-42,586.6		32,040.8			
	FSec			-104,051.4	1,962.7			
	Ref			38,372.0				2,758.8
	GNM				-15,919.8		-372.4	
	GM				-1,484.9		-2,875.8	
	GSec				-713.0			-539.3
	Ap			-55,551.8	-187,058.6			4,563.4
	Ac			-40,162.3	-33,785.0			64.1
	S							
	A							
	Res							
	O			-5.7	-0.5			-0.4
	NO							
	From the situation of 2010		-44,662.5	-161,399.2	21,443.5		-3,248.2	6,846.6

AP	AC	S	A	RES	O	NO	TOTAL 2002	% OF BIOME
2,469,071.5	1,104,576.4	51,192.2	135,978.4	510,265.7	8,079.1	1,225,362.9	24,242,423.6	21.7
327,834.6	55,853.9	13,835.5	28,361.5	43,739.9	9,614.0	294,018.2	5,395,952.2	4.8
55,907.3	14,196.0	1,227.7	2,334.4	9,380.0	164.2	4,017.9	781,642.6	0.7
283,913.3	141,643.7	3,908.2	2,526.0	446.1	991.0	86,767.7	2,840,762.3	2.5
357,809.8	257,956.2	3,078.5	4,392.5	7,937.6	5,961.1	21,592.5	3,097,837.5	2.8
10,340.1	12,812.5	1,063.9	454.0	156.8	3,468.5	293.2	230,156.8	0.2
4,439.7	1,266.8	40.6	527.1	45.4		48.6	46,148.6	0.0
34,439,259.4	7,633,441.8	244,160.8	44,593.1	33,965.7	19,147.5	2,455,890.0	49,988,145.0	44.8
1,859,769.1	18,034,845.6	86,876.9	30,369.0	10,700.0	3,355.4	179,536.6	21,125,319.9	18.9
		1,699,864.8				3,368.0	1,703,232.7	1.5
8,948.5	7,724.5	1,807.0	441,546.4	13,468.9	396.6	12,489.5	518,532.3	0.5
5,931.0	4,337.8	171.0	13,434.4	544,600.1	103.3	3,043.1	574,123.6	0.5
363.1	23.1	993.6	754.8	13.4	13,465.4	360.2	16,151.8	0.0
145,516.3	187,540.6	3,755.9	655.9	725.1	308.0	160,232.4	995,458.1	0.9
39,969,103.7	27,456,219.0	2,111,976.5	705,927.7	1,175,444.8	65,054.2	4,447,020.7	111,555,887.1	
35.8	24.6	1.9	0.6	1.1	0.1	4.0		

AP	AC	S	A	RES	O	NO	FROM THE SITUATION OF 2002
1,014,534.0	507,731.2	27,307.0		226,004.0	3,939.6		2,003,841.9
163,634.9	25,961.2	7,739.0		27,657.9	4,422.3		218,869.5
9,278.5	2,773.5	343.4		2,029.7	43.3		-87,620.5
46,488.6	29,291.6	842.3		100.0	199.2		118,052.5
13,308.6	14,626.5	283.9		662.2	586.0		13,175.0
400.1	752.2	100.9		14.9	328.3		-2,764.3
11.0	26.9	2.4		1.6			-1,210.4
	146,274.6	15,937.0		1,769.5	1,262.2		-72,803.7
-29,930.3		4,061.6		460.3	159.8		-99,131.8
-20.4	-0.4						-27.4
1,217,705.0	727,437.1	56,617.4		258,700.2	10,940.7		2,090,380.7

TABLE 3.99

Transition areas for land-use and land-cover identified in the Pampa biome for the period from 1994 to 2002 (hectares)

LAND-USE TRANSITION MATRIX IN THE PAMPA BIOME - 1994-2002 (ha)								
LAND USE IN 1994		LAND USE IN 2002						
		FNM	FM	FSEC	REF	GNM	GM	GSEC
1994	FNM	2,711,516.5	8,714.4		9,193.4			
	FM		29,328.7					
	FSec							
	Ref			32.3	237,139.2			280.4
	GNM				7,491.3	3,961,625.9	13,335.2	
	GM						319,731.9	
	GSec							
	Ap			66,604.7	1,522.2			130,486.3
	Ac			1,703.3	945.2			32,666.6
	S							
	A	20.2	0.1			323.6		
	Res				341.7			19.8
	O			83.4	1,032.6			150.2
	NO	95.8						
	Total 2002	2,711,632.5	38,043.2	68,423.7	257,665.5	3,961,949.5	333,067.1	163,603.3
	% of biome	15.2	0.2	0.4	1.4	22.2	1.9	0.9

TABLE 3.100

Net CO_2 emissions in the Pampa biome in the period from 1994 to 2002 (em Gg)

NET EMISSIONS MATRIX IN THE PAMPA BIOME - 1994-2002 (Gg CO_2)								
LAND USE IN 1994		LAND USE IN 2002						
		FNM	FM	FSEC	REF	GNM	GM	GSEC
1994	FNM		-40.9		412.5			
	FM		-275.3					
	FSec							
	Ref			3.1				31.4
	GNM				-1,110.6		-101.7	
	GM						-4,877.0	
	GSec							
	Ap			-1,298.0	-235.5			1,883.5
	Ac			-100.7	-162.8			-111.4
	S							
	A							
	Res							
	O			-4.8	-195.8			-5.2
	NO							
	From the situation of 2002		-316.2	-1,400.4	-1,292.2		-4,978.7	1,798.2

	AP	AC	S	A	RES	O	NO	TOTAL 1994	% OF BIOME
	41,351.2	34,031.9	313.0	5,644.9	663.4	3.5	10,572.9	2,822,005.2	15.8
	59.8	28.1		130.2				29,546.9	0.2
								0.0	0.0
	658.4	103.5	12.6				198.1	238,424.5	1.3
	87,175.8	306,034.4	3,963.3	21,277.3	3,090.2	9.0	1,740.4	4,405,742.8	24.6
	994.5	707.0		38.3				321,471.7	1.8
								0.0	0.0
	4,292,012.8	149,519.8	5,649.2	6,365.0	395.5	45.6	13,846.1	4,666,447.2	26.1
	77,486.8	3,056,245.4	585.7	57,670.1	35.0	6.8	5,356.4	3,232,701.2	18.1
			116,448.5					116,448.5	0.7
	169.3	4,173.1	88.7	1,855,055.6	90.6			1,859,921.2	10.4
	89.3	10.6		362.3	54,125.5			54,949.1	0.3
	246.5	54.4	5.2			133,272.8		134,845.1	0.8
	15.5	43.4						154.7	0.0
	4,500,259.9	**3,550,951.6**	**127,066.2**	**1,946,543.7**	**58,400.2**	**133,337.7**	**31,713.9**	**17,882,658.0**	
	25.2	**19.9**	**0.7**	**10.9**	**0.3**	**0.7**	**0.2**		

	AP	AC	S	A	RES	O	NO	FROM THE SITUATION OF 1994
	9,205.8	8,706.5	136.8		141.3	1.4		18,563.4
	22.1	8.8						-244.3
	65.4	11.9	2.0					113.8
	1,961.6	12,455.9	292.3		270.7	0.7		13,769.0
	24.2	27.2						-4,825.5
		2,528.9	315.2		24.0	2.4		3,220.4
	-1,238.0		25.0		1.5	0.1		-1,586.2
	-16.1	-1.0						-222.9
	10,025.1	**23,738.3**	**771.4**		**437.5**	**4.6**		**28,787.6**

TABLE 3.101

Transition areas for land-use and land-cover identified in the Pampa biome for the period from 2002 to 2010 (in hectares)

LAND-USE TRANSITION MATRIX IN THE PAMPA BIOME - PAMPA - 2002-2010 (ha)								
LAND USE IN 2002		LAND USE IN 2010						
		FNM	FM	FSEC	REF	GNM	GM	GSEC
2002	FNM	2,101,531.8			135,007.2			
	FM		36,024.6		67.4			
	FSec			32,258.9	2,214.1			
	Ref			365.4	236,843.1			589.4
	GNM				60,257.4	2,734,365.3	276.9	
	GM				2,381.0		290,362.6	
	GSec				1,574.1			110,876.9
	Ap			26,150.1	251,754.5			49,669.5
	Ac			5,148.5	11,571.6			26,191.0
	S							
	A	29,833.0	2,331.7	1,088.3	721.3	121,922.4	25,894.8	7,494.2
	Res			31.2	7.3			521.5
	O			3.5	5,622.1			1.3
	NO	10,236.1		6,860.0	768.3	942.6		395.9
	Total 2010	2,141,600.8	38,356.3	71,906.0	708,789.6	2,857,230.3	316,534.3	195,739.7
	% of biome	12.0	0.2	0.4	4.0	16.0	1.8	1.1

TABLE 3.102

Net CO_2 emissions in the Pampa biome in the period from 2002 to 2010 (in Gg)

NET EMISSIONS MATRIX IN THE PAMPA BIOME - 2002-2010 (Gg CO_2)								
LAND USE IN 2002		LAND USE IN 2010						
		FNM	FM	FSEC	REF	GNM	GM	GSEC
2002	FNM				7,640.4			
	FM		-338.2		12.3			
	FSec			-1,665.4	-143.1			
	Ref			56.2				100.7
	GNM				-8,910.8		-2.1	
	GM				-323.5		-4,429.0	
	GSec				-259.6			-1,691.2
	Ap			-511.0	-39,998.8			720.5
	Ac			-317.3	-2,039.0			-64.2
	S							
	A							
	Res							
	O			-0.2	-1,099.7			0.0
	NO							
	From the situation of 2010		-338.2	-2,437.6	-45,121.8		-4,431.1	-934.2

	AP	AC	S	A	RES	O	NO	TOTAL 2002	% OF BIOME
	386,182.9	76,105.0	1,336.7	8,229.0	638.0	822.2	1,779.7	2,711,632.5	15.2
	1,287.1	431.4	9.7	85.4			137.6	38,043.2	0.2
	20,706.0	12,708.5	99.9	67.7	114.2		254.4	68,423.7	0.4
	15,489.3	2,139.7	227.6	119.7	192.5	209.2	1,489.5	257,665.5	1.4
	514,059.6	593,453.2	5,119.0	48,829.9	3,762.7	176.0	1,649.5	3,961,949.5	22.2
	33,874.4	4,924.2	4.1	1,143.3	5.0		372.5	333,067.1	1.9
	31,673.7	18,042.0	69.4	1,110.5	198.3		58.5	163,603.3	0.9
	3,287,775.7	856,897.1	7,754.8	13,059.6	2,575.0	1,493.8	3,129.8	4,500,259.9	25.2
	291,011.3	3,200,340.5	643.3	14,337.3	1,266.9		441.0	3,550,951.6	19.9
			127,066.2					127,066.2	0.7
	33,205.8	105,054.2	425.7	1,607,626.2	2,995.0	6,918.8	1,032.3	1,946,543.7	10.9
	247.4	361.4		4,263.9	52,967.5			58,400.2	0.3
	504.0	840.4	819.2	43.7	153.7	125,349.9		133,337.7	0.7
	7,086.7	5,063.1	94.5	266.6				31,713.9	0.2
	4,623,104.0	4,876,360.7	143,670.2	1,699,182.8	64,868.8	134,969.8	10,344.8	17,882,658.0	
	25.9	27.3	0.8	9.5	0.4	0.8	0.1		

	AP	AC	S	A	RES	O	NO	FROM THE SITUATION OF 2002
	83,363.8	22,238.8	570.4		193.7	210.8		114,218.0
	500.2	145.8	4.6					324.7
	2,132.5	1,777.5	19.8		22.1			2,143.4
	2,441.9	376.0	47.5		42.1	46.7		3,111.2
	9,128.9	24,000.3	369.4		295.5	12.7		24,894.0
	814.2	212.8	0.3		0.4			-3,724.8
	-83.5	255.1	3.9		10.2			-1,765.1
		15,335.2	432.1		142.1	53.0		-23,826.9
	-5,071.5		23.6		51.8			-7,416.6
	-19.2	-15.9						-1,135.0
	93,207.4	64,325.6	1,471.7		757.9	323.3		106,823.1

TABLE 3.103

Transition areas for land-use and land-cover identified in the Pantanal biome for the period from 1994 to 2002 (hectares)

LAND-USE TRANSITION MATRIX IN THE PANTANAL BIOME - 1994-2002 (ha)									
LAND USE IN 1994		LAND USE IN 2002							
		FNM	FM	FSEC	REF	GNM	GM	GSEC	
1994	FNM	8,840,749.8	140,021.8		3,615.6				
	FM		187,187.0						
	FSec								
	Ref				449.8				
	GNM					3,402,600.4	50,775.3		
	GM						85,794.2		
	GSec								
	Ap			36,195.1	401.3			2,712.3	
	Ac			0.1					
	S								
	A	1,205.8	119.9			3,194.0			
	Res								
	O			52.8					
	NO	38.1							
	Total 2002	8,841,993.7	327,328.6	36,248.0	4,466.7	3,405,794.3	136,569.5	2,712.3	
	% of biome	58.4	2.2	0.2	0.0	22.5	0.9	0.0	11.9

TABLE 3.104

Net CO_2 emissions in the Pantanal biome in the period from 1994 to 2002 (Gg)

NET EMISSIONS MATRIX IN THE PANTANAL BIOME - 1994-2002 (Gg CO_2)									
LAND USE IN 1994		LAND USE IN 2002							
		FNM	FM	FSEC	REF	GNM	GM	GSEC	
1994	FNM		-410.7		812.3				
	FM		-1,098.2						
	FSec								
	Ref								
	GNM						-387.2		
	GM						-1,308.6		
	GSec								
	Ap			-551.8	-51.4			52.0	
	Ac			0.0					
	S								
	A								
	Res								
	O			-3.0					
	NO								
	From the situation of 2002		-1,508.9	-554.9	760.9		-1,695.9	52.0	

AP	AC	S	A	RES	O	NO	TOTAL 1994	% OF BIOME
675,522.3	4,570.2	2,638.6	6,904.3	31.6	595.4		9,674,649.6	63.9
5,155.8			773.7				193,116.4	1.3
							0.0	0.0
							449.8	0.0
161,305.4	17.9	10.0	748.9				3,615,457.8	23.9
3,778.7							89,572.9	0.6
							0.0	0.0
945,770.3	4,280.7	733.5	5.8		40.7		990,139.7	6.5
1,386.6	16,360.0						17,746.7	0.1
		7,240.1					7,240.1	0.0
245.1			535,625.6	37.3	3.5		540,431.1	3.6
				6.8			6.8	0.0
192.1	10.2				1,094.0		1,349.1	0.0
93.7							131.8	0.0
1,793,449.9	25,239.1	10,622.2	544,058.3	75.7	1,733.6	0.0	15,130,291.8	
11.9	0.2	0.1	3.6	0.0	0.0	0.0		

AP	AC	S	A	RES	O	NO	FROM THE SITUATION OF 1994
164,820.0	1,693.9	1,094.6		11.2	192.0		168,213.3
1,084.8							-13.4
7,058.7	1.5	0.8					6,673.8
-6.7							-1,315.3
	110.8	47.3			2.4		-390.8
-33.4							-33.4
-14.4	-0.5						-17.9
172,909.0	1,805.8	1,142.7		11.2	194.3		173,116.3

TABLE 3.105

Transition areas for land-use and land-cover identified in the Pantanal biome for the period from 2002 to 2010 (hectares)

LAND-USE TRANSITION MATRIX IN THE PANTANAL BIOME - 2002-2010 (ha)								
LAND USE IN 2002		LAND USE IN 2010						
		FNM	FM	FSEC	REF	GNM	GM	GSEC
2002	FNM	8,125,708.3	118,099.6		504.6			
	FM		325,124.9					
	FSec			26,186.4				
	Ref				449.8			
	GNM				15.4	3,123,615.9	4,805.5	
	GM						136,399.2	
	GSec							819.4
	Ap			65,324.4	1,752.3			38,518.1
	Ac			145.8	1,573.8			1.2
	S							
	A	2,031.1	451.6			10,387.7	425.2	
	Res							
	O							
	NO							
	Total 2010	8,127,739.4	443,676.1	91,656.6	4,295.9	3,134,003.5	141,629.9	39,338.7
	% of biome	53.7	2.9	0.6	0.0	20.7	0.9	0.3

TABLE 3.106

Net CO_2 emissions in the Pantanal biome in the period from 2002 to 2010 (Gg)

NET EMISSIONS MATRIX IN THE PANTANAL BIOME - 2002-2010 (Gg CO_2)								
LAND USE IN 2002		LAND USE IN 2010						
		FNM	FM	FSEC	REF	GNM	GM	GSEC
2002	FNM		-346.4		23.1			
	FM		-1,907.4					
	FSec			-2,127.7				
	Ref							
	GNM				-2.5		-36.6	
	GM						-2,080.5	
	GSec							-12.5
	Ap			-976.8	-301.3			751.0
	Ac			-10.1	-303.4			0.0
	S							
	A							
	Res							
	O							
	NO							
	From the situation of 2010		-2,253.8	-3,114.6	-584.1		-2,117.2	738.5

	AP	AC	S	A	RES	O	NO	TOTAL 2002	% OF BIOME
	549,930.9	812.1	607.0	45,736.8	69.5	525.0		8,841,993.7	58.4
	1,343.1			860.6				327,328.6	2.2
	9,945.0	116.5						36,248.0	0.2
		4,016.8						4,466.7	0.0
	254,274.7	8.2	36.4	23,037.3	1.0	0.1		3,405,794.3	22.5
	170.3							136,569.5	0.9
	1,892.9							2,712.3	0.0
	1,673,447.7	10,247.7	1,398.3	1,216.2	2.8	1,542.3		1,793,449.9	11.9
	18,552.6	4,963.0		2.6		0.1		25,239.1	0.2
			10,622.2					10,622.2	0.1
	629.6			530,104.9	17.7	10.5		544,058.3	3.6
					75.7			75.7	0.0
	511.1					1,222.5		1,733.6	0.0
								0.0	0.0
	2,510,697.9	20,164.3	12,663.9	600,958.4	166.7	3,300.5	0.0	15,130,291.8	
	16.6	0.1	0.1	4.0	0.0	0.0	0.0		

	AP	AC	S	A	RES	O	NO	FROM THE SITUATION OF 2002
	133,376.1	271.2	184.3		29.5	245.3		133,783.1
	324.0							-1,583.4
	862.2	12.8						-1,252.7
		616.5						616.5
	5,379.0	0.5	2.1		0.1	0.0		5,342.6
	6.8							-2,073.7
	3.1							-9.4
		208.7	77.8		0.2	91.1		-149.4
	-408.6					0.0		-722.0
	-38.2							-38.2
	139,504.4	1,109.7	264.2		29.8	336.4		133,913.3

TABLE 3.107

Transition areas for land-use and land-cover identified Brazil for the period from 1994 to 2002 (hectares)[6]

LAND-USE TRANSITION MATRIX IN BRAZIL - 1994-2002 (ha)								
LAND USE IN 1994	LAND USE IN 2002							
1994	FNM	FM	FSEC	REF	CS	GNM	GM	GSEC
FNM	369,455,072.2	48,962,726.9	798,320.7	151,652.6	235,584.8			
FM		104,253,805.6	34,268.6	3,659.2	23,704.6			
FSec			751,094.9	634.8				
Ref			84,435.6	5,266,860.5				11,197.6
CS								
GNM				45,542.7		50,437,237.9	6,315,625.5	17,176.0
GM				308.3			5,717,532.9	218.2
GSec				104.4				8,383.2
Ap			3,668,020.5	177,307.7				592,988.6
Ac			500,795.8	42,421.9				86,311.2
S								
A	3,103.1	280.5		19.9		4,426.7	19.2	
Res			10,641.4	342.2				923.0
O			1,389.4	1,041.7				220.3
NO	485,318.7	60,697.7	24,757.0	9,879.9	321.1	10,654.0	359.9	3.3
Total de 2002	369,943,494.0	153,277,510.6	5,873,723.9	5,699,775.9	259,610.6	50,452,318.7	12,033,537.5	717,421.5
% of biome	43.4	18.0	0.7	0.7	0.0	5.9	1.4	0.1

TABLE 3.108

Net anthropogenic CO_2 emissions in Brazil from 1994 to 2002[7]

NET EMISSIONS MATRIX IN BRAZIL - 1994-2002 (Gg CO_2)								
LAND USE IN 1994	LAND USE IN 2002							
1994	FNM	FM	FSEC	REF	CS	GNM	GM	GSEC
FNM		-274,319.5	437,773.1	43,786.2	27,194,6			
FM		-1,249,679.4	19,882.3	967.3	2,468,4			
FSec			-109,279.3	80.2				
Ref			4,458.4					1,294.6
CS								
GNM				-5,264.2			-48,167.2	822.1
GM				-28.1			-87,211.4	9.4
GSec				-15.7				-127.9
Ap			-63,436.3	-27,670.6				10,659.5
Ac			-30,755.3	-6,694.3				176.8
S								
A								
Res								
O			-55.5	-197.8				-7.5
NO								
From the situation of 2002		-1,523,998.9	258,587.5	4,963.0	29,663.0		-135,378.6	12,827.1

6 Secondary vegetations (FSec and GSec) in this period were mapped only in the Amazon biome. Class CS (selective logging) was not mapped during this period.
7 Secondary vegetations (FSec and GSec) in this period were mapped only in the Amazon biome. Class CS (selective logging) was not mapped during this period.

AP	AC	S	A	RES	O	NO	TOTAL 1994	% OF BIOME
25,984,512.0	2,502,474.6	199,668.1	16,490.4	151,611.1	16,692.2	502,196.3	448,977,002.0	52.7
761,763.8	13,036.4	19,394.4	923.1	512.2	5,205.7	7,467.2	105,123,741.0	12.3
612,188.8	4,138.2	1,117.1	8.8	0.6	715.4		1,369,898.6	0.2
142,679.3	59,844.2	1,009.9		36.2	20.0	13,520.7	5,579,604.1	0.7
3,546,539.8	1,439,989.9	41,801.0	23,003.5	10,540.2	1,313.2	54,265.5	61,933,035.3	7.3
28,414.2	39,373.3	611.5	38.3		24.5	818.5	5,787,339.7	0.7
8,690.9	0.0	47.9					17,226.4	0.0
139,290,084.3	2,997,328.5	355,639.9	10,013.2	5,600.2	4,271.8	607,575.7	147,708,830.3	17.3
2,679,903.7	48,060,211.6	114,294.0	60,515.8	1,376.6	1,029.4	316,524.9	51,863,384.9	6.1
		2,369,496.7				34.7	2,369,531.5	0.3
2,958.8	6,791.2	121.8	16,449,153.5	23,556.0	67.3	148.2	16,490,646.2	1.9
930.2	665.4	4.7	876.8	1,899,885.6		636.2	1,914,905.6	0.2
12,154.0	1,365.1	1,372.1	480.7	0.0	412,940.1		430,963.4	0.1
1,346,729.8	506,549.8	36,905.4	247,0	13,702.4	2,039.2	123,270.8	2,621,436.1	0.3
174,417,549.7	**55,631,768.3**	**3,141,484.7**	**16,561,751.0**	**2,106,821.2**	**444,318.9**	**1,626,458.7**	**852,187,545.2**	
20.5	**6.5**	**0.4**	**1.9**	**0.2**	**0.1**	**0.2**		

AP	AC	S	A	RES	O	NO	FROM THE SITUATION OF 1994
9,682,053.0	573,406.2	84,191.9		61,436.0	7,171.7		10,642,693.2
396,749.0	4,328.7	8,785.3		280.7	3,285.1		-812,932.4
131,285.6	818.3	385.4		0.1	188.1		23,478.5
13,646.4	6,586.4	155.8		5.5	3.1		26,150.3
188,247.4	88,059.2	4,346.9		947.3	140.9		229,132.4
1,049.5	2,587.6	59.3			2.3		-83,531.4
-25.9	0.0	1.9					-167.6
	52,397.2	20,538.2		249.6	230.8		-7,031.7
-42,074.9		5,244.7		47.3	34.7		-74,021.0
-707.4	-42.4						-1,010.6
10,370,222.6	**728,141.3**	**123,709.4**		**62,966.6**	**11,056.5**		**9,942,759.6**

TABLE 3.109

Transition areas for land-use and land-cover identified Brazil for the period from 2002 to 2010 (hectares)

LAND-USE TRANSITION MATRIX IN BRAZIL - 2002-2010 (ha)									
LAND USE IN 2002		LAND USE IN 2010							
		FNM	FM	FSEC	REF	CS	GNM	GM	GSEC
2002	FNM	257,782,744.0	59,576,232.8	1,738,990.4	1,037,488.6	1,077,192.4			
	FM		141,754,214.5	137,345.1	95,080.4	80,712.4			
	FSec			4,272,386.0	47,981.1	3,454.8			
	Ref			430,779.0	4,053,776.9				55,102.0
	CS			152,225.1		15,442.8			
	GNM				331,288.0		40,940,784.7	1,914,873.5	41,634.5
	GM				16,801.5			11,321,518.7	3,094.6
	GSec				15,575.0				534,615.0
	Ap			15,869,542.2	2,154,631.6	1,845.4			1,691,466.1
	Ac			1,393,930.4	427,288.3	15.0			190,515.1
	S								
	A	288,546.0	184,993.9	13,819.1	1,298.8	6.7	149,509.2	34,966.0	8,029.8
	Res			20,833.4	111.5				1,223.7
	O			21,169.8	5,973.9				108.2
	NO	261,987.8	8,114.2	295,483.4	31,710.5		17,731.5	9.2	15,878.1
	Total de 2010	258,333,277.9	201,523,555.4	24,346,504.1	8,219,006.2	1,178,669.6	41,108,025.4	13,271,367.5	2,541,667.0
	% of biome	30.3	23.6	2.9	1.0	0.1	4.8	1.6	0.3

TABLE 3.110

Net anthropogenic CO_2 emissions in Brazil from 2002 to 2010

NET EMISSIONS MATRIX IN BRAZIL - 2002-2010 (Gg CO_2)									
LAND USE IN 2002		LAND USE IN 2010							
		FNM	FM	FSEC	REF	CS	GNM	GM	GSEC
2002	FNM		-190,883.5	27,230.7	257,514.7	326,069.9			
	FM		-1,773,878.0	1,714.9	32,688.3	20,331.1			
	FSec			-691,443.9	3,082.2	819.9			
	Ref			54,816.8					9,225.9
	CS			-9,105.1	55.8	-1,433.2			
	GNM				-38,760.7			-11,343.4	2.7
	GM				-1,955.5			-173,662.7	8.6
	GSec				-2,778.0				-8,875.7
	Ap			-210,210.7	-339,849.7				33,183.1
	Ac			-81,754.9	-75,750.0				726.0
	S								
	A								
	Res								
	O			-538.4	-1,177.3				-3.5
	NO								
	From the situation of 2010		-1,964,761.5	-909,290.6	-166,930.1	345,787.7		-185,006.1	34,267.0

Note: This emissions matrix is not totally compatible with the transition matrix for Brazil in the period 2002-2010, given that in this one the part referring to the transitions in the Amazon biome involves an analysis

AP	AC	S	A	RES	O	NO	TOTAL 2002	% OF BIOME
25,351,075.4	4,763,886.4	100,283.7	652,243.8	819,479.4	79,907.7	16,963,969.3	369,943,494.0	43.4
1,621,696.0	157,204.9	20,124.8	334,808.0	79,243.6	18,764.7	8,978,316.1	153,277,510.6	18.0
1,294,837.6	129,182.1	4,452.3	8,704.6	12,235.8	822.5	99,667.1	5,873,723.9	0.7
536,817.5	385,005.1	5,217.9	3,010.0	917.3	1,577.7	227,572.5	5,699,775.9	0.7
63,614.5	27,210.0	0.6				1,117.6	259,610.6	0.0
4,388,778.7	1,659,017.4	20,174.2	194,881.1	149,949.0	12,007.2	798,930.4	50,452,318.7	5.9
268,303.3	50,082.2	4,415.0	42,947.8	14,141.2	3,635.2	308,598.0	12,033,537.5	1.4
115,482.3	46,990.4	252.9	1,887.9	1,202.5	53.5	1,361.9	717,421.5	0.1
133,035,733.9	13,323,667.4	455,405.2	148,393.1	181,420.9	53,720.1	7,501,723.6	174,417,549.7	20.5
5,241,169.5	47,617,890.4	160,335.2	55,420.1	32,193.3	9,378.2	503,632.9	55,631,768.3	6.5
		3,135,527.7				5,956.9	3,141,484.7	0.4
115,993.7	117,403.5	5,821.2	14,593,311.6	103,499.1	14,858.2	929,694.3	16,561,751.0	1.9
16,878.7	6,659.9	270.1	56,989.5	1,991,958.3	1,788.0	10,108.2	2,106,821.2	0.2
12,925.9	2,660.5	2,344.6	1,236.3	2,160.6	393,263.5	2,475.6	444,318.9	0.1
416,163.7	243,211.6	6,291.0	2,104.9	1,317.6	308.0	326,147.2	1,626,458.7	0.2
172,479,470.8	**68,530,071.7**	**3,920,916.3**	**16,095,938.7**	**3,389,718.7**	**590,084.5**	**36,659,271.6**	**852,187,545.2**	
20.2	**8.0**	**0.5**	**1.9**	**0.4**	**0.1**	**4.3**		

AP	AC	S	A	RES	O	NO	FROM THE SITUATION OF 2002
10,058,181.8	1,350,031.2	41,608.0		282,478.5	39,876.8		12,192,108.1
829,493.2	41,137.4	10,015.9		39,436.1	9,537.7		-789,523.4
488,551.5	22,765.8	1,406.6		2,455.9	847.1		-171,515.0
83,260.9	71,450.1	1,099.9		196.9	308.2		220,358.6
33,500.3	9,372.4			0.0	236.5		32,626.7
210,983.6	94,235.7	1,912.0		14,252.1	1,114.7		272,396.7
14,220.5	3,283.1	489.6		1,818.1	348.3		-155,450.1
456.4	905.9	15.1		53.5	3.2		-10,219.6
	234,546.2	25,422.4		7,707.0	3,057.9		-246,143.7
-83,178.4		7,141.4		1,186.2	393.3		-231,236.3
-735.7	-72.3						-2,527.2
11,634,734.0	**1,827,655.5**	**89,110.9**		**349,584.3**	**55,723.6**		**11,110,874.8**

of the intermediate 2005 situation.

3.5.2.8. Annual net anthropogenic CO_2 emissions for the period 1990 to 2010

The consolidated results presented in section 3.5.2.7 represent the estimates of the average net anthropogenic emissions for the period 1994 to 2002 for all biomes, and 2002 to 2010 for all biomes except for the Amazon, which was evaluated in two periods from 2002 to 2005, and from 2005 to 2010.

Based on these results, the net annual anthropogenic CO_2 emissions for the period 1990-1994 were recalculated.

Net annual anthropogenic CO_2 emissions for the period 1990-1994

This Third Inventory maintains the Second Inventory's approach, when gross emission values were updated in order to reflect carbon estimates of new stocks included (belowground living biomass, dead wood and litter), which were not included in the Initial Inventory. The average CO_2 emission values obtained were considered constant for the years from 1990 to 1994 for all the biomes, except for the Amazon, which had gross total emission values for the period from 1990 to 1994 distributed proportionally by year following gross deforestation variation values observed by the PRODES[8].

An amendment was made in relation to the Second Inventory related to CO_2 removal by sinks of the managed areas from 1990 to 1994, in which the same annual carbon removal of 0.62 t C/ha was considered throughout the years in the managed areas of forest physiognomy identified in 1994 and considered as the same since 1990 for all biomes. In this Inventory, each biome has its average removal rate: 0.43 t C/ha for the Amazon; 0.32 t C/ha for Atlantic Forest and Pampa (whose removals of managed areas had not been not included); 0.20 t C/ha for Cerrado and Pantanal; and 0.10 t C/ha for the Caatinga. Moreover, the forest physiognomy areas regarded as managed areas were amended for the year of 1994.

Net annual anthropogenic CO_2 emissions for the period 1994 to 2002

The average annual emission obtained for CO_2 emissions for the 1994-2002 period was calculated for all biomes, except for the Amazon biome, as a ratio of total net emissions for the period and the number of years of the period (8 years). Consequently, this results in a linear distribution of emissions throughout the period. The Amazon biome's gross annual emissions (basically associated with primary forests converted to other uses) were estimated by using an annual time series of gross deforestation generated by INPE (PRODES), resulting in an inconstant total emission for each year of the period considered.

Annual net anthropogenic emissions for the period 2002 to 2010

Net average annual emission for the period from 2002 to 2010 was calculated for the Amazon for two distinct periods: 2002-2005 and 2005-2010, adopting the same approach used for the period 1994-2002. The information available on deforestation for the periods 2002-2008, and 2008-2009 for other biomes, provided by the "Monitoring Project for the Brazilian Biomes Deforestation"[9], allowed the application of the same approach

8 Project for Estimating Gross Deforestation of the Brazilian Amazon (PRODES), which accounts for clear cutting in the region. Information available at: http://www.obt.inpe.br/prodes/index.php

9 A partnership of IBAMA Remote Sensing Center, Secretary of Biodiversity and Forests of the Ministry of Environment and UNDP. Available in: http://siscom.ibama.gov.br/monitorabiomas/index.htm used in the Amazon for other biomes. Exceptionally for the Cerrado, deforestation estimates for the period 2009-2010 was also originated from the abovementioned project. As a consequence, gross annual emissions for all biomes were calculated using existing gross deforestation data for each biome. For 2010, the same annual gross emission calculated for the year of 2009 for all biomes was presumed, except for the Amazon and the Cerrado.

Annual CO_2 removals were estimated based on even distribution for the considered period. The results are summarized in Table 3.111, which also lays out CO_2 caused by liming of soils.

TABLE 3.111

Summary of annual net anthropogenic CO_2 emissions for the period 1990-2010 per biome

SOURCE	1990	1995	2000	2005	2010	SHARE IN 2010*	VARIATION 2005-2010
	Gg					%	
Land-Use Change	751,867	1,832,113	1,188,458	1,790,368	300,312	96.6	-83.2
Amazon Biome	437,574	1,459,071	815,416	1,128,545	162,888	52.4	-85.6
Cerrado Biome	241,511	212,958	212,958	282,275	58,755	18.9	-79.2
Atlantic Forest Biome	26,115	111,072	111,072	329,662	69,104	22.2	-79.0
Caatinga Biome	28,643	23,774	23,774	14,382	-4,291	-1.4	-129.8
Pantanal Biome	18,161	21,640	21,640	21,450	2,606	0.8	-87.9
Pampa Biome	-137	3,598	3,598	14,054	11,250	3.6	-20.0
Liming	5,103	5,395	8,717	7,474	10,424	3.4	39.5
Total	**756,970**	**1,837,508**	**1,197,175**	**1,797,842**	**310,736**	**100.0**	**-82.7**

Other greenhouse gas emissions from burning

When the forest is converted to agricultural or livestock use, part of the original biomass is removed as commercial timber or as firewood for charcoal or other fuel uses. The remaining wood debris left on the field are usually burned in a non-efficient manner. As result, greenhouse gases such as CH_4, N_2O, CO and NO_x are emitted under this imperfect combustion. Here, only emissions associated with deforestation are calculated. Appendix II shows assessments and considerations on burnings that are not related to deforestation.

In order to evaluate what is being burned on the field it is necessary to estimate the fraction removed before combustion to be used somewhere else. In the Second Inventory, IBGE statistics on timber, charcoal and firewood annual consumption, which are derived from extractive activities in native forests, were used as proxy. The quantities of firewood, timber and charcoal derived from planted forests were not considered. The sum of timber and charcoal from vegetable extraction and silviculture provided by the IBGE is far below the data provided by the National Energy Balance (BEN), which is the main source of information for the Energy sector.

Hence, the Third Inventory considered, in the case of firewood and charcoal, only the firewood data informed by BEN, which includes firewood used for charcoal production and charcoal. As for timber harvesting, this Inventory considered the part derived from vegetable extraction and silviculture (for the production of paper and pulp and other uses), as informed by IBGE.

Quantities of firewood and wood extracted in round timbers had 25% humidity, according to the Reference Report of the Energy sector (Bottom-Up approach – Methodological Annex), in order to keep information coherent. Conversion to dry matter is necessary for the comparison with timber removed from forests to other uses and for the correct application of emission factors for non-CO_2 gases related to dry biomass.

Gross emissions resulting from forest conversion to other uses, except selective logging, and the ones resulting from the conversion of native grassland to other uses were converted to dry matter, first for CO_2 to C conversion, then by considering carbon as being 47% of this dry matter. From this dry matter, the quantities extracted proportionally to the gross emissions considered were deducted.

For the period 2005 a 2010 the fraction of carbon removed as commercial timber jumped from 3% to 7% of total dry matter available from deforestation. On the other hand, the fraction removed as charcoal and firewood jumped from 2% to 5% of total dry matter available from deforestation in the same period. This means that the biomass effectively burned decreased from 95% to 88% of the total biomass available over that period of deforestation.

As for the combustion factor, an average value was estimated for each biome, differentiating the vegetation structure between forest and native field, according to Table 3.112. Given that these factors were used for the estimate of burning associated with deforestation, priority has been given to works carried out in slash and burn areas. In the absence of such works, the values used are derived from burned areas, mainly for grassy field and savannah vegetation.

TABLE 3.112

Combustion factors by biome, according to the vegetation structure, for the estimate of emissions from deforestation-related combustion, and sources used

BIOME	STRUCTURE	COMBUSTION FACTOR	SOURCES
Amazon	Field	69.3 [2]	BARBOSA & FEARNSIDE, 2005
	Forest	35.6 [1]	WARD et al., 1992; KAUFFMAN et al., 1995; ARAUJO et al., 1999; FEARNSIDE et al., 1993; 1999; 2001; CARVALHO et al., 1995; 1998; 2001; DE ALENCASTRO GRAÇA et al., 1999
Cerrado	Field	88.0 [2]	CASTRO & KAUFFMAN, 1998
	Forest	43.5 [2]	CASTRO & KAUFFMAN, 1998
Caatinga	Field	88.0 [2]	Same as Cerrado
	Forest	43.5 [2]	Same as Cerrado
Atlantic Forest	Field	88.0 [2]	Same as Cerrado
	Forest	35.6 [1]	Same as Amazon

continues on the next page

BIOME	STRUCTURE	COMBUSTION FACTOR	SOURCES
Pampa	Field	94.4 [2]	FIDELIS et al., 2010
	Forest	35.6 [1]	Same as Amazon
Pantanal	Field	88.0 [2]	Same as Cerrado
	Forest	43.5 [2]	Same as Cerrado

[1]- Value calculated from works carried out in slashed and burned areas.
[2]- Value calculated from works carried out in burned areas.

Finally, emission factors of the 2006 Guidelines for non-CO_2 gases that corresponded to the biomes were applied, as shown in Table 3.113. It is indicated that CO_2 will not be considered again, since these fires are associated with deforestation and, as such, their CO_2 emissions have already been evaluated.

TABLE 3.113
Emission factors for greenhouse gases

GASES	SAVANNAS AND NATIVE FIELDS	TROPICAL FORESTS
	g/kg BURNED DRY MATTER	
CO_2	1,613	1,580
CO	65	104
CH_4	2.3	6.8
N_2O	0.21	0.20
NO_x	3.9	1.6

Source: IPCC (2006), Volume 4, Table 2.5.

Table 3.114 presents a summary of non-CO_2 gas emissions by biomass burning in forest areas converted into agricultural and livestock uses.

TABLE 3.114
Summary of non-CO_2 gas emissions by biomass combustion associated with forest and native grasslands converted into agricultural uses

GAS	1990	1995	2000	2005	2010	VARIATION 2005-2010
	Gg					(%)
CH_4	1,041.5	2,895.7	2,048.8	3,237.9	1,135.4	-64.9
CO	18,429.4	48,855.6	35,879.9	55,810.0	20,231.3	-63.7
N_2O	42.56	106.98	81.96	125.25	47.08	-62.4
NO_x	526.7	1,196.0	993.8	1,470.3	589.9	-59.9

3.6. WASTE

Solid waste disposal to land and domestic and industrial wastewater handling can produce greenhouse gas emissions. Solid waste can be disposed of in landfills or dumps, recycled or incinerated. Liquid waste may receive various forms of physical and chemical or biological treatments, whereas biological treatment can occur via aerobic or anaerobic decomposition. In turn, waste incineration, like every combustion, generates GHG emissions, depending on waste composition; however, this activity is not widespread in Brazil.

CH_4 is the most important gas produced in the Waste sector, and may occur as a result from both solid waste disposal to land and anaerobic wastewater handling. Significant quantities of emissions of CH_4 produced are released as a by-product of the waste anaerobic decomposition. The two major sources are waste disposal in landfills and anaerobic wastewater treatments.

N_2O emissions can also occur in domestic wastewater treatment, and are calculated on the basis of nitrogen content in food.

This inventory estimates CH_4 emissions from solid waste disposal to land and from domestic and industrial wastewater handling. CO_2 and N_2O emissions from incineration and N_2O emissions from human sewage treatment are also considered.

In order to estimate greenhouse gas emissions from the Waste sector, the following data were necessary: urban population, urban solid waste generation rates at municipal level and organic matter generation rates for wastewater treatment, besides incinerated quantities. These data were gathered during the entire period of the elaboration of estimates.

However, part of the data needed for the estimations are not available for the entire country. In addition, some data, such as waste disposal conditions, volume of generated waste, landfill or dump installations, as well as wastewater treatment systems, organic matter content and type of incinerated waste, present large uncertainty.

3.6.1. Solid waste disposal

Waste disposal in landfills and dumps generates CH_4 under certain conditions, including: the amount of waste, the deposit's age, the presence of an anaerobic environment, acidity and handling conditions and facilities. The better the landfill control conditions and the deeper the dump, which improve sanitary conditions, the greater CH_4 emission potential.

The methodology for estimating CH_4 emissions from solid waste disposal to land was the first order decay method (Tier 2), as described in the Good Practice Guidance 2000. According to this method, CH_4 emissions persist over a long period of time, after waste disposal. The following data were necessary for the Tier 2 method application: urban population, climate data (annual temperature and rainfall averages), quantity of waste disposed, waste composition, quality of landfill operation and quantities of recovered and oxidized CH_4, since 1970.

Data related to urban population of all municipalities in Brazil used in these estimates correspond to those available in IBGE censuses for 1970, 1980, 1991 and 2000, and the 2010 Population Count. Waste generation types and rates vary due to the country's large territorial extension and to regional, economic and social differences.

The product of waste generation rate per capita and urban population estimated the amount of waste disposed in landfills. Solid waste generation per capita rate was estimated based on data from CETESB and from the Brazilian Association of Public Cleaning and Special Waste Companies (ABRELPE in the Portuguese acronym). In the past, according to studies conducted by CETESB, the rate of waste generation per capita ranged between 0.4 and 0.7 kg/capita/day, with an estimated average daily rate of 0.5 kg/hab. This value was adopted in this Inventory as primary data of 1970. As of 2008 this rate became data published by ABRELPE (ABRELPE, 2008; 2009; 2010), calculated for each region of the country. Thus, the rate of the years between 1970 and 2008 is estimated by the linear interpolation of the rates of 1970 and 2008.

Data on waste composition were classified as recommended in the Good Practice Guidance 2000 in the following types of waste: paper and textiles; garden and other nonfood putrescible; food waste and wood and straw. Linear regressions were used in estimates for each region of the country based on the waste composition data available for some states and municipalities.

The following recommended classification was used for the methane correction factor: managed landfills (1.0), unmanaged sites with a depth equal to or greater than five meters (0.8), and unmanaged sites with a depth less than five meters (0.4). Furthermore, default values were adopted for the fraction of degradable organic carbon that truly degrades (0.5) and for the fraction of methane in landfill gas (0.5).

To estimate CH_4 emissions, the amount of methane recovered/oxidated should be discounted. For the 1990-2002 period, these amounts were deemed to be zero. From 2003 onwards, CH_4 emissions reductions were considered according to the monitoring reports for landfill CDM activity projects, for which there was monitoring reports checked by Designated Operational Entities, as the regulation of CDM Executive Board.

It should be noted that small quantities of CH_4 are deducted of the states emissions where are the CDM project activities. As a landfill can receive waste from several municipalities, the amount of recovered methane can be higher than the corresponding emission of a municipality, estimated on the basis of its urban population and other parameters described throughout the document.

For cities with over 1,000,000 inhabitants, the existence of managed landfills was assumed. For these cases, the oxidation factor (OX) – which reflects CH_4 combustion that may happen in the landfill surface – of 0.1 was adopted, according to the Good Practice Guidance 2000. For cities with fewer inhabitants, this factor was assumed to be null.

Based on these assumptions, CH_4 emissions from solid waste disposal to land were estimated and are shown in Table 3.115.

TABLE 3.115
CH_4 emissions from solid waste disposal

SOURCE	1990	1995	2000	2005	2010	VAR. 2005/2010
	(Gg CH_4)					(%)
Solid waste disposal	824.4	965.3	1,149.4	1,237.1	1,327.0	7.3

An increase in CH_4 emissions was identified for the period due to demographic growth, changes in habits, life quality improvement and industrial development, which caused an increase in the amount of waste generated. However, the activities of CDM projects contributed to reduce part of this increase, due to the recovery and oxidation of CH_4. The national emissions would be higher without the reductions achieved by the CDM projects, which were 208.4 Gg CH_4 in 2010.

3.6.2. Waste incineration

Given the difficulty in disposing of solid waste in Brazil's metropolitan regions, alternative ways have been considered and waste incineration stands out among the possible alternatives identified.

Incineration of urban waste has been more often considered as an alternative in large cities due to the increasing cost of waste transportation to landfills, since these are getting farther away from metropolitan regions. This practice is applied to a small fraction of total treated waste, and is most used for hazardous waste from industry and clinical waste, which, in general, cannot be disposed of in common landfills and require special treatment. The incineration of solid waste and municipal wastewater sludge was disregarded since they were not relevant in the period.

For the estimation of emissions of CO_2 and N_2O from the incineration of waste, the 2000 Good Practice Guidance methodology was used. According to this methodology, the type of waste being incinerated determines the estimate of CO_2 emissions, the carbon contained in the type of waste, its fraction of fossil carbon and the burning efficiency of the incinerators. Similarly, the estimate of N_2O emissions is determined by the type and quantity of waste incinerated and the emission factor for each type of waste.

For the carbon fossil part of the waste, the following Good Practice Guidance 2000 default values were used: 60 g C / g clinical waste and 50 g C / g hazardous waste of industrial origin. The same value was adopted for fossil carbon percentage in the other types of waste, and for this calculation the default values of the Good Practice Guidance 2000 were used.

Regarding the incinerators burning efficiency, no national data were identified. Thus, Good Practice Guidance 2000 default values were adopted. 2006 Guidelines default values were applied for the N_2O emission factor, since this information was not available in the IPCC previous guidelines.

Data for hazardous waste incineration were obtained from the Brazilian Association of Waste Treatment Companies (ABETRE, 2006), National Sanitation Information System (SNIS) and incinerator operators and manufacturers that responded to the data request made by CETESB. Emissions are shown in Table 3.116.

TABLE 3.116

CO_2 and N_2O emissions from solid waste incineration

GAS	1990	1995	2000	2005	2010	VAR. 2005/2010
	(Gg)					(%)
CO_2	19	78	95	128	175	36.7%
N_2O	0.00	0.00	0.01	0.01	0.01	0.0%

3.6.3. Wastewater treatment

Wastewater with high organic matter content has great CH_4 emission potential, such as domestic and commercial wastewater, effluents from food and beverage industries and those from the pulp and paper industry. In the case of domestic wastewater, N_2O emissions can occur due to the nitrogen content in human food. N_2O emissions were estimated by the amount of nitrogen present in human waste.

3.6.3.1. Domestic and commercial wastewater

CH_4 emissions were estimated based on the amount of organic material present in wastewater, expressed in terms of Biochemical Oxygen Demand (BOD), which represents the amount of oxygen consumed by microorganisms in the biochemical oxidation of organic matter.

Several systems are used for treating effluents in Brazil. Nevertheless, a large amount of sewage is discharged directly into rivers and ocean, without treatment. According to the National Survey on Basic Sanitation (PNSB) (IBGE, 1989; 2000; 2008), the untreated domestic wastewater thrown into water bodies has reduced, but the advances were not very significant once compared to the population increase during the same period. Among the various collective options for the biological treatment, the most commonly used in Brazil are the stabilization lagoons and the various modifications of the activated sludge process, particularly those that employ the concept of extended aeration and biological filters.

The emission of CH_4 is estimated from the organic matter present in wastewater, expressed in terms of Biochemical Oxygen Demand (BOD). The volume of wastewater generated per person depends on the quantity of water consumed and usually corresponds to 80% of this consumption. The organic unit load varies from country to country, between 0.02 and 0.08g BOD per inhabitant per day. The average BOD per capita of 0.054 kg BOD/ (hab. day) in Brazil was used. For the maximum production capacity of methane, the default value of the 2000 Good Practice Guidance, equal to 0.60 kg CH_4/kg BOD, was used.

The population considered in this study is the one generating wastewater, given that domestic effluents are generated the by the use of water for the transportation of domestic waste. The population that generates wastewater can be estimated by the product between the total population of Brazil and the fraction of households with sinkhole. This fraction is obtained by the ratio of the total households and households without a sinkhole (IBGE 1991; 2000; 2010).

The organic matter of domestic wastewater can be increased by launching industrial effluents into the urban sewage systems or reduced by rainfall infiltrations in the sewage system. However, these data were considered to be null, since there is no information on it. Anaerobic treatments in wastewater plants were considered, and they include anaerobic digester for sludge, anaerobic processes in reactors and ponds, latrines and septic systems. Organic matter discharges into the sea, rivers and lakes, in which CH_4 emissions occur through anaerobic reactions, were also considered.

Methane recovered in anaerobic reactors and in anaerobic digesters of activated sludge systems was considered to be completely destroyed in a burner, since that is the common practice in Brazil. Therefore, it was considered that 100% of the recovered methane is burned. Burner's efficiency was considered to be of approximately 50%. Methane oxidation was considered null for emissions at septic systems and anaerobic lagoon systems and for discharges of untreated wastewater into water bodies.

Besides CH_4, N_2O emissions from human waste were also estimated based on population and on average annual consumption per capita of protein, by state or region and the country's population.

Data for protein consumption per capita were taken from FAO's publication (FAO, 2009). The study identified average values of 76.8g/day/person for the period 1994-1996, 79.4g/day/person for the period 1999-2001 and 84.5g/day/person for the period 2003-2005. Population data were the same as those used for CH_4 estimates.

CH_4 and N_2O emissions due to the treatment of domestic and commercial wastewater are presented in Table 3.117 for the years 1990, 1995, 2000, 2005 and 2010.

TABLE 3.117

Emissions from domestic and commercial wastewater treatment

GAS	1990	1995	2000	2005	2010	VAR. 2005/2010
	(Gg)					(%)
CH_4	266.7	304.3	371.7	436.6	512.8	17.5%
N_2O	4.32	4.83	5.67	6.60	7.20	9.1%

3.6.3.2. Industrial wastewater

Industrial wastewater has been traditionally treated through the use of pond or activated sludge processes and biological filters, besides the use of anaerobic reactors.

For this Inventory, industrial activities were kept with the greatest potential for methane emissions selected for the Second Inventory, excluding emissions due to the consumption of cotton because of the uncertainties about the destination. The improvement of the data survey for the estimation of emissions from industrial effluents included a survey to update and review the emission data of organic load, in addition to the update of the effluent treatment of each industrial sector.

For the estimation of the emissions of CH_4, data of the industrial production and the emission factor for each of the sectors considered were used. The data relating to the industrial production of these sectors are presented in Table 3.118.

TABLE 3.118

Industrial production in main sectors that contribute to industrial wastewater emission

PRODUCT [UNIT]	1990	1995	2000	2005	2010	VAR. 2005/2010 (%)
Sugar [t] (a)	7,214,050	12,651,628	19,387,603	26,685,095	32,956,359	23.5%
Raw milk [1000 L] (b1)	14,484,000	18,110,938	22,014,202	24,660,202	30,163,539	22.3%
Alcohol [m^3] (a)	11,920,335	12,751,811	12,983,108	15,388,567	25,690,918	66.9%
Cellulose [t] (c)	4,351,143	5,936,000	7,463,000	10,352,000	14,164,000	36.8%
Beer [1000 L] (b2)	3,749,150	8,037,262	9,023,303	9,865,939	12,947,054	31.2%
Slaughtering of poultry [t] (e)	1,604,696	2,317,657	3,316,897	6,411,962	8,609,058	34.3%
Slaughtering of cattle [t] (e)	2,835,762	2,533,950	2,163,855	6,144,629	7,445,632	21.2%
Slaughtering of swine [t] (e)	729,545	824,572	672,962	2,886,889	4,075,714	41.2%
Pasteurized milk [1000 L] (d)	4,054,000	3,150,000	1,630,000	1,550,000	1,690,000	9.0%

Source: (a) Unica, 2014; (b1) Abia, 2010; (b2) Abia, 2014; (c) IBA (2014); (d) ABVL, 2014; (e) IBGE - PIA - Product, 1998 to 2004 and IBGE - Statistical yearbook, 1990 to 1993 and 2011.

Despite the great potential of methane emissions due to the high organic wastewater load, sugar and ethanol industry effluents do not represent a source of CH_4 emissions, since their effluents are discharged directly into the soil as fertilizer without anaerobic treatment. Emissions from this sector were considered null, as in the previous inventories.

Table 3.119 presents the data on the emission of organic load used in the estimate, which, once multiplied by the maximum production capacity of CH_4 0.60 $kgCH_4.kgBOD^{-1}$, provides the emission factor for each industrial sector.

TABLE 3.119
Organic load emission for each industrial sector

INDUSTRIAL SECTOR	ORGANIC LOAD EMISSION (kg BOD / t)
Sugar	200
Raw milk	16.8
Alcohol	220
Cellulose	64.8
Beer	9.45
Poultry	5.85
Cattle	32.5
Swine	32.5
Pasteurized milk	16.8

Emissions estimates from industrial wastewater treatment are presented in Table 3.120.

TABLE 3.120
CH_4 emissions from industrial wastewater treatment

GAS	1990	1995	2000	2005	2010	VAR. 2005/2010
	($Gg\ CH_4$)					(%)
CH_4	82.6	149.1	233.1	388.3	622.9	60.4%

CHAPTER IV
UNCERTAINTY OF THE ESTIMATES

CHAPTER IV
UNCERTAINTY OF THE ESTIMATES

The estimates of the anthropogenic emissions and removals of greenhouse gases presented in this Inventory are subject to uncertainties due to various causes, from the lack of precision of the basic data to incomplete knowledge of the processes that result in emissions or removals of greenhouse gases.

The 2000 Good Practice Guidance recognizes that the uncertainty of the estimates cannot be totally eliminated and that the main objective should be to produce accurate estimates, i.e., which are neither underestimated nor overestimated, while at the same time and whenever possible, seeking to improve estimate precision.

According to these recommendations, in the generation of the estimates presented in this Inventory, attempt was made to ensure that they were not biased. For some activities this objective may not be fully achieved, whether due to either the impossibility of estimating values for some subsectors, or the inappropriate default parameters used in the absence of appropriate values for national conditions. These cases were highlighted in the previous sections.

Estimate precision varied depending on the characteristics of each sector, the data available and the resources that could be invested for determining more fitting emission factors for Brazilian circumstances. In that sense, emphasis was given to the most relevant sectors in terms of greenhouse gas emissions.

The uncertainty of the inventory is due to uncertainty associated with each activity data, emission factors and other parameters used in the estimates. Quantifying uncertainty for individual data items is as or more difficult to assess as the actual information sought.

For many sectors, it was not possible to make a detailed uncertainty analysis of the estimates, since that would require a considerable effort in analyzing the accuracy and precision of basic information used. Still, a general assessment of the accuracy of the Inventory has been conducted on the basis of the reasoning/knowledge of experts in specific areas and the use of default values described by the IPCC. The objective was just to identify the sectors of the Inventory where most resources should be used in the future.

The precision associated with the activity data and the emission factors, as well as the emission or removal estimates, is expressed in the ±x% form, meaning the 95% confidence interval limits for a value shown.

Considering that the joint participation of the three most important gases (CO_2, CH_4 and N_2O) is more than 99% in 2010, only these three gases will have their uncertainties analyzed.

The analysis of the uncertainties in each sector was made through the simplified approach of the 2000 Good Practice Guidance, except for the Waste Treatment sector, which used the Monte Carlo method. The uncertainties shown in the following tables are calculated for the year 2010. The following charts show the time series of the emissions with the upper and lower limits indicated by the uncertainties calculated for all years.

4.1. UNCERTAINTY OF CO_2 EMISSION AND REMOVAL ESTIMATES

Table 4.1 shows the results of the analysis of uncertainty for CO_2 emission and removal estimates.

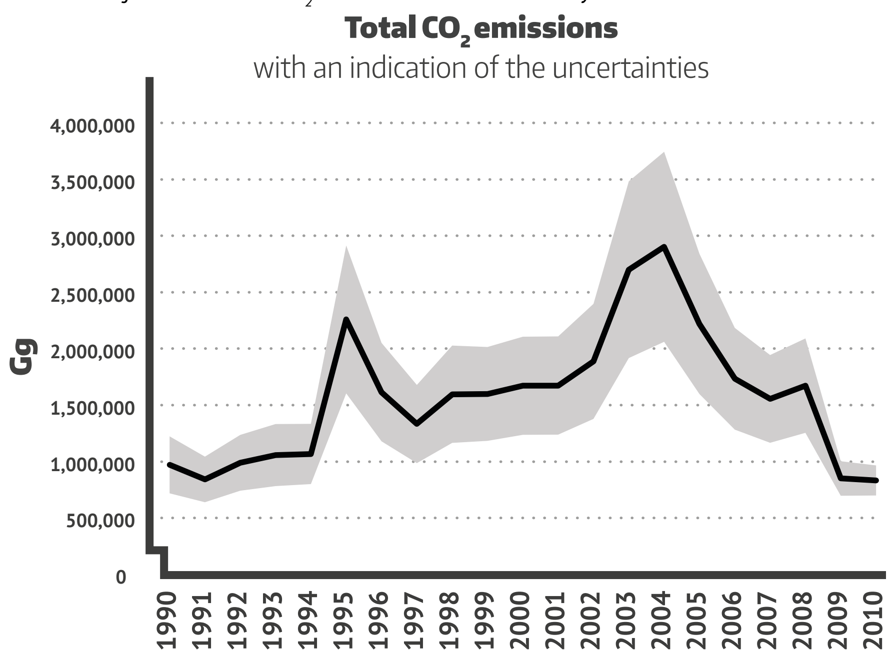
TABLE 4.1

Precision of the CO_2 emission and removal estimates in 2010

SECTOR	UNCERTAINTIES (%)
Energy	3
Fossil fuel combustion	3
Fugitive emissions	25
Coal Mining	32
Extraction and Transportation of Oil and Natural Gas	28
Industrial Processes	3
Cement Production	4
Lime Production	10
Other Uses of Limestone and Dolomite	21
Iron and Steel Production	6
Aluminum Production	6
Chemical Industry	7
Other industries	4
Land use, Land-Use Change and Forestry	32
Waste	57
TOTAL	**14**

FIGURE 4.1

Evolution of the Brazilian CO_2 emissions with uncertainty limits



4.2. UNCERTAINTY OF CH_4 EMISSION ESTIMATES

Table 4.2 shows the results of the analysis of uncertainty for CH_4 emission estimates.

TABLE 4.2

Precision of CH_4 emission estimates in 2010

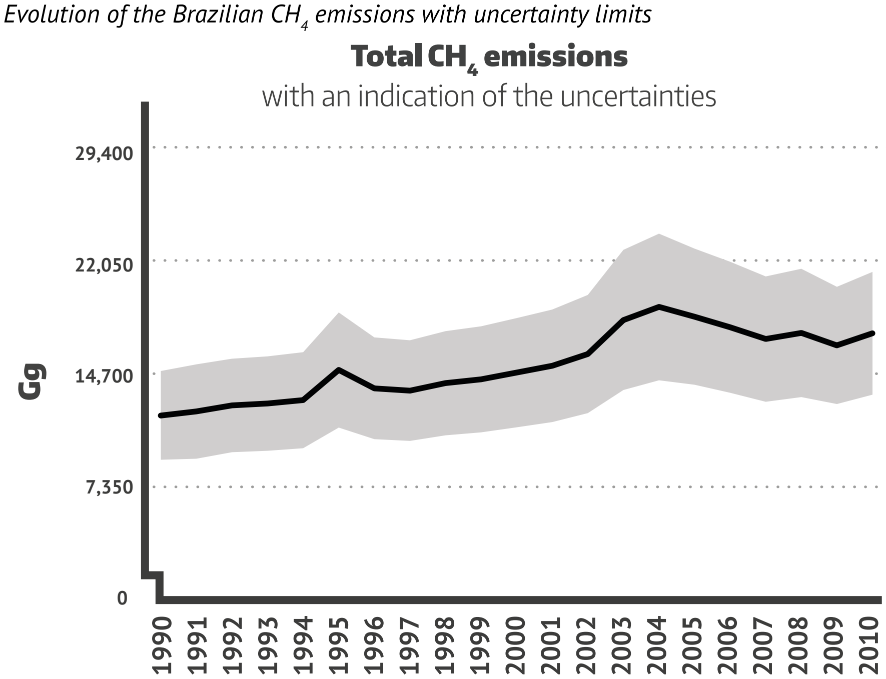
SECTOR	UNCERTAINTY (%)
Energy	**54**
Fuel Combustion	73
Fugitive Emissions	45
Coal Mining	73
Extraction and Transportation of Oil and Natural Gas	54
Industrial Processes	**11**
Iron and Steel Production	15
Others from Metallurgy	15
Chemical Industry	17

continues on the next page

SECTOR	UNCERTAINTY (%)
Agriculture	**31**
Enteric Fermentation	34
Manure Management	38
Rice Cultivation	45
Crop Residue Burning	32
Land use, Land-Use Change and Forestry	**72**
Waste	**16**
Solid wastes	23
Wastewater	23
Industrial	30
Domestic	35
TOTAL	**24**

FIGURE 4.2

Evolution of the Brazilian CH_4 emissions with uncertainty limits



4.3. UNCERTAINTY OF N_2O EMISSION ESTIMATES

Table 4.3, shows the results of the analysis of uncertainty for N_2O emission estimates.

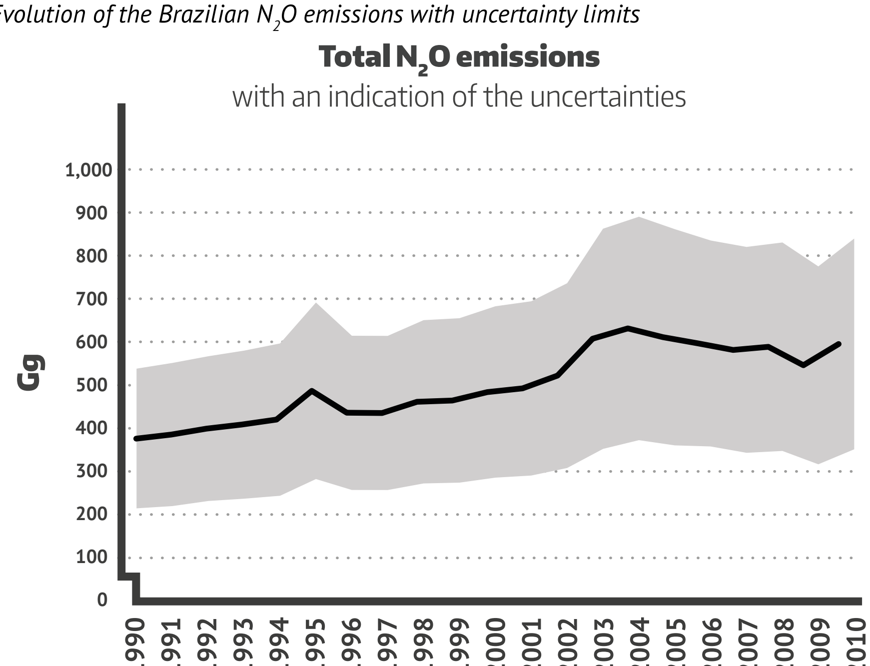
TABLE 4.3

Precision of N_2O emission estimates in 2010

SECTOR	UNCERTAINTY(%)
Energy	**101**
Industrial processes	**9**
Chemical industry	5
Metallurgical Industry	16
Agriculture	**49**
Manure management	43
Agricultural soils	51
Grazing animals	81
Other direct sources	54
Indirect emissions	102
Crop Residue Burning	51
Land use, Land-Use Change and Forestry	**101**
Waste	**15**
TOTAL	**42**

FIGURE 4.3

Evolution of the Brazilian N_2O emissions with uncertainty limits



A comparison can be made with the emissions of CO_2e. For such, the GWP-SAR figures were used.

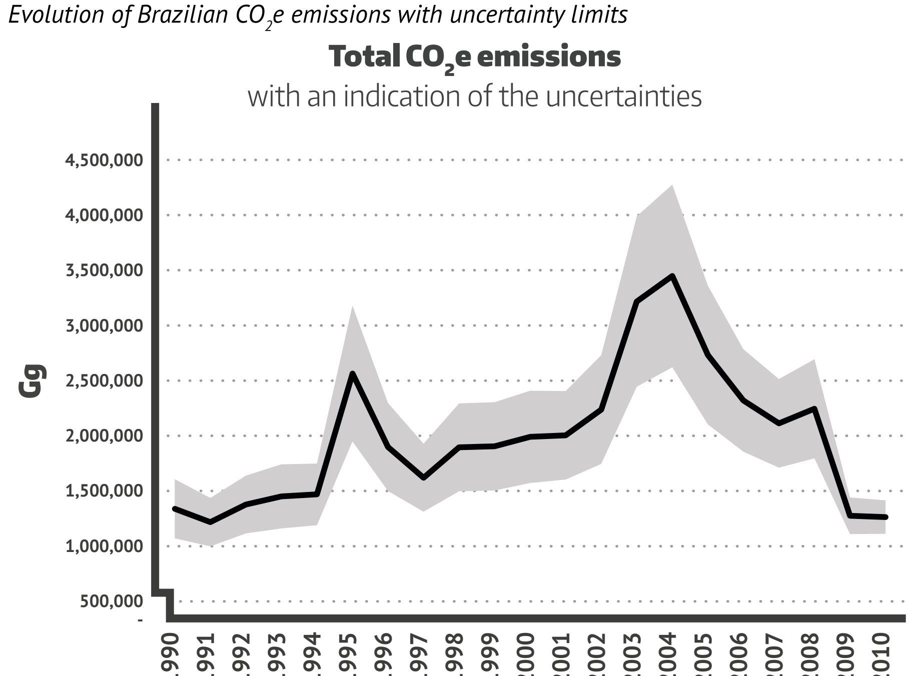
TABLE 4.4

Precision of Brazilian CO_2e emissions estimates

GAS	EMISSIONS 2010 (Gg)	UNCERTAINTY (%)	GWP	EMISSIONS 2010 (Gg CO_2e)
CO_2	739,671	14	1	739,671
CH_4	16,688.2	24	21	350,452
N_2O	560.49	42	310	173,752
TOTAL		**12**		**1,263,875**

FIGURE 4.4

Evolution of Brazilian CO_2e emissions with uncertainty limits



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APPENDIX I

METHODOLOGICAL DESCRIPTION FOR THE INVENTORY OF LAND USE, LAND-USE CHANGE AND FORESTRY

APPENDIX I

METHODOLOGICAL DESCRIPTION FOR THE INVENTORY OF LAND USE, LAND-USE CHANGE AND FORESTRY

1. DETAILED METHODOLOGY FOR THE LAND USE, LAND-USE CHANGE AND FORESTRY SECTOR

1.1. LAND REPRESENTATION

The national territory was subdivided into spatial units (cells) in the form of polygons, which resulted from the integration of the following data sources (information plans/layers):

- Brazilian biomes;
- Municipal limits;
- Previous vegetation (phytophysiognomy);
- Soil types;
- Managed areas (Protected areas and indigenous land);
- Land use and cover for the Cerrado, Atlantic Forest, Caatinga, Pampa and Pantanal biomes in 1994, 2002 and 2010; and,
- Land use and cover for the Amazon biome in 1994, 2002, 2005 and 2010.

The crossing of information plans generated polygons that covered the entire national territory, for each year analyzed. Each polygon pertains to a biome, municipality, soil type, and previous vegetation and land use/cover in the years of interest. The analysis of the geo-referenced polygons allows identifying whether there have been land use/cover changes through the years studied or not (for example, areas of primary forest converted into other uses, or agricultural areas which remained as agricultural areas). Out of the crossing the information together with the carbon stock data previously mentioned, it was possible to estimate the CO_2 emissions for all the periods considered. Each layer will be further detailed below.

Brazilian biomes

The division of the territory into six large biomes was based on the limits defined by the Brazilian Institute of Geography and Statistics (IBGE, 2004) in cooperation with the Ministry of the Environment (MMA). This division is associated with a number of environmental factors, such as the type of predominant vegetation, topography and/or climatic conditions of the region. The distribution and area of the biomes are shown in Figure A1.1 and Table A1.1.

FIGURE A1.1

Distribution of the Brazilian biomes in the national territory (IBGE, 2004)

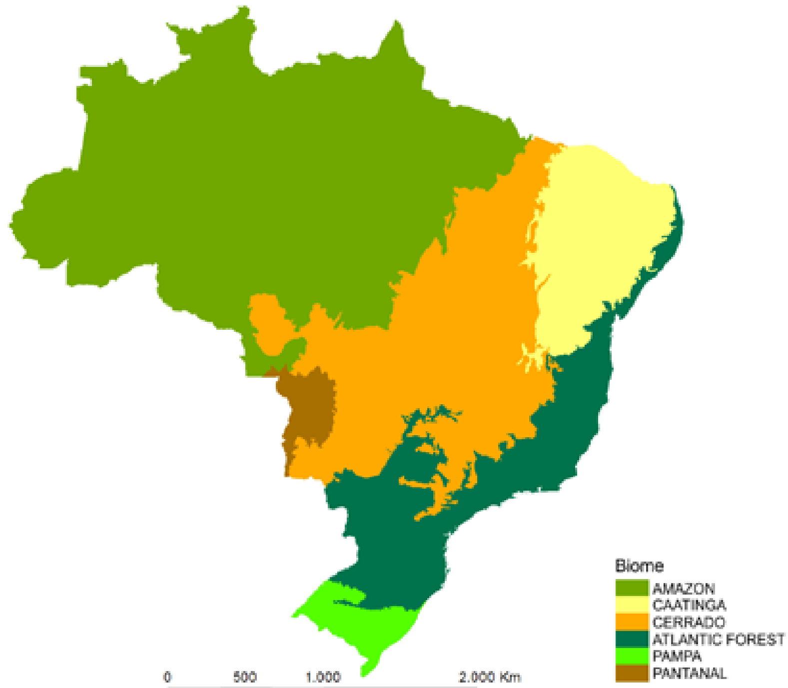


TABLE A1.1

Area of the Brazilian biomes

CONTINENTAL BRAZILIAN BIOMES	APPROXIMATE AREA (km²)	SHARE (%)
Amazon	4,196,943	49.29
Cerrado	2,036,448	23.92
Atlantic Forest	1,110,182	13.04
Caatinga	844,453	9.92
Pampa	176,496	2.07
Pantanal	150,355	1.76
Brazil	**8,514,877**	**100.00**

Source: IBGE, 2004[10].

10 The difference between the country's total area according to the data herein (852,151,763.5) and the data on the IBGE website (851,576,704.9) is 575,058.6 ha (0.06%), which might be due calculation parameters themselves, as a result of the projection used, besides the correction of overlapings in files in shapefile format.

Municipal borders

The inclusion of an information plan with political boundaries (country, states and municipalities) aimed at facilitating specific consultations for each national region and identifying areas that are more affected with deforestation and/or are converted to other uses. Moreover, these data lead to auxiliary information on crops and silviculture from census data of the IBGE, agricultural data and others.

The IBGE's 2010 Digital Municipal Grid was used in this study. This version portrays the current situation of Brazil's Political-Administrative Division, which adds the creation of one municipality to the data used in 2005, going from 5,564 municipalities to 5,565.

Previous vegetation (phytophysiognomy)

According to the IBGE's (2004) Vegetation Map of Brazil, forest formations cover more than 60% of the national territory. These formations include humid forests (typical of regions that rainfalls are abundant all year long) and seasonal forests (typical of dryer regions), which, despite being present in all biomes, are more usual in the Amazon and Atlantic Forest, respectively.

Savannah formations are predominant in the Cerrado but also occur in other regions of the country, including the Amazon. The steppe savanna occurs mainly in the northeastern Caatinga, but also in some areas of Roraima, Mato Grosso's Pantanal and a small part of the extreme west of Rio Grande do Sul. The steppe formation corresponds to the grasslands, plateau and prairies in the far southern area of Brazil, in the Pampa biome. Campinaranas can be found in Amazon, in the Rio Negro Basin.

Areas of pioneering formations, which are home to sandbank vegetation, mangroves and marshes, and the so-called vegetation refuges, are also identified, besides vegetation refuges, usually comprised of relic mounds (IBGE, 2012).

The original map of 2004, made available by the IBGE at a scale 1:5,000,000 (http://www.ibge.gov.br) also includes regions of ecological tensions, where contacts between the two phytophysiognomies occur.

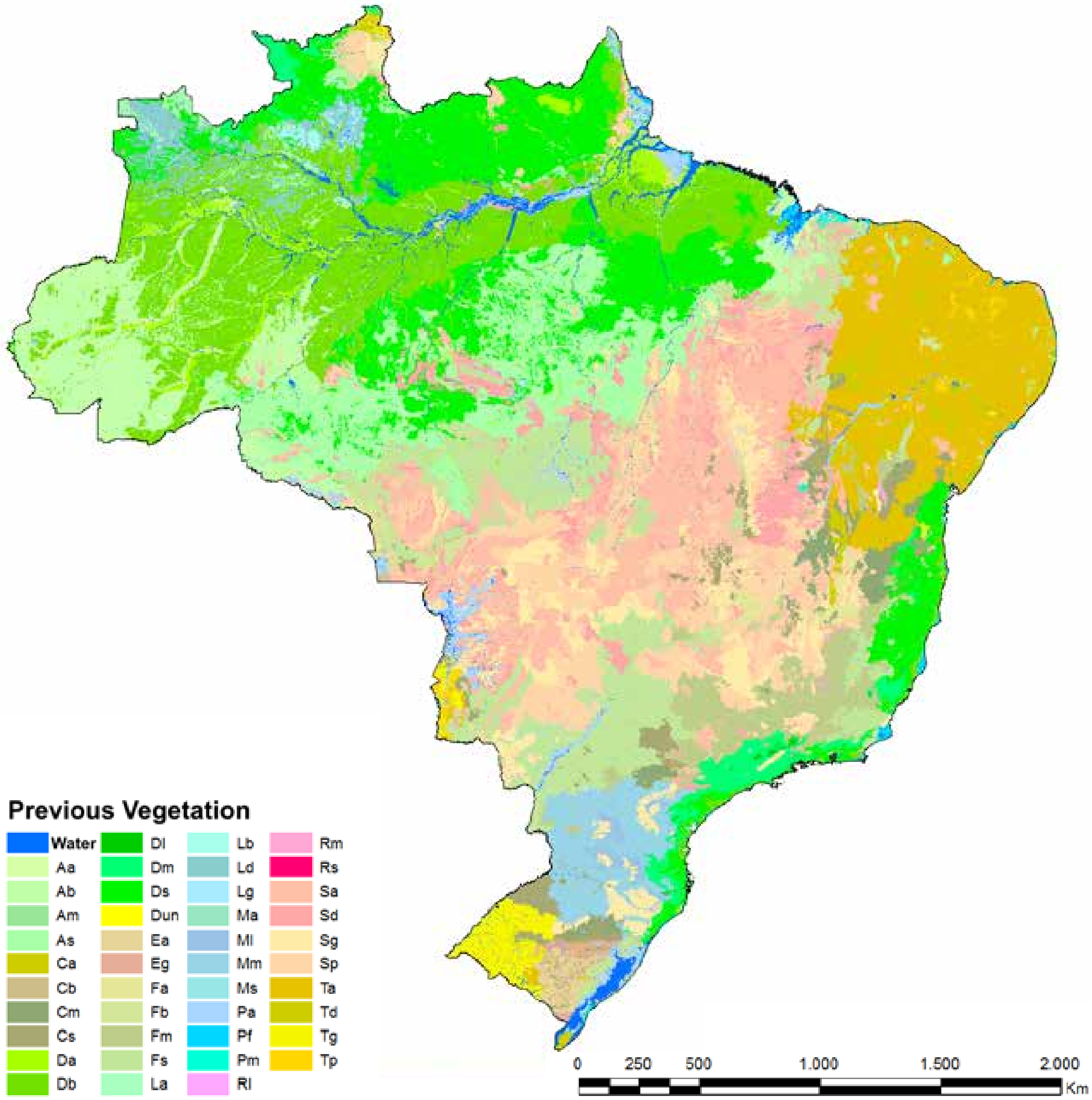
The available map of the Project of Conservation and Sustainable Use of the Biodiversity – PROBIO I (http://www.mma.gov.br/biodiversidade/projetos-sobre-a-biodiveridade/), of the Ministry of Environment (MMA), at scale (1:250,000), was used in the Second Inventory as a basis for the definition of phytophysiognomies. As the maps generated by the PROBIO I also had information related to the anthropized areas for all the biomes, these areas were re-categorized based on the Vegetation Map of the IBGE and on a visual interpretation of the images of TM/Landsat-5 for the year of 1994 (the same used in the Second Inventory). The resulting map presented re-categorized areas of ecotones and of transitions, according to the dominant phytophysiognomy.

Consequently, the vegetation map produced by the Second National Inventory and used herein, called the "map of previous vegetation", is a result of the combination of the PROBIO I (MMA) and IBGE (2004) maps together, with visual interpretation of images of 1994 for the anthropized areas.

The phytophysiognomies observed in the map of previous vegetation were grouped as forest or grassland according to its formation/structure (Table A1.2). This classification was also based on the Technical Manual of the Brazilian Vegetation (IBGE, 2012); FAO's classification system for the land cover and the FAO's Forest Resources Assessment (FRA) (FAO, 2010).

FIGURE A1.2

Map of previous vegetation (phytophysiognomies) of the Brazilian biomes



Source: Second National Inventory, modified from PROBIO I (MMA), IBGE (2004) and TM/Landsat-5 images.

TABLE A1.2

Structure of vegetation, phytophysiognomies and respective abbreviations

STRUCTURE	PHYTOPHYSIOGNOMIES	ABBREVIATION
Forest	Alluvial Open Humid Forest	Aa
	Lowland Open Humid Forests	Ab
	Open Montane Humid Forest	Am
	Open Submontane Humid Forest	As
	Alluvial Deciduous Seasonal Forest	Ca
	Lowland Deciduous Seasonal Forest	Cb
	Montane Deciduous Seasonal Forest	Cm
	Submontane Deciduous Seasonal Forest	Cs
	Alluvial Dense Humid Forest	Da
	Lowland Dense Humid Forests	Db
	Montane Dense Humid Forest	Dm
	High montane Dense Humid Forest	Dl
	Submontane Dense Humid Forest	Ds
	Wooded Steppe	Ea
	Alluvial Semi deciduous Seasonal Forest	Fa
	Lowland Semi deciduous Seasonal Forest	Fb
	Montane Semi deciduous Seasonal Forest	Fm
	Submontane Semi deciduous Seasonal Forest	Fs
	Wooded Campinarana	La
	Forested Campinarana	Ld
	Alluvial Mixed Humid Forest	Ma
	Montane Mixed High Humid Forest	Ml
	Montane Mixed Humid Forest	Mm
	Submontane Mixed High Humid Forest	Ms
	Fluvial and/or lacustre influenced Vegetation [11]	Pa
	Pioneering formation of Fluviomarine influence (mangroves)[10]	Pf
	Pioneering formation of marine influence (sand banks)[10]	Pm
	Wooded Savanna	Sa
	Forested Savanna	Sd
	Wooded Steppe Savanna	Ta
	Forested Steppe Savanna	Td

continues on the next page

11 Phytophysiognomies of pioneer formations such as fluviomarine (Pf) and marine (Pm) influenced and vegetations such as fluvial and/or lacustre influenced (Pa), have been reclassified as Grasslands for the Pampa biome, given that, particularly for this region, they have grassland influence, as per the literature and photos analysed.

STRUCTURE	PHYTOPHYSIOGNOMIES	ABBREVIATION
Grassland	Woody Grass Steppe	Eg
	Park Steppe	Ep
	Shrubby Campinarana	Lb
	Woody-grass Campinarana	Lg
	High Montane Vegetational Refuge	Rl
	Montane Refuge	Rm
	Submontane Refuge	Rs
	Woody-grass Savanna	Sg
	Park Savanna	Sp
	Woody Grass Steppe Savanna	Tg
	Park Steppe Savanna	Tp

Soil carbon stocks

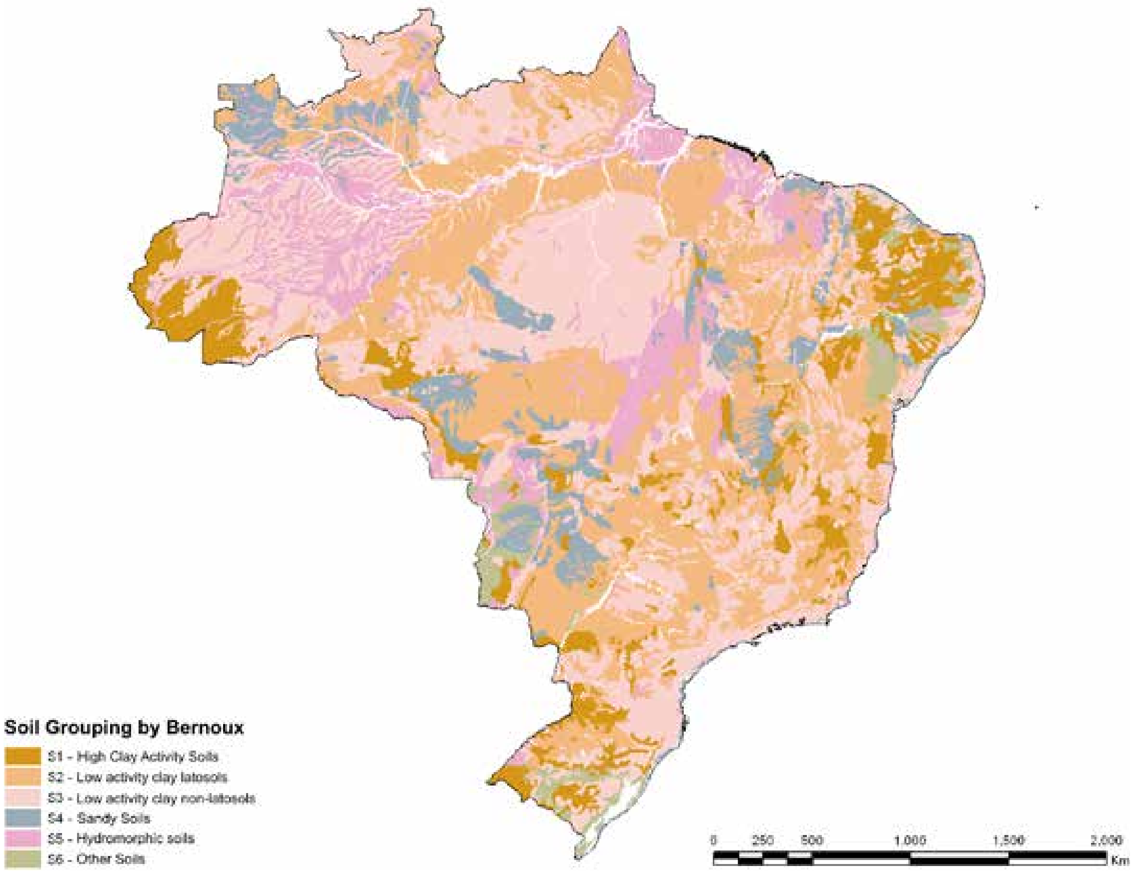
The changes in soil carbon stock were estimated following the methodology used in the Second National Inventory. The estimates followed the methodology proposed by Bernoux et al. (2002), consisting of the following steps:

1 adaptation of the EMBRAPA (2003), at scale 1:5,000,000;
2 adaptation of the IBGE vegetation map (IBGE, 2004), at scale 1:5,000,000 (see above);
3 making/creation of the soil and vegetation association map.

Firstly, the 69 classes categorized into the 18 soil orders of the Brazilian system of soil classification were reclassified as per the IPCC (1996; 2003), which takes into consideration soil texture, base saturation and moisture. The details of this class association are presented in Bernoux et al. (2002). Thus, classes were reclassified into six large soil groups: Soils with high clay activity (S1); Oxisols with low clay activity (S2); Non-Oxisols with low clay activity (S3); Sandy soils (S4); Organic soils (S5) and Other soils (S6). This results are shown in Figure A1.3.

FIGURE A1.3

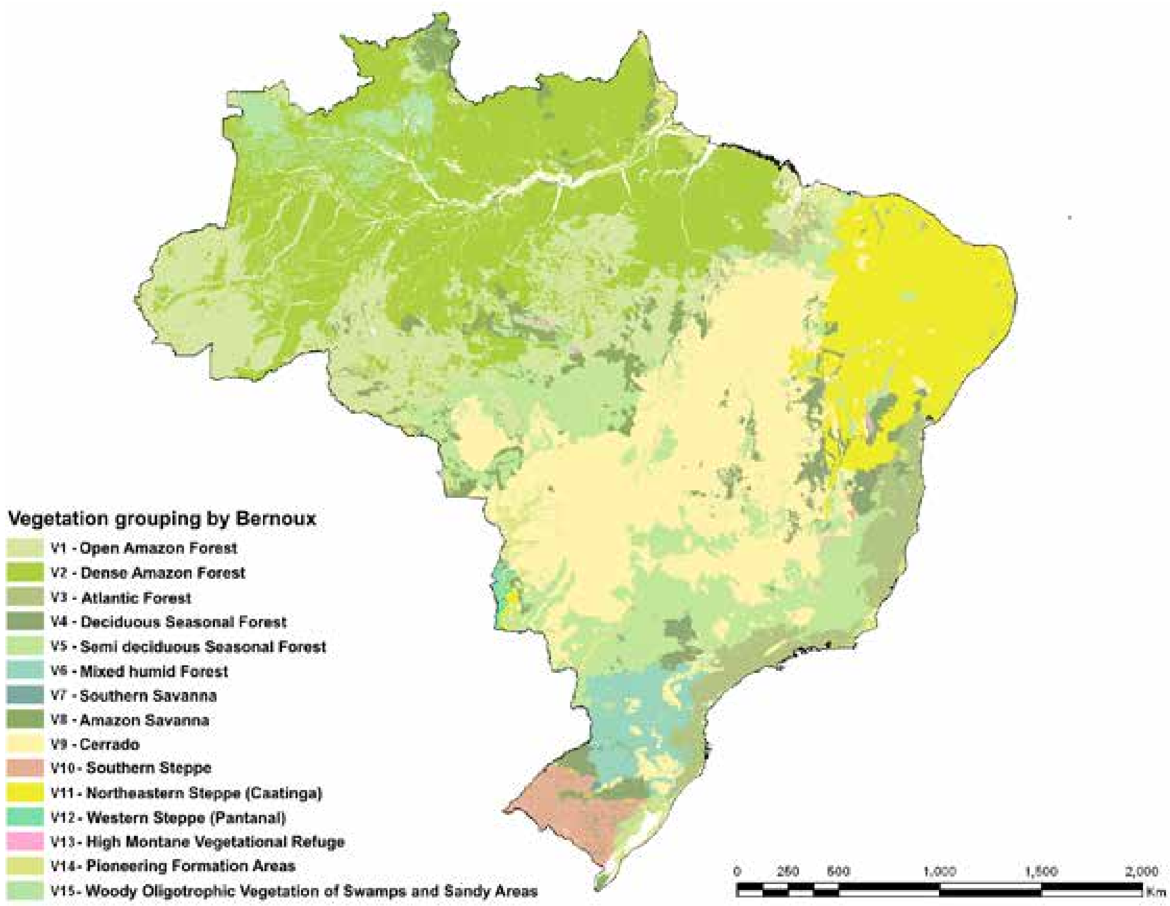
Grouping and distribution of soil classes throughout the national territory, adapted from Bernoux et al. (2002)



Then, vegetation classes were grouped in 15 categories. The classification strategy was using the main vegetation groups as a starting group, grouping them up according with the dominant vegetation and/or location (BERNOUX et al., 2002). For this classification key, the categories were distributed as follows: Open Amazon Forest (V1), Dense Amazon Forest (V2), Atlantic Forest (V3), Deciduous Seasonal Forest (V4), Semi deciduous Seasonal Forest (V5), Mixed Humid Forest (V6), Southern Savanna (V7), Amazon Savanna (V8), Cerrado (V9), Southern Steppe (V10), Northeastern Steppe (Caatinga) (V11), Western Steppe (Pantanal) (V12), High Montane Vegetational Refuge (V13), Pioneering Formation Areas (V14) and Woody Oligotrophic Vegetation of Swamps and Sandy Areas (V15). The result is shown in Figure A1.4.

FIGURE A1.4

Grouping and distribution of vegetation classes throughout the national territory, as per Bernoux et al. (2002)



Finally, from detailed calculations in Bernoux et al. (2002), it was possible to assign a carbon stock value for each vegetation-soil association up to 30 cm deep, as shown in Table A1.3. The values shown correspond to the mean values proposed by Bernoux et al. (2002). Figure A1.5 shows the distribution of soil carbon stock in the territory.

TABLE A1.3

Soil carbon stocks per vegetation-soil association. Cells highlighted in gray represent inexistent categories

VEGETATION CATEGORIES	SOIL					
	S1	S2	S3	S4	S5	S6
	(t C/ha)					
V1	50.9	47.5	48.9	41.1	43.6	78.7
V2	32.2	51.9	46.9	50.6	52.7	48.1
V3	58.3	52.3	42.9	63.3	35.8	417.8
V4	46.7	30.8	40.0	25.9	32.7	31.8
V5	40.9	44.3	37.4	27.0	53.6	31.6
V6	98.8	102.5	56.8		85.4	

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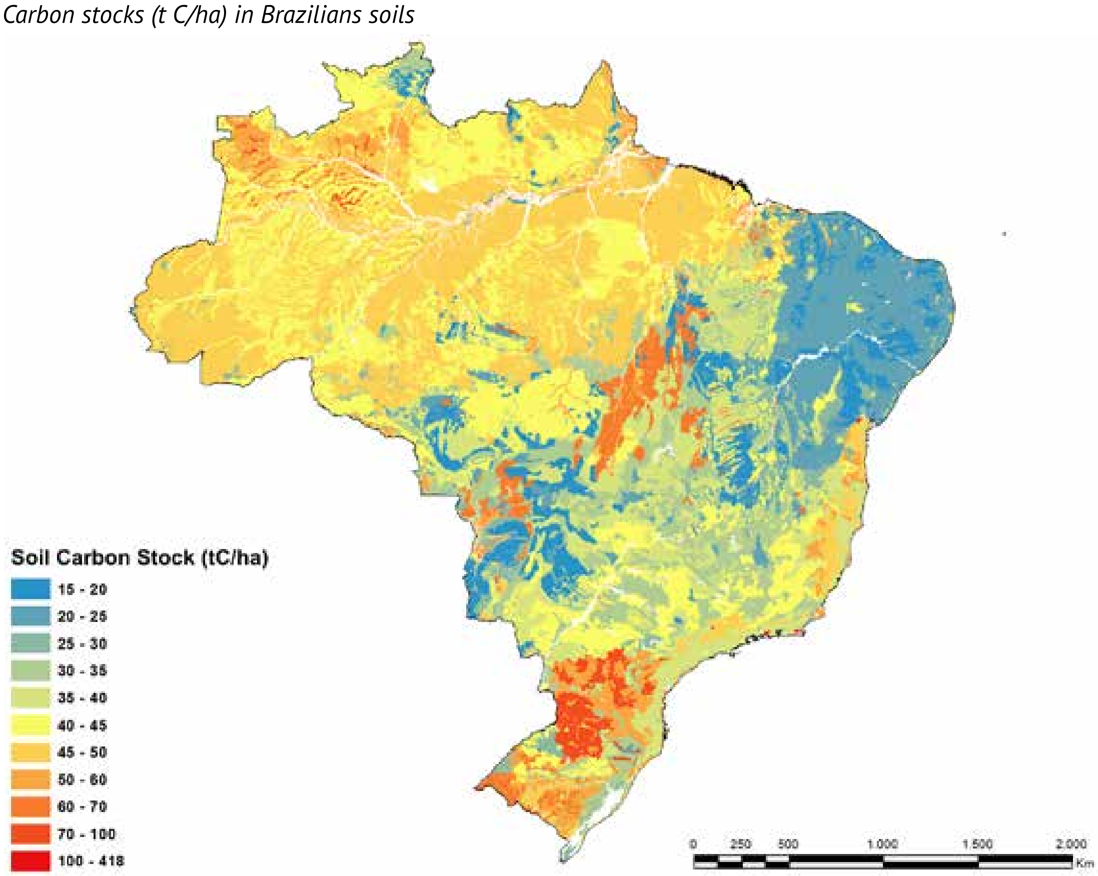
VEGETATION CATEGORIES	SOIL					
	S1	S2	S3	S4	S5	S6
	(t C/ha)					
V7	64.2	90.9	51.6		74.2	32.8
V8	48.0	19.8	38.1	43.7	34.6	29.0
V9	24.4	43.1	36.0	19.2	66.5	32.9
V10	66.0	46.6	61.2		33.8	49.9
V11	24.2	25.8	26.2	15.1	25.1	20.9
V12	33.8		35.2	35.4	105.2	21.7
V13	34.1	50.4[1]	39.9			
V14	73.0	41.3[1]	33.1	50.2	59.2	37.2
V15	50.9[2]	46.8	48.1	61.7	90.5	120.9

[1] *Single value reported.*
[2] *Refer to particularities described in Bernoux et al. (2002).*
Source: Bernoux et al. (2002).

FIGURE A1.5
Carbon stocks (t C/ha) in Brazilians soils



Source: Bernoux et al. (2002)

Land Use

The IPCC (2003, 2006) defines six broad land-use categories: Forest land, Grassland (including sub-category Grazing), Cropland, Wetlands, Settlements and Other Land. The categories defined in this report were as follows:

Forest Land

Forest Lands are characterized by densification of trees, reducing the amount of light that reaches the soil, which limits the development of bushes and grasses (IBGE, 2012). This category was defined by the phytophysiognomy of previous vegetation. So, as per the Table A1.2, which characterizes the phytophysiognomy as a function of its structure (forest or grassland), it was possible to adapt this classification to the one proposed by the IPCC (2006).

The following sub-categories of Forest Land were created:

I. Primary Forest in a Managed Area (FM)

The Primary Forest in a Managed Area refers to forests in which human action did not cause significant alterations in its original structure and composition. Also found in managed areas, considered as Protected Areas (PAs) or Indigenous Lands (IL).

It should be pointed out that Protected Areas were created between 1994 and 2010, as provided by Law No. 9,985/2000, and new IL were delimited by FUNAI. Table A1.4 summarizes quantitatively the representation of these areas by biome, in 1994, 2002 and 2010. Figure A1.6 shows a visual distribution of them in the observed years.

TABLE A1.4

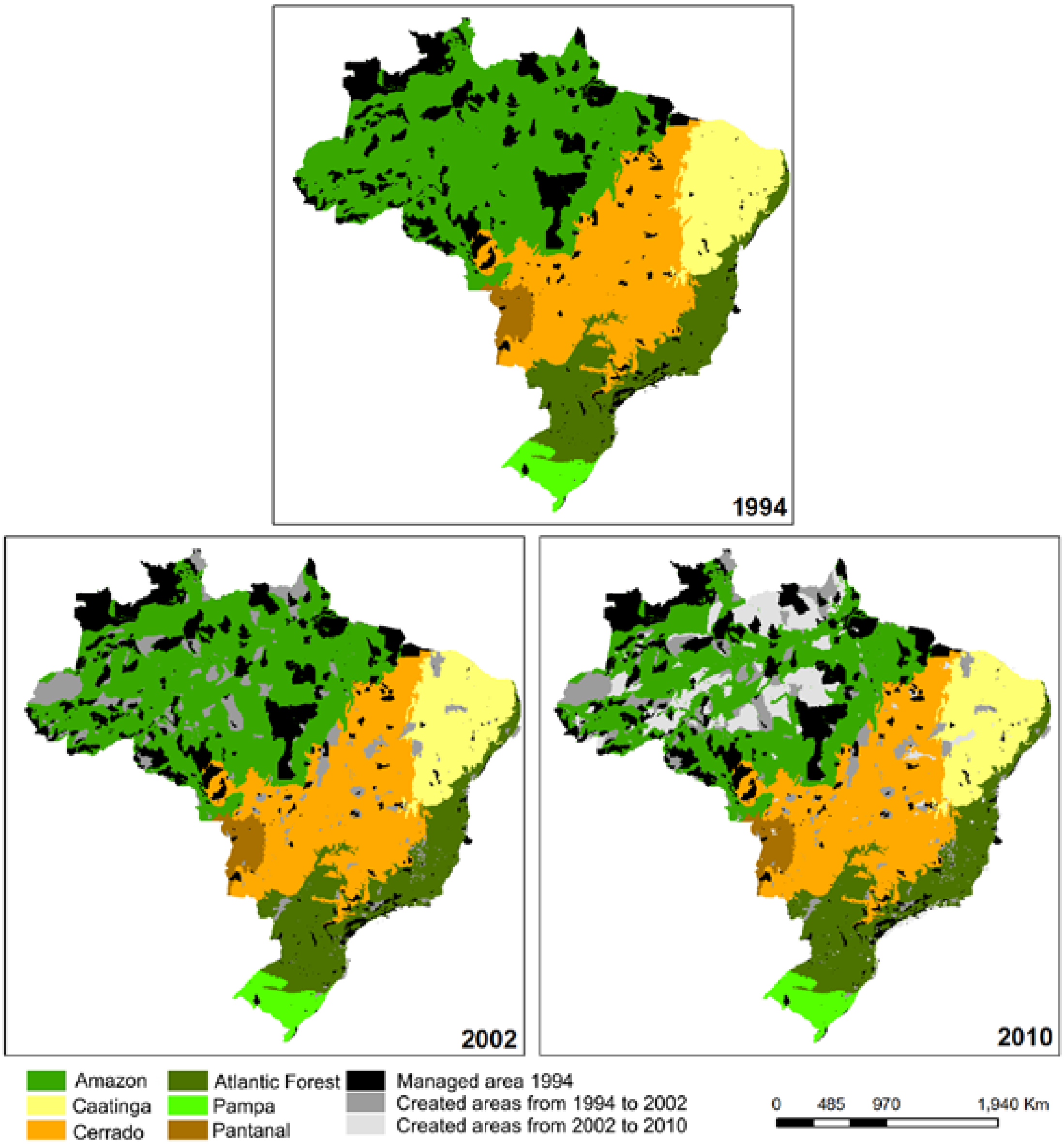
Protected Areas (PA) and Indigenous Lands (IL) considered in 1994, 2002 and 2010[12]

BIOME	MANAGED AREAS (PA and IL) (ha)					
	1994	% BIOME 1994	2002	% BIOME 2002	2010	% BIOME 2010
Amazon	99,823,994.50	23.72	141,983,295.01	33.73	205,629,087.80	48.86
Cerrado	848,696.06	0.42	5,118,482.32	2.51	6,586,236.57	3.23
Caatinga	11,244,862.91	13.58	22,941,789.13	27.71	25,279,428.81	30.54
Atlantic Forest	5,710,351.70	5.12	9,897,023.15	8.87	10,681,769.67	9.58
Pantanal	502,985.19	3.32	614,120.31	4.06	614,591.48	4.06
Pampa	365,325.87	2.04	561,503.85	3.14	714,500.74	4.00
TOTAL	**118,496,216.24**	**13.91**	**181,116,213.76**	**21.25**	**249,505,615.06**	**29.28**

12 The increase in managed areas during the period 1994-2002 in comparison with the Second Inventory is due to more information available for indigenous lands. For the Third Inventory, an official letter was sent to FUNAI requesting information as to creation dates (delimitation, declaration, homologation). That information in systematized form allowed for the inclusion of areas that existed in the period 1994-2002, but were not considered in the Second Inventory, for example the Indigenous Land located in the higher part of the Rio Negro River. Ultimately, it is a review point and addition of information.

FIGURE A1.6

Distribution of Protected Areas and Indigenous Land considered in 1994, 2002 and 2010



II. Primary Forest in Unmanaged Areas (FNM)

Primary Forest in Unmanaged Areas is also presented in this report as to ensure that all the national territory is considered. However, greenhouse emissions or removals from these areas are not estimated because they are not considered anthropogenic. However, should land changes occur in those areas, their emissions must be accounted for.

III. Forests with Selective Logging (CS)

Selective logging refers to removal of wood with commercial value from native forests in the Amazon. This processes comprises the opening of trails and yards for the extraction and storage of wood, but not necessarily clear cut (VERISSIMO et al., 1992; ASNER et al., 2005). These areas can be further explored, converted to agricultural use, or abandoned (HOLDSWORTH & UHL, 1997; NEPSTAD et al., 1999).

The accounting of such areas in the estimates of emissions and/or removals of carbon is important, given that without a plan for appropriate management, they represent one of the major causes of forest degradation, leaving behind forest clearing, roads, damaged forests as well as erosion and soil compaction, changes in the nutrients cycle and on the flora and structural vegetation composition (VERISSIMO et al., 1995; MATRICARDI et al., 2010).

IV. Secondary Forest (FSec)

Secondary forests have been identified as regeneration areas of primary forests (whether managed or not), which have been changed in at least one of the periods considered herein (1994, 2002 and, in the Amazon, 2005). Areas of secondary vegetation were only directly identified from primary forests in the Amazon biome, without intermediate conversion into anthropogenic use, with space medium resolution satellite images. Forest degradation areas in the Amazon are monitored by the DEGRAD Project[13].

V. Reforestation (Ref)

Comprise single-cropping areas formed by tree species, mostly exotic ones, such as *Eucalyptus* spp. and *Pinus* spp.

Grasslands

Grasslands are identified by the predominance of herbaceous vegetation. Like Forests, the definition of this category was based on the phytophysiognomy map. The portions of the territory that were not categorized as anthropized or as water bodies (rivers and lagoons and reservoirs) were classified according to the map of previous vegetation.

a. Grasslands with Managed Native Vegetation (GM)

Refer to areas located in Protected Areas (PA) and Indigenous Lands (TI).

b. Grassland with Unmanaged Native Vegetation (GNM)

Like Unmanaged Primary Forests (FNM), Grasslands with Unmanaged Native Vegetation (GNM) are also presented in this report to ensure that all the national territory is considered. Greenhouse gas emissions and carbon removals from these areas are not estimated unless land changes occur, in which case emissions must be accounted for.

c. Secondary Grassland Vegetation (GSec)

Includes native grassland vegetation that had been converted and is in regeneration process. The reasoning for the identification of grassland vegetation in regeneration was the same adopted for Secondary Forests, as described above.

13 *The forest degradation mapping system in the Brazilian Amazon (DEGRAD) maps degraded forest areas with a tendency of being converted into clear cut on an yearly basis. More information at http://www.obt.inpe.br/degrad/).*

d. Pasture (Ap)

Encompasses areas set aside for grazing and that have been established by planting. Include both degraded pastures and those in good conditions.

Cropland (Ac)

Encompasses all areas cultivated with annual and perennial crops, such as corn, soybeans, sugar cane, rice, coffee, fruit, among others.

Wetlands (A and Res)

Extension of natural or artificial, permanent or temporary, stagnant or running, fresh, brackish or salted salt marshes, swamps, peat bogs or waters. Encompass: a) lakes and rivers (A) including water bodies and b) Reservoirs (Res) for artificial lakes, flooded areas by the creation of hydroelectric power plants, i.e., regions covered with water due to human interference.

Settlements (S)

Areas characterized by continuous construction and the existence of social equipment for basic functions such as housing and circulation.

Other areas (O)

Rock formations, mining areas, and dunes.

Not Estimated (NE)

Areas not identified in the categories above due to continuous cloud cover and shadows in the satellite images available.

Table A1.5 shows all the land use and cover categories and sub-categories considered in this report along with their associated abbreviations.

TABLE A1.5
Land use and cover categories and sub-categories

ABBREVIATION	LAND USE	LAND COVER (IPCC)
FNM	Unmanaged Forest	Forest
FM	Managed Forest	
FSec	Secondary Forest	
CS	Forest with Selective Wood Extraction	
Ref	Reforestation	

continues on the next page

ABBREVIATION	LAND USE	LAND COVER (IPCC)
GNM	Grassland with Unmanaged Native Vegetation	Grassland
GM	Grasslands with Managed Native Vegetation	
GSec	Secondary Grassland Vegetation	
Ap	Pasture	
Ac	Cropland	Cropland
S	Settlements	Settlements
A	Rivers and lakes	Wetlands
Res	Reservoirs	
O	Other Uses	Other land
NE	Not Estimated	

1.1.1. Construction of transition matrices between categories and sub-categories for land use

After land use/cover maps for each year considered were obtained, they were crossed with other layer plans generating polygons associated with information of biome, previous vegetation, soil carbon stock, and municipal grid. The analysis of the polygons identified land use/cover changes among the years considered and correspondent emissions were calculated.

The transition matrices present, in short form, areas that are under the same category of land use and those that are converted into another category between the inventoried periods, as shown in Table A1.6. The main diagonal of the matrix identifies areas that remain under a same land-use category. Transition matrices are presented for all biomes for the 2002-2010 period, except for the Amazon, in which case transition matrices are shows for the 2002-2005 and 2005-2010 periods.

Although this Inventory aims at estimating emissions occurred between 2002 and 2010, an update of estimates for the 1994-2002 period was carried out. From that update and review of activity data, estimates were recalculated so as to ensure consistency of estimates in the different periods assessed.

It must be observed that the forest areas under selective logging were considered only for the Amazon biome due to the impact of the net carbon emissions and the established available methodology for the detection by remote images.

Conversions that involve water for forest/grasslands and vice-versa may represent a natural dynamics of the wetlands and reflect the periods that they are covered or not by water. Nonetheless, these areas do not represent land-use change as they only seasonally vary. This variation occurred due to the fact that the images used are not always of the same month. Thus, greenhouse gas emissions and removals involved in this cover dynamics were not accounted for, as they are considered natural and not human-induced.

Finally, it should be pointed out that the eight-year interval between Inventories (1994-2002-2010) makes it impossible to verify the annual land conversion dynamics. For instance, land classified as forest in 2002 and as cropland in 2010 could have undergone an intermediate step, for example, from forest in 2002 to grassland in 2006, and then from grassland to cropland in 2010. This issue may be resolved as national inventories advance to be produced at shorter periods of time, allowing for a more precise estimation of the annual net anthropogenic emissions.

TABLE A1.6

Land use/cover transition matrix. Gray transitions refer to the ones that were impossible to account for in this Inventory

	2010														
2002	FNM	FM	FSEC	REF	CS	GNM	GM	GSEC	AP	AC	S	A	RES	O	NE
FNM															
FM															
FSec															
Ref															
CS															
GNM															
GM															
GSec															
Ap															
Ac															
S															
A															
Res															
O															
NE															

1.1.2. Estimates of emissions by sources and removals for assessed transitions

Net emission estimates are performed for each polygon with rules that vary according to each possible transition for the land use identified in the previous stage. That is to say, from 2002 to 2010 for Cerrado, Atlantic Forest, Caatinga, Pampa and Pantanal, and from 2002 to 2005 and then 2005 to 2010 for the Amazon. The approach used for the current Inventory is the same that was applied for the Second National Inventory, according to the 1996 Guidelines and is founded on two assumptions:

i CO_2 flow from or to the atmosphere refers to changes in carbon stocks in existing biomass and in the soils; and

ii changes in carbon stocks can be estimated by first assessing the rates of land-use change and the practices associated with land-use change (for instance, deforestation, selective logging etc.). The impact of these practices on carbon stocks and the biological response to a specific land-use category can then be assessed.

The Good Practice Guidance LULUCF (IPCC, 2003) methodology establishes that CO_2 emissions during a certain period of time can be estimated as the difference in carbon stocks at the beginning and the end of the period considered, for each one of the transitions defined in Table A1.6. These net annual estimates were generated taking into consideration all the carbon stocks: living biomass (above and belowground), dead organic matter (litter and dead wood) and soil organic carbon. The IPCC default approach (2003) was adopted to estimate carbon stocks changes, represented by equations 3.1.1 and 3.1.2 of the Guidance.

Equation 3.1.1

$$\Delta C = \sum_{ijk} \left[A_{ijk} \bullet (C_I - C_L)_{ijk} \right]$$

where:

ΔC: is the change in carbon stock (t C/year)

A: is the land area (ha)

ijk: correspond to type of climate *i*, type of vegetation *j* and management practice *k*

C_I: annual increment in carbon stock (t C/ha/year)

C_L: annual decrease in carbon stock (t C/ha/year)

Equation 3.1.2

$$\Delta C = \sum_{ijk} \left(C_{t_2} - C_{t_1} \right) / (t_2 - t_1)_{ijk}$$

where:

C_{t1} : carbon stock at time t 1 (t C)

C_{t2} : carbon stock at time t2 (t C)

The equations used for estimating anthropogenic emissions and removals associated with carbon stock change in living biomass and dead organic matter for each of the transitions indicated in Table A1.6 are detailed in the Reference Report "Greenhouse Gas Emissions in the Land-Use Change and Forestry Sector" of this Third Inventory.

Due to the impossibility of identifying the moment that the use conversion occurred for the assessed time interval, as per the Second Inventory, land-use changes were assumed to occur in the middle of the period. As a consequence, forest in 2002 converted to agriculture in 2010 had its use changed in 2006 (in the middle of the period, thus, 4 years).

1.1.3. Emissions and removals associated with soil carbon stock changes

The methodology for estimating changes in soil carbon stocks uses the average carbon stock in the soil under primary (native) vegetation as a reference for each of the soil-vegetation associations, as described in Table A1.3. In accordance with the Good Practice Guidance (IPCC, 2003), changes in carbon stock in soils due to land-use conversions are assumed to occur over a 20 years period.

The general equation for estimating changes in soil carbon is described below and is based on Equation 3.3.3 of the Good Practice Guidance (IPCC, 2003), adapted in order to consider period T between inventories.

$$ES_i = A_i \times \mathrm{Csolo} \quad (\mathrm{fc}(\mathrm{t_o}) - \mathrm{fc}(\mathrm{t_f})) \times (T/2)/20$$

where:

ES_i: Net emission of polygon *i* in period *T* due to the variation in soil carbon (t C)

A_i : area of polygon *i* (ha)

Csolo : organic soil carbon stock as per the polygon's soil-vegetation association (reference carbon)

fc(t) : soil carbon change factor at moment *t* (adimensional)

The carbon change factors, shown in Table 6.19, are defined by the equation:

$$fc(t) = f_{LU} \times f_{MG} \times f_I$$

where:

f_{LU} : carbon change factor for land use or land-use change;

f_{MG} : carbon change factor for management regime;

f_I : carbon change factor from additions of organic matter.

1.1.4. Data

Land Use/Cover Map

The information on land use/cover for each year is obtained through visual interpretation of a mosaic of satellite imagery of the national territory. Each area was associated with one of the land-se categories/sub-categories defined, generating maps of land use and cover for the assessed years. The methodological steps are as follows.

Image selection

Firstly, a database was set up based on imagery of TM of the LANDSAT-5 satellite. Images of the sensor LISS-III of the Indian satellite Resourcesat-1 were also used for the Atlantic Forest, Caatinga and Amazon biomes. Image selection considered mainly areas with cloud cover, given that they should be the smallest possible. Images acquired at nearby dates are a priority, thus minimizing climate and time variations (especially those related to land use and occupation), when merging scenes acquired at different dates. The presence of unrecoverable noise was also considered.

TM/Landsat-5 images of the Second National Inventory were used for the years 1994 and 2002. 368 TM/Landsat-5 images and 29 LISS-III/Resourcesat-1 images were selected for the year 2010. Exceptionally for the Amazon, 199 TM/Landsat-5 images were selected for the year 2005. Further details are presented in the Reference Report "Greenhouse Gas Emissions in the Land-Use Change and Forestry Sector".

Image processing

This stage involved basically the recording of the images and management of histograms (contrast application). The selected TM/Landsat-5 images of 2010 were geo-referenced based on points of control on the images of 2002, as a crossroad. This procedure assured that the mapped changes refer to changes occurred on the land and not between two scenes. Scenes of the year 2005 in relation to the images of 2002 were also registered for the Amazon biome. The geo-referenced images of the LISS-III/Resourcesat-1 followed the same procedure.

Themed mapping

After correcting the satellite images for contrast and brightness in order to facilitate the identification of areas by the interpreters, all the areas with any type of human intervention, water bodies and reservoirs were mapped. In order to identify areas of selective logging in the Amazon, digital processing techniques were used, according to the DETEX[14] approach, to highlight the changes in the spectral response of the forests with intervention.

Remaining areas (not mapped) were considered as primary vegetation areas. They were classified as either forests or grasslands, managed or unmanaged, according to information of the previous vegetation map (phytophysiognomies) and managed areas map (Protected Areas and Indigenous Land), respectively.

The categorization of Forests and Secondary Grasslands (FSec and GSec) was made through observation of areas in previous years. For example, areas classified as vegetation (grasslands or forests) in 2010, which had previously been classified as another type of cover (in 1994, 2002 or 2005), were considered as Grasslands or Secondary Forests.

The themed mapping process was carried out considering 6 ha as minimum mapping area, with final output scale at 1:250,000.

Land use and cover maps

Land use and cover maps for the entire national territory for the years 1994, 2002 and 2010 are shown in A1.7. The maps for 1994 and 2002 provide the activity data to estimate the net greenhouse gas emissions were updated to assure a higher consistency on the classification. For the Amazon, maps for 1994 and 2002 of the Second Inventory were corrected and used, generating maps for 2005 and 2010 (Figure A1.8). Maps for the other biomes are shown in Figures A1.9 to A1.13.

14 Project DETEX (Selective Logging Detection) is a system developed by INPE to monitor timber exploitation in the Amazon.

FIGURE A1.7

Land use / cover maps of Brazil for 1994, 2002 and 2010

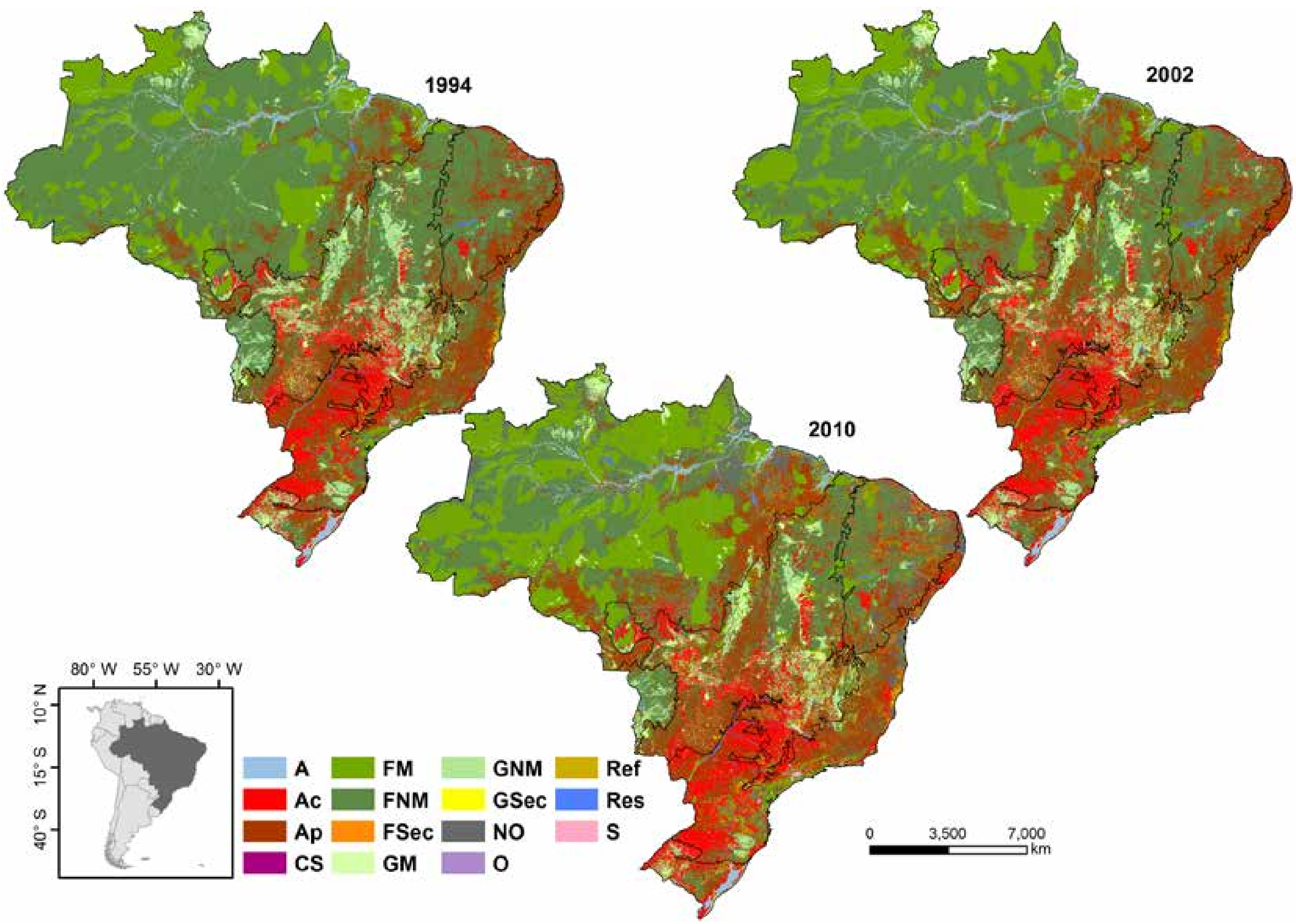


FIGURE A1.8

Land use / cover maps of the Amazon biome for 1994, 2002, 2005 and 2010

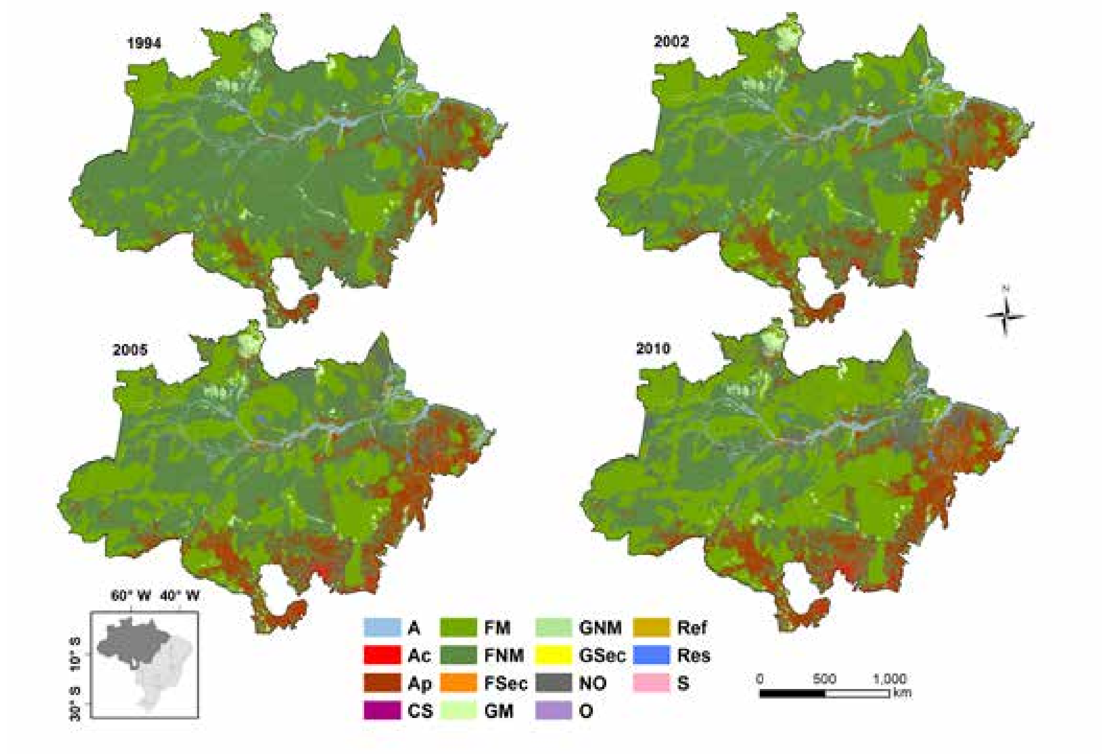


FIGURE A1. 9

Land use / cover maps of the Cerrado biome for 1994, 2002, and 2010

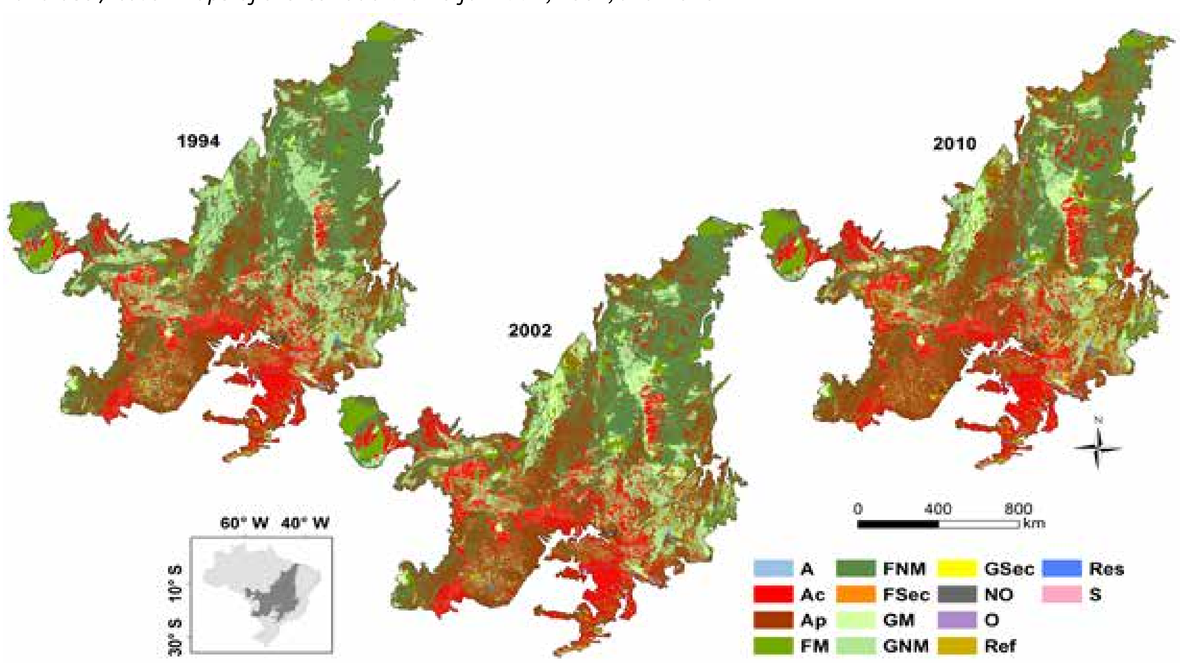


FIGURE A1.10

Land use / cover maps of the Atlantic Forest biome for 1994, 2002, and 2010

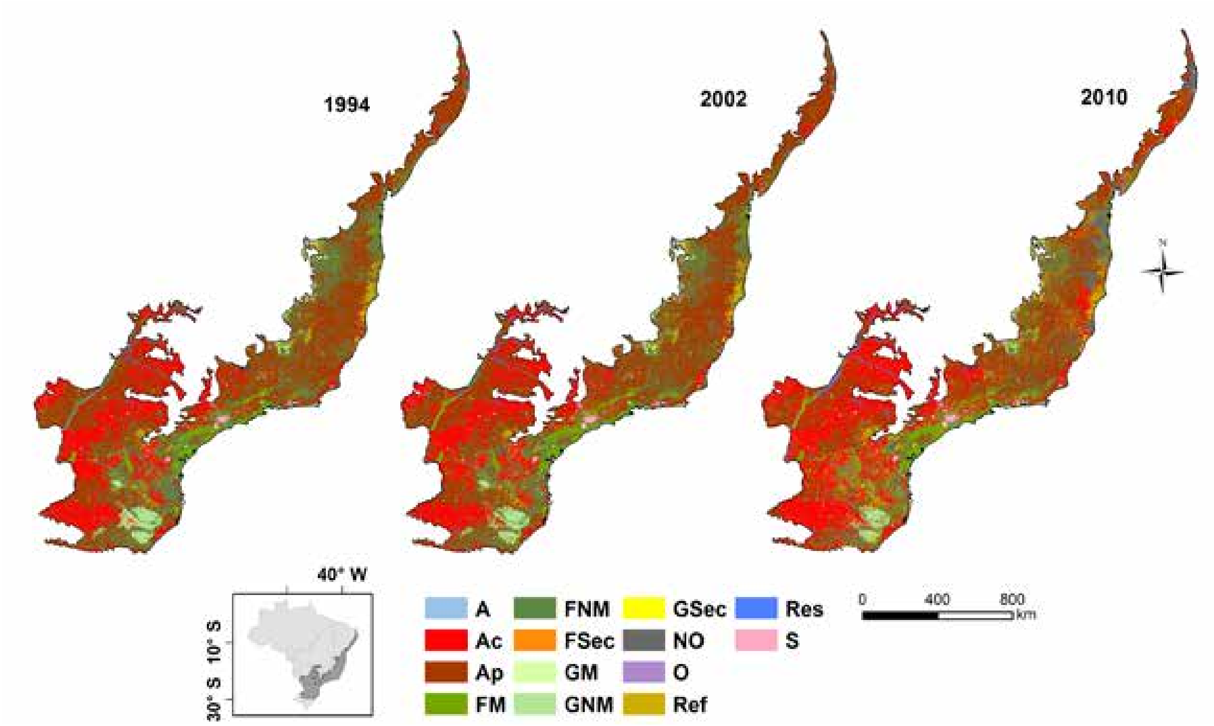


FIGURE A1.11

Land use / cover maps of the Caatinga biome for 1994, 2002, and 2010

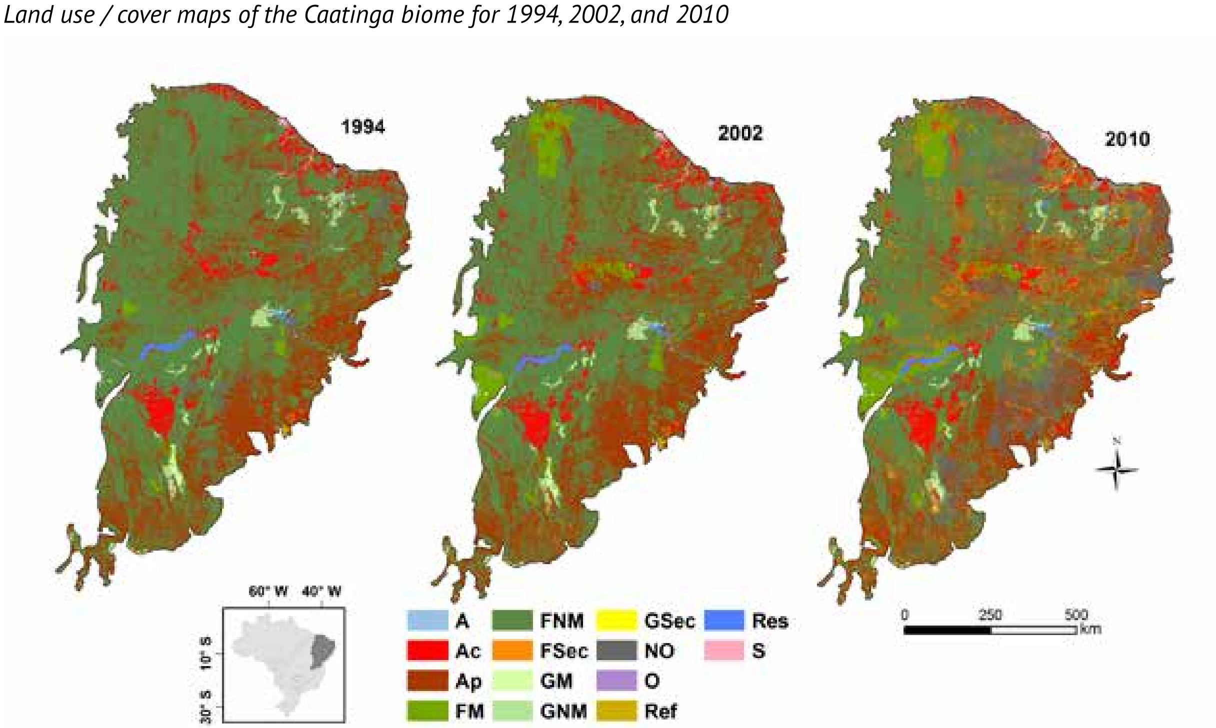


FIGURE A1.12

Land use / cover maps of the Pampa biome for 1994, 2002, and 2010

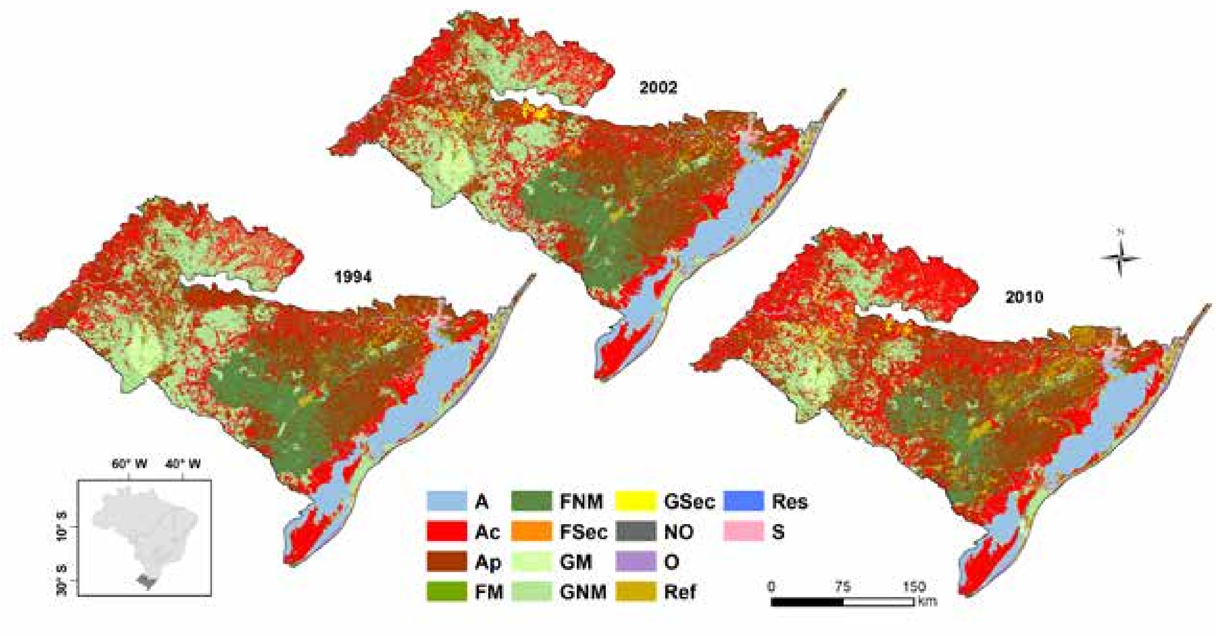
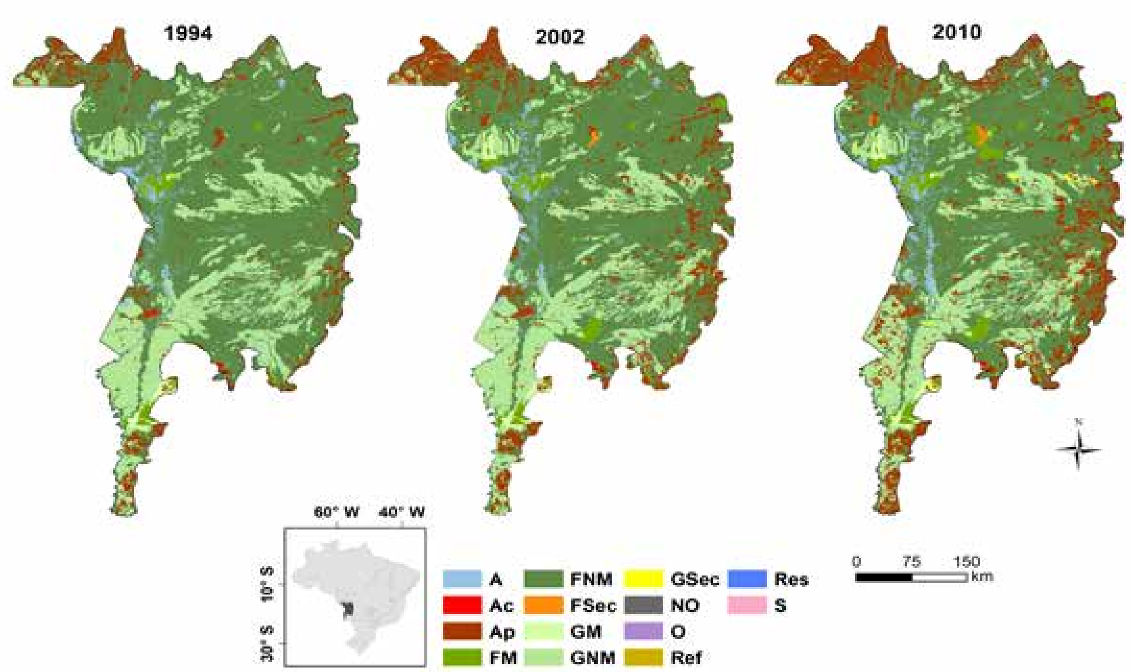


FIGURE A1.13

Land use / cover maps of the Pantanal biome for 1994, 2002, and 2010



Carbon stock changes in living biomass and dead organic matter

The values of carbon stock of phytophysiognomies of each Brazilian biome were estimated from values of living biomass, both above and belowground, and dead organic matter (dead wood and litter). The approaches used for these estimates were the following:

a. Calculation of stocks from structural data of the vegetation

The use of structural data of the vegetation (DBH and height) collected in the field was prioritized, obtained from plots of forest inventories. The structural data relate to those of RADAMBRASIL project to the Amazon; the PROBIO project provided by Embrapa Informatics for the Pantanal; the Forest Inventory of Tocantins to the Cerrado and measurements carried out by researchers from the Federal University of Pernambuco for the Caatinga. Allometric equations surveys were conducted so the most appropriate ones were applied to the data for each region (BROWN, 1997; MELO et al., 2007 in PINHEIRO, 2008; DELITTI et al., 2006). In addition to Brown's equation (BROWN, 1997) based on rainfall levels and seasonal trends used to the Amazon, other Brown's equation was also used (BROWN, 1997; equation 3.2.1) for some of the phytophysiognomies in the Cerrado, Caatinga and Atlantic Forest biomes, in an attempt to adjust the equation to the climate of the phytophysiognomies. Equations of Melo et al (2007 *apud* PINHEIRO, 2008) for 'the phytophysiognomy Sa and Sd, and Delitti et al. (2006) for the plant physiognomies Sp were used for the Pantanal biome.

b. Biomass data out of literature review

Biomass values from other phytophysiognomies not covered in the databases above were obtained from a review of the scientific literature. Papers already published referring to the dry matter of the vegetation were chosen when they had a studied area corresponding to the phytophysiognomy of the biome.

When such assessment was not possible, papers carried on the same phytophysiognomy, but in other biome, were chosen; taking into consideration factors as altitude, latitude, and geographic distance, temperature and rainfall. This assessment was carried on with the aid of the Geographic System of Information (GSI).

Flora and structural resemblance together with other phytophysiognomy were assessed when a representative value was not found for the specific phytophysiognomy, so that the value of the biomass could be used. In some cases, in the absence of a published biomass value, allometric equations were applied to the research plant sociological results, with average individual density per hectare, diameter at breast height (DBH) and basal area. Under theses cases, the selected allometric equations are pan-tropical, using as a dependent variable the DBH and the research developed by Brown (1997). The choice among the allometric equations presented by Brown (1997) was made in accordance with phytophysiognomy, diameter of the trees and environmental characteristics, such as precipitation and distribution of rainfall throughout the year (seasonality).

Whenever possible, preference has been given to the papers exhibiting values of biomass for a greater number of reservoirs (such as aboveground biomass for tree strata, shrub and herbaceous, that cover the trunk, bark, branches and leaves; belowground biomass; dead organic matter, which includes dead wood and litter). The sampling effort and the phytophysiognomy distribution were also considered as selection criteria.

c. Use of expansion factors and ratio

In the absence of values of belowground biomass or the dead organic matter biomass, factors based on a literature review were used, particularly to the ratio of belowground and aboveground biomass (root-to-shoot) to estimate the belowground biomass as well as the ratio of the dead and living biomass (dead wood stocks/live biomass) and of the litter of the living biomass to estimate dead organic matter. In this case expansion factors were prioritized calculated with biomass values obtained in the same vegetation type, preferably in the biome of interest. When such values were not found, expansion factors, ratio and values associated with vegetation with similar in structure, deciduousness and flora were used.

d. Use of IPCC default values

When values to represent the estimates to the ratio of belowground and aboveground biomass (root-to-shoot) and dead organic matter were not found in the literature, default values established by the IPCC (2003, 2006) were used; in accordance with the specific biome climatic zone and the ecological zone and biomass vegetation, when applicable.

e. Consultations to multiple sources of evidence

The decisions about the values of living biomass and dead organic matter were endorsed, whenever possible, via consultation to studies of phytosociology, management plans, technical reports, in addition to contact with research experts in vegetation type and biomes. Photos of vegetation covers, found in publications and on Google Earth, were also used to endorse the distribution and classification of vegetation.

Other biomass researches were used as multiple evidence sources aiming at comparing the values adopted and minimizing the chances of choosing a non-representative study; with higher or lower biomass values for the relevant phytophysiognomy.

f. Carbon in the Forest and Grassland biomass

The biomass of different carbon stocks in Forest and Grassland areas was converted into carbon using the IPCC default values (2006) presented in Table A1.7.

TABLE A1.7

Carbon percentage in stocks of aboveground biomass, belowground biomass, dead wood, and litter in Forest and Grasslands (IPCC, 2006)

STOCKS	FORESTS	GRASSLANDS
Aboveground biomass	47%	47%
Belowground biomass	47%	47%
Dead wood (either lying on the ground or standing)	47%	50%
Litter	47%	40%

Methods and data used to estimate biomass and carbon stock of each phytophysiognomy in each biome are described below. Further details of methods and values used are presented in the "Greenhouse Gas Emissions in the Land-Use Change and Forestry Sector" Reference Report.

Amazon Biome

Data collected from the RADAMBRASIL Project

Like in the Second Inventory, estimates for the Amazon biome's vegetation biomass were mostly based on the forest inventory and phytophysiognomy maps from the RADAMBRASIL Project. Out of the 29 phytophysiognomies, nine cover approximately 90% of the biome as follows: Alluvial Open Humid Forest (Aa), Lowland Open Humid Forests (Ab), Open Submontane Humid Forest (As), Alluvial Dense Humid Forest (Da), Montane Dense Humid Forest (Dm), Submontane Dense Humid Forest (Ds), Submontane Semi deciduous Seasonal Forest (Fs), Forested Campinarana (Ld).

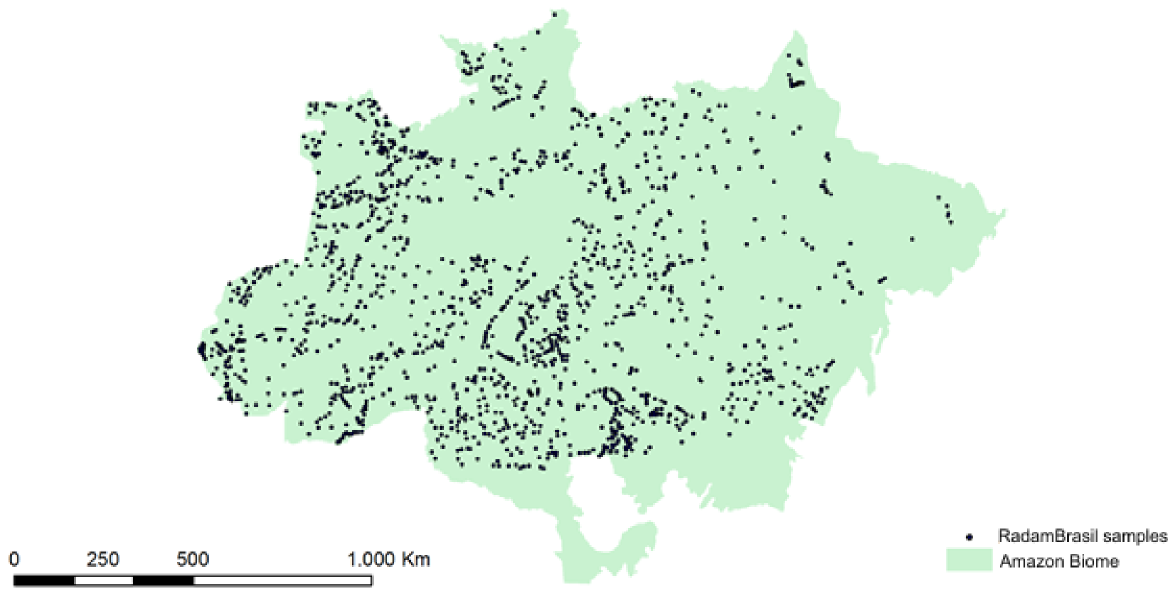
For the Third Inventory, only the samples of the RADAMBRASIL that presented locations with geographic coordinates were used; samples that had only volume information of the RADAMBRASIL were disregarded. Samples that did not present a representative number per phytophysiognomy (less than 10 samples per phytophysiognomy). On the first part of this task, values of diameter at breast height (DBH[15]) of 100,222 trees measured in 1,668 samples of RADAMBRASIL.

Subsequently, a regionalization of the biomass values was proposed as a function of the basal area distribution of the arboreal individuals for all the Amazon biome. For this stage, less representative samples were included to aggregate more information of the inventoried regions. As a result, data of 102,837 trees measured in 1,682 samples of RADAMBRASIL were used for this regionalization (Figure A1.14).

15 *CBH values measured by RADAMBRASIL were converted into DBH, as this is the input standard for allometric equations. For the converstion, the following equation was used:* $DBH = \frac{CBH}{\pi}$

FIGURE A1.14

Distribution of samples provided by the RADAMBRASIL Project



Selection of the allometric equations

The Third Inventory tested different allometric equations, in an attempt to define one that could better represent the phytophysiognomy variation of all the biome (BROWN, 1997; CARVALHO JR. et al., 1998; ARAÚJO et al., 1999; BAKER et al., 2004; CHAVE et al., 2005). The choice of these equations was made based on the regional broadness of the collection of the field data, sample density and spatial distribution of the samples – as to represent the large variability of the forest. The following equations were tested:

$AGB_{initial} = 42.69 - 12.8 \text{ X DBH} + 1.242 \text{ X DBH}^2$, by Brown (1997) (Equation 1)

$AGB_{initial} = EXP^{-2.134+(2.53 x \ln(DBH))}$, by Brown (1997) (Equation 2)

$AGB_{initial} = 0.6 \text{ X } (4.06 \text{ X } DBH^{1.76})$, by Araújo et al. (1999) (Equation 3)

$AGB_{initial} = 1000 \text{ x } 0.6 \text{ x } EXP^{3.323+2.546 x \ln(\frac{DBH}{100})}$

by Carvalho Jr. et al. (1998) (Equation 4)

$AGB_{initial} = EXP^{2.42 x \ln(DBH)-2}$, by Baker et al. (2004) (Equation 5)

$AGB_{initial} = EXP^{0.33 x \ln(DBH)+0.933 x \ln(DBH)^2 - 0.122 x \ln(DBH)^3 - 0.37}$,

by Baker et al. (2004) (Equation 6)

$AGB_{initial} = 0.642 \text{ X } EXP^{-1.499+2.148 x \ln(DBH)+0.207 x \ln(DBH)^2 - 0.0281 x \ln(DBH)^3}$,

by Chave et al. (2005) (Equation 7)

where $AGB_{initial}$ corresponds to the tree's dry matter in kg and the tree's DBH is given in cm.

All the trees had their biomass calculated by each of different equations above. Subsequently, the following steps were followed: (1) all the biomass of the trees within the sample of the RADAMBRASIL (AGBinicial) was summed; (2) these samples were separated by phytophysiognomy and (3) the average of the AGBinitial (t/ha) of the samples for each phytophysiognomy were calculated, as each sample of the RADAMBRASIL has one hectare.

Expansion factors and ratio

As the trees sampled by the RADAMBRASIL have a DBH higher or equal to 31.83 cm, two expansion factors were applied in order to include trees with a DBH from 10 to 31.83 cm based on the phytophysiognomy (dense and open forest)[16], as proposed by Nogueira et al. (2008) and presented in Table A1.8. These authors also used data of RADAMBRASIL and collected data on field of different regions of the Amazon in order to estimate this proportion.

Result is:

$$AVERAGE(AGB_{correction} \times ha^{-1}) = AVERAGE(AGB_{initial} \times ha^{-1}) \times Correction\ factor_{10<DBH<31.83}$$

TABLE A1.8

Expansion factors for the inclusion of biomass of tress with DBH between 10 and 31.83cm of the RADAMBRASIL Project's phytophysiognomies

PHYTOPHYSIOGNOMY	FOREST TYPE	EXPANSION FACTOR 10<DBH<31.83 CM
Aa	Open	1.506
Ab	Open	1.506
As	Open	1.506
Da	Dense	1.537
Db	Dense	1.537
Dm	Dense	1.537
Ds	Dense	1.537
Fs	Open	1.506
Ld	Open	1.506

Source: Nogueira et al. (2008).

Other ratios were also applied according to Nogueira et al. (2008) in different regions of Amazon to open and dense forests in order to include palm trees, lianas, underbrush, herb layer, dead wood, litter and belowground biomass. Table A1.9 presents these expansion factors and ratios per stock. Based on the values, the following equation applies:

$$AVERAGE(AGB_{total} \times ha^{-1}) = AVERAGE(AGB_{correction} \times ha^{-1}) + (AVERAGE(AGB_{correction} \times ha^{-1}) \times Total\ Correction\ factor)$$

16 *Trees with DBH between 10 and 31.83cm correspond to a relative contribution of 33.6% for open forests and 34.9% for dense forests in the Amazon (NOGUEIRA et al., 2008).*

TABLE A1.9

Expansion factors and ratio (in dry biomass percentage) for the inclusion of the biomass of palm trees, lianas, underbrush, herb layer, dead wood, litter and belowground biomass in dense and open forests in the Amazon region

FOREST TYPE	PALM TREES	LIANAS	UNDERBURSH	HERB LAYER	DEAD WOOD	LITTER	BELOWGROUND BIOMASS	TOTAL
Dense	1.90	3.40	4.30	0.21	9.40	4.10	31.00	54.31
Open	8.60	2.10	3.90	0.21	8.10	5.90	10.00	38.81

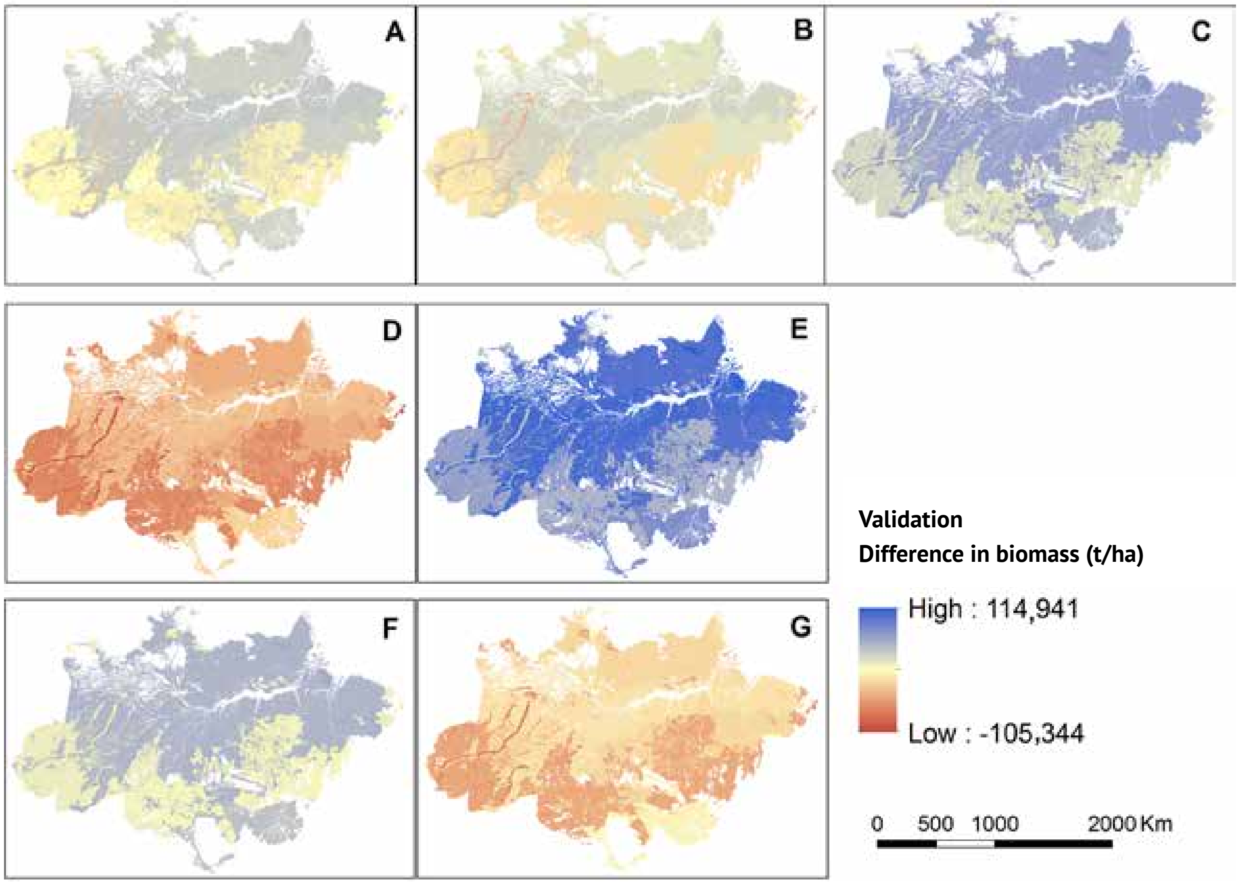
Source: Nogueira et al. (2008); Fearnside et al. (1992).

Allometric equation comparison

In order to compare the biomass values obtained by each of the allometric equations tested, values of the aboveground biomass were used for the forest inventories made available by Mitchard et al. (2014). These inventories are part of the projects Amazon Forest Inventory Network (RAINFOR), Tropical Ecology Assessment and Monitoring (TEAM), Amazon Tree Diversity Network, Program for Research in Biodiversity (*Programa de Pesquisa em Biodiversidade* – PPBio), besides other obtained from the scientific literature. Parts of these projects were distributed through the Brazilian Amazon and the biomass was estimated based on an allometric equation using the DBH, height and density. Because it is an independent database, these data were used to assess the differences of the equations tested in the Third Inventory. As a consequence, the average aboveground biomass map by phytophysiognomy created by Mitchard et al. (2014) was compared, by subtraction, with other average aboveground biomass map by phytophysiognomy generated from different allometric equations (Figure A1.15). The lowest variations are found mainly in A and B, that is, resulting from the application of equations 1 and 2 of Brown (1997) (Figure A1.15). This indicates a convergence between the values obtained by the application of this allometric equation to the RADAMBRASIL data and data collected via other database with additional structural parameters (height and density of wood). The equations proposed by Brown (1997) are based on pan-tropical data, which include collection in the Amazon and represent the variation found in tropical forests.

FIGURE A1.15

Difference between aboveground biomass estimated by Mithchard et al. (2014) and results of equations 1 (A), 2 (B), 3 (C), 4 (D), 5 (E), 6 (F) and 7 (G)



A comparison of biomass estimates by different allometric equations due to the increase of DBH was performed (Figure A1.16). Under this assessment the Higuchi et al. (1998) equation was also included, as used in the Second Inventory. Both the Higuchi et al. (1998) and the quadratic equation 1 of Brown (1997) tend to underestimate bigger individuals (Figure A1.16). However, Brown (1997) suggests the use of the equation (2) (exponential) for trees with DBH lower than 160cm and quadratic equation (1) for trees with DBH greater or equal 160 cm. According to the histogram of Figure A1.17, which represents the frequency of the trees inventoried by the RADAMBRASIL by classes of DBH, there is a higher incidence of trees with DBH ranging from 31.83 to 130cm. Consequently, the exponential equation of Brown (1997) is more indicated as the major part of the biomass is concentrated in samples with DBH lower than 160cm. Thus, the underestimation of individuals with a DBH higher than 160cm, due to the application of the quadratic equation (1), would be compensated by the overestimation of trees with DBH next to the 160cm threshold.

FIGURE A1.16

Aboveground biomass calculated from equations 1, 2, 3, 4, 5, 6, 7, and Higuchi et al. (1998) for DBH values

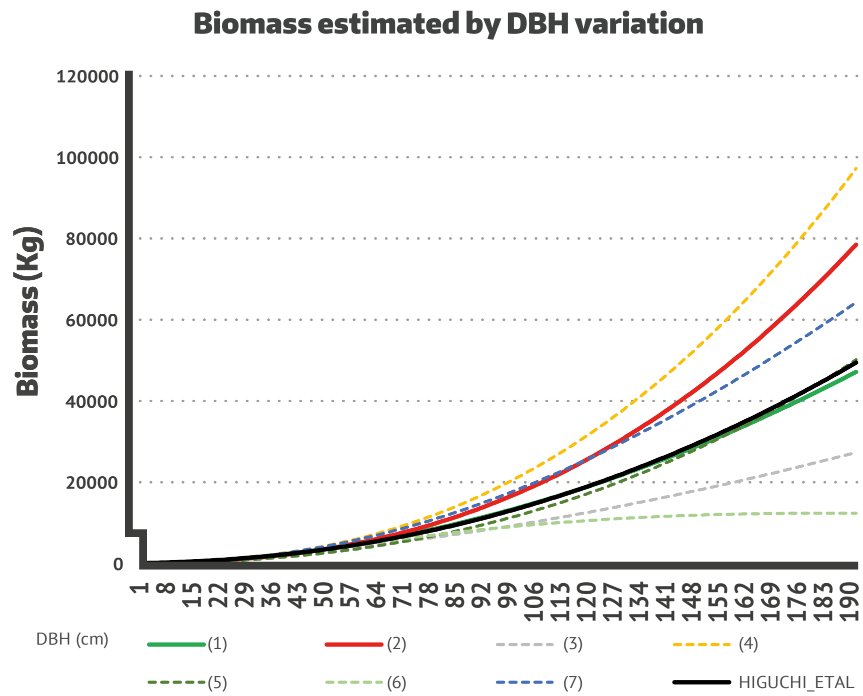
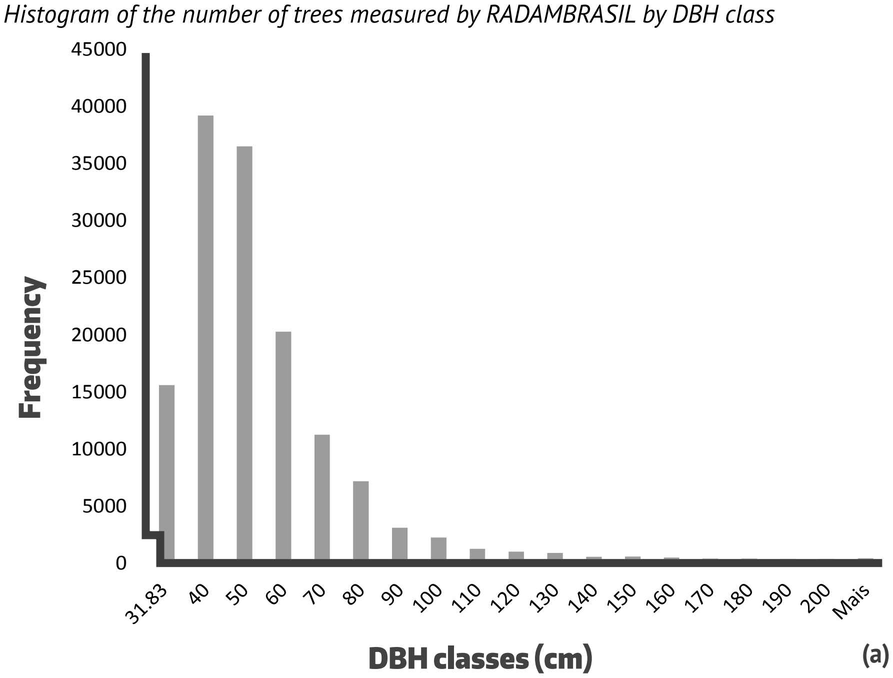


FIGURE A1.17

Histogram of the number of trees measured by RADAMBRASIL by DBH class



Based on previous analyses, the Third Inventory used the equations of Brown (1997) to replace the equations of Higuchi et al. (1998), applied on the Second Inventory, as per the following criteria:

$AGB_{initial} = EXP^{-2.134+(2.53 \times \ln(DBH))}$, for trees with DBH < 160 cm

$AGB_{initial} = 42.69 - 12.8 \times DBH + 1.242 \times DBH^2$, for trees with DBH ≥ 160 cm

The expansion factors and ratio explained above (Tables 6.8 and 6.9) were applied to the equations to estimate the average total biomass by phytophysiognomy.

Phytophysiognomies not represented in RADAMBRASIL

Data of literature review was used for the remaining 20 physiognomies of the Amazon biome, which represent almost 10% of the total area of the biome. For Low Lands Deciduous Seasonal Forests (Cb) and Submontane Deciduous Seasonal Forest (Cs), and also Alluvial Semideciduous Seasonal Forests (Fa) and Lowland Semideciduous Seasonal Forests (Fb), the value used for all stocks was estimated by Nogueira et al. (2008).

The same value of the Montana Dense Humid Forest (Dm) was used for the Montane Semideciduous Seasonal Forest (Fm), which, in turn, was obtained by RADAMBRASIL. This was decided due to the lack of studies about this phytophysiognomy in the region and due to the proximity of its fragments (Fm and Dm) in the biome.

The values of the aboveground biomass and litter presented by Barbosa & Ferreira (2004) in the Amazonian grassland were used for the Wooded Campinaranas (La) and Woody-Grass Campiranas (Lg). In order to estimate the belowground biomass of these phytophysiognomies a correction factor was used (ratio of below and aboveground biomass) in campinarana in Venezuela according to Bongers et al. (1985). Specifically to La, a correction factor of the IPCC (2003) for the estimates of dead wood was used.

For the Woody-Grass Campinaranas (Lg), the values of the study by Bongers et al (1985), conducted in the Venezuelan Amazon, were used due to the lack of information regarding the biomass of this phytophysiognomy in the Brazilian Amazon. The authors present values for all stocks considered herein.

The Vegetation with Fluvial and/or Lacustrine Influence (Pa), present in the meadows of the Amazon, had as a reference of the aboveground biomass and dead wood the study carried out by Xavier (2009) in the Central Amazon. For the belowground biomass the value found by Cattanio et al. (2004) was chosen. The accumulated litter was estimated based on the application of the regression equation for the decomposition of litter along the time by Cabianchi (2010) to the litter pool data found by Cattanio et al. (2004). The values of dead wood were those found by Chao et al. (2008).

As for the pioneering formations of fluvial-marine influence (mangrove or Pf), the aboveground biomass values proposed by Hutchison et al. (2013) were used for the mangroves in Brazil. These values also represent the equation to estimate the belowground biomass, used to calculate this stock. The ratio of dead wood was obtained based on the study of Fernandes (1997), developed in this phytophysiognomy and biome, whereas the value of the litter was the one found on the work of Ramos and Silva et al. (2007) in the state of Rio Grande do Norte. The values of the pioneering formation of marine influence (sand banks or Pm) were the same used in the sand banks of the Atlantic Forest biome.

For the Wooded Savanna (Sa) in the Amazon, the value used was the same value proposed for this phytophysiognomy in the Cerrado biome. For the Forested Savanna (Sd) the value adopted was the one adopted for this phytophysiognomy in the Cerrado biome, in the states of Tocantins, Piauí and Maranhão.

For the Grassy-Woody savannas (Sg) and Park (Sp), as well as for the Wooded Steppe Savannas (Ta), Grassy-Woody (Tg) and Park (Tp), values of aboveground biomass, dead wood and litter submitted by Barbosa & Fearnside (2005) in the Amazon were used. For the estimation of the belowground biomass ratios proposed by Miranda et al. (2014) were used.

The values by Barbosa & Fearnside (1999) were chosen for the Forested Steppe Savanna (Td) and Montane Refuge (Rm) in the Amazon biome; for the estimation of belowground biomass, the ratios by Miranda et al. (2014) were applied.

Map of the average total biomass per phytophysiognomy of the Amazon

In order to elaborate the map for the total average biomass of the phytophysiognomy of the Amazon (Figure A1.20), the values of total average biomass by phytophysiognomy (Table A1.10) and the file in shapefile format of the previous vegetation were united.

TABLE A1.10
Total average biomass (TB) by area unit (t/ha) for the different phytophysiognomies in the Amazon biome

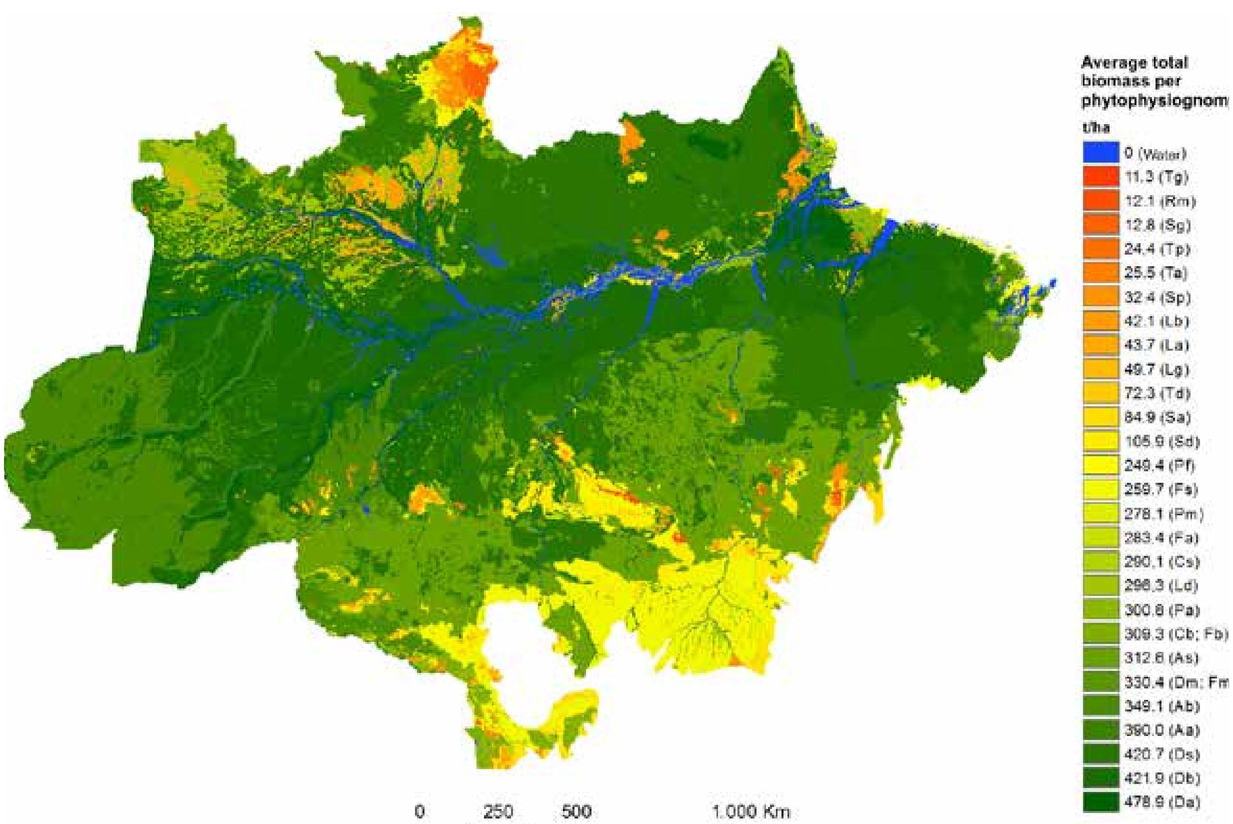
ABBREVIATION	PHYTOPHYSIOGNOMY	TB (t/ha)
Aa	Alluvial Open Humid Forest	390.00
Ab	Lowland Open Humid Forest	349.11
As	Open Submontane Humid Forest	312.65
Cb	Lowland Deciduous Seasonal Forest	309.30
Cs	Submontane Deciduous Seasonal Forest	290.10
Da	Alluvial Dense Humid Forest	478.92
Db	Lowland Dense Humid Forest	421.87
Dm	Montane Dense Humid Forest	330.36
Ds	Submontane Dense Humid Forest	420.66
Fa	Floresta Estacional Semidecidual aluvial	283.40
Fb	Lowland Semi Deciduous Seasonal Forest	309.30
Fm	Montane Semi Deciduous Seasonal Forest	330.36
Fs	Submontane Semi Deciduous Seasonal Forest	259.70
La	Wooded Campinarana	117.10
Lb	Shrubby Campinarana	40.76
Ld	Forested Campinarana	296.34
Lg	Woody-grass Campinarana	51.58
Pa	Fluvial and/or lacustre influenced Vegetation	300.81
Pf	Pioneering formation of fluviomarine influence	302.44

continues on the next page

ABBREVIATION	PHYTOPHYSIOGNOMY	TB (t/ha)
Pm	Pioneering formation of marine influence	278.09
Rm	Montane Refuge	12.12
Sa	Wooded Savanna	84.94
Sd	Forested Savanna	105.88
Sg	Woody-Grass Savanna	25.24
Sp	Park Savanna	32.42
Ta	Wooded Steppe Savanna	25.45
Td	Forested Steppe Savanna	72.33
Tg	Woody-Grass Steppe Savanna	11.24
Tp	Park Steppe Savanna	24.44

FIGURE A1.18

Total biomass map for the Amazon with average values per phytophysiognomy



Regionalization of the biomass based on RADAMBRASIL samples

The distribution of biomass within the same phytophysiognomy is not always uniform, mainly in a extensive biome, which can be confirmed by the amplitude of the standard deviation of the RADAMBRASIL samples in a same phytophysiognomy (Table A1.11). This heterogeneity may be explained by climatic, geological, pedological, geomorphological and/or ecological factors, among others. According to Malhi et al. (2006), the basal area has considerable local variations, and may be used to represent the variation of biomass within the same phytophysiognomy or even between the different plant physiognomies of the Amazon. Hence, in order to explore the data distribution of the data of RADAMBRASIL and better represent the spatial variation of the biomass, its regionalization as a function of the distribution of the basal area was chosen for all the Amazon biome.

TABLE A1.11

Average total biomass values (TB) and standard deviation (SD) of the phytophysiognomies of the Amazon biome obtained from RADAMBRASIL data

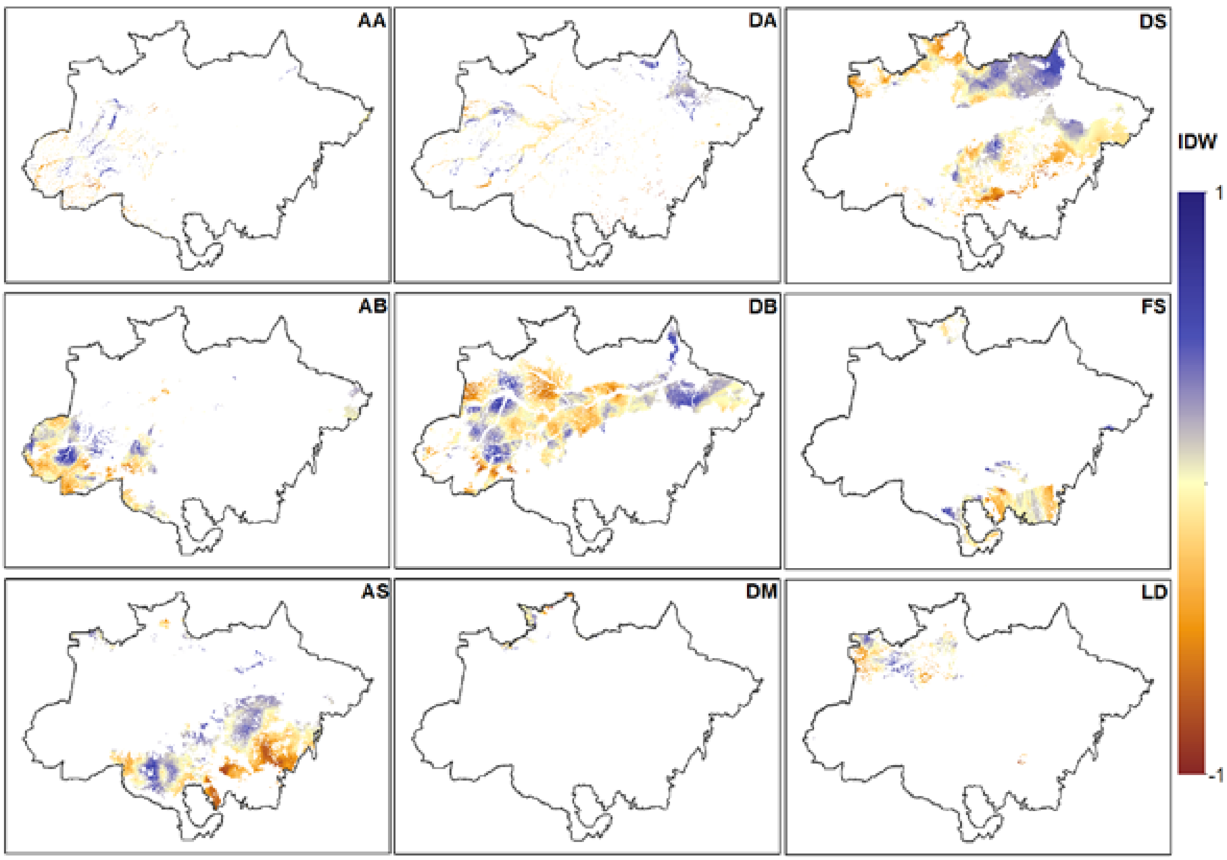
PHYSIONOGMY	TB (t/ha)	SD (t/ha)
Aa	390.00	174.90
Ab	349.11	125.39
As	312.65	139.88
Da	478.92	224.73
Db	421.87	145.52
Dm	330.36	114.55
Ds	420.66	182.63
Fs	259.70	98.72
Ld	296.34	112.00

To obtain this result, an interpolation of the spatial basal area was performed, calculated based on the 1682 samples of the RADAMBRASIL, through the Inverse Weighted Distance (IDW) method, as proposed by Malhi et al. (2006). The expansion factors and ratio proposed by Nogueira et al. (2008) were applied for inclusion of the individuals between 10 and 31.8 cm DBH (Table A1.8).

Then, in accordance with Malhi et al. (2006) methodology, the outliers were extracted to decrease the effect called by the authors as “bullseye”, resulting from the interpolation by the IDW method. After the exclusion of the outliers, an IDW interpolated surface was created, generated by the ArcMap software. Afterwards, the IDW surface was cut out by each of the nine phytophysiognomies, based on the previous vegetation map. The next step was to normalize each one of the nine IDW surfaces cutouts so that their values would vary from -1 to 1 (Figure A1.19).

FIGURE A1.19

IDW values distribution maps, as normalized per phytophysiognomy of RADAMBRASIL



After this process, these normalized IDW cutouts were turned into mosaics, and a single map was generated (in raster format) with all phytophysiognomies together. Finally, the downscaled biomass was calculated in function of the basal area following the equation below.

$$Bio_{reg} = Bio_{average} + (SD_{biomass} \times IDW_{mos})$$

Where:

Bio_{reg}: *raster* of downscaled biomass[17];

$Bio_{average}$: *raster* of average biomass per phytophysiognomy;

$SD_{biomass}$: *raster* of standard deviation of the biomass per phytophysiognomy; and

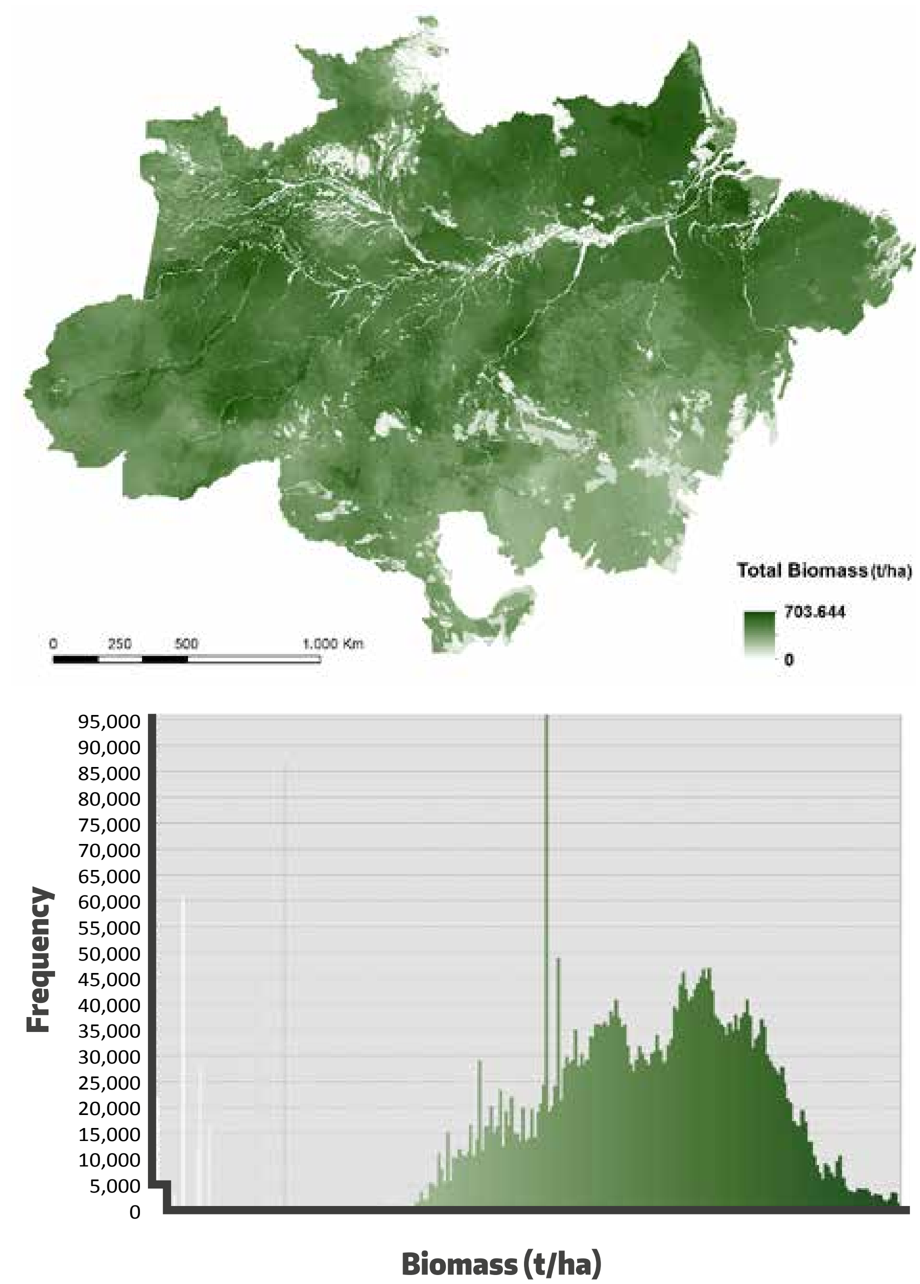
DW_{mos} : *raster* of IDW turned into mosaic.

It is worth noting that the standard deviation of the biomass of the phytophysiognomies not sampled by RADAMBRASIL was approached with value zero, leaving their values of downscaled biomass always equal to their averages. As a consequence, it was possible to create a map of the total downscaled biomass per phytophysiognomy (Figure A1.20). The histogram below of the map represents the distribution of the biomass values (Figure A1.20).

17 *The downscaled biomass* raster *might be created for each stock or considering the sum of all stocks, according with the* raster *used (average of total biomass per phytophysionogmy, aboveground biomass, belowground biomass, litter or dead wood).*

FIGURE A1.20

Total biomass map, including living and dead biomass, downscaled by phytophysiognomy in the Amazon (a) and histogram of total biomass values (b)



(a)

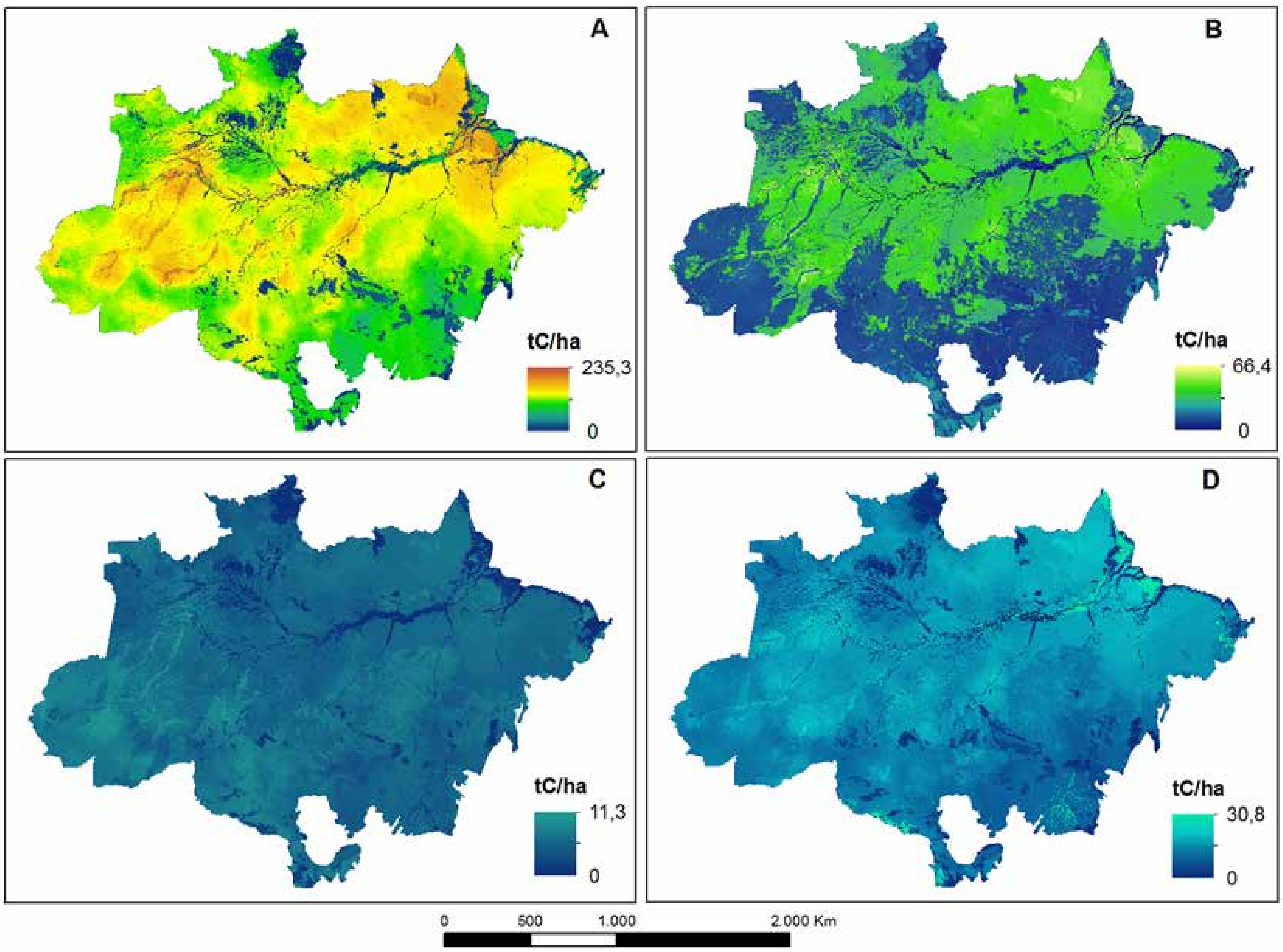
(b)

Regionalization of carbon stocks

The downscaled biomass map was converted into carbon stock as per the Table A1.7. Afterwards, the maps for each of the stocks were created (aboveground biomass, belowground biomass, dead wood and litter) (Figure A1.21).

FIGURE A1.21

Carbon stock maps (t C/ha) of the Amazon based on the downscaled biomass maps from different stocks (Aboveground – A; Belowground – B; Litter – C and Dead Wood – D)

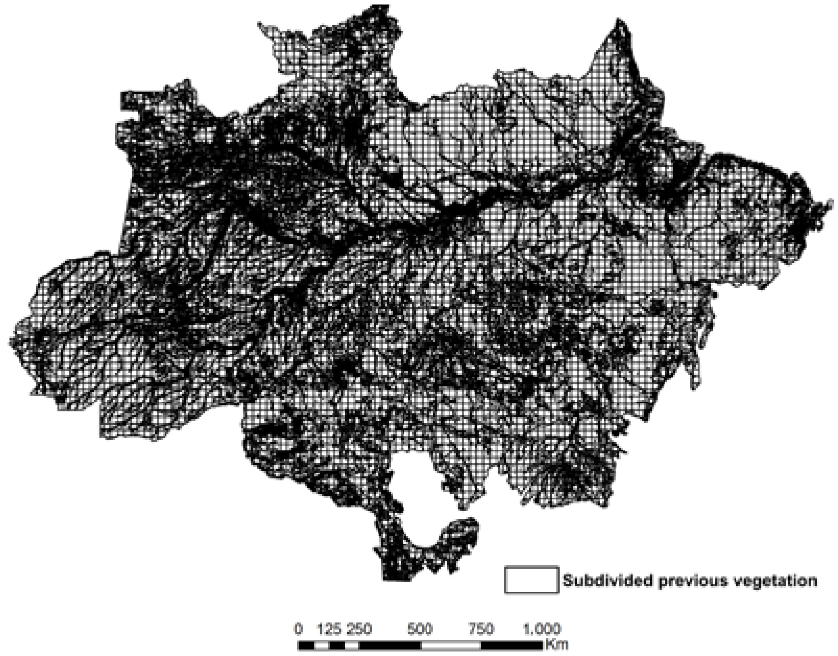


It was necessary to establish a process of zoning statistics in order to transfer the carbon values from pixels to polygons, which compose the maps of the carbon stock account. This map is a vector representation of the previous vegetation in a cellular space[18] with resolution of 0.25 decimal degrees (Figure A1.22), in a shapefile format. Average values for the carbon stocks of pixels to shapefile were attributed. The pixels that were on the edge between two or more shapes (pixel's edge) were considered centroid[19], that it to say, to the shape they were within.

18 Cellular space is a homogeneous spacial assessment unit composed of a regular cell grid where each cell representes a set of attributes.
19 Centroid is the point that corresponds to the geometric center of a certain shape.

FIGURE A1.22

Vector representation of previous vegetation in a cellular space with resolution of 0.25 decimal degrees



Figures A1.23 and A1.26 show maps for each stock as a result of a combination of downscaled carbon stock as a function of the basal area and in the phytophysiognomy map subdivided by cellular spaces. Finally, Figure A1.27 shows the total carbon stock map of the Amazon biome. Table A1.12 presents the values of the average total carbon stock used for each one of the 29 phytophysiognomies of the Amazon biome, references of where the values, expansion factors and ratios were taken from, criteria for choice and other works whose values were taken into consideration.

FIGURE A1.23

Downscaled map of aboveground biomass carbon stock (t C/ha) in the Amazon

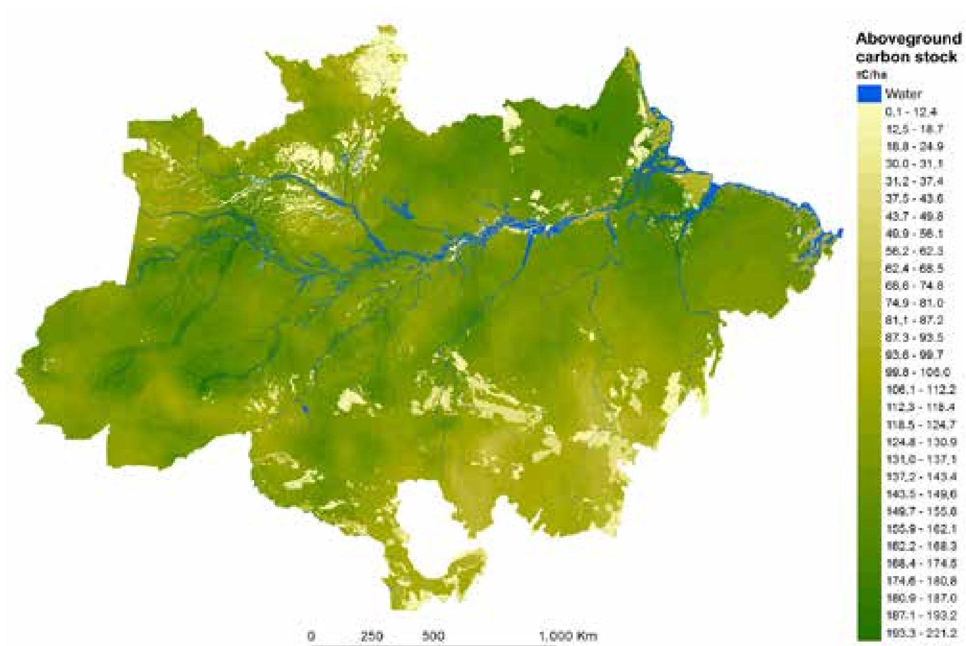


FIGURE A1.24

Downscaled map of dead wood carbon stock (t C/ha) in the Amazon

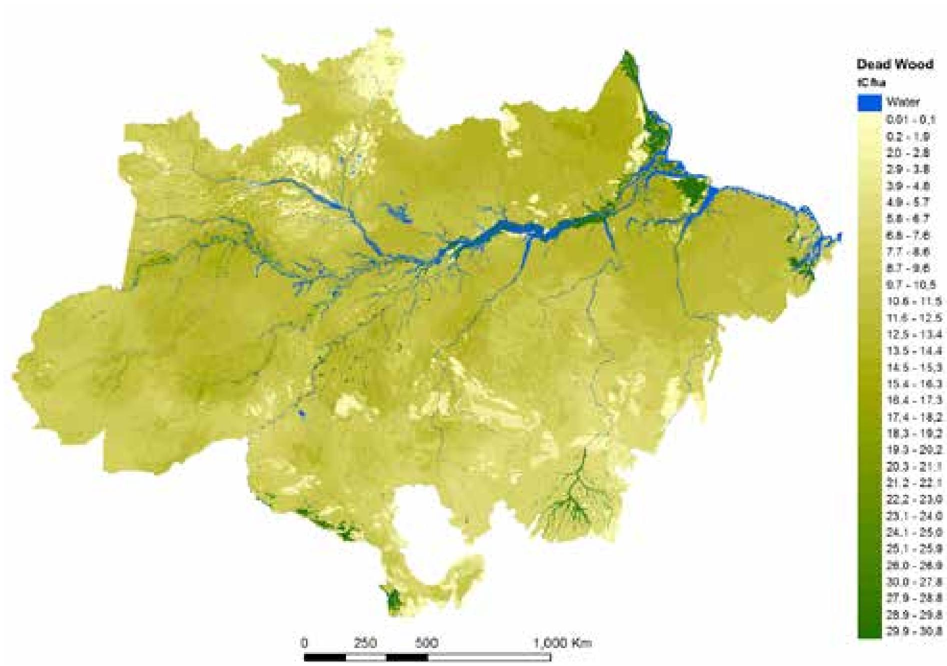


FIGURE A1.25

Downscaled map of litter carbon stock (t C/ha) in the Amazon

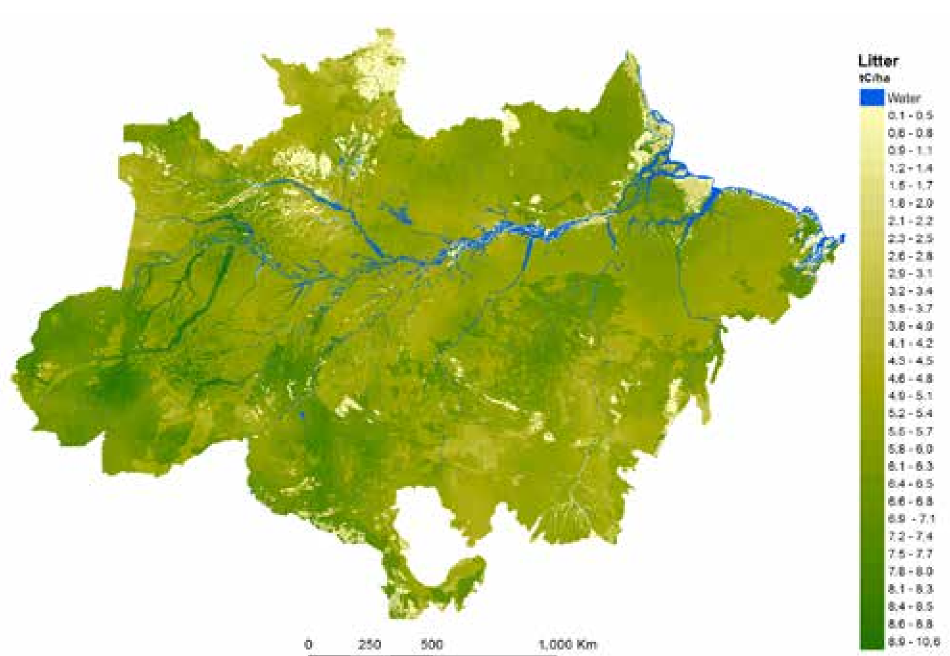


FIGURE A1.26

Downscaled map of belowground biomass carbon stock (t C/ha) in the Amazon

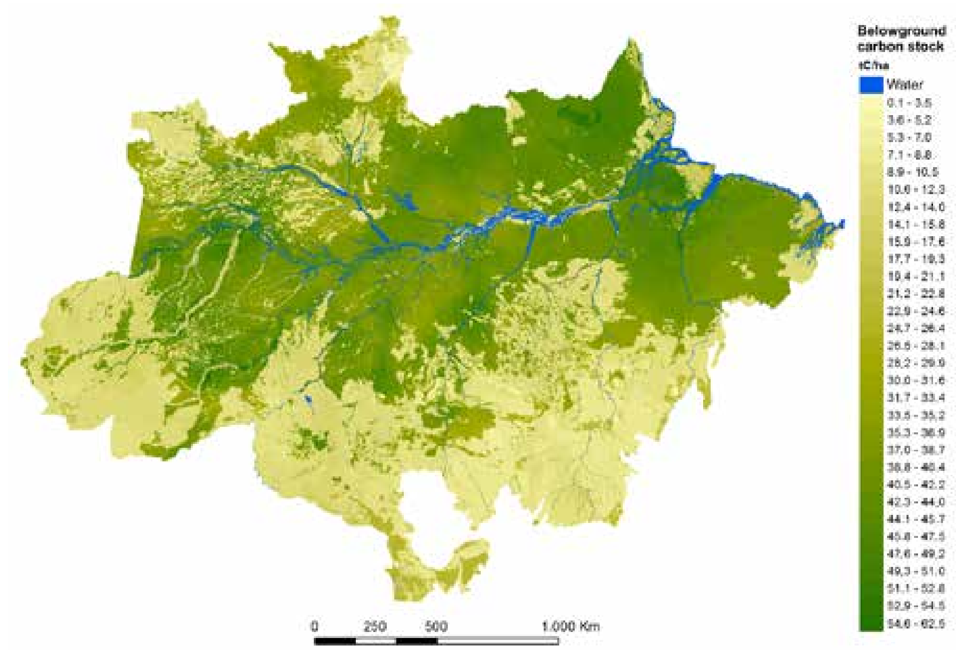


FIGURE A1.27

Downscaled map of total carbon stock, including live and dead biomass, in the Amazon

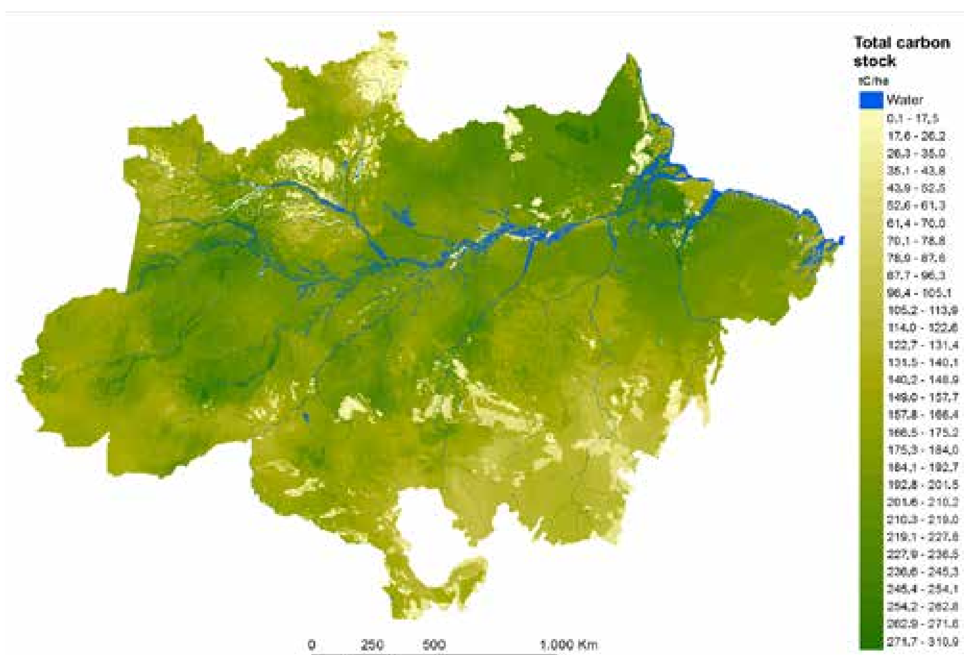


TABLE A1.12

Total carbon stock by area unit (t C/ha) of the phytophysiognomies in the Amazon, origin biome of the estimates for aboveground biomass; sources used to generate total carbon stock; criteria used in choosing sources; other sources used

ABBRE-VIATION	TOTAL STOCK (t C/ha)	BIOME	SOURCES	CHOICE CRITERION	OTHER SOURCES
Aa	183.3	Amazon	RADAMBRASIL (trees); Brown (1997) (allometric equation); Nogueira et al. (2008) (underbrush, palm trees, lianas, belowground biomass, dead wood, litter); Fearnside (1992) (herbaceous plants)	Biome phytophysiognomy; geographic coverage; sample effort	Carvalho Jr. et al. (1998); Araújo et al. (1999); Cummings et al. (2002); Baker et al. (2004); Chave et al. (2005)
Ab	164.08	Amazon	RADAMBRASIL (trees); Brown (1997) (allometric equation); Nogueira et al. (2008) (underbrush, palm trees, lianas, belowground biomass, dead wood, litter); Fearnside (1992) (herbaceous plants)	Biome phytophysiognomy; geographic coverage; sample effort	Carvalho Jr et al. (1998); Araújo et al. (1999); Cummings et al. (2002); Baker et al. (2004); Chave et al. (2005)
As	146.94	Amazon	RADAMBRASIL (trees); Brown (1997) (allometric equation); Nogueira et al. (2008) (underbrush, palm trees, lianas, belowground biomass, dead wood, litter); Fearnside (1992) (herbaceous plants)	Biome phytophysiognomy; geographic coverage; sample effort	Carvalho Jr. et al. (1998); Araújo et al. (1999); Cummings et al. (2002); Baker et al. (2004); Chave et al. (2005)
Cb	145.37	Amazon	Nogueira et al. (2008) (all stocks)	Biome phytophysiognomy; number of stocks; RADAMBRASIL samples	NA
Cs	136.35	Amazon	Nogueira et al. (2008) (all stocks)	Biome phytophysiognomy; number of stocks; RADAMBRASIL samples	NA
Da	225.09	Amazon	RADAMBRASIL (trees); Brown (1997) (allometric equation); Nogueira et al. (2008) (underbrush, palm trees, lianas, belowground biomass, dead wood, litter); Fearnside (1992) (herbaceous plants)	Biome phytophysiognomy; geographic coverage; sample effort	Carvalho Jr. et al. (1998); Araújo et al. (1999); Cummings et al. (2002); Baker et al. (2004); Chave et al. (2005)
Db	198.28	Amazon	RADAMBRASIL (trees); Brown (1997) (allometric equation); Nogueira et al. (2008) (underbrush, palm trees, lianas, belowground biomass, dead wood, litter); Fearnside (1992) (herbaceous plants)	Biome phytophysiognomy; geographic coverage; sample effort	Alves et al. (1997); Carvalho Jr. et al. (1998); Araújo et al. (1999); Cummings et al. (2002); Baker et al. (2004); Chave et al. (2005); Nascimento et al. (2007)
Dm	155.27	Amazon	RADAMBRASIL (trees); Brown (1997) (allometric equation); Nogueira et al. (2008) (underbrush, palm trees, lianas, belowground biomass, dead wood, litter); Fearnside (1992) (herbaceous plants)	Biome phytophysiognomy; geographic coverage; sample effort	Alves et al. (1997); Carvalho Jr et al. (1998); Araújo et al. (1999); Cummings et al. (2002); Baker et al. (2004); Chave et al. (2005)
Ds	197.71	Amazon	RADAMBRASIL (trees); Brown (1997) (allometric equation); Nogueira et al. (2008) (underbrush, palm trees, lianas, belowground biomass, dead wood, litter); Fearnside (1992) (herbaceous plants)	Biome phytophysiognomy; geographic coverage; sample effort	Alves et al. (1997); Carvalho Jr. et al. (1998); Araújo et al. (1999); Cummings et al. (2002); Baker et al. (2004); Chave et al. (2005)

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ABBRE-VIATION	TOTAL STOCK (t C/ha)	BIOME	SOURCES	CHOICE CRITERION	OTHER SOURCES
Fa	133.2	Amazon	Nogueira et al. (2008) (all stocks)	Biome phytophysiognomy; number of stocks; RADAMBRASIL samples	NA
Fb	145.37	Amazon	Nogueira et al. (2008) (all stocks)	Biome phytophysiognomy; number of stocks; RADAMBRASIL samples	Nascimento et al. (2007)
Fm	155.27	Amazon	Same as Dm in Amazon	Fragments close to Dm	NA
Fs	122.06	Amazon	RADAMBRASIL (trees); Brown (1997) (allometric equation); Nogueira et al. (2008) (underbrush, palm trees, lianas, belowground biomass, dead wood, litter); Fearnside (1992) (herbaceous plants)	Biome phytophysiognomy; geographic coverage; sample effort	Carvalho Jr. et al. (1998); Araújo et al. (1999); Baker et al. (2004); Chave et al. (2005)
La	20.52	Amazon	Barbosa and Ferreira (2004) (aboveground biomass and litter); Bongers et al. (1985) (aboveground biomass); IPCC (2006) (dead wood)	Belowground biomass and litter in meadow in the Amazon	Barbosa and Fearnside (1999); Barbosa et al. (2010)
Lb	19.68	Amazon	Barbosa and Ferreira (2004) (aboveground biomass and litter); Bongers et al. (1985) (aboveground biomass); IPCC (2006) (dead wood)	Belowground biomass and litter in meadow in the Amazon	NA
Ld	139.28	Amazon	RADAMBRASIL (trees); Brown (1997) (allometric equation); Nogueira et al. (2008) (underbrush, palm trees, lianas, belowground biomass, dead wood, litter); Fearnside (1992) (herbaceous plants)	Biome phytophysiognomy; geographic coverage; sample effort	Carvalho Jr. et al. (1998); Araújo et al. (1999); Barbosa and Fearnside (1999); Baker et al. (2004); Barbosa and Ferreira (2004); Chave et al. (2005)
Lg	23.21	Amazon	Bongers et al. (1985) (all stocks)	Biome phytophysiognomy; number of stocks	Barbosa and Fearnside (1999); Barbosa and Ferreira (2004); Barbosa et al. (2010)
Pa	141.38	Amazon	Xavier (2009) (aboveground biomass and dead wood); Cattanio et al. (2004) (belowground biomass and deposited litter); Cabianchi (2010) (decomposition rate); Chao et al. (2008) (dead wood)	Alongside river plains	NA
Pf	117.2	Brazil	Hutchison et al. (2013) (above and belowground biomass); Fernandes (1997) (dead wood); Ramos and Silva et al. (2007) (litter)	Review and modelling about mangroves, value for Brazil	Fromard et al. (1998); Silva et al. (1998); Cogliatti-Carvalho and Mattos-Fonseca (2004); Medeiros and Sampaio (2008); Santos (2013)
Pm	130.7	Atlantic Forest	Same as Atlantic Forest	Phytophysiognomy	Silva et al. (2010)
Rm	5.67	Amazon	Barbosa and Fearnside (1999) (aboveground biomass, dead wood and litter); Miranda et al. (2014) (belowground biomass)	Biome phytophysiognomy	Ottmar et al. (2001)

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ABBRE-VIATION	TOTAL STOCK (t C/ha)	BIOME	SOURCES	CHOICE CRITERION	OTHER SOURCES
Sa	39.92	Cerrado	Same as Cerrado	Phytophysiognomy	Barbosa and Fearnside (2005); Scolforo et al. (2008a); Fearnside et al. (2009); Haidar et al. (2013)
Sd	49.76	Cerrado	Same as Cerrado – TO/MA/PI	Phytophysiognomy; northern Brazil	Scolforo et al. (2008a); Fearnside et al. (2009); Morais et al. (2013)
Sg	6.01	Amazon	Barbosa and Fearnside (1999) (aboveground biomass, dead wood and litter); Miranda et al. (2014) (belowground biomass)	Biome phytophysiognomy; number of stocks	Barbosa and Fearnside (1999); Ottmar et al. (2001); Fearnside et al. (2009)
Sp	15.21	Amazon	Barbosa and Fearnside (1999) (aboveground biomass, dead wood and litter); Miranda et al. (2014) (belowground biomass)	Biome phytophysiognomy; number of stocks	Barbosa and Fearnside (1999); Ottmar et al. (2001); Fearnside et al. (2009)
Ta	11.96	Amazon	Barbosa and Fearnside (1999) (aboveground biomass, dead wood and litter); Miranda et al. (2014) (belowground biomass)	Biome phytophysiognomy; number of stocks	Fearnside et al. (2009)
Td	33.99	Amazon	Barbosa and Fearnside (1999) (aboveground biomass, dead wood and litter); Miranda et al. (2014) (belowground biomass)	Biome phytophysiognomy; number of stocks	Fearnside et al. (2009)
Tg	5.27	Amazon	Barbosa and Fearnside (1999) (aboveground biomass, dead wood and litter); Miranda et al. (2014) (belowground biomass)	Biome phytophysiognomy; number of stocks	Fearnside et al. (2009)
Tp	11.45	Amazon	Barbosa and Fearnside (1999) (aboveground biomass, dead wood and litter); Miranda et al. (2014) (belowground biomass)	Biome phytophysiognomy; number of stocks	Barbosa and Fearnside (1999); Fearnside et al. (2009)

Comparison PRODES x TNC

Methodological differences are the main source of divergent values for the Amazon deforestation rates when the Third National Communication (TNC) and the PRODES data are considered. Methodological differences range from projects goals to implementing scales and monitored areas. PRODES' goal is to monitor clear cut deforestation[20], which is carried out at a 1:75,000 scale, allowing a more precise measure than that of the TNC, carried out at a 1:125,000 scale. PRODES takes into account areas defined as "forests" in the Legal Amazon, and does not monitor the areas that are considered as "non-forest"[21].

20 "Clear-cut deforestation is the one resulting in the complete removal of forest cover and replacement with other covers and uses (agriculture, grazing, urban, hydroelectric plants, etc.)" (INPE, 2013).

21 According to the PRODES' methodology, "non-forest areas" refer to areas identified in the images as composed of vegetation cover other than forest cover.

The TNC, on the other hand, considers the entire national territory with its six biomes, and monitors all forest and non-forest (grasslands) areas, following the definition of previous vegetation, produced by the Second National Communication (SNC). Formation areas considered as forests in SNC and TNC exceed the areas considered by PRODES as forests for the Amazon biome (Table I). In order to minimize these methodological differences, the same scenes used in PRODES were used in the mapping of the Third Inventory, although observed at two different scales according to each project. However, some images with large cloud cover were replaced (91 scenes for 2005 and 54 scenes for 2010, in a total of 198). For the sake of comparing results, a subtraction of the accumulated deforested areas of both projects for the years of interest was performed. For the purposes of this Inventory, deforestation was considered as the sum of the areas of Ac, Ap, FSec, GSec, Res, Ref, O and S, against the sum of PRODES' deforested area and residues[22] (Figure I). It is indicated that the differences between the deforested areas of the two projects have, for the most part, values near zero km² (86%, 91%, 91% and 90% of occurrences are shown between -50 and 50 km² in the comparisons for 1994, 2002, 2005 and 2010, respectively, as shown in the histograms and average values in Figure I). Furthermore, some regions where with higher deforestation rates in this inventory (red cells) correspond to PRODES' non-forest regions (Figure I, Tables I to IV). The total correspondence among the deforested areas shown in this document and PRODES' non-forest areas was 0.2% in 1994; 0.1% in 2002; 4.4% in 2005 and 4.5% in 2010. In relation to the increase of areas that were not monitored due to larger cloud cover at the time of mapping, it can be seen that it also occurred in PRODES (Figure III). It should be noted that the comparison with the map of 1994 was only possible when considering data of PRODES 1997, as the first period of digital PRODES is 1997-2000. Therefore, the main methodological differences that hinder the direct comparison of numbers and results of these projects are underscored herein.

TABLE I

Comparison of forest and non-forest areas in TNC and PRODES

COVER	TNC	PRODES REDUCED TO THE LIMIT OF THE AMAZON BIOME USED IN TNC[2]	PRODES (LEGAL AMAZON)[3]
	AREA (km²)[1]		
Forest	3,964,940	3,800,956	3,894,571
Grasslands/Non- Forest	112,747	290,924	957,606
Hydrography	131,092	116,899	163,957
Total	**4,208,779**	**4,208,779**	**5,016,134**

1. Values may vary in relation to other official figures due to the geographic standards used for calculations.
2. The forest area was estimated by the difference between the total area of the Amazon Biome and the non-forest area and hydrography of PRODES within that limit.
3. The forest area was estimated by the difference between the total area of the Legal Amazon and the non-forest area and hydrography of PRODES.

22 *"Deforested areas that were detected by PRODES in a year that is not the year of occurrence" (Almeida et al., 2009).*

FIGURE I

Differences between the accumulated deforested area mapped in the Third National Communication (TNC) and PRODES for the years of interest in the Amazon biome. Analysis was prepared considering a cellular grid of 0.25 x 0.25 degrees (average of 704 km²/cell). The range of values centralized in zero is represented in gray in the maps. It should be pointed out that the first comparison comprises the years of 1994 (TNC) and 1997 (PRODES) due to the availability of digital data in PRODES. Green spots indicate TNC deforestation values that are lower than those of PRODES (negative values), orange to red spots indicate TNC deforestation values that are higher than those of PRODES (positive values)

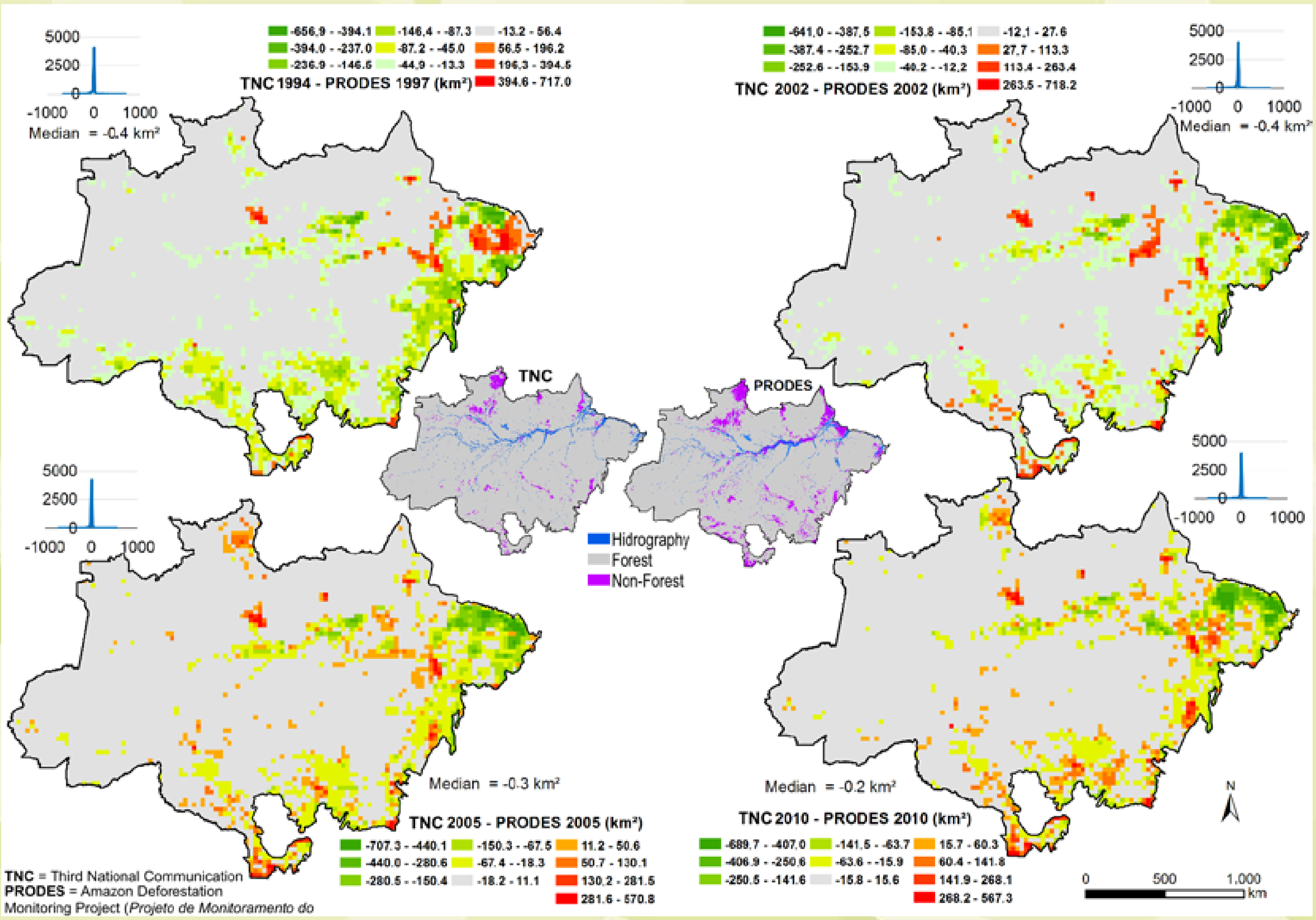

TABLE II

Correspondence area between the TNC map (1994) and PRODES (1997) for the Amazon Biome

TNC (1994)		PRODES 1997 CORRESPONDENCE						TOTAL TNC CORRESPONDENCE IN PRODES
CLASS	AREA (ha)	DEFORESTATION (ha)	%	HYDROGRAPHY (ha)	%	NON-FOREST (ha)	%	%
FNM	271,381,689.0	11,895,283.3	4	28,785.8	0	777,644.8	0	5
FM	93,479,430.7	563,229,1	1	2,933.7	0	53,896.0	0	1
FSec	1,369,898.6	1,095,476.5	80	1.5	0	0.0	0	80
Ref	296,464.8	118,420.3	40	0,0	0	1,453.1	0	40
CS	0.0	-	-	-	-	-	-	-
GNM	8,215,886.9	147,141.4	2	0.0	0	177.6	0	2
GM	2,703,248.7	5,462.4	0	0.0	0	18,769.2	1	1
GSec	17,226.4	11,083.7	64	0.0	0	0.0	0	64
Ap	28,353,961.2	23,181,811.9	82	617.4	0	48,839.3	0	82
Ac	628,971.5	436,744.8	69	0.0	0	0.0	0	69
S	189,812.3	137,389.2	72	12.9	0	981.7	1	73
A	12,746,052.5	202,469.6	2	324,727.6	3	16,159.9	0	4
Res	597,552.7	3,472.0	1	104.2	0	149.5	0	1
O	56,585.6	42,319.9	75	66.0	0	48.6	0	75
NE	841,117.3	368,892.1	44	58.8	0	974.5	0	44

TABLE III

Correspondence area between the TNC map (2002) and PRODES (2002) for the Amazon Biome

TNC (2002)		CORRESPONDENCE IN THE ACCUMULATED PRODES 1997-2002						TOTAL TNC CORRESPONDENCE WITHIN PRODES
CLASS	AREA (ha)	DEFORESTATION (ha)	%	HYDROGRAPHY (ha)	%	NON-FOREST (ha)	%	%
FNM	216,641,049.9	9,069,072.0	4	28,227.1	0	757,009.9	0	5
FM	132,228,135.4	1,713,066.2	1	2,751.6	0	55,812.7	0	1
FSec	3,262,749.7	2,464,150.2	76	113.0	0	2,174.5	0	76
Ref	356,342.8	162,507.9	46	0.0	0	1,453.0	0	46
CS	259,610.6	32,663.4	13	0.0	0	0.0	0	13

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TNC (2002)		CORRESPONDENCE IN THE ACCUMULATED PRODES 1997-2002						TOTAL TNC CORRESPONDENCE WITHIN PRODES
CLASS	AREA (ha)	DEFORESTATION (ha)	%	HYDROGRAPHY (ha)	%	NON-FOREST (ha)	%	%
GNM	6,457,514.3	111,130.5	2	0.0	0	177.6	0	2
GM	4,176,741.0	11.806,9	0	0.0	0	18,672.5	0	1
GSec	33,784.0	10,154.5	30	0.0	0	0.0	0	30
Ap	42,670,445.4	38,074,897.5	89	1,199.3	0	65,967.4	0	89
Ac	1,074,882.7	832,669.3	77	0.0	0	0.0	0	77
S	282,686.3	241,842.4	86	33.6	0	1,464.9	1	86
A	12,723,954.3	269,336.4	2	324,780.4	3	16,159.9	0	5
Res	629,406.6	7,793.2	1	104.2	0	152.3	0	1
O	62,112.4	48,449.3	78	98.9	0	49.4	0	78
NE	18,483.0	1,850.1	10	0.0	0	0.0	0	10

TABLE IV
Correspondence area between the TNC map (2005) and PRODES (2005) for the Amazon Biome

TNC (2005)		CORRESPONDENCE IN THE ACCUMULATED PRODES 1997-2005						TOTAL TNC CORRESPONDENCE WITHIN PRODES
CLASS	AREA (ha)	DEFORESTATION (ha)	%	HYDROGRAPHY (ha)	%	NON-FOREST (ha)	%	%
FNM	176,275,517.8	7,723,642.1	4	697,138.0	0	8,259,718.1	5	9
FM	144,755,378.3	1,603,573.5	1	321,845.8	0	6,813,495.8	5	6
FSec	6,125,466.7	4,479,980.4	73	34,790.0	1	302,420.3	5	79
Ref	263,115.6	136,120.4	52	26.4	0	119,059.9	45	97
CS	1,218,740.8	58,086.8	5	27.8	0	797.5	0	5
GNM	5,679,039.9	94,980.3	2	15,796.9	0	4,712,704.7	83	85
GM	4,195,440.4	14,790.9	0	8,248.2	0	3,662,592.6	87	88
GSec	140,991.1	26,979.8	19	3,236.4	2	102,148.4	72	94
Ap	46,234,663.7	41,694,475.8	90	58,605.2	0	1,561,102.0	3	94
Ac	3,070,124.2	2,585,880.6	84	209.2	0	383,073.8	12	97

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TNC (2005)		CORRESPONDENCE IN THE ACCUMULATED PRODES 1997-2005						TOTAL TNC CORRESPONDENCE WITHIN PRODES
CLASS	AREA (ha)	DEFORESTATION (ha)	%	HYDROGRAPHY (ha)	%	NON-FOREST (ha)	%	%
S	358,318.7	310,703.8	87	2,055.3	1	33,231.4	9	97
A	12,570,987.8	250,312.3	2	9,404,230.6	75	1,176,001.1	9	86
Res	663,792.0	17,093.2	3	610,285.8	92	2,140.8	0	95
O	77,824.6	59,447.6	76	2,879.3	4	4,666.4	6	86
NE	19,248,496.6	1,537,551.3	8	206,754.4	1	1,619,444.4	8	17

TABLE V

Correspondence area between the TNC map (2010) and PRODES (2010) for the Amazon Biome

TNC (2010)		CORRESPONDENCE IN THE ACCUMULATED PRODES 1997-2010						TOTAL TNC CORRESPONDENCE WITHIN PRODES
CLASS	AREA (ha)	DEFORESTATION (ha)	%	HYDROGRAPHY (ha)	%	NON-FOREST (ha)	%	%
FNM	130,459,613.9	5,999,160.3	5	599.910,2	0	6,928,118.1	5	10
FM	179,507,012.8	1,444,800.3	1	364.327,6	0	7,645,892.0	4	5
FSec	8,161,610.1	5,322,220.6	65	42.805,4	1	410,931.3	5	71
Ref	349,650.5	222,269.8	64	12,7	0	117,639.7	34	97
CS	1,178,669.6	20,028.0	2	7,5	0	1,255.4	0	2
GNM	4,396,023.6	79,292.3	2	14,245.1	0	3,632,787.7	83	85
GM	4,804,004.5	15,829.0	0	7,776.9	0	4,149,008.7	86	87
GSec	190,546.9	30,303.7	16	3,306.2	2	147,417.9	77	95
Ap	49,941,425.1	45,254,571.2	91	57,353.2	0	1,727,276.8	3	94
Ac	3,424,779.0	2,959,181.6	86	90.4	0	371,009.0	11	97
S	392,539.3	343,550.8	88	2,805.1	1	34,558.8	9	97
A	12,182,193.2	247,132.3	2	9,258,761.8	76	1,342,433.7	11	89
Res	639,247.1	22,236.6	3	582,398.4	91	1,193.2	0	95
O	90,201.5	68,656.4	76	2,896.0	3	6,365.3	7	86
NE	25,160,381.4	3,116,038.1	12	768,567.5	3	2,590,409.5	10	26

FIGURE II

Cloud-covered area at the moment of mapping (Amazon Biome) and PRODES (Legal Amazon), in the years of interest (TM/LANDSAT-5 images). The area that was not estimated by PRODES was obtained by the sum of cloud-covered areas and areas not-observed, and is available at http://www.dpi.inpe.br/prodesdigital/prodesmunicipal.php

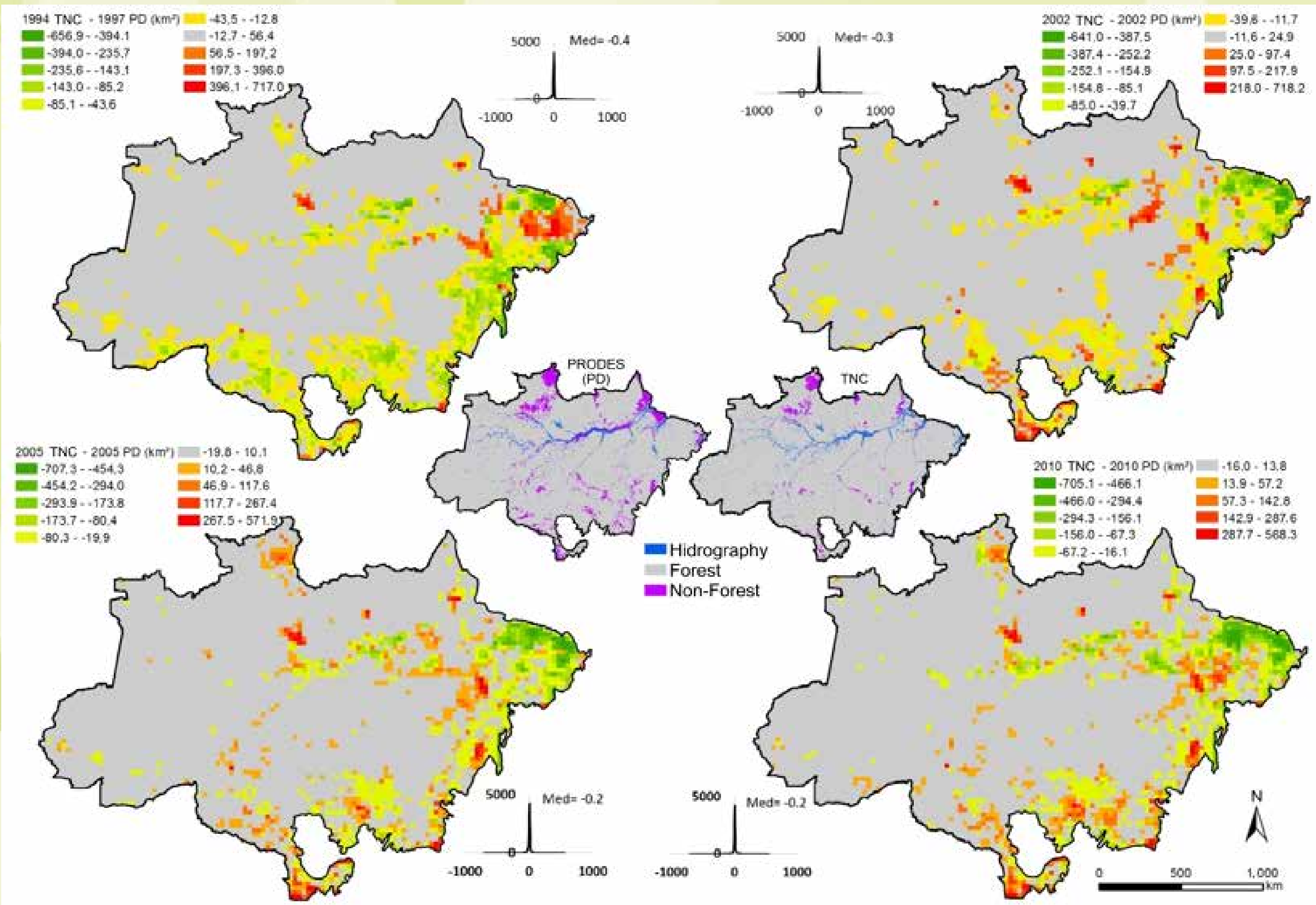
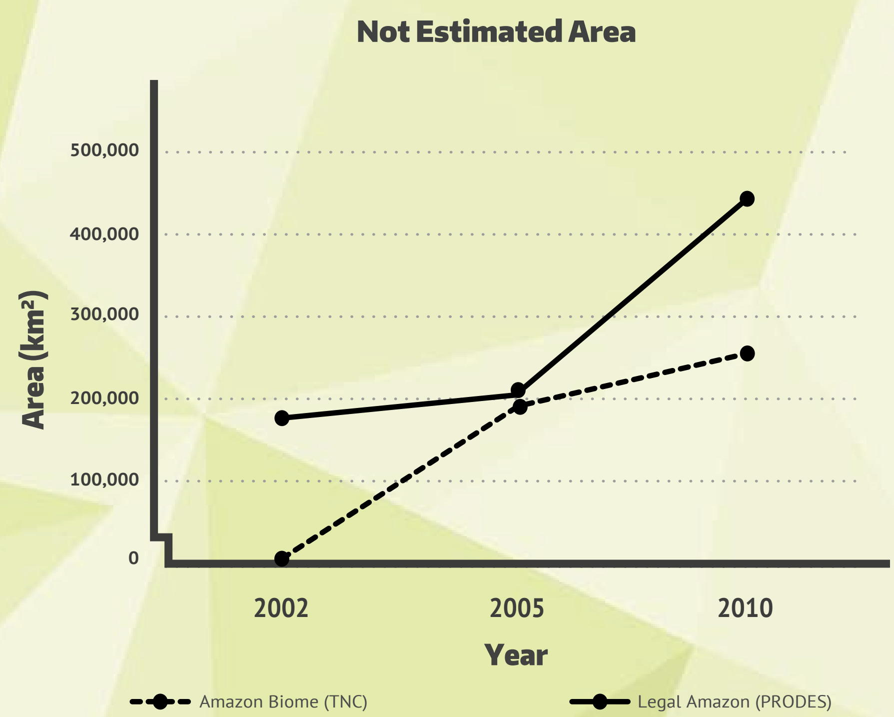


FIGURE III

Not Estimated areas in TNC and PRODES due to cloud cover



Cerrado Biome

The Cerrado is Brazil's second largest biome and comprises a wide latitudinal range, which extends from the coastline of the state of Maranhão to Southern Brazil. Thus, the choice was to regionalize the values of carbon stock of one given phytophysiognomy per Brazilian state whenever possible or when the values varied greatly between different regions of the biome. Environmental factors such as rainfall and seasonality were also considered for the assignment of values to phytophysiognomies, since these abiotic characteristics influence the characteristics of the vegetation.

The six phytophysiognomies that had their values downscaled per states were: Forested Savanna (Sd), Montane Deciduous Seasonal Forests (Cm) and Submontane Deciduous Seasonal Forests (Cs), Alluvial Semideciduous Seasonal Forests (Fa), Lowland Semideciduous Seasonal Forests (fb) and Submontane Semideciduous Seasonal Forests (Fs).

For the Woodland Savanna (Cerradão or Sd), the values were divided into the following groups of states:

1. São Paulo, according to Pinheiro (2008), in Cerradão in Assis (SP);
2. Minas Gerais, Goiás, Distrito Federal and Bahia, according to the Forest Inventory of Minas Gerais (SCOLFORO et al., 2008a);
3. Mato Grosso and Mato Grosso do Sul, with the same value as the Sd in the Pantanal;
4. Tocantins, Maranhão and Piauí, according to the Forest Inventory of the State of Tocantins (HAIDAR et al., 2013), using Brown's allometric equation (BROWN, 1997).

The belowground biomass of each group of Sd was estimated based on ratios for forests in the Cerrado (MIRANDA et al., 2014); the dead wood was estimated according to the IPCC default value (2003) and the litter was based on the correction factor calculated for Cerradão (MORAIS et al., 2013).

The Forested Savanna (Sa) encompasses the Open Wooded Savanna (Cerrado *stricto sensu)*, Dense and Sparse Cerrado. For this phytophysiognomy, a study with broad geographic coverage in Cerrado and number of pools was chosen: aboveground biomass, dead wood and litter (OTTMAR et al., 2001). For the estimation of the belowground biomass, the ratio for trees and shrubs of Cerrado was applied (MIRANDA et al., 2014).

For the Park Savanna (Sp), which encompasses the phytophysiognomies *Campo Sujo* (shrubby field) and *Campo de Murundu* (mound field), an average of two total carbon stock values was calculated to represent the variation of biomass in this phytophysiognomy as a whole. Ottmar et al. (2001) was chosen to represent shrubby fields with prominent herb layer, due to greater geographic coverage and the number of aboveground biomass and dead organic matter stocks considered. For this value, with lower biomass, the ratio for grassland vegetation in Cerrado (MIRANDA et al., 2014) was used to estimate the belowground biomass. The other reference used represented the areas of greater biomass in Sp, and the same value adopted for Sp was used in the Pantanal biome.

For the Woody Grass Savannah (Sg), the study carried out in clean grassland in the Cerrado biome was chosen, with broader geographic coverage and more stocks (aboveground biomass and dead organic matter) (OTTMAR et al., 2001). The belowground biomass of Sg was estimated based on the ratio for grassland vegetation in Cerrado (MIRANDA et al., 2014). For the Montane Refuge (Rm), the same Sg values were adopted, due to the lack of studies evaluating the aboveground biomass in this phytophysiognomy itself.

Due to the absence of values for Wooded Steppe (Ea) in the Cerrado biome, values of aboveground biomass in the *sensu stricto* Cerrado and Cerrado Grassland were used (SCOLFORO et al., 2008a) in the state of Minas Gerais, where this phytophysiognomy is noticed. For the estimation of belowground biomass, the ratio in the savanna vegetation in Cerrado was used (MIRANDA et al., 2014), while for dead wood and litter, the ratio of Ottmar et al. (2001) was used.

As the Cerrado borders other four Brazilian biomes (Amazon, Atlantic Forest, Caatinga and Pantanal), in the absence of values for the forest phytophysiognomies in Cerrado, values of the phytophysiognomies in nearby biomes were used. For the Lowland Deciduous Seasonal Forest (Cb) the same value as the Pantanal biome was used.

For the Alluvial Open Humid Forests (Aa) and the Lowland (Ab), as well as for the Alluvial Dense Humid Forest (Da), the same values applied to these phytophysiognomies in the Amazon biome were used.

For the Montane Dense Humid Forests (Dm) and Montane Semideciduous Seasonal Forests (Fm), as well as for the pioneering formations of marine influence (Pm or Sandbank), the same values of these phytophysiognomies for the Atlantic Forest biome were used. The Mixed Humid Forests are restricted to the Southeast (state of São Paulo) and South (state of Paraná) in Brazil. In this case, the same values for the High-Montane Mixed Humid Forests (Ml) and Montane (Mm) in the Atlantic Forest were used.

The Montane Deciduous Seasonal Forest (Cm) was downscaled in: 1) the states of Minas Gerais, Bahia and Goiás with the same value chosen for this phytophysiognomy within the Caatinga biome; and 2) in the state of São Paulo, same value adopted for Cm in the Pantanal biome.

The Submontane Deciduous Seasonal Forest (Cs) was downscaled in: 1) the states of Minas Gerais, Bahia, Goiás, Federal District, Tocantins, Piauí and Maranhão with the same value for Cs in the Caatinga; and 2) the state of Mato Grosso, Mato Grosso do Sul and São Paulo, with Cs value for the Pantanal biome.

The Lowland Semideciduous Seasonal Forest (Fb) was downscaled as follows: 1) state of Mato Grosso, the same value of Fb in the Amazon; and 2) states of Goiás and Minas Gerais, the same value of this phytophysiognomy in the Atlantic Forest biome.

For the Open Submontane Humid Forests (As) and Submontane Dense Humid Forests (Ds), the values of aboveground biomass obtained from the data of the Forest Inventory of the State of Tocantins (HAIDAR et al., 2013) with application of the allometric equation described by Brown (1997) were chosen. The biomass of underbrush, lianas, palm trees, underground biomass, litter, and dead wood were estimated using Nogueira et al. (2008) ratios, from non-dense As Forests to Ds dense forests.

The Alluvial Semideciduous Seasonal Forest (Fa) was downscaled as follows:

1 states of Tocantins and Pará: average value of aboveground biomass of riparian and gallery forest of the Inventory of the State of Tocantins (HAIDAR et al., 2013), as of the application of the Brown equation (1997);
2 states of Minas Gerais, Goiás, Distrito Federal and Bahia: the same value of Fa for the Atlantic Forest biome.
3 states of São Paulo and Paraná: the aboveground biomass value in riparian semideciduous mesophilic forest in the state of São Paulo (MOREIRA-BURGER & DELITTI, 1999);
4 states of Mato Grosso and Mato Grosso do Sul: same value used of the Fa for the Pantanal biome.

For the estimation of the belowground biomass and dead wood of Fa, the IPCC default ratios were used (2003, 2006). For litter, a ratio calculated on the basis of the study of Moreira-Burger & Delitti (1999) was used for the states grouped into 1, 2 and 4. For São Paulo and Paraná (group 3), these authors assessed the litter (MOREIRA-BURGUER & DELITTI, 1999), and the use of ratios was not necessary.

The Submontane Semideciduous Seasonal Forest (Fs) was downscaled by the states:

1 Piauí, Maranhão and Bahia: value obtained from the DBH of trees (DAP > 10 cm), using a Brown's allometric equation (1997), in the states of Piauí and Maranhão (HAIDAR et al., 2013; FRANÇOSO et al., 2013).
2 Minas Gerais, Tocantins, Goiás, Distrito Federal, Mato Grosso, Mato Grosso do Sul, São Paulo and Rondônia: value obtained in the Forest Inventory of the state of Minas Gerais (SCOLFORO et al., 2008c).

The belowground biomass of Fs was calculated on the basis of the IPCC default ratio (2006). For dead wood, the correction factor used was in accordance with the IPCC (2003) and, as for litter, the correction factor was calculated based a work done in Fm (AMARO et al., 2013)

The Vegetation with Fluvial and/or Lacustrine Influence (Pa) had the value of aboveground biomass based on two studies carried out in paths of Cerrado. In one of them, the authors calculated the aboveground biomass for the herbaceous vegetation in a path in Tocantins (FIDELIS et al., 2013). In another study, the authors presented parameters such as average density of individuals per hectare and basal area for the vegetation of shrubs and trees of a path in the state of Minas Gerais (BAHIA et al., 2009) and, based on these parameters, the aboveground biomass was calculated by using an allometric equation (BROWN, 1997). The authors of the study made in TO reported the belowground biomass of the herbaceous component. For the belowground biomass of the shrub-tree component, the ratio according to Miranda et al. (2014) was used for forest phytophysiognomies in Cerrado. For the dead wood, the default correction factor of the IPCC (2003) was used in relation to the shrubs-tree aerial biomass. For the litter of the herbaceous component, a correction factor calculated for Clean Grassland was used from Ottmar et al. (2001) and for the shrub-tree component, a correction factor was calculated in accordance with Moreira-Burger & Delitti (1999).

For the pioneering formations of fluviomarine influence (Pf or Mangrove), located in Cerrado biome on the coastline of Maranhão, the same value of Pf in the Amazon biome was used. This value was based on a literature review and modeling about mangroves in the world, with a value for Brazil (HUTCHISON et al., 2013).

For the Forested Steppe Savanna (Td) and Wooded Steppe Savanna (Ta), the same values of these phytophysiognomies in the Caatinga biome were used. For the Park Steppe Savanna (Tp) and Woody Grass Steppe Savanna (Tg), the same values used for these phytophysiognomies in the Amazon biome were adopted, also due to the lack of studies performed in the Caatinga biome.

Table A1.13, shows the total carbon stock value used for the phytophysiognomies of the Cerrado biome, references of where the ratios and expansion factors were extracted, criteria for the choice and other works whose values were considered.

TABLE A1.13

Total carbon stock per area unit (t C/ha) of phytophysiognomies in the Cerrado biome, downscaled by state whenever possible; biome of origin of the aboveground biomass estimate; sources used to generate total carbon stock; criteria used when choosing sources; other sources used

ABBRE-VIATION	REGIONALIZATION	TOTAL STOCK (t C/ha)	BIOME	SOURCES	CHOICE CRITERION	OTHER SOURCES USED
Aa	Single value	183.3	Amazon	Same as Amazon	Phytophysiognomy; next to the Amazon	NA
Ab	Single vlue	164.08	Amazon	Same as Amazon	Phytophysiognomy; next to the Amazon	NA
As	Single value	88.17	Cerrado	Haidar et al. (2013) (aboveground biomass); Brown (1997) (allometric equation); Nogueira et al. (2008) (belowground biomass, dead wood, litter)	Similar phytophysiognomy; sample effort	NA
Cb	Single value	105.11	Pantanal	Same as Pantanal	Phytophysiognomy; next to Pantanal	Scariot & Sevilha (2005); Scolforo et al. (2008b); Pereira et al. (2011); Coelho et al. (2012)
Cm	MG / BA / GO	62.7	Caatinga	Same as Caatinga	Similar phytophysiognomy; next to Caatinga	Scariot & Sevilha (2005); Pereira et al. (2011); Coelho et al. (2012)
	SP	127.83	Pantanal	Same as Cs no Pantanal	Similar phytophysiognomy	
Cs	MG / BA / GO / TO / PI / DF / MA	62.7	Caatinga	Same as Caatinga	Similar phytophysiognomy; next to Caatinga	Scariot & Sevilha (2005); Scolforo et al. (2008b); Pereira et al. (2011); Coelho et al. (2012)
	MS / SP / MT	127.83	Pantanal	Same as Pantanal	Phytophysiognomy; next to Pantanal	
Da	Single value	225.09	Amazon	Same as Amazon	Phytophysiognomy; next to the Amazon	NA
Dm	Single value	177.75	Atlantic Forest	Same as Atlantic Forest	Phytophysiognomy; next to Cerrado	NA

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ABBRE-VIATION	REGIONALIZATION	TOTAL STOCK (t C/ha)	BIOME	SOURCES	CHOICE CRITERION	OTHER SOURCES USED
Ds	Single value	118.48	Cerrado	Haidar et al. (2013) (aboveground biomass); Brown (1997) (allometric equation); Nogueira et al. (2008) (belowground biomass, dead wood, litter)	Similar phytophysiognomy	RADAMBRASIL; Tiepolo et al. (2002); Britez et al. (2006); Borgo (2010); Lindner and Sattler (2011)
Ea	Single value	27.85	Cerrado	Scolforo et al. (2008a) (aboveground biomass); Miranda et al. (2014) (belowground biomass); Ottmar et al. (2001) (dead wood, litter)	Similar phytophysiognomy; biome; sample effort	NA
Fa	TO / PA	98.27	Cerrado	Haidar et al. (2013) (aboveground biomass); Brown (1997) (allometric equation); IPCC, 2006 (belowground biomass); IPCC (2003) (dead wood); Moreira-Burger &Delitti (1999) (litter)	Similar phytophysiognomy; biome	Paula et al. (1990, 1993); Imanã-Encinas et al. (1995)
	MG / GO / DF / BA	75.89	Atlantic Forest	Same as Atlantic Forest	Similar phytophysiognomy; greater sample effort	
	SP / PR	86.08	Atlantic Forest	Moreira-Burger & Delitti (1999) (aboveground biomass, litter); IPCC (2006) (belowground biomass); IPCC (2003) (dead wood)	Similar phytophysiognomy	
	MT / MS	167.52	Pantanal	Same as Pantanal	Similar phytophysiognomy; next to Pantanal	
Fb	MT	145.37	Amazon	Same as Amazon	Same phytophysiognomy; next to the Amazon	NA
	GO / MG	87.55	Atlantic Forest	Same as Atlantic Forest	Similar phytophysiognomy; next to the Atlantic Forest; sample effort	Britez et al. (2006)
Fm	Single value	106.88	Atlantic Forest	Same as Atlantic Forest	Phytophysiognomy; next to the Atlantic Forest; number of stocks	Britez et al. (2006); Boina (2008); Scolforo et al. (2008c); Ribeiro et al. (2009); Haidar (2008); Françoso et al. (2013)

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ABBRE-VIATION	REGIONALIZATION	TOTAL STOCK (t C/ha)	BIOME	SOURCES	CHOICE CRITERION	OTHER SOURCES USED
Fs	PI / MA / BA	54.98	Cerrado	Haidar (2008); Françoso et al. (2013) (aboveground biomass); Brown (1997) (allometric equation); IPCC (2006) (belowground biomass); IPCC (2003) (dead wood); Amaro et al. (2013) (litter)	Similar phytophysiognomy	Metzker et al. (2011)
	MG / TO / GO / SP / MT / MS / RO / PR	87.55	Atlantic Forest	Scolforo et al. (2008c) (aboveground biomass); IPCC (2006) (belowground biomass); IPCC (2003) (dead wood); Amaro et al. (2003) (litter)	Similar phytophysiognomy; greater sample effort	Metzker et al. (2011)
Ml	Single value	142.66	Atlantic Forest	Same as Atlantic Forest	Phytophysiognomy; number of stocks	Britez et al. (2006)
Mm	Single value	142.66	Atlantic Forest	Same as Atlantic Forest	Phytophysiognomy; number of stocks	Britez et al. (2006)
Pa	Single value	36.24	Cerrado	Bahia et al. (2009) (aboveground biomass – trees and bushes); Brown (1997) (allometric equation); Fidelis et al. (2013) (herbaceous and belowground biomass); Miranda et al. (2014) (belowground biomass); IPCC (2003) (dead wood); Ottmar et al. (2001) and Moreira-Burger & Delitti (1999) (litter)	Biome's phytophysiognomy	NA
Pf	Single value	117.2	Brasil	Hutchison et al. (2013) (above and belowground biomass); Fernandes (1997) (dead wood); Ramos & Silva et al. (2007) (litter)	Review and modelling on mangroves, value for Brazil	Fromard et al. (1998); Silva et al. (1998); Cogliatti-Carvalho & Mattos-Fonseca (2004); Medeiros and Sampaio (2008); Santos (2013); Estrada et al. (2014)
Pm	Single value	130.7	Atlantic Forest	Same as Atlantic Forest	Phytophysiognomy	NA
Rm	Single value	18.49	Cerrado	Same as Sg no Cerrado	Similar phyphysionomy in the biome; number of stocks	NA

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ABBRE-VIATION	REGIONALIZATION	TOTAL STOCK (t C/ha)	BIOME	SOURCES	CHOICE CRITERION	OTHER SOURCES USED
Sa	Single value	39.92	Cerrado	Ottmar et al. (2001) (aboveground biomass, dead wood, litter); Miranda et al. (2014) (belowground biomass)	Biome's phytophysiognomy; geographic coverage; number of stocks	Kauffman et al. (1994); Castro & Kauffman (1998); Abdala et al. (1998); Durigan (2004); Barbosa & Fearnside (2005); Rezende et al. (2006); Felfili (2008); Pinheiro (2008); Scolforo et al. (2008a); Ribeiro et al. (2011); Haidar et al. (2013); Miranda (2012)
Sd	SP	68.99	Cerrado	Pinheiro (2008) (aboveground biomass); Miranda et al. (2014) (belowground biomass); IPCC (2003) (dead wood); Morais et al. (2013) (litter)	Phytophysiognomy in the state of SP; in the biome	Durigan (2004); Fernandes et al. (2008)
	MG / GO / DF / BA	52.42	Cerrado	Scolforo et al. (2008a) (aboveground biomass); Miranda et al. (2014) (belowground biomass); IPCC (2003) (dead wood); Morais et al. (2013) (litter)	Phytophysiognomy in the state of MG; in the biome	
	MT / MS / RO	103.45	Pantanal	Same as Pantanal	Phytophysiognomy in the state of MS; in the biome	
	TO / MA / PI	49.76	Cerrado	Haidar et al. (2013) (aboveground biomass); Brown (1997) (allometric equation); Miranda et al. (2014) (belowground biomass); IPCC (2003) (dead wood); Morais et al. (2013) (litter)	Phytophysiognomy in the state of TO; in the biome	
Sg	Single value	18.49	Cerrado	Ottmar et al. (2001) (aboveground biomass, litter); Miranda et al. (2014) (belowground biomass)	Same phytophysiognomy; same biome; geographic coverage; number of stocks sampled	Kauffman et al. (1994); Castro & Kauffman (1998); Barbosa & Fearnside (2005)
Sp	Single value	24.65	Cerrado	Ottmar et al. (2001) (aboveground biomass, dead wood, litter); Miranda et al. (2014) (belowground biomass); Same as Pantanal	Biome's phytophysiognomy; geographic coverage; number of stocks; biomass variation in Sp	Kauffman et al. (1994); Castro & Kauffman (1998); Barbosa & Fearnside (2005)

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ABBRE-VIATION	REGIONALIZATION	TOTAL STOCK (t C/ha)	BIOME	SOURCES	CHOICE CRITERION	OTHER SOURCES USED
Ta	Single value	15.23	Caatinga	Same as Caatinga	Phytophysiognomy; sample effort	NA
Td	Single value	30.54	Caatinga	Same as Caatinga	Phytophysiognomy; sample effort	NA
Tg	Single value	5.27	Amazon	Same as Amazon	Phytophysiognomy	NA
Tp	Single value	11.45	Amazon	Same as Amazon	Phytophysiognomy	NA

Caatinga biome

The Caatinga occupies the Northeast region of Brazil and the Northern part of the state of Minas Gerais. It is a region subject to a semiarid climate, high luminous intensity, high annual temperatures, irregularity in the rainfall period and relatively low altitudes (which do not exceed 2,000 m). The action of these factors results in a vegetation with adaptations to water shortage, usually small sized and possessing discontinuous canopy, small leaves and branched individuals, with thorns or spines.

The greater part of the Caatinga biome (around 86%) is covered by phytophysiognomies that are typical of Northeastern hinterlands region. For the Wooded Steppe (Ta) and Forested (Td) Savannas, data provided by PhD Eliza Albuquerque, of the Federal Rural University of Pernambuco (UFRPE), were used. In this study, based on 79 plots distributed along Zona da Mata, Harsh and Hinterlands of the state of Pernambuco, researchers estimated the aboveground biomass (tree, shrub and herbaceous), belowground (thin and thick roots) and dead organic matter (dead wood and litter) (ALBUQUERQUE, 2015). The preference for the use of these data to estimate the biomass of the two most representative phytophysiognomies of the biome was due to the large number of sample units, the broader inclusion of stocks and their distribution, which was based on the Agro-ecological Zoning of Pernambuco (ZAPE) (SILVA et al., 2001).

For the Park Steppe Savannas (Tp) and Woody Grass (Tg), the values of aboveground biomass and dead organic matter were chosen from the work developed in these phytophysiognomies in the Amazon biome (BARBOSA & FEARNSIDE, 2005). For the estimation of the belowground biomass, the IPCC ratio for semiarid grassland (IPCC, 2006) was used.

The same value used for this phytophysiognomy in the states of Tocantins, Maranhão and Piauí in the Cerrado biome was used for the Forested Savanna (Sd). For the Wooded Savanna (Sa), the same value of Sa in the Cerrado biome was used, since its occurrence is mainly in the transition zone between the two biomes in the states of Piauí, Bahia and Minas Gerais.

For the Park Savanna (Sp), due to its occurrence in the central region of Bahia and the northern Minas Gerais, the values of aboveground biomass and dead organic matter in shrubby fields in the Cerrado biome were chosen (OTTMAR et al., 2001), in addition to the application of the ratio for the estimation of belowground biomass for grassland vegetation in Cerrado (MIRANDA et al., 2014).

The same value of this phytophysiognomy in the Cerrado biome was used in the Woody Grass Savanna (Sg), as it represents small areas distributed in the central region of Bahia and northern Minas Gerais, close to the transition between the biomes.

For the Montane Refuge (Rm), the average value of aboveground biomass in clean grassland was chosen, according to Ottmar et al. (2001). This value was added to the belowground biomass, the only stock that was not considered by the authors, using the IPCC ratio for semiarid grassland (IPCC, 2006).

For the Lowland Open Humid Forests (Ab), Open Montane Humid Forests (Am) and Open Submontane Humid Forests (As), a single value calculated for the open humid forests in the Atlantic Forest was used, as these phytophysiognomies in the Caatinga occur close to that biome.

A single value based on studies carried out in the Atlantic Forest biome was used for the Lowland (Cb), Montane (Cm) and Submontane (Cs) Deciduous Seasonal Forests. The aboveground biomass was obtained from data of the mature High Land Deciduous Forest of the Forest Inventory of Minas Gerais (SCOLFORO et al., 2008b). For the inclusion of the belowground biomass, the IPCC ratio (2006) was used. The estimation of dead wood and litter was carried out using the ratios proposed by the IPCC (2003) and Morais et al. (2013), respectively.

For the Alluvial Semideciduous Seasonal Forest (Fa), represented by small fragments in northern Minas Gerais, the same value of this phytophysiognomy in the Atlantic Forest biome was used. For the Lowland Semideciduous Seasonal Forest (Fb), which occurs in southern Ceará, bordering the state of Pernambuco, the same Fb value was used, also in the Atlantic Forest.

For the Montane Semideciduous (Fm) and Submontane (Fs) Seasonal Forests, a single value for Fs was used in the states of Piauí, Maranhão and Bahia in the Cerrado biome, since they occur in regions close to the borders of this biome in Piauí and Maranhão, besides fragments in Bahia, Ceará, Pernambuco, Bahia, Sergipe and Paraíba.

With respect to the pioneering phytophysiognomies, the ones of fluvial-marine influence (Pf or mangrove) were chosen so that the same value proposed for Pf in the Amazon biome could be used, since this value is based on a literature review and modeling value for Brazil (HUTCHISON et al., 2013).

As for the Vegetation with Fluvial and/or Lacustrine Influence (Pa), the aboveground biomass was estimated based on the application of Brown's allometric equation (BROWN, 1997) with the average basal area and individual density in flood plains of Carinhanha River, on the border of the states of Minas Gerais and Bahia, at the confluence with São Francisco River (PEREIRA, 2013) because it occurs in areas close to major rivers in the Northeast (in flood plains), mainly the São Francisco River. The ratios for belowground biomass and dead wood were those proposed by the IPCC (2003, 2006), while litter was estimated from the ratio calculated in the study carried out by Moreira-Burger & Delitti (1999).

For the small fragments of Submontane Dense Humid Forest (Ds) to the east of Bahia, the same value for this phytophysiognomy in the Atlantic Forest was used.

Table A1.14 presents the total carbon stock values used for the phytophysiognomies of the Caatinga biome, references of where the values, expansion factors and ratios were extracted, choice criteria and other works whose values were considered.

TABLE A1.14

Total carbon stock per area unit (t C/ha) of phytophysiognomies in the Caatinga biome; biome of origin of the aboveground biomass estimate; sources used to generate total carbon stock; criteria used when choosing sources; other sources used

ABBRE-VIATION	TOTAL STOCK (t C/ha)	BIOME	SOURCE	CHOICE CRITERION	OTHER SOURCES USED
Ab	47.03	Atlantic Forest, Cerrado, Amazon	Same as Atlantic Forest	In Open Humid Forest; bordering Atlantic Forest	NA
Am	47.03	Atlantic Forest, Cerrado, Amazon	Same as Atlantic Forest	In Open Humid Forest; bordering Atlantic Forest	NA
As	47.03	Atlantic Forest, Cerrado, Amazon	Same as Atlantic Forest	In Open Humid Forest; bordering Atlantic Forest	NA
Cb	62.7	Caatinga	Scolforo et al. (2008b) (aboveground biomass); IPCC (2006) (belowground biomass); IPCC (2003) (dead wood); Morais et al. (2013) (litter)	Similar phytophysiognomy; in the biome	Scariot & Sevilha (2005); Pereira et al. (2011); Coelho et al. (2012)
Cm	62.7	Caatinga	Scolforo et al. (2008b) (aboveground biomass); IPCC (2006) (belowground biomass); IPCC (2003) (dead wood); Morais et al. (2013) (litter)	Similar phytophysiognomy; in the biome	Scariot & Sevilha (2005); Pereira et al. (2011); Coelho et al. (2012)
Cs	62.7	Caatinga	Scolforo et al. (2008b) (aboveground biomass); IPCC (2006) (belowground biomass); IPCC (2003) (dead wood); Morais et al. (2013) (litter)	Similar phytophysiognomy; in the biome	Scariot & Sevilha (2005); Pereira et al. (2011); Coelho et al. (2012)
Ds	151.42	Atlantic Forest	Same as Atlantic Forest	In the phytophysiognomy; bordering Atlantic Forest	RADAMBRASIL; Tiepolo et al. (2002); Britez et al. (2006); Borgo (2010); Lindner and Sattler (2011); Haidar et al. (2013)
Fa	75.89	Atlantic Forest	Same as Atlantic Forest	In the phytophysiognomy; geographic proximity	Paula et al. (1990, 1993); Imanã-Encinas et al. (1995); Moreira-Burger & Delitti (1999); Haidar et al. (2013)
Fb	87.55	Atlantic Forest	Same as Atlantic Forest	Similar phytophysiognomy; geographic proximity	Britez et al. (2006); Moreira-Burger & Delitti (1999)
Fm	54.98	Cerrado	Same as Fs no Cerrado (PI/MA/BA)	Similar phytophysiognomy; next to Cerrado	Britez et al. (2006); Ribeiro et al. (2008); Amaro et al. (2013); Torres et al. (2013)
Fs	54.98	Cerrado	Same as Cerrado (PI/MA/BA)	Similar phytophysiognomy; next to Cerrado	Britez et al. (2006); Scolforo et al. (2008c); Metzker et al. (2011)
Pa	66.88	Atlantic Forest	Pereira (2013) (aboveground biomass); Brown (1997) (allometric equation); IPCC (2006) (belowground biomass); IPCC (2003) (dead wood); Moreira-Burger and Delitti (1999) (litter)	In the phytophysiognomy in the biome	Tiepolo et al. (2002); Britez et al. (2006)
Pf	117.2	Brasil	Hutchison et al. (2013) (above and belowground biomass); Fernandes (1997) (dead wood); Ramos and Silva et al. (2007) (litter)	Review and modelling on mangroves, value for Brazil	Fromard et al. (1998); Silva et al. (1998); Cogliatti-Carvalho & Mattos-Fonseca (2004); Medeiros & Sampaio (2008); Santos (2013); Estrada et al. (2014)

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ABBRE-VIATION	TOTAL STOCK (t C/ha)	BIOME	SOURCE	CHOICE CRITERION	OTHER SOURCES USED
Pm	123.67	Atlantic Forest	Assis et al. (2011) (aboveground biomass and litter deposited); IPCC (2006) (belowground biomass); Veiga (2010) (dead wood and litter); Pires et al. (2006) (decomposition constant); Kristensen et al. (2008) (decomposition regression equation)	Phytophysiognomy	Britez et al. (2006)
Rm	16.24	Cerrado	Ottmar et al. (2001) (aboveground biomass and litter); IPCC (2006) (belowground biomass)	Similar phytophysiognomy; number of stocks	Barbosa & Fearnside (1999)
Sa	39.92	Cerrado	Same as Cerrado	Similar phytophysiognomy; geographic proximity; number of stocks	Paula et al. (1998); Scolforo et al. (2008a); Haidar et al. (2013)
Sd	49.76	Cerrado	Same as Cerrado (TO/MA/PI)	Similar phytophysiognomy; geographic proximity	Scolforo et al. (2008a); Morais et al. (2013)
Sg	18.49	Cerrado	Same as Cerrado	Similar phytophysiognomy; geographic proximity; number of stocks	Barbosa & Fearnside (2005);
Sp	17.61	Cerrado	Ottmar et al. (2001) (aboveground biomass, litter); Miranda et al. (2014) (belowground biomass)	Similar phytophysiognomy; number of stocks; occurrence in the phytophysiognomy	Barbosa & Fearnside (2005)
Ta	15.23	Caatinga	ALBUQUERQUE (2015) (all stocks)	In the phytophysiognomy in the biome; sample effort; number of stocks	Tiessen et al. (1998); Amorim et al. (2005); Accioly et al. (2008); Alves (2011); Sampaio & Costa (2011); Menezes et al. (2012); Souza et al. (2012); Cabral et al. (2013); Costa (2013); Mendonça et al. (2013)
Td	30.54	Caatinga	ALBUQUERQUE (2015) (all stocks)	In the phytophysiognomy in the biome; sample effort; number of stocks	Menezes et al. (2012); Souza et al. (2012); Cabral et al. (2013); Costa (2013)
Tg	4.63	Amazon	Barbosa & Fearnside (2005) (aboveground biomass, dead wood, litter); IPCC (2006) (belowground biomass)	In the phytophysiognomy, number of stocks	NA
Tp	10.06	Amazon	Barbosa & Fearnside (2005) (aboveground biomass, dead wood, litter); IPCC (2006) (belowground biomass)	In the phytophysiognomies, number of stocks	NA

Atlantic Forest Biome

The Atlantic Forest covers the Eastern Brazilian shelf. Due to its wide latitudinal extension, it covers a wide range of climate zones and has heterogeneous vegetation. The biome is composed of a mosaic of dense, open and mixed humid forests; deciduous and semideciduous seasonal forests; altitudes grasslands, mangroves and sandbanks.

The Submontane Semideciduous Seasonal Forest (Fs), the most representative of the biome, had its aboveground biomass estimated based on the work by Metzker et al. (2011), carried out in this phytophysiognomy in the state of Minas Gerais. On the other hand, the belowground biomass and the dead wood were estimated based on the IPCC default ratios (2003; 2006), while the ratio calculated from the data by Amaro et al. (2013) was used for litter, in Montane Semideciduous Seasonal Forest (Fm). The work by Amaro et al. (2013) was also used to estimate the total biomass of Fm, because the authors presented values for all stocks in this phytophysiognomy in the Atlantic Forest.

The average of the aboveground biomass values in Mature Riparian Semideciduous Forest of the Inventory of Minas Gerais (SCOLFORO et al., 2008c) was used for the Alluvial Semideciduous Seasonal Forest (Fa). The belowground biomass and dead wood were estimated according to default ratios of the IPCC (2003, 2006), while litter was estimated based on the ratio in a riparian mesophilic forest (MOREIRA-BURGER & DELITTI, 1999).

Values of Mature Semideciduous Seasonal Forest presented by Scolforo et al. (2008c) in the Inventory of the state of Minas Gerais were used for the Lowland Semideciduous Seasonal Forest (Fb), in the Atlantic Forest biome. The stocks of belowground biomass and dead wood were estimated based on the default values of the IPCC (2003, 2006), while litter was estimated by the ratio obtained from Amaro et al. (2003).

The Mixed Humid Forest or Araucaria Forest occurs mainly in the southern region of the country (states of Santa Catarina, Paraná and Rio Grande do Sul), in addition to São Paulo and Minas Gerais. For the Submontane Mixed High Humid Forests (Ms), Montana (Mm) and High Humid Forest (Ml), values of aboveground and belowground biomass as well as those regarding litter obtained by Watzwalick et al. (2012), in Paraná, were used. In order to estimate the dead wood, the ratio proposed by the IPCC (2003) was used.

For the fragments of Alluvial Mixed Humid Forest (Ma) in the states of Santa Catarina and Paraná, aboveground biomass and litter values were obtained from the study of Socher et al. (2008), also in the state of Paraná. In order to estimate the belowground biomass and the dead wood, IPCC ratios (2003, 2006) were used.

The Dense Humid Forest is a perennial forest, that is, evergreen, which occurs in virtually the entire length of the Atlantic Forest biome. For the Alluvial Dense Humid Forest (Da), the aboveground biomass values calculated by Britez et al. (2006) in Santa Catarina and Rio Grande do Sul were used. For the belowground biomass estimate, the ratio by Monkany et al. (2006) was used; for the dead wood, the IPCC ratio (2003) was applied; and for litter, the ratio obtained from the work by Socher et al. (2008) was used.

For the Lowland (Db), Submontane (Ds) and Montana (Dm) Dense Humid Forests, the studies by Alves et al. (2010) for the aboveground biomass were used; that of and Vieira et al. (2011) was applied for belowground biomass, dead wood and litter, carried out in the state of São Paulo. It is worth noting that values for each of these Dense Humid Forests (Db, Ds and Dm) are presented. For the High-Montane Dense Humid Forest (Dl), the value of aboveground biomass calculated by Britez et al. (2006) was used based on the work carried out in Paraná. In order to estimate the remaining stocks of Dl, the same proportions mentioned before for the Da phytophysiognomy were used.

For the Alluvial (Aa), the Lowland (Ab), the Montane (Am) and the Submontane (As) Open Humid Forests, whose fragments occur in the states of Minas Gerais, Espirito Santo, Pernambuco and Alagoas, a single value was chosen. The estimate of aboveground biomass was obtained from the average of seven values calculated using the individual density and average diameter in the equation developed by Brown (1997). The studies used were distributed in Rondônia, Pernambuco and Maranhão (SILVEIRA, 2009; FERRAZ & RODAL, 2006; GAMA et al. 2007). The other stocks were estimated according to the ratios by Mokany et al. (2006) for the belowground biomass; the IPCC ratio (2003) was used for dead wood; and those of Socher et al. (2008) were applied for litter.

For the Deciduous Seasonal Forest or Alluvial Broadleaved (Ca), found mainly in Rio Grande do Sul, the average of the aboveground biomass values of Mature Riparian Deciduous Forest presented in the Forest Inventory of Minas Gerais (SCOLFORO et al., 2008b) was used. The ratio proposed by the IPCC (2003, 2006) was used to incorporate the belowground biomass and dead wood; the ratio in Riparian Semideciduous Mesophilic Forest (MOREIRA-BURGER & DELITTI, 1999) was used for litter.

For the fragments of Low Land Deciduous Seasonal Forest (Cb), located in the state of Rio Grande do Norte, the same value of this phytophysiognomy within the Caatinga biome was adopted.

The values obtained from the work by Brun (2004), conducted in the state of Rio Grande do Sul, were used for the Montane (Cm) and Submontane (Cs) Deciduous Seasonal Forests, which mainly occur in Bahia and in the South and Southeast regions of the country. The author evaluates all stocks, except that of dead wood, which was estimated according to the IPCC ratio (2003).

The value for Wooded Steppe (Ea) was the same as that used for this phytophysiognomy in the Cerrado in the Forest Inventory of Minas Gerais (SCOLFORO et al., 2008a), a state where Ea occurs in the Atlantic Forest. For Woody Grass Steppe (Eg) the same value of this phytophysiognomy in the Pampa biome was chosen, since this phytophysiognomy occurs in the transition with the Atlantic Forest in Rio Grande do Sul.

The Vegetation with Fluvial and/or Lacustrine Influence (Pa), in the Atlantic Forest, present mainly forest structure and occur in the lowland areas of the rivers. Its aboveground biomass was estimated from the average of the values calculated by Britez et al. (2006), in Paraná. The other stocks were obtained from ratios for belowground biomass by Mokany et al. (2006); for dead wood, those by the IPCC (2003) were used; and for litter, those by Moreira-Burger & Delitti (1999) were applied.

For the pioneering formations of fluvial-marine influence (mangroves or Pf), the same value of carbon stock of the Amazon biome was used, which resulted from aboveground biomass according to Hutchison et al. (2013) for mangroves in Brazil.

The aboveground biomass value for pioneering formations of marine influence (Pm) was extracted from Alves et al. (2010), also published in Assis et al. (2011), for the sandbank vegetation of the state of São Paulo. For the belowground biomass, the IPCC ratio (2006) was used. For the value of dead wood, the value by Veiga (2010) was used, in the same study area of Alves et al. (2010) and Assis et al. (2011). Litter was estimated based on the decomposition equation (KRISTENSEN et al., 2008), the decomposition rate constant (PIRES et al., 2006) and the litter deposition value (ASSIS et al., 2011).

For the Montane (Rm) and Submontane (Rs) Refuges, the same value proposed for this phytophysiognomy in the Cerrado biome was used (OTTMAR et al., 2001), due to lack of information regarding the biomass for these phytophysiognomies and the biome itself. As for the High-Montana Refuge (Rl), values of aboveground biomass and litter of Clean Grasslands at altitudes above 1,000m submitted by Ottmar et al. (2001) were chosen, adding the belowground biomass based on the grassland vegetation ratio in the Cerrado (MIRANDA et al., 2014). Since it is a grassland vegetation, the stock of dead wood was not considered for this phytophysiognomy.

For the following typical phytophysiognomies of the Cerrado Forested (Sd), Wooded (Sa) and Woody Grass (Sg) Savannas occurring in the Atlantic Forest biome, the same values proposed for these phytophysiognomies in the Cerrado biome were adopted, since they occur mainly in transitional areas between them, especially in the state of Minas Gerais. For Sd, the value for the Cerrado was chosen in the States of Minas Gerais, Bahia and Distrito Federal (SCOLFORO et al., 2008a). For Park Savanna (Sp), Shrubby Field values in Goiás, Minas Gerais and Distrito Federal, according to Ottmar et al. (2011) were used, adding belowground biomass based on the ratio for grassland vegetation (MIRANDA et al., 2014), a stock that was not considered by the authors.

As Wooded Steppe (Ta) and Forested (Td) Savannas occur in the Northeast region, including in the state of Pernambuco, the same values for these phytophysiognomies in the Caatinga biome were used. For the Steppe Woody Grass Savanna (Tg), the value used for the Pampa was chosen, as this phytophysiognomy occurs within the limits with this biome.

Table A1.15 presents the total carbon stock values used for the phytophysiognomies of the Atlantic Forest biome, as well as references of where the values and expansion factors and ratios were extracted, biome of the aboveground biomass value, choice criteria and other works whose values were considered.

TABLE A1.15

Total carbon stock per area unit (t C/ha) of phytophysiognomies in the Atlantic Forest biome; biome of origin of the aboveground biomass estimate; sources used to generate total carbon stock; criteria used when choosing sources; other sources used

ABBRE-VIATION	TOTAL STOCK (t C/ha)	BIOME	SOURCE	CHOICE CRITERION	OTHER SOURCES USED
Aa	47.03	Atlantic Forest, Cerrado, Amazon	Silveira (2009); Ferraz & Rodal (2006); Gama et al. (2007) (aboveground biomass); Brown (1997) (allometric equation); Mokany et al. (2006) (belowground biomass); IPCC (2003) (dead wood); Socher et al. (2008) (litter)	Works in Open Humid Forest	NA
Ab	47.03	Atlantic Forest, Cerrado, Amazon	Silveira (2009); Ferraz & Rodal (2006); Gama et al. (2007) (aboveground biomass); Brown (1997) (allometric equation); Mokany et al. (2006) (roots); IPCC (2003) (dead wood); Socher et al. (2008) (litter)	Works in Open Humid Forest	NA
Am	47.03	Atlantic Forest, Cerrado, Amazon	Silveira (2009); Ferraz & Rodal (2006); Gama et al. (2007) (aboveground biomass); Brown (1997) (allometric equation); Mokany et al. (2006) (raízes); IPCC (2003) (dead wood); Socher et al. (2008) (litter)	Works in Open Humid Forest	NA

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ABBRE-VIATION	TOTAL STOCK (t C/ha)	BIOME	SOURCE	CHOICE CRITERION	OTHER SOURCES USED
As	47.03	Atlantic Forest, Cerrado, Amazon	Silveira (2009); Ferraz & Rodal (2006); Gama et al. (2007) (aboveground biomass); Brown (1997) (allometric equation); Mokany et al. (2006) (belowground biomass); IPCC (2003) (dead wood); Socher et al. (2008) (litter)	Works in Open Humid Forest	NA
Ca	121.76	Caatinga	Scolforo et al. (2008b) (aboveground biomass); IPCC (2006) (belowground biomass); IPCC (2003) (dead wood); Moreira-Burger and Delitti (1999) (litter)	Similar phytophysiognomy; sample effort	Scariot & Sevilha (2005); Pereira et al. (2011); Coelho et al. (2012)
Cb	62.7	Caatinga	Same as Caatinga	Similar phytophysiognomy; sample effort; next to Caatinga	Scariot & Sevilha (2005); Pereira et al. (2011); Coelho et al. (2012)
Cm	106.41	Atlantic Forest	Brun (2004) (aboveground biomass, belowground biomass, litter); IPCC (2003) (dead wood)	Similar phytophysiognomy in the biome; number of stocks	Scariot & Sevilha (2005); Scolforo et al. (2008b); Pereira et al. (2011); Coelho et al. (2012)
Cs	106.41	Atlantic Forest	Brun (2004) (aboveground biomass, belowground biomass, litter); IPCC (2003) (dead wood)	Similar phytophysiognomy in the biome; number of stocks	Scariot & Sevilha (2005); Scolforo et al. (2008b); Pereira et al. (2011); Coelho et al. (2012)
Da	173.83	Atlantic Forest	Britez et al. (2006) (aboveground biomass); Mokany et al. (2006) (belowground biomass); IPCC (2003) (dead wood); Socher et al. (2008) (litter)	In the phytophysiognomy in the biome	RADAMBRASIL; Tiepolo et al. (2002)
Db	128.42	Atlantic Forest	Alves et al. (2010) (aboveground biomass); Vieira et al. (2011) (belowground biomass, dead wood, litter)	In the phytophysiognomy in the biome; number of stocks	RADAMBRASIL; Tiepolo et al. (2002); Rolim et al. (2005); Britez et al. (2006); Assis et al. (2011); Sousa Neto et al. (2011)
Dl	105.53	Atlantic Forest	Britez et al. (2006) (aboveground biomass); Mokany et al. (2006) (belowground biomass); IPCC (2003) (dead wood); Socher et al. (2008) (litter)	In the phytophysiognomy in the biome	RADAMBRASIL
Dm	177.75	Atlantic Forest	Alves et al. (2010) (aboveground biomass); Vieira et al. (2011) (belowground biomass, dead wood, litter)	In the phytophysiognomy in the biome; number of stocks	RADAMBRASIL; Tiepolo et al. (2002); Britez et al. (2006); Cunha et al. (2009); Lindner and Sattler (2011); Sousa Neto et al. (2011)
Ds	151.42	Atlantic Forest	Alves et al. (2010) (aboveground biomass); Vieira et al. (2011) (belowground biomass, dead wood, litter)	In the phytophysiognomy in the biome; number of stocks	RADAMBRASIL; Tiepolo et al. (2002); Britez et al. (2006); Borgo (2010); Lindner and Sattler (2011); Sousa Neto et al. (2011)

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ABBRE-VIATION	TOTAL STOCK (t C/ha)	BIOME	SOURCE	CHOICE CRITERION	OTHER SOURCES USED
Ea	27.85	Cerrado	Same as Cerrado	In similar phytophysiognomy; próxima ao Cerrado	NA
Eg	2.12	Pampa	Same as Pampa	In the phytophysiognomy; next to Pampa	Oliveira et al. (2009)
Fa	75.89	Atlantic Forest	Scolforo et al. (2008c) (aboveground biomass); IPCC (2006) (belowground biomass); IPCC (2003) (dead wood); Moreira-Burger & Delitti (1999) (litter)	Similar phytophysiognomy; sample effort	Britez et al. (2006); Wittman et al. (2008); Haidar et al. (2013)
Fb	87.55	Atlantic Forest	Scolforo et al. (2008c) (aboveground biomass); IPCC (2006) (belowground biomass); IPCC (2003) (dead wood); Amaro et al. (2003) (litter)	Similar phytophysiognomy in the biome; sample effort	Britez et al. (2006); Nogueira et al. (2008)
Fm	106.88	Atlantic Forest	Amaro et al. (2003) (todos os reservatórios)	In the phytophysiognomy in the biome; number of stocks	Britez et al. (2006); Boina (2008); Scolforo et al. (2008c); Ribeiro et al. (2009); Haidar (2008); Françoso et al. (2013); Torres et al. (2013)
Fs	123.05	Atlantic Forest	Metzker et al. (2011) (aboveground biomass); IPCC (2006) (belowground biomass); IPCC (2003) (dead wood); Amaro et al. (2003) (litter)	In the phytophysiognomy in the biome	RADAMBRASIL; Britez et al. (2006); Scolforo et al. (2008c); Haidar (2008); Françoso et al. (2013);
Ma	123.21	Atlantic Forest	Socher et al. (2008) (aboveground biomass and litter); IPCC (2006) (belowground biomass); IPCC (2003) (dead wood)	In the phytophysiognomy in the biome	Britez et al. (2006)
Ml	142.66	Atlantic Forest	Watzlawick et al. (2012) (aboveground biomass, belowground biomass, litter); IPCC (2003) (dead wood)	Similar phytophysiognomy in the biome; number of stocks	Britez et al. (2006); Klauberg et al. (2010)
Mm	142.66	Atlantic Forest	Watzlawick et al. (2012) (aboveground biomass, belowground biomass, litter); IPCC (2003) (dead wood)	In the phytophysiognomy in the biome; number of stocks	Britez et al. (2006)
Ms	142.66	Atlantic Forest	Watzlawick et al. (2012) (aboveground biomass, litter); IPCC (2003) (dead wood)	Similar phytophysiognomy in the biome; number of stocks	Britez et al. (2006); Klauberg et al. (2010)

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ABBRE-VIATION	TOTAL STOCK (t C/ha)	BIOME	SOURCE	CHOICE CRITERION	OTHER SOURCES USED
Pa	105.38	Atlantic Forest	Britez et al. (2006) (aboveground biomass); Mokany et al. (2006) (belowground biomass); IPCC (2003) (dead wood); Moreira-Burger & Delitti (1999) (litter)	In the phytophysiognomy in the biome	Tiepolo et al. (2002)
Pf	117.2	Brasil	Hutchison et al. (2013) (aboveground and belowground biomass); Fernandes (1997) (dead wood); Ramos and Silva et al. (2007) (litter)	Review and modelling about mangroves, value for Brazil	Fromard et al. (1998); Silva et al. (1998); Cogliatti-Carvalho & Mattos-Fonseca (2004); Medeiros & Sampaio (2008); Santos (2013); Estrada et al. (2014)
Pm	130.7	Atlantic Forest	Alves et al. (2010) (aboveground biomass); IPCC (2006) (belowground biomass); Veiga (2010) (dead wood); Pires et al. (2006) (decomposition constant); Kristensen et al. (2008) (equation for the regression decomposition); Assis et al. (2011) (deposited litter)	Phytophysiognomy in the biome, number of stocks	Britez et al. (2006)
Rl	14.5	Cerrado	Ottmar et al. (2001) (aboveground biomass, litter); Miranda et al. (2014) (belowground biomass)	Similar phytophysiognomy	NA
Rm	18.49	Cerrado	Same as Cerrado	Similar phytophysiognomy	Barbosa & Fearnside (1999)
Rs	18.49	Cerrado	Same as Cerrado	Similar phytophysiognomy	NA
Sa	39.92	Cerrado	Same as Cerrado	In the phytophysiognomy; next to Cerrado; number of stocks	Scolforo et al. (2008a); Haidar et al. (2013)
Sd	52.42	Cerrado	Same as Cerrado (MG/GO/DF/BA)	In the phytophysiognomy; next to Cerrado; sample effort	Durigan (2004); Pinheiro (2007); Morais et al. (2013)
Sg	18.49	Cerrado	Same as Cerrado	In the phytophysiognomy; geographic coverage; number of stocks	Kauffman et al. (1994); Castro & Kauffman (1998); Barbosa & Fearnside (2005)
Sp	17.61	Cerrado	Ottmar et al. (2001) (aboveground biomass, litter); Miranda et al. (2014) (belowground biomass)	In the phytophysiognomy; next to Cerrado; number of stocks	Barbosa & Fearnside (2005)

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ABBRE-VIATION	TOTAL STOCK (t C/ha)	BIOME	SOURCE	CHOICE CRITERION	OTHER SOURCES USED
Ta	15.23	Caatinga	Same as Caatinga	In the phytophysiognomy; number of stocks; next to Caatinga	NA
Td	30.54	Caatinga	Same as Caatinga	In the phytophysiognomy; number of stocks; next to Caatinga	NA
Tg	12.6	Pampa	Same as Pampa	Similar phytophysiognomy; next to Pampa	NA

Pampa Biome

The Pampa biome occurs only in the state of Rio Grande do Sul in Brazil, besides the neighboring countries of Argentina and Uruguay. Temperate fields predominate in this biome, characterized by herbaceous vegetation, but there are also forest and shrub formations from mountains to plains.

Studies carried out on the Pampa biome and in the state of Rio Grande do Sul were given priority. In the absence of such studies, phytophysiognomies values in other biomes were used, preferably from the Atlantic Forest, adjacent to the Pampa. In this last case, values of similar phytophysiognomies were used, always as close as possible to the Brazilian Pampa.

For the Wooded Steppe (Ea), the values found for the Argentine Chaco (GASPARRI et al., 2008) were chosen. This work was chosen because an aboveground biomass value was not found for this phytophysiognomy in the Pampa biome itself and due to the geographic proximity and the structural resemblance to this phytophysiognomy. The ratios used by the authors to estimate the belowground biomass (IPCC, 2006), dead wood (IPCC, 2003) and litter (regional value) were kept because they were considered adequate. For the Wooded Steppe Savanna (Ta), the same values of Ea in the Pampa biome were chosen, also due to the lack of studies found in this phytophysiognomy.

For Woody Grass Steppe (Eg), aboveground and belowground biomass values in the Pampa biome in Rio Grande do Sul were used (FIDELIS et al., 2006). A value for dead wood was not estimated because this is a strictly herbaceous phytophysiognomy. For litter, a fixed value of a literature review presented in the book Grasses and Grasslands Ecology (COUPLAND, 1993 *apud* GIBSON, 2009, table 7.2) was used.

For the Alluvial (Ca), the Montane (Cm) and the Submontane (Cs) Deciduous Seasonal Forests; the Montane (Dm) and Submontane (Ds) Dense Humid Forests, as well as for the Submontane (Fs) and Montane (Fm) Semideciduous Seasonal Forests, the same values and correction factors of these phytophysiognomies for the Atlantic Forest were used.

For Lowland Semideciduous Seasonal Forest (Fb), we used the aboveground biomass and litter values accumulated in riparian semideciduous mesophilic forest (MOREIRA-BURGER & DELITTI, 1999), obtained in the Atlantic Forest biome. For the belowground biomass and dead wood, IPCC default ratios (2003, 2006) were used.

For the Forested Savanna (Sd), values of aboveground, belowground biomass, and litter for Savannah-like vegetation (*Cerradão*) in the Cerrado biome (MORAIS et al., 2013) were used. The IPCC ratio was used to estimate dead wood.

For the vegetation of fluvial and/or lacustrine influence (Pa), a review of pioneering formations of fluvial-marine influence (Pf) and pioneering formations of marine influence (Pm), works and management plans of protected areas on the coast and in the region of Lagoa dos Patos was carried out (KNAK, 1999; BRACK, 2006; DUARTE & BENCKE, 2006; JACOBI et al., 2013) along with a review of the scientific literature as well as of pictures of these vegetation in the Pampa biome. Those analyzes concluded that the structure of those vegetation covers is predominantly formed by grassland and swamps. As a result, values of the work carried out in *Spartina densiflora* Brongn swamp in Lagoa dos Patos, in Rio Grande do Sul, were adopted (CUNHA et al., 2005).

The Woody Grass Steppe Savanna (Tg) occurs to the West of the biome and in the borders of Argentina and Uruguay. For this grassland phytophysiognomy, the values of aboveground and belowground biomass, and litter in the Uruguayan grasslands, characterized by herbaceous vegetation in the Basin of Rio de La Plata, (PARUELO et al., 2010) were adopted. For the Woody-Grass Savanna (Sg), the same value used for Tg was adopted, due to the fact that the two phytophysiognomies are close to each other and are structurally similar (that is, strictly grassland).

Table A1.16 presents the total carbon stock values used for the phytophysiognomies of the Pampa biome, references to estimate total carbon stocks, biome of the aboveground biomass value, choice criteria and other sources used.

TABLE A1.16

Total carbon stock per area unit (t C/ha) of phytophysiognomies in the Pampa biome; biome of origin of the aboveground biomass estimate; sources used to generate total carbon stock; criteria used when choosing sources; and other sources used

ABBRE-VIATION	TOTAL STOCK (t C/ha)	BIOME	SOURCE	CHOICE CRITERION	OTHER SOURCES USED
Ca	121.76	Caatinga	Scolforo et, al. 2008b (aboveground biomass); IPCC, 2006 (belowground biomass); IPCC, 2003 (dead wood); Moreira-Burger & Delitti, 1999 (litter). Same as Atlantic Forest	Similar phytophysiognomy; sample effort	Scariot & Sevilha (2005); Pereira et al. (2011); Coelho et al. (2012)
Cm	106.41	Atlantic Forest	Brun, 2004 (aboveground and belowground biomass, litter); IPCC, 2003 (dead wood). Same as Atlantic Forest	Similar phytophysiognomy; next to Pampa in the state of RS; number of stocks	Scariot & Sevilha (2005); Vogel et al. (2006); Scolforo et al. (2008b); Pereira et al. (2011); Coelho et al. (2012)
Cs	106.41	Atlantic Forest	Brun, 2004 (aboveground and belowground biomass); IPCC, 2003 (dead wood). Same as Atlantic Forest	Similar phytophysiognomy; next to Pampa in the state of RS; number of stocks	Scariot & Sevilha (2005); Vogel et al. (2006); Scolforo et al. (2008b); Pereira et al. (2011); Coelho et al. (2012)

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ABBRE-VIATION	TOTAL STOCK (t C/ha)	BIOME	SOURCE	CHOICE CRITERION	OTHER SOURCES USED
Dm	177.75	Atlantic Forest	Same as Atlantic Forest	In the phytophysiognomy; number of stocks; bordering Atlantic Forest	Tiepolo et al., 2002; Britez et al., 2006; Cunha et al., 2009; Lindner & Sattler, 2011; Sousa Neto et al., 2011
Ds	151.42	Atlantic Forest	Same as Atlantic Forest	In the phytophysiognomy; number of stocks; bordering Atlantic Forest	Tiepolo et al., 2002; Britez et al., 2006; Cunha et al., 2009; Lindner & Sattler, 2011; Sousa Neto et al., 2011
Ea	55.74	Chaco argentino	Gasparri et al. (2008) (all stocks)	Similar phytophysiognomy	Manrique et al. (2009); fotos
Eg	2.12	Pampa	Fidelis et al. (2006) (aboveground and belowground biomass); Gibson (2009) (litter)	In the phytophysiognomy the biome	Oliveira et al. (2009)
Fb	86.08	Atlantic Forest	Moreira-Burger & Delitti (1999) (aboveground biomass and litter); IPCC (2006) (belowground biomass); IPCC (2003) (dead wood)	Similar phytophysiognomy; next to rivers	Britez et al., 2006; Scolforo et al. (2008c)
Fm	106.88	Atlantic Forest	Same as Atlantic Forest	In the phytophysiognomy; number of stocks	Britez et al. (2006); Boina (2008); Scolforo et al. (2008c); Ribeiro et al. (2009); Haidar (2008); Torres et al. (2013); Françoso et al. (2013)
Fs	123.05	Atlantic Forest	Same as Atlantic Forest	In the phytophysiognomy	Britez et al. (2006); Scolforo et al. (2008c); Haidar (2008); Françoso et al. (2013)
Mm	142.66	Atlantic Forest	Same as Atlantic Forest	In the phytophysiognomy; number of stocks	NABritez et al., 2006
Pa	12.57	Pampa	Cunha et al. (2005) (all stocks)	In the phytophysiognomy the biome; predominant herbaceous vegetation	Knak, 1999; Brack, 2006; Duarte & Bencke, 2006; Jacobi et al., 2013; fotos
Pf	12.57	Pampa	Cunha et al. (2005) (all stocks)	Similar phytophysiognomy, predominant herbaceous vegetation	Knak, 1999; Brack, 2006; Duarte & Bencke, 2006; Jacobi et al., 2013; pictures Hutchison et al., 2013
Pm	12.57	Pampa	Cunha et al. (2005) (all stocks)	Similar phytophysiognomy, predominant herbaceous vegetation	Knak, 1999; Brack, 2006; Duarte & Bencke, 2006; pictures Jacobi et al., 2013
Sd	49.96	Atlantic Forest	Morais et al. (2013) (aboveground and belowground biomass; litter); IPCC (2003)	In the phytophysiognomy; number of stocks	Durigan, 2004; Pinheiro, 2008; Scolforo et al., 2008a; Miranda et al., 2014
Sg	12.6	Uruguayan Pampa	Paruelo et al., 2010 (all stocks) Same as Tg in Pampa	Similar phytophysiognomy; next to Tg	Ottmar et al. (2011)

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ABBRE-VIATION	TOTAL STOCK (t C/ha)	BIOME	SOURCE	CHOICE CRITERION	OTHER SOURCES USED
Ta	55.74	Argentinean Chaco	Gasparri et al., 2008 (all stocks) Same as Ea in Pampa	Similar phytophysiognomy; climate zone	Manrique et al. (2009); fotos
Tg	12.6	Pampa uruguaio	Paruelo et al. (2010) (all stocks)	Similar phytophysiognomy; geographic proximity; review article	Caña et al. (2013)

Pantanal Biome

In addition to the aquatic-influenced vegetation (river-flood) a large vegetation mosaic with forest, savannah and grassland formations represents the Pantanal biome. These vegetal formations are also bordered by the Chaco to the south, the Amazon to the north, the Atlantic Forest and the Cerrado to the south and east of the biome. Thus, the biomass values of the Pantanal vegetation were obtained from data collected in the field and literature references preferably in the biome itself and, when this was not possible, references of the neighboring biomes were used, such as the Amazon, Cerrado and Atlantic Forest.

The data collected in the field in these phytophysiognomies in the Pantanal were used for the Wooded (Sa) and Forested (Sd) Savannas, from projects carried out in a partnership between EMBRAPA and PROBIO, developed from 1997 to 2005 (SILVA, J. V. S.[23]). After a survey of allometric equations to estimate the aboveground biomass in the Cerrado (ex.: DELITTI et al., 2006; REZENDE et al., 2006; SALIS et al., 2004; PINHEIRO, 2007), the ones used by Pinheiro (2007) were chosen, according to Melo et al. (2007) for stricto sensu Cerrado and Cerradão. In these equations the quadratic diameter and the height of trees with diameter at breast height (DBH) greater or equal to 10cm were considered. For the Wooded (Sa) and Forested Savana (Sd), 18 and 24 5x20cm plots distributed in the biome were used, respectively. For the belowground biomass, ratios of savannas and forests in the Cerrado by Miranda et al. (2014) for Sa and Sd, respectively, were used. For Sa the ratio for dead wood and litter in Dense, Typical and Shallow Cerrado, according to the data by Ottmar et al. (2001), were used. For Sd IPCC default ratios (2003) for dead wood were used; and for litter, data according to Cerradão by Morais et al. (2013).

The Park Savanna (Sp) in the Pantanal includes the *paratudal, canjiqueiral, lixeiral, campo sujo, cerrado de pantanal, and campo de murundus* vegetation (IBGE, 2012). The aboveground woody biomass was calculated from the equation of Delitti et al. (2006) with the data collected by Haidar et al. (2013) in Park Savannah in Tocantins (in 10 wetland areas of Bananal Island region) of trees with 30cm diameter and higher than 5cm from the ground. Added to this value, the aboveground herbaceous biomass average in Shallow Cerrado, according to Ottmar et al. 2001. For the belowground biomass the ratio of savanna vegetation was adopted, according to Miranda et al. (2014). For dead wood and litter the ratios in Shallow Cerrado were chosen, according to Ottmar et al. (2001).

23 SILVA, J. V. S. (National Center for Technological Research on Agricultural Information, Brazilian Agricultural Research Corporation, EMBRAPA, Campinas). Personal communication, 2014.

Given that the Woody Grass Savanna (Sg) is a strictly grassland vegetation, the same total carbon stock value of this phytophysiognomy in the Cerrado biome was considered.

The steppe savannas are concentrated in the southern Pantanal, in the state of Mato Grosso do Sul (SILVA & CAPUTO, 2010). For Forested Steppe Savanna (Td) the average of the aboveground biomass values of the work by Padilha (2011), conducted in this phytophysiognomy, was used. For the calculation of the belowground biomass the ratio of the forest physiognomies in the Cerrado was used (MIRANDA et al., 2014), for dead wood the IPCC default ratio (2003) was used, and for litter the ratio in Cerradão (MORAIS et al., 2013) was used. For the Wooded (Ta or *Chaco*), Park (Tp, *Carandazal or Paratudal*) and Woody Grass (Tg) Steppe Savannas, regional biomass values for the Pantanal were not found, so the same values of these phytophysiognomies of the Amazon biome were used.

The Vegetation with Fluvial and/or Lacustre Influence (Pa) corresponds to plant communities that occur in the wetlands seasonally flooded in the Pantanal. One of the communities that predominate in these plains is the *Cambarazal*, characterized by a vegetation dominated by *Cambara* tree species (*Vochysia divergens* Pohl). As a result, the aboveground biomass was calculated based on the average of four succession stages of *Cambarazal* in the Pantanal, presented by Schongart et al. (2011). The belowground biomass was estimated by the ratio calculated from Stape et al. (2011) in open *Cambarazal*, also in the Pantanal. For the estimate of dead wood the IPCC default ratio (2003) was adopted, and for litter the ratio in riparian semideciduous mesophilic forest was used (MOREIRA-BURGER & DELITTI, 1999).

For the aboveground biomass of the Alluvial Deciduous Seasonal Forest (Ca) the average values of the dry matter weight of trees in Mature Riparian Deciduous Forest was used (SCOLFORO et al., 2008b). For the Lowland (Cb) and Submontane (Cs) Deciduous Seasonal Forests, the aboveground biomass was estimated based on the application of Brown's allometric equation (1997, equation 3.2.1), calculated based on the mean basal area and density of individuals (CBH > 15cm), presented by Lima et al. (2009) in these phytophysiognomies of the Pantanal. For the calculation of the belowground biomass and dead wood of these phytophysiognomies, the IPCC default values (2003, 2006) were used. For litter, ratios in Cerradao were used (MORAIS et al., 2013) for Cb and Cs, and mesophilic forests riparian deciduous forest (MOREIRA-BURGER & DELITTI, 1999) for Ca.

For the Alluvial Semideciduous Seasonal Forest (Fa), the aboveground biomass value in flooded seasonal riparian forest in the Pantanal by Wittman al. (2008) was used. For the calculation of the belowground biomass and dead wood, the IPCC default values (2003, 2006) were used. For litter, the ratio in riparian semideciduous mesophilic forest (MOREIRA-BURGER & DELITTI, 1999) was used.

For Submontane Semideciduous Seasonal Forest (Fs), the same values of this phytophysiognomy in the Atlantic Forest biome were adopted. For the Lowland Semideciduous Seasonal Forest (Fb), the values of the carbon stock of this phytophysiognomy in the Amazon biome were used due to its location at northern Pantanal.

Table A1.17 presents the total carbon stock values used for the phytophysiognomies of the Pantanal biome, references of where the values, expansion factors and ratios were taken from, the biome of the aboveground biomass, choice criteria and other sources used.

TABLE A1.17

Total carbon stock per area unit (t C/ha) of phytophysiognomies in the Pantanal biome; biome of origin of the aboveground biomass estimate; sources used to generate total carbon stock; criteria used when choosing sources; and other sources used

ABBRE-VIATION	TOTAL STOCK (t C/ha)	BIOME	SOURCE	CHOICE CRITERION	OTHER SOURCES USED
Ca	121.76	Caatinga	Same as Atlantic Forest	Similar phytophysiognomy	Scariot & Sevilha (2005); Pereira et al. (2011); Coelho et al. (2012)
Cb	105.11	Pantanal	Lima et al. (2009) (aboveground biomass); Brown (1997) (allometric equation); IPCC (2006) (belowground biomass); IPCC (2003) (dead wood); Morais et al. (2013) (litter)	In the biome phytophysiognomy	Scariot 7 Sevilha (2005); Scolforo et al. (2008b); Pereira et al. (2011); Coelho et al. (2012)
Cs	127.83	Pantanal	Lima et al. (2009); Brown (1997) (allometric equation); IPCC (2006) (belowground biomass); IPCC (2003) (dead wood); Morais et al. (2013) (litter)	In the biome phytophysiognomy	Scariot & Sevilha (2005); Scolforo et al. (2008b); Pereira et al. (2011); Coelho et al. (2012)
Fa	167.52	Pantanal	Wittman et al. (2008) (aboveground biomass); IPCC (2006) (belowground biomass); IPCC (2003) (dead wood); Moreira-Burger & Delitti (1999) (litter)	Values in similar phytophysiognomy	Paula et al. (1990, 1993); Imanã-Encinas et al. (1995); Haidar et al. (2013)
Fb	145.37	Amazon	Same as Amazon	In the phytophysiognomy; next to the Amazon	Moreira-Burger & Delitti (1999)
Fs	123.05	Atlantic Forest	Same as Atlantic Forest	In the phytophysiognomy	Scolforo et al. (2008c); Haidar (2008); Françoso et al. (2013)
Pa	81.60	Pantanal	Schongart et al. (2011) (aboveground biomass); Stape et al. (2011) (belowground biomass); IPCC (2003) (dead wood); Moreira-Burger & Delitti (1999) (litter)	In the biome phytophysiognomy, predominant vegetation	Ottmar et al. (2001); Bahia et al. (2009); Fidelis et al. (2013)
Sa	55.92	Pantanal	EMBRAPA/PROBIO (aboveground biomass); Melo et al. (2007) em Pinheiro (2008) (allometric equation); Miranda et al. (2014) (belowground biomass); Ottmar et al. (2001) (dead wood and litter)	In the biome phytophysiognomy; geographic coverage	Salis et al. (2004); Fernandes et al. (2008); Scolforo et al. (2008a); Stape et al. (2011)
Sd	103.45	Pantanal	EMBRAPA/PROBIO (aboveground biomass); Melo et al. (2007) in Pinheiro (2008) (allometric equation); Miranda et al. (2014) (roots); IPCC (2003) (dead wood); Morais et al. (2013) (litter)	In the biome phytophysiognomy; geographic coverage	Salis et al. (2004); Fernandes et al. (2008); Scolforo et al. (2008a)
Sg	18.49	Cerrado	Same as Cerrado	Same phytophysiognomy	Kauffman et al. (1994); Castro & Kauffman (1998); Cardoso et al. (2000, 2003); Barbosa and Fearnside (2005)

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ABBRE-VIATION	TOTAL STOCK (t C/ha)	BIOME	SOURCE	CHOICE CRITERION	OTHER SOURCES USED
Sp	31.68	Cerrado	Haidar et al., 2013 (woody aboveground biomass); Delitti et al. (2006) (allometric equation); Miranda et al. (2014) (belowground biomass); Ottmar et al. (2001) (herbaceous biomass, dead wood and litter)	Phytophysionomy and structure of similar vegetation	Stape et al. (2011)
Ta	11.96	Amazon	Same as Amazon	Same phytophysiognomy	Bonino (2006); Fearnside et al. (2009); Silva & Caputo (2010)
Td	99.32	Pantanal	Padilha (2011) (aboveground biomass); Miranda et al. (2014) (belowground biomass); IPCC (2003) (dead wood); Morais et al. (2013) (litter)	Values in the phytophysiognomy in the biome	Barbosa & Fearnside (1999); Bonino (2006); Fearnside et al. (2009)
Tg	5.27	Amazon	Same as Amazon	Same phytophysiognomy	Silva & Caputo (2010); Fearnside et al. (2009)
Tp	11.45	Amazon	Same as Amazon	Same phytophysiognomy	Silva & Caputo (2010); Fearnside et al. (2009)

1.1.5. Definition of the emission factors and other parameters needed to estimate emissions and removals of CO_2

This section presents the specific values adopted for other parameters in the equations used to estimate changes in carbon stock from 2002-2010, including, exceptionally for the Amazon, the year 2005. Whenever possible, country specific values were used instead of the default values (Tier 1) from the 2003 and 2006 Good Practice Guidance of the IPCC.

Annual removal of carbon in managed areas

For the annual removal of carbon in managed forest areas, different values were adopted for the biomes (Table A1.18). However, this regionalization was not possible for the managed grasslands vegetation due to the absence of literature references per biome.

The annual total increment value of 0.52 t C/ha year for managed grassland areas in all biomes was chosen. This value was derived from the aboveground biomass in cerrado grassland with three years without burning (CIANCIARUSO et al., 2010) and includes the increase of belowground biomass from a conservative ratio of 20% on the aboveground increment (IPCC, 2006).

For the Amazon biome, the total annual increment used for managed forest areas was 0.34 t C/ha year, which is the average of 25 values for the Brazilian Amazon (BAKER et al., 2004). The average values of the belowground biomass ratio for the dense and open forest in the Amazon for the 25.8% aboveground increment (NOGUEIRA et al., 2008) were considered. Consequently, the total annual increment used for the managed forest in the Amazon biome was 0.43 t C/ha.

For the Cerrado biome, the average of the two highest and lowest values was chosen (0.1 to 0.3 t C/ha year) in a flux tower of CO_2 in Forested Savanna for this biome (ROCHA et al., 2002), reaching an incremental value of 0.2 t C/ha year. These towers vary in carbon flux in all the stocks on which this element is part, and it is not necessary to add a ratio for the belowground biomass in this case.

In the Atlantic Forest, the total annual increment value for aboveground biomass (0.27 t C/ha), found in this biome (SCARANELLO, 2010), was used. A ratio of 20% of the belowground biomass increment (IPCC, 2006) was chosen, resulting in a total increment of 0.32 t C/ha for the managed forest areas for this biome.

Annual increment values of primary vegetation to the Caatinga biome were not found. Based on consultation with an expert researcher (PAREYN, 2014), a minimum value for Cerrado was chosen, that is, an annual increment of 0.1 t C/ha.

For the Pantanal biome, annual increment values of primary forest vegetation were not found. Due to the proximity and large area occupied by phytophysiognomies that are typical of the Cerrado, an increment value was chosen. Thus, the increment value of total annual carbon for the managed forest vegetation in the Pantanal was 0.2 t C/ha.

In the Pampa biome, due to the proximity to the Atlantic Forest biome and the lack of regional information, the same value adopted for the total increment of the Atlantic Forest was used, resulting in a value of 0.32 t C/ha per year.

A Table A1.18 presents a summary of the values adopted for annual carbon increment of the managed forest vegetation of the Brazilian biomes and, when necessary, the ratio to add the belowground increment, in addition to the respective references used.

TABLE A1.18

Annual aboveground and belowground biomass increment (t C/ha) of managed primary forest vegetation per biome, percentage of belowground increment in relation to that of aboveground, and references used

BIOME	ABOVEGROUND BIOMASS INCREMENT (t C/ha)	RATIO (%) (BELOWGROUND BIOMASS INCREMENT)	TOTAL INCREMENT (t C/ha)	REFERENCE
Amazon	0.34	25.8	0.43	Baker et al. (2004); Nogueira et al. (2008)
Cerrado			0.2	Rocha et al. (2002)
Atlantic Forest	0.30	20	0.32	Scaranello (2010); IPCC (2006)
Caatinga			0.1	Rocha et al. (2002)
Pantanal			0.2	Same as Cerrado
Pampa	0.30	20	0.32	Same as Atlantic Forest

Average annual carbon removal in secondary vegetation areas

A decision was made to regionalize by biome, whenever possible, the values for annual increment of secondary vegetation. In addition, distinct historical uses that preceded the secondary vegetation formation (pasture, agriculture and other uses) were also sought. Besides that, the estimates of carbon stock changes were included for secondary forests with a history of having been forest (primary or secondary forest vegetation and reforestation.

1) Secondary vegetation developed from previous forest areas

The regionalization was possible only in the secondary forest vegetation (Table A1.19), a single value for Brazil for the secondary grassland vegetation was adopted. The total annual increment value for the grassland secondary vegetation was 0.52 t C/ha (CIANCIARUSO et al., 2010), the same value for managed fields.

For the secondary forest vegetation in the Amazon biome, the aboveground increment value was 3.94 t C/ha per year (ALVES et al., 1997), with a correction factor for the belowground biomass of 25.8% (NOGUEIRA et al., 2008) over this increment. As a result, the total incremental annual value for the secondary forests in the Amazon was 4.96 t C/ha.

For the Cerrado biome, the aboveground increment value for the secondary vegetation obtained in this biome was 1.41 t C/ha per year (DURIGAN, 2004), with a ratio for belowground biomass of 22% over this increment (MIRANDA et al., 2014) and an application of 47% to convert biomass into carbon stock. As a result, the total incremental annual value for the secondary forests in Cerrado was 1.72 t C/ha.

For the Atlantic Forest biome, an annual aboveground increment value of 4.46 t C/ha for the secondary vegetation obtained in this biome (MELO & DURIGAN, 2006) was adopted, with a ratio for the belowground biomass of 20% over aboveground biomass (IPCC, 2006), resulting in a total incremental value of 5.35 t C/ha per year.

For the Caatinga biome, the aboveground increment value for the secondary vegetation obtained in this biome (0.47 t C/ha per year) (PAREYIN, 2014; GARIGLIO et al., 2010; ISAIA et al., 1992) was adopted, with a ratio for the belowground biomass of 27% over native vegetation under regeneration in this same biome, according to Costa et al. (2014). As a result, the total incremental annual value for the secondary forests in Caatinga was 0.6 t C/ha.

For the secondary forest vegetation of the Pampa biome, the aboveground increment value of 1.4 t C/ha was adopted, with a ratio for the belowground biomass of 26% over aboveground biomass, based on a study carried out in the state of Rio Grande do Sul (BRUN, 2004). As a result, the total incremental annual value for the Pampa biome was 1.76 t C/ha.

For the Pantanal biome, the aboveground increment value for the secondary vegetation obtained in this biome was 2.25 t C/ha. This value was calculated based on the secondary vegetation *Cambarazal* (*Vochysia divergens*) on this biome (SCHONGART et al., 2011). The ratio of 23% of this value was used for the belowground biomass, based on a study of Stape et al. (2011), also on the *Cambarazal* in Pantanal. As a result, the total incremental annual value is 2.77 t C/ha for this biome.

TABLE A1.19

Average annual increment of carbon stocks in living biomass in secondary forest vegetation areas per biome; annual average increment of carbon stock of aboveground biomass; ratio of belowground biomass for the aboveground biomass; and respective literature reference

BIOME	ABOVEGROUND BIOMASS INCREMENT t C/ha	REFERENCE USED FOR ABOVEGROUND BIOMASS INCREMENT	RATIO A:B (%)	REFERENCE USED FOR RATIO A:B	TOTAL INCREMENT t C/ha
Amazon	3.94	Alves et al. (1997)	25.8	Nogueira (2008)	4.96
Cerrado	1.41	Durigan (2004)	22	Miranda et al. (2014)	1.72
Atlantic Forest	4.46	Melo and Durigan (2006)	20	IPCC (2006)	5.35
Caatinga	0.47	Gariglio et al. (2010); Isaia et al. (1992)	27	Costa et al. (2014)	0.60
Pantanal	2.25	Schongart et al. (2011)	23	Stape et al. (2011)	2.77
Pampa	1.4	Brun (2004)	26	Brun (2004)	1.76

2) Secondary vegetation developed from planted pasture areas

The value used for the annual increment of secondary vegetation developed from planted pasture areas was 2.85 t C/ha for all the biomes. This value was calculated from an average for secondary vegetation as planted pasture up to 10 years of age in the Amazon (FELDPAUSCH et al., 2007), and with the addition of 20% for root increment (IPCC, 2006).

3) Secondary vegetation developed from agricultural areas

The value adopted for the total annual increment of secondary vegetation developed from agricultural areas was 4.73 t C/ha for all biomes. This value results from an average of secondary vegetation values between 2-to-9-years of age developed from diversified crops (ALVES et al., 1997), with the addition of 20% for the increment in belowground biomass (IPCC, 2006).

4) Secondary vegetation with other land-use history

Open-pit mining was considered as other land-use history. The total annual increment to secondary forest vegetation developed from mining areas was 0.59 t C/ha for all biomes. This value was calculated from the density of individuals per hectare and the diameter at breast height (DBH) of a mining area under 9-years recovery (SALOMÃO et al., 2007), with application of the Brown equation (BROWN, 1997), adding 20% to the aboveground increment based on the ratio for belowground biomass (IPCC, 2006).

Annual carbon removal in forest areas submitted to selective logging

The annual increment value adopted for forest vegetation where selective logging occurred was 0.02% (HUANG & ASNER, 2010) in relation to the remaining carbon stock after logging. This was only applied to the Amazon biome.

Average carbon stock in secondary vegetation areas

The average carbon stock in secondary vegetation areas was obtained based on the mean values found in the Amazon (FEARNSIDE & GUIMARAES, 1996; ALVES et al., 1997), Atlantic Forest (MELO & DURIGAN, 2006) and Pantanal biomes (SCHONGART et al., 2011), for secondary forest vegetation at different ages. This resulted in an average carbon stock value of 44% of the primary vegetation (managed and unmanaged forest) for the secondary vegetation in all Brazilian biomes.

Carbon loss in forest area submitted to selective logging

The average carbon loss value of 29% was adopted (HUANG & ASNER, 2010) in relation to the total carbon stock of the phytophysiognomy when a forest area is submitted to selective logging in the Amazon.

Carbon stock and removal in reforestation area

For the reforestations with Eucalyptus spp. the value of 44 m^3/ha/yr for average mean increment was adopted (BRACELPA, 2014), corresponding to an increment value of living biomass of 14.24 t C/ha/year. The density of wood and the canopy/trunk and root/trunk ratio were considered to include the carbon contained in the trunk, canopy and roots of the plants, using an allometric equation (IPCC, 2003). For the calculation of the average carbon of a reforestation area, a seven-year cycle between the cuts, resulting in the average stock value of 49.83 t C/ha, was considered.

For the reforestations with *Pinus spp.* the value of 38 m^3/ha/yr was adopted of average increment (BRACELPA, 2014), corresponding to an increment value of 11.60 t C/ha/year. The density of wood and the canopy/trunk and root/trunk ratios were considered to include the carbon contained in the trunk, canopy and roots of the plants, using an allometric equation (IPCC, 2003). A 15-year cycle was considered between the cuts for the calculation of the average carbon, resulting in the average stock value of 87.03 t C/ha.

Average carbon stock in planted pasture areas

The carbon stock in the living biomass of non-shrubby planted pasture was estimated with the IPCC default values (2003) (Table 3.4.9, page 3.125), adapting them to the different climate zones associated with the biomes and adopting the value of 0.47 t C/t m.s. For the Pampa biome a value of 6.35 t C/ha was adopted because it is associated with a humid temperate region. For the Caatinga the adopted value (4.09 t C/ha) refers to a dry tropical region. For the other biomes, the value of 7.57 t C/ha was adopted, because it is associated with tropical humid region.

Carbon stock in agricultural areas

For the perennial crops in agricultural areas that remain as agricultural areas, the carbon stock was IPCC's default value of table 3.3.2 (IPCC, 2003), with climatic zone differentiations associated with each biome considered. Except for the Caatinga, all the biomes were attributed the value of tropical wet zones (21 t C/ha).

For Caatinga the default value of 9 t C/ha was considered, associated with dry tropical zones. The average annual increment for the aboveground biomass in areas with perennial crops were based on the IPCC's default values (IPCC, 2003), presented in Table 3.3.2, consistently to the one used to generate the abovementioned stock estimates. As a consequence, the value of 1.8 t C/ha/year was used for the Caatinga, 2.6 t C/ha/year for other biomes.

For annual agriculture areas the value of 5 t C/ha was adopted for the carbon stock as recommended in the IPCC (2003).

Carbon stock in the biomass in reservoirs, settlements and other land

A carbon value of zero is assumed for biomass in reservoir areas (Res), settlements (S) and other land (O).

Soil carbon alteration factor

The carbon change factors due to land use (f_{LU}), management regime (f_{MG}) and additions (f_I), were chosen from the default values in the Good Practice Guidance (IPCC, 2003), and are shown in Table A1.20.

TABLE A1.20

Carbon change factors due to land-use change

LAND USE	f_{LU}	f_{MG}	f_I	f_C
FNM	1	-	-	1
FM	1	-	-	1
FSec	1	-	-	1
Ref [1]	0.58	1.16	1	0.673
CS	1	-	-	1
GNM	1	-	-	1
GM	1	-	-	1
GSec	1	-	-	1
Ap[2]	1	0.97	1	0.97
Ac[1]	0.58	1.16	0.91	0.612
S	0	-	-	0
A	0	-	-	0
Res	0	-	-	0
O	0	-	-	0

[1]*Good Practice Guidance LULUCF (IPCC, 2003), Table 3.3.4.*
[2]*Good Practice Guidance LULUCF (IPCC, 2003), Table 3.4.5.*

APPENDIX II

FIRES NOT ASSOCIATED WITH DEFORESTATION

APPENDIX II

FIRES NOT ASSOCIATED WITH DEFORESTATION

Fire scars for the year 2010 were mapped in the Amazon, Cerrado, and Caatinga biomes with a view to evaluating, in the next inventories, greenhouse gas emissions from fires not associated with deforestation.

Despite the fact that these fires are not associated with deforestation, proximity with anthropogenic activities (for example, roads, settlements, selective logging, previous fires) may facilitate the occurrence of fires (ALENCAR et al., 2004).

For the purpose of this mapping, the biomes were considered in all their extent. Fires scars from vegetal biomass combustion were identified by visual interpretation of the same satellite images (mostly TM/Landsat-5 images) used for the mapping of land use and cover of 2010. Exclusively for the Cerrado biome, heat spots detections by NOAA satellites (12, 15, 16, 17, 18 and 19), AQUA, TERRA, ERS-2, GOES (10 and 12) and MSG-02, equipped with different sensors, were used.

Fire scars, or even the active heat spots, were mapped at a 1:125,000 scale. Only natural fires were considered (FNM, FM, GNM and GM), that is, only those occurring outside previously-mapped polygons with some anthropogenic use, according to item 6.1.1.2. It is important to point out that burned areas whose formats are regular and located around areas previously-mapped as anthropogenic (mostly pastures or agriculture) were considered as fires associated with deforestation, and therefore, have been mapped according to the use attributed to the region. On the other hand, burned areas with an irregular format, whose location did not allow a land-use attribution or where the scar showed that fires went out of control (accidental fires) have been mapped at fires not associated with deforestation.

It is important to highlight that the same satellite images used for the inventory of the LULUCF sector cover, mostly, the period from June to October 2010 (representing 77% of the images in the Amazon biome, 73% of the images in the Cerrado biome and 43% of the images in the Caatinga). Fires after the day the images were collected were not taken into account. Other images dating back from 2009 might have been considered in the 2010 survey.

The final result was a digital map, with representation off ire scars per biome at a 1:250,000 scale. Products may be checked, by biome, in Figures A2.1, A2.2 and A2.3. Quantifications of burned areas by state and biome are show in Figure A2.4 and Tables A2.1, A2.2 and A2.3.

FIGURE A2.1

Distribution of fire scars mapped in 2010 in the Amazon biome

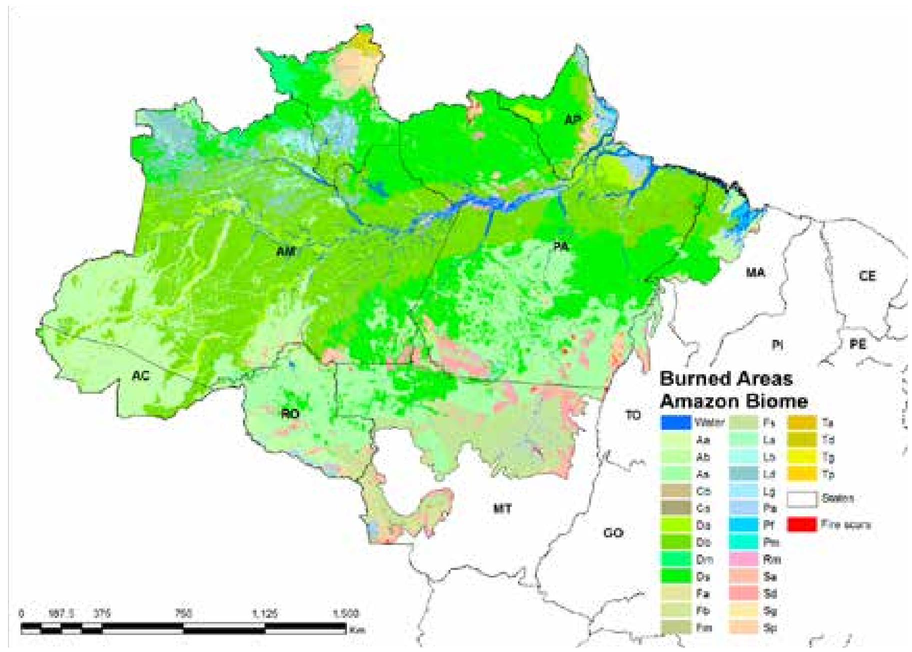

FIGURE A2.2

Distribution of fire scars mapped in 2010 in the Cerrado biome

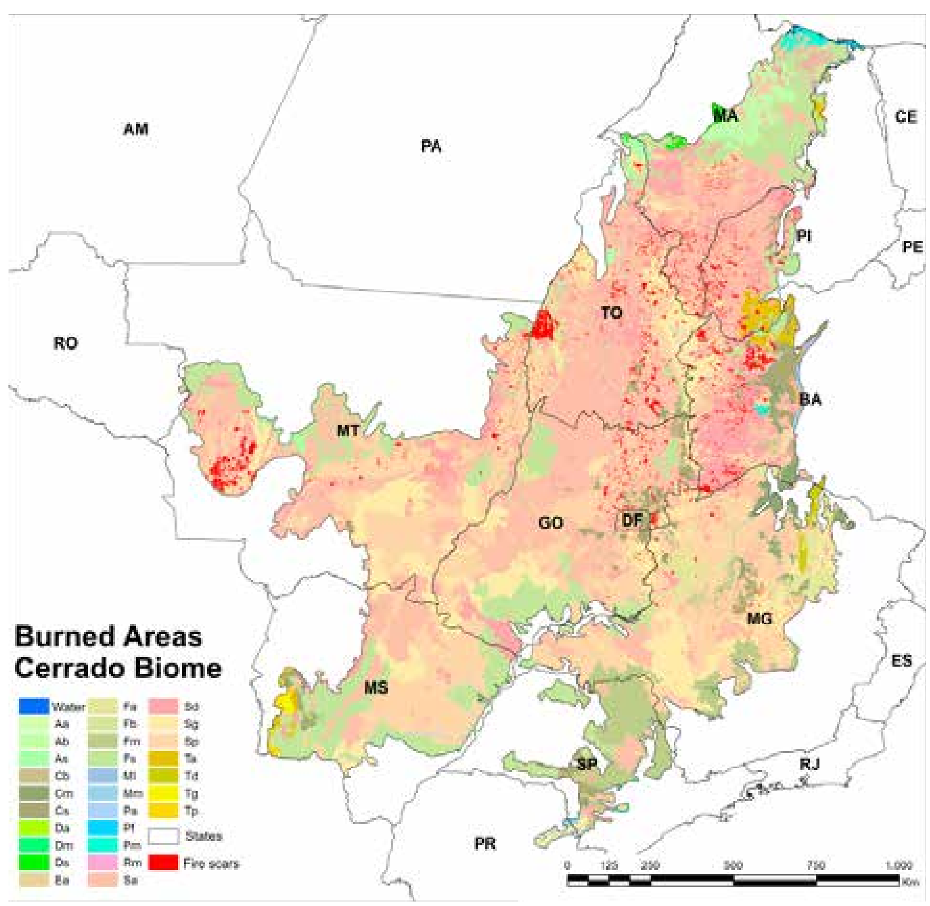

FIGURE A2.3

Distribution of fire scars mapped in 2010 in the Caatinga biome

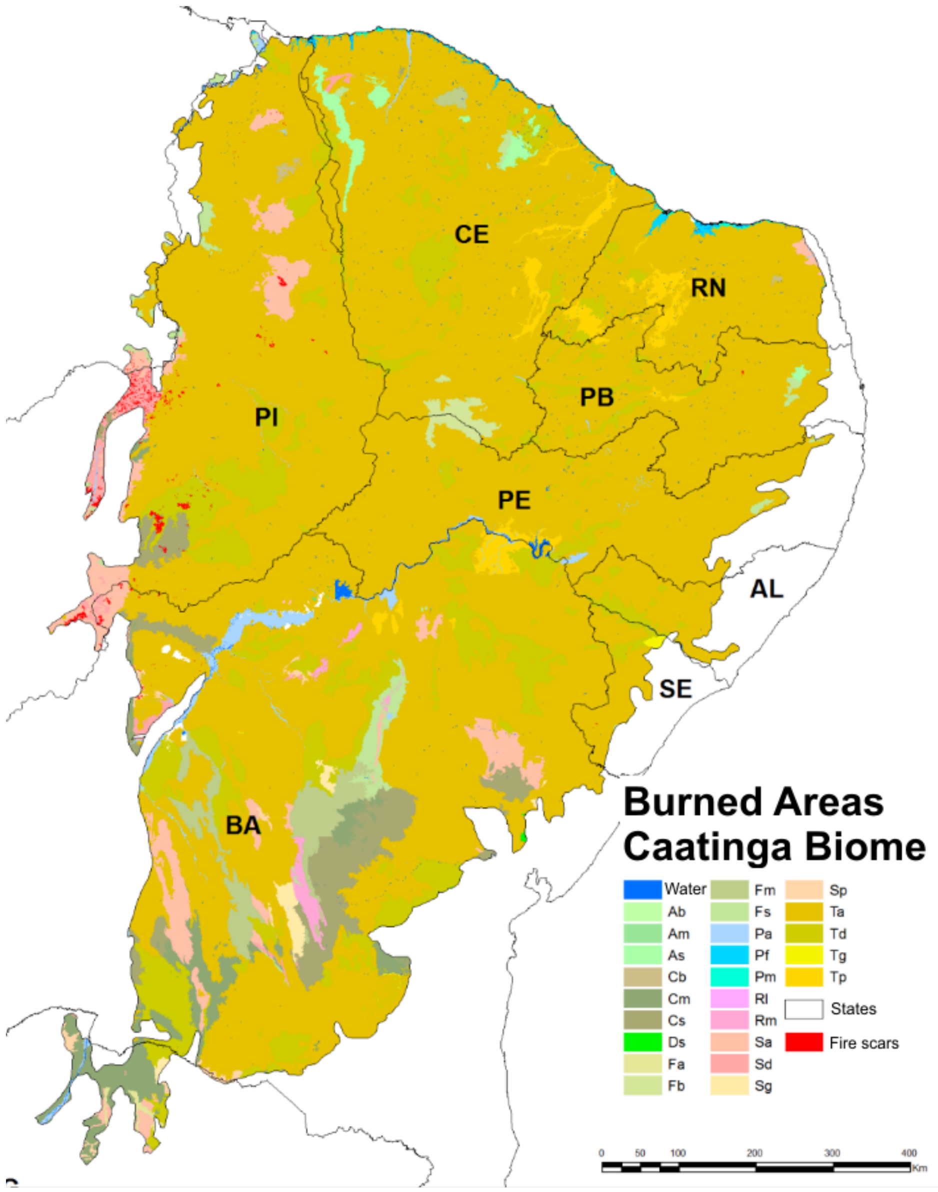

FIGURE A2.4

Quantification of burned areas by state in the Amazon (a), Cerrado (b) and Caatinga (c) biomes in 2010

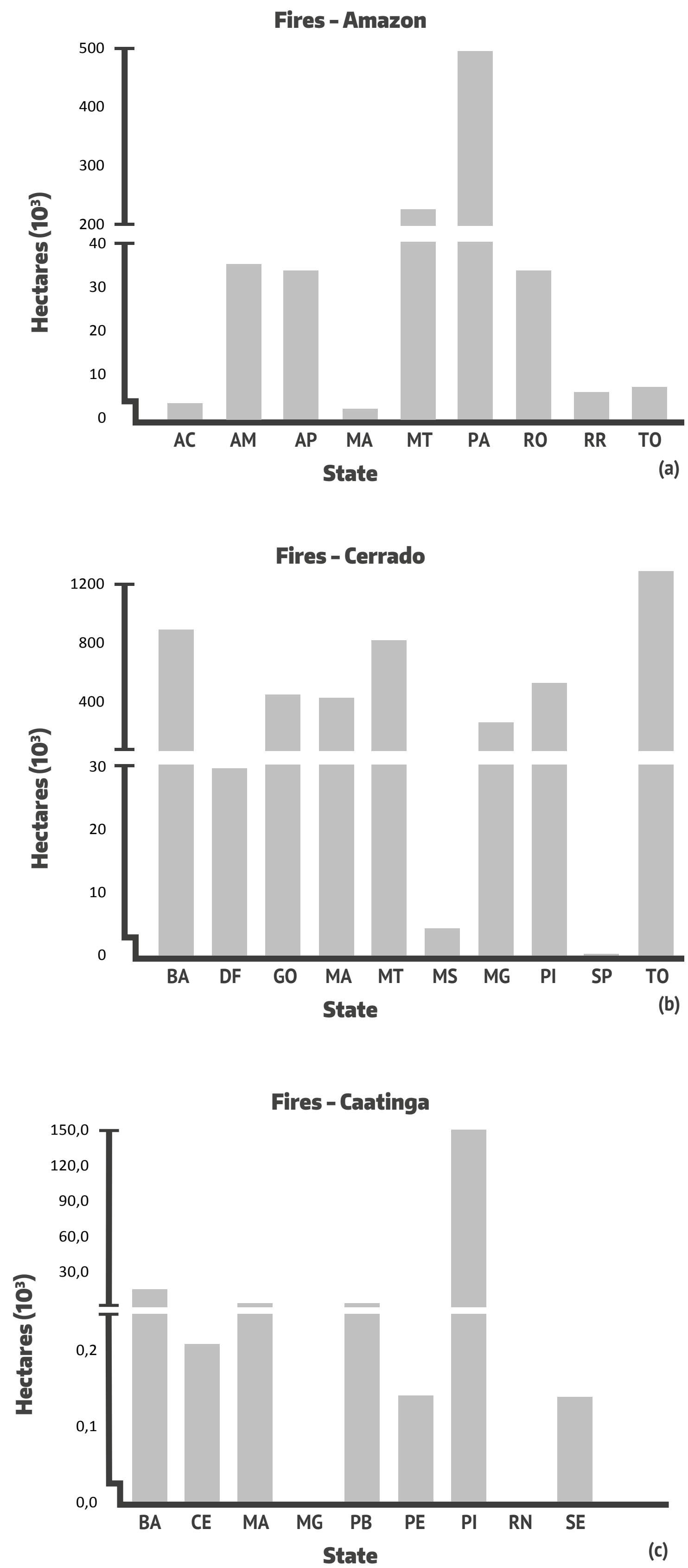

TABLE A2.1

Quantification of burned areas in the Amazon biome in 2010

FIRES IN THE AMAZON BIOME IN 2010					
STATE	ABBREVIATION	GRASSLANDS	FOREST	TOTAL AREA	PERCENTAGE OF BIOME
		(ha)			
Acre	AC	-	2,965.1	2,965.1	0.001%
Amazonas	AM	25,862.1	7,823.0	33,685.1	0.008%
Amapá	AP	26,003.3	6,585.4	32,588.7	0.008%
Maranhão	MA	-	1,447.1	1,447.1	0.000%
Mato Grosso	MT	67,310.8	158,739.4	226,050.2	0.054%
Pará	PA	247,229.0	241,674.1	488,903.1	0.116%
Rondônia	RO	13,897.1	18,660.5	32,557.6	0.008%
Roraima	RR	2,590.7	2,785.7	5,376.4	0.001%
Tocantins	TO	-	6,442.5	6,442,.	0.002%
TOTAL		382,893.0	447,122.9	830.015,9	0.197%

TABLE A2.2

Quantification of burned areas in the Cerrado biome in 2010

FIRES IN THE CERRADO BIOME IN 2010					
STATE	ABBREVIATION	GRASSLAND	FOREST	TOTAL AREA	PERCENTAGE OF THE BIOME
		(ha)			
Bahia	BA	232,734.2	671,010.3	903,744.5	0.443%
Distrito Federal	DF	18,509.9	10,888.5	29,398.4	0.014%
Goiás	GO	244,576.9	200,090.3	444,667.3	0.218%
Maranhão	MA	162,157.5	260,959.9	423,117.4	0.207%
Minas Gerais	MG	198.265.9	52,331.6	250,597.5	0.123%
Mato Grosso do Sul	MS	2,086.2	2,646.8	4,733.0	0.002%
Mato Grosso	MT	294,952.7	527,530.7	822,483.4	0.403%
Piauí	PI	1,707.7	526,953.4	528,661.1	0.259%
São Paulo	SP		459.1	459.1	0.000%
Tocantins	TO	719,574.5	594,109.0	1,313,683.5	0.644%
TOTAL		1,874,565.5	2,846,979.7	4,721,545.2	2.315%

TABLE A2.3

Quantification of burned areas in the Caatinga biome in 2010

FIRES IN THE CAATINGA BIOME IN 2010					
STATE	ABBREVIATION	GRASSLAND	FOREST	TOTAL AREA	PERCENTAGE OF THE BIOME
		(ha)			
Bahia	BA	4,222.3	11,650.3	15,872.5	0.019%
Ceará	CE	-	209.9	209.9	0.000%
Maranhão	MA	-	3,049.3	3,049.3	0.004%
Minas Gerais	MG	-	0.7	0.7	0.000%
Paraíba	PB	-	1,078.4	1,078.4	0.001%
Pernambuco	PE	-	141.6	141.6	0.000%
Piauí	PI	-	147,996.3	147,996.3	0.179%
Rio Grande do Norte	RN	-	0.0	0.0	0.000%
Sergipe	SE	-	138.2	138.2	0.000%
TOTAL		**4,222.3**	**164,264.6**	**168,486.8**	**0.203%**

Values for combustion factors were established by group of phytophysiognomies and biome. After careful review of literature, priority was given to values calculated in the phytophysiognomies and in the biome, according to Tables A2.4, A2.5 and A2.6.

TABLE A2.4

Biomass combustion factors per group of phytophysiognomies in the Amazon biome, biome of origin, and respective bibliographic references

GROUP	PHYTOPHYSIOGNOMIES	COMBUSTION FACTOR (%)	BIOME	REFERENCES
Dense Humid Forests	Da, Db and Ds	32.5 [1]	Amazon	WARD et al., 1992; KAUFFMAN et al., 1995; ARAUJO et al., 1999; FEARNSIDE et al., 1993; 1999; 2001; CARVALHO JR et al., 1995; 1998; 2001
Open Humid Forests	Aa, Ab, As	45.0 [1]	Amazon	KAUFFMAN et al., 1995; GRAÇA et al., 1999
(Decidual and Semidecidual) Seasonal Forests	Cs, Fa, Fb, Fs	46.4 [2]	Amazon	BALCH et al., 2008
Pioneering vegetation	Pa	20.1 [2]	Amazon	ARAUJO et al., 1999
Forested vegetation	Sd, Td	33.0 [2]	Cerrado	CASTRO & KAUFFMAN, 1998
Arboreal vegetation	Sa, La	43.5 [2]	Cerrado	CASTRO & KAUFFMAN, 1998
Shrubby vegetation and parks	Sp, Tp, Lb	53.9 [2]	Cerrado	BARBOSA & FEARNSIDE, 2005
Woody-grass vegetation	Sg, Tg, Lg, Rm	77.1 [2]	Cerrado	BARBOSA & FEARNSIDE, 2005

[1] Value calculated from papers describing slash-and-burn.
[2] Value calculated from papers describing only fires.

TABLE A2.5

Biomass combustion factors per group of phytophysiognomies in the Cerrado biome, biome of origin, and respective bibliographic references

GROUP	PHYTOPHYSIOGNOMIES	COMBUSTION FACTOR (%)	BIOME	REFERENCES
Dense Humid Forests	Dm, Ds	32.5 [1]	Amazon	WARD et al., 1992; KAUFFMAN et al., 1995; ARAUJO et al., 1999; FEARNSIDE et al., 1993; 1999; 2001; CARVALHO JR et al., 1995; 1998; 2001
Open Humid Forests	Aa, Ab, As	45.0 [1]	Amazon	KAUFFMAN et al., 1995; ALENCASTRO GRAÇA et al., 1999
(Decidual and Semidecidual) Seasonal Forests	Cm, Cs, Fa, Fb, Fs, Fm	46.4 [2]	Amazon	BALCH et al., 2008
Palm swamp	Pa	18.3 [2]	Cerrado	CASTRO & KAUFFMAN, 1998
Sandbanks	Pm	46.4 [2]	Amazon	BALCH et al., 2008
Forested vegetation	Sd, Td	33.0 [2]	Cerrado	CASTRO & KAUFFMAN, 1998
Arboreal vegetation	Sa, Ta	43.5 [2]	Cerrado	CASTRO & KAUFFMAN, 1998
Shrubby vegetation and parks	Sp, Tp	84.0 [2]	Cerrado	CASTRO & KAUFFMAN, 1998
Woody-grass vegetation	Sg, Tg	92.0 [2]	Cerrado	CASTRO & KAUFFMAN, 1998

[1] *Value calculated from papers describing slash-and-burn.*
[2] *Value calculated from papers describing only fires.*

TABLE A2.6

Biomass combustion factors per group of phytophysiognomies in the Caatinga biome, biome of origin, and respective bibliographic references

GROUP	PHYTOPHYSIOGNOMIES	COMBUSTION FACTOR (%)	BIOME	REFERENCES
Forest formations	Cm, Cs, Fm, Fs, Pa, Sd, Td	33.0 [2]	Cerrado	CASTRO & KAUFFMAN, 1998
Arboreal vegetation	Sa, Ta	43.5 [2]	Cerrado	CASTRO & KAUFFMAN, 1998
Park vegetation	Sp	84.0 [2]	Cerrado	CASTRO & KAUFFMAN, 1998

[1] *Value calculated from papers describing slash-and-burn.*
[2] *Value calculated from papers describing only fires.*

Tables A2.7, A2.8 and A2.9 show burned areas in the different phytophysiognomies by structure (grasslands and forest) and biome (Amazon, Cerrado and Caatinga), respective combustion factors and biomass value (aboveground with dead organic matter, including dead wood and litter), to which the combustion factor was applied.

TABLE A2.7
Burned areas not associated with deforestation, by phytophysiognomy of the Amazon biome in 2010

STRUCTURE	PHYTOPHYSIOGNOMY	BURNED AREA (ha)	ABOVEGROUND BIOMASS (t /ha)	COMBUSTION FACTOR
Grassland	Lb	108.4	15.91	0.539
	Lg	233.4	7.65	0.771
	Rm	156.6	3.10	0.771
	Sg	80,946.3	3.28	0.771
	Sp	300,566.8	8.04	0.539
	Tg	18.7	2.83	0.771
	Tp	672.2	6.12	0.539
Forest	Aa	720.6	361.91	0.450
	Ab	9,325.6	323.96	0.450
	As	54,883.1	290.12	0.450
	Cs	2,941.5	241.89	0.464
	Da	7,736.2	382.70	0.325
	Db	98,457.9	337.12	0.325
	Ds	103,050.5	336.15	0.325
	Fa	4,126.2	236.40	0.464
	Fb	384.7	258.00	0.464
	Fs	32,696.5	240.99	0.464
	La	151.3	17.50	0.435
	Pa	72,469.1	264.61	0.201
	Pf	0.5	185.97	0.201
	Sa	52,590.7	36.78	0.435
	Sd	7,279.5	90.30	0.330
	Td	183.0	29.00	0.330
TOTAL		**829,699.1**		

TABLE A2.8

Burned areas not associated with deforestation, by phytophysiognomy of the Cerrado biome in 2010

STRUCTURE	PHYTOPHYSIOGNOMY	BURNED AREA (ha)	ABOVEGROUND BIOMASS (t /ha)	COMBUSTION FACTOR
Grassland	Sg	351,533.3	9.83	0.920
	Sp	1,520,948.4	19.68	0.840
	Tg	1,690.2	2.83	0.920
	Tp	393.6	6.12	0.840
Forest	Aa	691.5	361.91	0.450
	Ab	1,183.7	323.96	0.450
	As	1,528.3	172.46	0.450
	Cm	14,670.3	172.11	0.464
	Cs	94,157.1	172.11	0.464
	Dm	1.7	318.02	0.325
	Ds	208.9	198.00	0.325
	Fa	82,742.7	188.79	0.464
	Fb	3,151.3	206.36	0.464
	Fm	6,355.8	193.10	0.464
	Fs	66,842.2	127.35	0.464
	Pa	4,934.2	61.60	0.183
	Pm	1,296.3	216.56	0.464
	Sa	1,875,647.4	36.78	0.435
	Sd	654.178.1	124.58	0.330
	Ta	39,359.2	25.10	0.435
	Td	31.0	46.70	0.330
Total		**4,786,487.0**		

TABLE A2.9
Burned areas not associated with deforestation, by phytophysiognomy of the Caatinga biome in 2010

STRUCTURE	PHYTOPHYSIOGNOMY	BURNED AREA (ha)	ABOVEGROUND BIOMASS (t /ha)	COMBUSTION FACTOR
Grassland	Sp	4,222.3	10.81	0.840
Forest	Cm	662.5	115.32	0.330
	Cs	8,922.3	115.32	0.330
	Fm	0.2	99.98	0.330
	Fs	2,439.2	99.98	0.330
	Pa	33.6	120.96	0.330
	Sa	35,483.8	36.78	0.435
	Sd	57,062.1	90.30	0.330
	Ta	31,467.5	25.10	0.435
	Td	28,193.4	46.70	0.330
Total		**168,486.8**		

The burned area, aboveground biomass and combustion factor values allow for the estimation of burned dry matter in each of the Amazon, Cerrado and Caatinga biomes' phytophysiognomies. Subsequently, with the emission factors shown in Table 3.113 of the National Inventory, based on the 2006 IPCC Guidelines, the correspondent greenhouse gas emissions may be obtained. Table A2.10 shows the estimates of emissions related to fires not associated with deforestation in 2010.

TABLE A2.10
Emissions related to fires not associated with deforestation in 2010

BIOME	CO_2	CO	CH_4	N_2O	NO_X
	Gg				
Amazon	67,249	4,426.5	289.4	8.51	68.1
Cerrado	172,632	6,956.6	246.2	22.48	417.4
Caatinga	5,696	229.5	8.1	0.74	13.8

Results related to emissions from fires not associated with deforestation were not incorporated to this inventory, for the following reasons:

>> Regarding CO_2 emissions, biomass recovery after combustion occurs in the years to come, and depends on the regeneration capacity of different vegetation formations as they are not associated with deforestation. The monitoring of these areas recovery might determine whether future removals will be equivalent to emissions from combustion, given that frequent fires may reduce the resilience of the vegetation.

- >> Regarding emissions of other gases, the ones that are not removed with the regeneration of vegetation, it was not possible to consider them since there has not been the same quantification for previous years, nor has a correlation with an approximate calculation been identified.
- >> In addition, it was not possible to evaluate the successional or transition paths in burned areas along a historical series in order to guarantee the time consistency of the series of national inventories regarding this type of emission.

The abovementioned aspects demand methodological improvements in order to assess the impacts of fires not associated with deforestation when accounting for greenhouse gas emissions. This analysis is another step to understanding the occurrence of fires not associated with deforestation, and the incorporation of the corresponding non-CO_2 gas emissions to the inventory in the coming editions. It is important to bear in mind that emissions from fires associated with deforestation are incorporated in the inventory (item 3.5.2.8).

APPENDIX III

GREENHOUSE GAS EMISSIONS ESTIMATES BY GAS AND SECTOR, FROM 1990 TO 2010

CO_2

SECTOR	1990	1991	1992	1993	1994	1995	1996	1997
Energy	169,985	175,607	179,327	185,010	193,669	209,124	225,121	239,744
Fossil Fuels Combustion	162,431	168,246	171,882	177,434	185,665	201,610	217,300	231,140
Energy Subsector	21,271	20,860	22,802	22,866	23,841	25,281	27,799	31,218
Industrial Subsector	35,558	37,042	37,612	38,308	39,443	43,068	48,127	51,129
Steel Industry	4,436	4,606	4,905	5,154	5,423	5,388	5,352	5,201
Chemical Industry	8,606	8,811	9,080	8,578	9,114	10,057	11,493	13,352
Other industries	22,516	23,625	23,627	24,576	24,906	27,623	31,282	32,576
Transport Subsector	79,338	83,405	83,708	86,899	91,283	100,457	107,864	114,496
Air Transport	4,232	4,606	3,854	4,180	4,446	4,732	4,509	5,324
Road Transport	70,094	73,931	74,786	77,159	82,058	90,916	97,772	105,030
Other Means of Transport	5,012	4,868	5,068	5,560	4,779	4,809	5,583	4,142
Residential Subsector	13,842	14,220	14,717	15,257	15,239	15,942	16,598	16,619
Agriculture Subsector	9,846	10,272	10,569	11,676	12,332	13,222	13,803	14,342
Other Sectors	2,576	2,447	2,474	2,428	3,527	3,640	3,109	3,336
Fugitive Emissions	7,554	7,361	7,445	7,576	8,004	7,514	7,821	8,604
Coal Mining	1,353	1,316	1,200	1,247	1,348	920	654	902
Extraction and Transportation of Oil and Natural Gas	6,201	6,045	6,245	6,329	6,656	6,594	7,167	7,702
Industrial Processes	43,551	49,037	47,440	50,742	51,516	54,643	58,317	61,125
Cement Production	11,062	11,776	9,770	10,164	10,086	11,528	13,884	15,267
Lime Production	3,688	3,755	3,948	4,241	4,098	4,104	4,248	4,338
Production of Ammonia	1,683	1,478	1,516	1,684	1,689	1,785	1,754	1,829
Iron and Steel Production	21,601	26,118	26,417	28,206	29,392	30,130	30,866	32,521
Ferroalloy Production	116	119	197	191	178	215	237	171
Production of Non-Ferrous Metals except Aluminum	897	857	803	1,518	1,279	1,762	2,197	1,466
Aluminum Production	1,574	1,901	2,011	1,946	1,955	1,965	1,981	1,975
Other industries	2,930	3,033	2,778	2,792	2,839	3,154	3,150	3,558
Land use, Land-Use Change and Forestry	756,970	616,425	761,554	821,046	821,387	1,837,508	1,191,467	898,942
Land-Use Change	751,867	611,706	754,774	812,396	812,396	1,832,113	1,184,596	891,436

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
		Gg											
	249,209	260,751	267,646	276,893	273,412	268,111	282,581	290,621	295,611	308,967	327,452	315,649	347,974
	239,746	250,628	256,909	265,172	262,194	256,912	271,741	276,744	282,729	295,498	313,245	297,215	332,760
	32,223	39,123	40,484	44,837	39,776	39,449	45,372	47,343	47,967	47,494	58,186	47,616	58,857
	51,874	55,314	59,008	58,128	58,426	56,218	56,999	60,019	60,817	66,790	66,810	63,657	68,306
	4,594	4,302	4,657	4,510	4,759	4,891	4,975	5,526	5,491	6,012	5,811	4,543	5,642
	12,343	13,551	13,942	13,930	14,161	13,508	14,353	14,624	14,880	15,598	14,283	14,446	13,847
	34,937	37,461	40,409	39,688	39,506	37,819	37,671	39,869	40,446	45,180	46,716	44,668	48,817
	121,389	120,217	121,748	124,867	127,290	126,675	134,513	135,182	139,533	145,186	150,798	149,354	168,364
	5,857	6,017	6,206	6,626	6,677	5,871	6,193	6,316	6,563	7,220	7,325	8,330	9,751
	111,067	109,634	111,337	113,548	115,889	116,036	123,083	123,519	127,773	131,881	136,931	134,781	151,481
	4,465	4,566	4,205	4,693	4,724	4,768	5,237	5,347	5,197	6,085	6,542	6,243	7,132
	16,760	17,095	17,179	17,247	16,675	15,532	15,863	15,591	15,616	16,123	16,530	16,738	17,249
	13,824	14,496	14,152	15,579	15,207	15,291	15,075	14,964	15,162	16,096	17,473	16,785	17,346
	3,676	4,383	4,338	4,514	4,820	3,747	3,919	3,645	3,634	3,809	3,448	3,065	2,638
	9,463	10,123	10,737	11,721	11,218	11,199	10,840	13,877	12,882	13,469	14,207	18,434	15,214
	1,004	1,150	1,291	1,936	1,151	1,208	1,429	1,381	1,246	1,510	1,658	1,758	1,846
	8,459	8,973	9,446	9,785	10,067	9,991	9,411	12,496	11,636	11,959	12,549	16,676	13,368
	62,611	61,714	65,991	63,423	66,195	67,056	69,452	68,016	67,476	73,561	75,910	66,738	80,786
	16,175	16,439	16,047	15,227	14,390	13,096	13,273	14,349	15,440	17,200	18,884	19,031	21,288
	4,141	4,352	5,008	4,811	4,956	5,064	5,505	5,356	5,410	5,666	5,690	5,060	5,950
	1,718	1,943	1,663	1,396	1,567	1,690	1,934	1,922	1,968	1,866	1,811	1,576	1,739
	33,319	31,680	35,552	34,845	37,516	38,683	39,805	37,509	36,051	39,422	39,825	31,690	38,360
	562	482	545	608	573	937	938	932	942	1,080	1,142	1,018	1,195
	1,201	1,319	1,606	1,431	1,582	1,724	1,788	1,855	1,901	2,112	1,813	1,914	4,332
	2,007	2,079	2,116	1,879	2,176	2,198	2,408	2,472	2,646	2,739	2,753	2,544	2,543
	3,488	3,420	3,454	3,226	3,435	3,664	3,801	3,621	3,118	3,476	3,992	3,905	5,379
	1,145,470	1,137,736	1,197,175	1,192,787	1,401,764	2,311,652	2,501,327	1,797,842	1,399,630	1,193,617	1,294,043	379,257	310,736
	1,138,370	1,131,002	1,188,458	1,184,833	1,391,958	2,300,008	2,489,746	1,790,368	1,392,216	1,183,866	1,283,495	370,862	300,312

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(CO_2 continuing)

SECTOR	1990	1991	1992	1993	1994	1995	1996	1997
Amazon Biome	437,574	297,413	440,481	498,103	498,103	1,459,071	811,554	518,394
Cerrado Biome	241,511	241,511	241,511	241,511	241,511	212,958	212,958	212,958
Other Biomes	72,782	72,782	72,782	72,782	72,782	160,084	160,084	160,084
Application of Limestone in soils	5,103	4,719	6,780	8,650	8,991	5,395	6,871	7,506
Waste	19,0	31,0	54,0	61,0	66,0	78,0	78,0	78,0
TOTAL	**970,525**	**841,100**	**988,375**	**1,056,859**	**1,066,638**	**2,101,353**	**1,474,983**	**1,199,889**
For information purposes only								
Bunker fuels	6,086	5,584	6,239	6,914	7,298	8,667	10,077	10,835
Air Transport	4,366	3,147	3,610	3,619	3,539	4,520	5,541	5,911
Shipping	1,720	2,437	2,629	3,295	3,759	4,147	4,536	4,924
CO_2 emissions from biomass	165,792	166,171	165,294	163,296	173,888	168,791	171,036	177,229

CH_4

SECTOR	1990	1991	1992	1993	1994	1995	1996	1997
Energy	545.8	548.5	535.5	499.2	494.7	473.6	464.3	479.7
Fossil Fuels Combustion	455.3	454.0	450.5	410.5	408.9	388.1	389.0	393.6
Energy Subsector	25.5	24.6	23.0	23.3	24.4	23.1	22.5	23.4
Industrial Subsector	15.7	14.8	15.3	15.5	17.7	18.1	19.2	19.3
Steel Industry	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Other industries	15.5	14.6	15.1	15.3	17.5	17.9	19.0	19.1
Transport Subsector	72.6	76.3	76.4	76.7	80.3	85.8	91.4	92.2
Residential Subsector	318.4	316.8	316.9	277.4	269.4	243.7	238.6	241.5
Other Sectors	23.1	21.5	18.9	17.6	17.1	17.4	17.3	17.2
Fugitive Emissions	90.5	94.5	85.0	88.7	85.8	85.5	75.3	86.1
Coal Mining	49.7	54.3	44.2	47.0	42.4	41.1	25.5	32.6
Extraction and Transportation of Oil and Natural Gas	40.8	40.2	40.8	41.7	43.4	44.4	49.8	53.5

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	Gg												
	765,328	757,960	815,416	811,791	1,018,916	1,638,185	1,827,923	1,128,545	738,993	530,643	630,272	199,576	162,888
	212,958	212,958	212,958	212,958	212,958	282,275	282,275	282,275	282,275	282,275	282,275	92,617	58,755
	160,084	160,084	160,084	160,084	160,084	379,548	379,548	379,548	370,948	370,948	370,948	78,669	78,669
	7,100	6,734	8,717	7,954	9,806	11,644	11,581	7,474	7,414	9,751	10,548	8,395	10,424
	84,0	88,0	95,0	95,0	99,0	117,0	120,0	128,0	136,0	155,0	159,0	168,0	175,0
	1,457,374	**1,460,289**	**1,530,907**	**1,533,198**	**1,741,470**	**2,646,936**	**2,853,480**	**2,156,607**	**1,762,853**	**1,576,300**	**1,697,564**	**761,812**	**739,671**
	12,105	13,881	13,639	15,545	15,823	14,094	14,362	14,766	15,150	16,347	19,998	15,461	18,550
	6,621	5,397	4,626	5,388	4,381	4,035	4,303	4,707	4,543	4,936	5,675	5,167	5,784
	5,484	8,484	9,013	10,157	11,442	10,059	10,059	10,059	10,607	11,411	14,323	10,294	12,766
	177,266	180,876	166,435	174,763	190,568	207,531	219,888	228,285	242,166	263,098	285,428	281,666	303,170

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	Gg												
	488.1	498.6	511.8	542.9	571.9	568.7	605.2	684.8	647.9	634.6	639.4	686.3	629.1
	393.9	396.4	392.8	403.7	440.1	460.9	471.4	478.6	478.6	465.4	466.5	446.3	448.2
	21.1	21.4	20.7	20.7	22.2	25.8	28.4	29.2	29.9	32.6	36.7	30.3	34.5
	20.5	21.9	19.9	22.1	23.9	26.0	28.0	28.4	31.7	33.1	32.9	31.9	34.4
	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3
	20.4	21.7	19.7	21.9	23.7	25.8	27.8	28.2	31.5	32.9	32.7	31.7	34.1
	88.7	81.9	75.6	73.1	73.2	74.6	75.3	74.4	68.5	68.1	67.9	62.3	66.9
	247.2	255.3	261.5	272.8	304.9	316.7	321.1	327.6	329.0	311.1	307.1	300.8	290.1
	16.4	15.9	15.1	15.0	15.9	17.8	18.6	19.0	19.5	20.5	21.9	21.0	22.3
	94.2	102.2	119.0	139.2	131.8	107.8	133.8	206.2	169.3	169.2	172.9	240.0	180.9
	33.0	34.0	43.3	60.0	44.0	41.0	48.0	49.1	48.3	54.9	58.6	52.3	39.2
	61.2	68.2	75.7	79.2	87.8	66.8	85.8	157.1	121.0	114.3	114.3	187.7	141.7

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(CH_4 continuing)

SECTOR	1990	1991	1992	1993	1994	1995	1996	1997
Industrial Processes	47.1	42.1	39.6	43.0	44.2	41.2	37.9	38.2
Chemical Industry	5.2	5.2	5.4	6.0	6.6	6.6	6.6	7.4
Production of Metals	41.9	36.9	34.2	37.0	37.6	34.6	31.3	30.8
Agriculture	9,185.6	9,474.1	9,639.0	9,681.3	9,865.1	10,058.2	9,742.2	9,887.9
Enteric Fermentation	8,223.9	8,470.3	8,596.8	8,625.8	8,786.7	8,957.1	8,738.7	8,899.2
Cattle	7,808.9	8,049.5	8,175.2	8,218.7	8,370.5	8,534.3	8,413.3	8,572.9
Dairy Cattle	1,197.7	1,245.1	1,279.3	1,258.3	1,262.8	1,297.1	1,081.0	1,123.9
Beef Cattle	6,611.2	6,804.4	6,895.9	6,960.4	7,107.7	7,237.2	7,332.3	7,449.0
Other Animals	415.0	420.8	421.6	407.1	416.2	422.8	325.4	326.3
Manure Management	421.6	435.5	443.0	447.1	457.9	471.6	431.0	442.3
Cattle	191.2	197.6	200.4	201.2	204.6	208.7	200.3	204.7
Dairy Cattle	35.9	37.5	38.4	37.7	37.6	38.5	31.1	32.6
Beef Cattle	155.3	160.1	162.0	163.5	167.0	170.2	169.2	172.1
Swine	159.5	161.8	161.9	164.4	169.4	173.7	146.4	149.1
Poultry	48.4	53.3	57.8	59.2	61.3	66.3	65.9	69.9
Other Animals	22.5	22.8	22.9	22.3	22.6	22.9	18.4	18.6
Rice Cultivation	433.6	462.9	490.8	511.9	505.8	510.8	456.0	430.3
Burning of Agricultural Wastes	106.5	105.4	108.4	96.5	114.7	118.7	116.5	116.1
Land use, Land-Use Change and Forestry	1,041.5	959.3	1,153.3	1,222.4	1,213.2	2,895.7	2,016.2	1,657.1
Waste	1,173.7	1,219.9	1,270.4	1,314.2	1,361.2	1,418.7	1,470.6	1,530.0
Solid Wastes	824.4	852.2	882.2	910.2	938.7	965.3	994.4	1,025.4
Effluents	349.3	367.7	388.2	404.0	422.5	453.4	476.2	504.6
Industrial	82.6	94.0	107.8	116.4	126.9	149.1	162.3	178.0
Domestic	266.7	273.7	280.4	287.6	295.6	304.3	313.9	326.6
TOTAL	**11,993.7**	**12,243.9**	**12,637.8**	**12,760.1**	**12,978.4**	**14,887.4**	**13,731.2**	**13,592.9**
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Bunker fuels	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Air Transport	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Shipping	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
		Gg											
	36.0	40.0	43.7	40.0	41.4	47.9	55.5	54.9	56.5	58.4	56.5	39.2	45.3
	7.9	8.3	9.0	8.6	8.3	8.9	9.3	9.4	12.4	12.7	11.5	11.9	11.8
	28.1	31.7	34.7	31.4	33.1	39.0	46.2	45.5	44.1	45.7	45.0	27.3	33.5
	9,963.9	10,111.9	10,382.3	10,757.6	11,121.3	11,666.8	12,195.7	12,357.7	12,293.0	11,707.1	11,955.4	12,166.2	12,415.6
	8,979.5	9,057.6	9,349.5	9,713.3	10,050.1	10,574.9	11049.3	11,213.8	11,162.0	10,573.0	10,730.3	10,908.0	11,158.0
	8,650.5	8,722.2	9,005.8	9,368.0	9,708.9	10,228.3	10,698.6	10,855.7	10,801.9	10,220.4	10,376.3	10,555.6	10,798.4
	1,136.7	1,143.1	1,177.9	1,206.7	1,236.6	1,268.8	1,320.5	1,371.4	1,396.3	1,296.8	1,331.4	1,384.6	1,424.0
	7,513.8	7,579.1	7,827.9	8,161.3	8,472.3	8,959.5	9,378.1	9,484.3	9,405.6	8,923.6	9,044.9	9,171.0	9,374.4
	329.0	335.4	343.7	345.3	341.2	346.6	350.7	358.1	360.1	352.6	354.0	352.4	359.6
	448.8	461.1	479.7	500.5	500.6	519.6	533.0	543.9	545.6	558.0	575.4	593.3	608.1
	207.0	209.0	215.9	224.4	223.6	235.9	248.5	254.0	252.9	245.3	249.0	253.4	258.7
	33.0	33.2	34.1	34.7	35.5	36.4	38.5	39.7	40.4	40.6	41.5	43.1	44.0
	174.0	175.8	181.8	189.7	188.1	199.5	210.0	214.3	212.5	204.7	207.5	210.3	214.7
	152.2	158.6	166.5	174.5	176.7	180.5	178.4	178.7	179.8	188.5	196.0	207.2	214.9
	70.9	74.6	78.1	82.4	81.2	83.8	86.6	91.5	93.2	104.9	111.2	113.7	115.3
	18.7	18.9	19.2	19.2	19.1	19.4	19.5	19.7	19.7	19.3	19.2	19.0	19.2
	416.2	479.9	448.1	431.7	451.4	440.6	477.3	463.7	438.8	423.5	474.2	486.0	464.2
	119.4	113.3	105.0	112.1	119.2	131.7	136.1	136.3	146.6	152.6	175.5	178.9	185.3
	1,984.3	1,979.1	2,048.8	2,048.4	2,321.9	3,898.7	4,148.9	3,237.9	2,565.3	2,324.4	2,441.7	1,221.3	1135.5
	1,587.1	1,683.8	1,754.2	1,799.4	1,887.2	2,002.2	2,018.4	2,062.0	2,178.8	2,241.7	2,277.4	2,336.0	2,462.7
	1,053.3	1,111.9	1,149.4	1,177.4	1,219.5	1,288.5	1,243.3	1,237.1	1,310.3	1,301.0	1,266.4	1,257.8	1,327.0
	533.8	571.9	604.8	622.0	667.7	713.7	775.1	824.9	868.5	940.7	1,011.0	1,078.2	1,135.7
	193.3	216.4	233.1	238.0	271.1	304.2	352.2	388.3	417.8	475.6	530.4	581.7	622.9
	340.5	355.5	371.7	384.0	396.6	409.5	422.9	436.6	450.7	465.1	480.6	496.5	512.8
	14,059.4	**14,313.4**	**14,740.8**	**15,188.3**	**15,943.7**	**18,184.3**	**19,023.7**	**18,397.3**	**17,741.5**	**16,966.2**	**17,370.4**	**16,449.0**	**16,688.2**
	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.2
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.2

N_2O

SECTOR	1990	1991	1992	1993	1994	1995	1996	1997
Energy	14.08	14.11	14.00	13.91	14.53	15.03	15.98	17.31
Fuels Combustion	14.02	14.06	13.94	13.85	14.47	14.97	15.91	17.24
Industrial Subsector	2.54	2.53	2.59	2.65	2.97	2.97	3.02	3.16
Transport Subsector	3.75	3.91	3.93	4.05	4.28	5.14	6.09	7.07
Other Sectors	7.73	7.62	7.42	7.15	7.22	6.86	6.80	7.01
Fugitive Emissions	0.06	0.05	0.06	0.06	0.06	0.06	0.07	0.07
Industrial Processes	11.83	14.56	13.60	17.28	17.47	18.57	14.68	13.20
Chemical Industry	10.69	13.46	12.55	16.14	16.31	17.45	13.62	12.12
Nitric Acid Production	1.81	1.93	1.89	2.00	2.01	2.05	2.07	2.12
Adipic Acid Production	8.63	11.25	10.41	13.84	13.99	15.08	11.22	9.66
Other Productions	0.25	0.28	0.25	0.30	0.31	0.32	0.33	0.34
Metals Production	1.14	1.10	1.05	1.14	1.16	1.12	1.06	1.08
Agriculture	303.54	311.30	320.00	323.49	334.67	340.16	318.98	329.47
Manure Management	10.03	10.58	10.93	10.92	11.21	11.49	10.62	10.89
Cattle	2.90	2.96	3.00	3.01	3.04	3.07	2.83	2.89
Swine	2.43	2.48	2.49	2.43	2.48	2.54	1.95	1.97
Poultry	4.40	4.83	5.13	5.18	5.39	5.58	5.60	5.79
Other Animals	0.30	0.31	0.31	0.30	0.30	0.30	0.24	0.24
Agricultural Soils	290.75	297.99	306.26	310.07	320.49	325.59	305.34	315.57
Direct Emissions	184.07	188.19	193.71	195.06	201.60	205.28	191.67	198.00
Animals on Pasture	129.73	133.73	135.65	135.36	137.50	140.20	130.03	132.95
Synthetic Fertilizers	9.81	9.79	10.94	12.52	14.74	14.27	14.98	16.23
Animal Manure	14.90	15.31	15.77	15.64	15.87	16.40	14.76	15.30
Agricultural Waste	15.32	14.99	16.92	17.05	18.94	19.80	17.23	18.79
Organic Soils	14.31	14.37	14.43	14.49	14.55	14.61	14.67	14.73
Indirect Emissions	106.68	109.80	112.55	115.01	118.89	120.31	113.67	117.57
Burning of Agricultural Wastes	2.76	2.73	2.81	2.50	2.97	3.08	3.02	3.01

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
		Gg											
	18.24	18.91	18.99	20.04	21.39	22.74	24.13	24.96	25.53	27.02	28.77	28.29	31.97
	18.16	18.82	18.88	19.93	21.27	22.62	24.02	24.75	25.37	26.87	28.60	28.00	31.76
	3.44	3.61	3.34	3.62	3.83	4.08	4.34	4.43	4.91	5.20	5.20	5.28	5.73
	7.98	8.31	8.67	9.23	9.85	10.34	11.02	11.46	11.46	12.42	13.42	13.83	16.47
	6.74	6.90	6.87	7.08	7.59	8.20	8.66	8.86	9.00	9.25	9.98	8.89	9.56
	0.08	0.09	0.11	0.11	0.12	0.12	0.11	0.21	0.16	0.15	0.17	0.29	0.21
	20.09	20.06	21.14	17.36	21.48	19.95	27.48	24.27	26.17	4.41	3.75	2.01	2.15
	19.07	18.98	19.94	16.25	20.29	18.62	25.99	22.83	24.78	2.94	2.28	1.01	0.93
	2.06	2.06	2.09	2.06	2.14	2.14	2.21	2.24	2.20	2.07	1.58	0.79	0.80
	16.75	16.62	17.51	13.90	17.80	16.19	23.48	20.29	22.31	0.57	0.37	0.14	0.13
	0.26	0.30	0.34	0.29	0.35	0.29	0.30	0.30	0.27	0.30	0.33	0.08	0.00
	1.02	1.08	1.20	1.11	1.19	1.33	1.49	1.44	1.39	1.47	1.47	1.00	1.22
	337.23	339.71	355.93	366.75	382.26	412.38	419.86	428.97	433.03	445.43	448.06	453.87	472.08
	10.87	11.16	11.49	11.88	11.80	12.16	11.29	12.82	12.93	13.70	14.31	14.65	14.83
	2.92	2.93	2.98	3.05	3.13	3.22	2.13	3.29	3.29	3.27	3.33	3.40	3.46
	1.99	2.04	2.06	2.11	2.03	2.04	2.13	2.17	2.20	2.22	2.24	2.30	2.35
	5.72	5.95	6.20	6.47	6.40	6.65	6.78	7.11	7.19	7.97	8.50	8.71	8.78
	0.24	0.24	0.25	0.25	0.24	0.25	0.25	0.25	0.25	0.24	0.24	0.24	0.24
	323.27	325.61	341.72	351.96	367.37	396.81	405.04	412.62	416.30	427.77	429.20	434.58	452.45
	202.19	204.21	213.85	221.03	230.01	247.99	253.43	257.09	259.54	266.16	269.13	271.45	282.31
	134.44	135.85	140.12	144.62	150.82	158.19	164.86	167.45	166.82	162.37	164.36	166.83	170.24
	18.06	17.16	21.28	20.70	23.09	27.95	28.31	27.51	28.83	34.64	31.33	32.11	35.74
	15.56	15.65	15.88	16.00	16.12	16.64	15.44	17.81	18.14	18.94	20.15	21.30	21.33
	19.34	20.70	21.66	24.74	24.95	30.12	29.67	29.11	30.48	34.88	37.90	35.76	39.49
	14.79	14.85	14.91	14.97	15.03	15.09	15.15	15.21	15.27	15.33	15.39	15.45	15.51
	121.08	121.40	127.87	130.93	137.36	148.82	151.61	155.53	156.76	161.61	160.07	163.13	170.14
	3.09	2.94	2.72	2.91	3.09	3.41	3.53	3.53	3.80	3.96	4.55	4.64	4.80

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SECTOR	1990	1991	1992	1993	1994	1995	1996	1997
Land use, Land-Use Change and Forestry	42.56	41.18	47.09	49.08	48.71	106.98	80.69	70.31
Waste (Domestic Wastewater)	4.32	4.43	4.53	4.63	4.73	4.83	4.93	5.12
TOTAL	**376.33**	**385.58**	**399.22**	**408.39**	**420.11**	**485.57**	**435.26**	**435.41**
For information purposes only								
Bunker fuels	0.13	0.11	0.12	0.13	0.13	0.16	0.19	0.20
Air Transport	0.12	0.09	0.10	0.10	0.10	0.13	0.15	0.16
Shipping	0.01	0.02	0.02	0.03	0.03	0.03	0.04	0.04

HFC-23

SECTOR	1990	1991	1992	1993	1994	1995	1996	1997
Production of HCFC-22	0.1202	0.1375	0.1636	0.1723	0.1566	0.1530	0.0890	0.0953
TOTAL	**0.1202**	**0.1375**	**0.1636**	**0.1723**	**0.1566**	**0.1530**	**0.0890**	**0.0953**

HFC-32_POT

SECTOR	1990	1991	1992	1993	1994	1995	1996	1997
Use of HFCs, PFCs and SF_6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TOTAL	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**

HFC-125_POT

SECTOR	1990	1991	1992	1993	1994	1995	1996	1997
Use of HFCs, PFCs and SF_6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TOTAL	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	Gg												
	80.06	79.95	81.96	81.99	90.07	144.95	152.41	125.25	105.16	97.90	101.45	51.66	47.08
	5.33	5.54	5.68	5.79	6.08	6.38	6.49	6.61	6.72	6.83	6.96	7.08	7.21
	460.95	**464.17**	**483.70**	**491.93**	**521.28**	**606.40**	**630.37**	**610.06**	**596.61**	**581.59**	**588.99**	**542.91**	**560.49**
	0.22	0.22	0.20	0.23	0.22	0.20	0.20	0.21	0.21	0.23	0.27	0.23	0.27
	0.18	0.15	0.13	0.15	0.13	0.12	0.12	0.13	0.13	0.14	0.16	0.15	0.17
	0.04	0.07	0.07	0.08	0.09	0.08	0.08	0.08	0.08	0.09	0.11	0.08	0.10

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	Gg												
	0.0130	0.0972	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0130	**0.0972**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	Gg												
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0718	0.0420	0.0872	0.1059
	0.0000	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0000**	**0.0718**	**0.0420**	**0.0872**	**0.1059**

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	Gg												
	0.0000	0.0000	0.0071	0.0392	0.0508	0.0548	0.1207	0.1249	0.2517	0.2850	0.3021	0.3587	0.5012
	0.0000	**0.0000**	**0.0071**	**0.0392**	**0.0508**	**0.0548**	**0.1207**	**0.1249**	**0.2517**	**0.2850**	**0.3021**	**0.3587**	**0.5012**

HFC-134A

SECTOR	1990	1991	1992	1993	1994	1995	1996	1997
Use of HFCs, PFCs and SF_6	0.0004	0.0009	0.0042	0.0080	0.0685	0.0028	0.0471	0.1641
TOTAL	0.0004	0.0009	0.0042	0.0080	0.0685	0.0028	0.0471	0.1641

HFC-143A_POT

SECTOR	1990	1991	1992	1993	1994	1995	1996	1997
Use of HFCs, PFCs and SF_6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TOTAL	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

HFC-152A_POT

SECTOR	1990	1991	1992	1993	1994	1995	1996	1997
Use of HFCs, PFCs and SF_6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TOTAL	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

CF_4

SECTOR	1990	1991	1992	1993	1994	1995	1996	1997
Production of aluminum	0.3022	0.3365	0.3565	0.3348	0.3231	0.3060	0.2976	0.2027
TOTAL	0.3022	0.3365	0.3565	0.3348	0.3231	0.3060	0.2976	0.2027

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	Gg												
	0.2804	0.3803	0.4988	0.6310	0.7691	0.9056	1.0533	1.2279	1.4488	1.7220	2.0187	2.3359	2.7196
	0.2804	**0.3803**	**0.4988**	**0.6310**	**0.7691**	**0.9056**	**1.0533**	**1.2279**	**1.4488**	**1.7220**	**2.0187**	**2.3359**	**2.7196**

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	Gg												
	0.0000	0.0000	0.0075	0.0271	0.0398	0.0500	0.1037	0.0929	0.2157	0.2520	0.3074	0.3209	0.4671
	0.0000	**0.0000**	**0.0075**	**0.0271**	**0.0398**	**0.0500**	**0.1037**	**0.0929**	**0.2157**	**0.2520**	**0.3074**	**0.3209**	**0.4671**

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	Gg												
	0.0000	0.0000	0.0001	0.0295	0.0081	0.0238	0.0543	0.1748	0.2800	0.0000	0.0000	0.0000	0.0000
	0.0000	**0.0000**	**0.0001**	**0.0295**	**0.0081**	**0.0238**	**0.0543**	**0.1748**	**0.2800**	**0.0000**	**0.0000**	**0.0000**	**0.0000**

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	Gg												
	0.2276	0.2013	0.1465	0.1147	0.1351	0.1362	0.1241	0.1239	0.1219	0.1174	0.1145	0.0823	0.0767
	0.2276	**0.2013**	**0.1465**	**0.1147**	**0.1351**	**0.1362**	**0.1241**	**0.1239**	**0.1219**	**0.1174**	**0.1145**	**0.0823**	**0.0767**

C_2F_6

SECTOR	1990	1991	1992	1993	1994	1995	1996	1997
Production of aluminum	0.0263	0.0290	0.0311	0.0290	0.0279	0.0264	0.0261	0.0157
TOTAL	0.0263	0.0290	0.0311	0.0290	0.0279	0.0264	0.0261	0.0157

SF_6

SECTOR	1990	1991	1992	1993	1994	1995	1996	1997
Production of magnesium	0.0058	0.0058	0.0070	0.0101	0.0099	0.0101	0.0097	0.0127
Use of HFCs, PFCs and SF_6	0.0042	0.0040	0.0040	0.0040	0.0041	0.0041	0.0041	0.0042
TOTAL	0.0100	0.0098	0.0110	0.0141	0.0140	0.0142	0.0138	0.0169

CO

SECTOR	1990	1991	1992	1993	1994	1995	1996	1997
Energy	9,592.6	9,695.5	9,470.6	9,380.3	9,632.1	9,636.3	9,784.5	9,423.3
Fossil Fuels Combustion	9,592.6	9,695.5	9,470.6	9,380.3	9,632.1	9,636.3	9,784.5	9,423.3
Energy Subsector	1,398.0	1,303.1	1,214.8	1,250.1	1,292.5	1,208.5	1,148.9	1,171.4
Industrial Subsector	758.1	749.5	735.6	792.2	837.7	815.1	858.4	852.4
Steel Industry	2.5	2.7	2.8	4.0	3.2	3.2	4.8	6.4
Food and Beverage	182.3	185.7	170.6	172.0	178.1	175.8	179.7	179.3
Other industries	573.3	561.1	562.2	616.2	656.4	636.1	673.9	666.7
Transport Subsector	5,902.9	6,118.9	6,006.1	5,993.7	6,192.3	6,419.3	6,608.8	6,217.0
Road Transport	5,856.4	6,074.7	5,965.7	5,949.0	6,144.5	6,373.4	6,559.5	6,166.6
Other Transports	46.5	44.2	40.4	44.7	47.8	45.9	49.3	50.4
Residential Subsector	1,443.2	1,433.6	1,427.2	1,254.8	1,218.4	1,098.7	1,072.1	1,084.7
Other Sectors	90.4	90.4	86.9	89.5	91.2	94.7	96.3	97.8

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
		Gg											
	0.0172	0.0154	0.0117	0.0092	0.0117	0.0115	0.0100	0.0104	0.0104	0.0099	0.0096	0.0064	0.0059
	0.0172	**0.0154**	**0.0117**	**0.0092**	**0.0117**	**0.0115**	**0.0100**	**0.0104**	**0.0104**	**0.0099**	**0.0096**	**0.0064**	**0.0059**

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
		Gg											
	0.0101	0.0098	0.0103	0.0095	0.0122	0.0147	0.0170	0.0191	0.0216	0.0260	0.0260	0.0130	0.0000
	0.0047	0.0049	0.0050	0.0051	0.0053	0.0056	0.0060	0.0061	0.0063	0.0064	0.0081	0.0084	0.0087
	0.0148	**0.0147**	**0.0153**	**0.0146**	**0.0175**	**0.0203**	**0.0230**	**0.0252**	**0.0279**	**0.0324**	**0.0341**	**0.0214**	**0.0087**

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
		Gg											
	9,166.2	8,745.5	8,181.0	7,825.7	8,176.5	8,110.5	8,270.6	8,194.7	7,841.1	7,815.7	7,893.6	7,212.9	7,695.9
	9,166.2	8,745.5	8,181.0	7,825.7	8,176.5	8,110.5	8,270.6	8,194.7	7,841.1	7,815.7	7,893.6	7,212.9	7,695.9
	1,065.1	1,098.9	1,104.3	1,083.3	1,148.5	1,347.4	1,498.8	1,528.1	1,536.2	1,653.3	1,778.4	1,418.0	1,617.9
	916.3	999.0	1,036.8	1,035.1	1,059.6	1,160.2	1,223.3	1,283.5	1,363.5	1,448.6	1,541.2	1,558.8	1,710.3
	6.2	7.1	8.2	7.3	8.7	9.8	11.0	11.4	11.5	12.2	12.3	9.5	11.4
	186.7	191.9	187.5	189.8	191.8	192.5	200.3	204.8	214.8	223.8	230.5	236.8	260.9
	723.4	800.0	841.1	838.0	859.1	957.9	1,012.0	1,067.3	1,137.2	1,212.6	1,298.4	1,312.5	1,438.0
	5,982.6	5,410.1	4,776.2	4,389.7	4,508.1	4,080.0	4,002.7	3,807.3	3,358.9	3,200.3	3,065.2	2,752.8	2,933.7
	5,928.4	5,358.1	4,724.6	4,339.0	4,460.7	4,035.0	3,955.1	3,761.8	3,315.5	3,153.5	3,014.6	2,701.5	2,875.0
	54.2	52.0	51.6	50.7	47.4	45.0	47.6	45.5	43.4	46.8	50.6	51.3	58.7
	1,107.6	1,142.1	1,172.3	1,221.8	1,361.6	1,418.9	1,439.1	1,468.4	1,472.8	1,397.7	1,382.2	1,361.6	1,306.7
	94.6	95.4	91.4	95.8	98.7	104.0	106.7	107.4	109.7	115.8	126.6	121.7	127.3

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(CO continuing)

SECTOR	1990	1991	1992	1993	1994	1995	1996	1997
Industrial Processes	900.8	810.4	759.8	819.5	834.3	778.0	714.8	707.5
Iron and Steel Production	775.0	669.2	628.1	686.2	708.4	656.2	577.6	603.4
Ferroalloy Production	60.8	81.9	69.6	84.2	73.6	64.2	97.2	65.2
Production of Non-Ferrous Metals	44.4	36.1	36.2	21.8	22.8	27.6	8.7	6.8
Other Productions	20.6	23.2	25.9	27.3	29.5	30.0	31.3	32.1
Agriculture	3,627.6	3,590.2	3,696.5	3,289.4	3,908.1	4,045.8	3,968.2	3,957.5
Cotton crop residues burning	128.4	114.8	80.0	31.9	16.8	0.0	0.0	0.0
Sugarcane burning	3,499.2	3,475.4	3,616.5	3,257.5	3,891.3	4,045.8	3,968.2	3,957.5
Land use, Land-Use Change and Forestry	18,429.4	17,390.4	20,397.4	21,446.1	21,286.6	48,855.6	35,319.7	29,864.8
TOTAL	**32,550.4**	**31,486.5**	**34,324.3**	**34,935.3**	**35,661.1**	**63,315.7**	**49,787.2**	**43,953.1**
For information purposes only								
Bunker fuels	0.9	0.6	0.7	0.7	0.7	0.9	1.1	1.1
Air Transport	0.9	0.6	0.7	0.7	0.7	0.9	1.1	1.1
Shipping	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

NO_X

SECTOR	1990	1991	1992	1993	1994	1995	1996	1997
Energy	1,639.8	1,705.7	1,743.9	1,800.7	1,870.0	1,977.5	2,098.4	2,155.0
Fossil Fuels Combustion	1,639.8	1,705.7	1,743.9	1,800.7	1,870.0	1,977.5	2,098.4	2,155.0
Energy Subsector	214.9	226.3	245.3	247.9	256.2	266.6	289.2	332.0
Industrial Subsector	134.8	138.4	140.9	146.1	159.5	169.9	180.9	193.7
Steel Industry	10.4	11.1	12.3	12.9	13.3	12.3	10.7	11.5
Other industries	124.4	127.3	128.6	133.2	146.2	157.6	170.2	182.2
Transport Subsector	1,138.8	1,184.9	1,198.9	1,236.6	1,274.2	1,352.6	1,435.5	1,429.5
Road Transport	1,021.6	1,070.7	1,080.7	1,105.7	1,159.2	1,237.5	1,300.1	1,327.8
Other Transports	117.2	114.2	118.2	130.9	115.0	115.1	135.4	101.7

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
		Gg											
	653.4	724.7	790.5	723.4	764.0	886.8	1,037.9	1,022.4	997.3	1,037.7	1,027.7	665.8	809.6
	558.3	623.9	676.1	637.4	662.1	745.3	888.3	867.3	836.4	865.4	849.6	508.4	633.2
	54.9	60.9	72.5	44.7	56.6	90.2	94.8	96.7	97.6	104.5	106.7	82.5	96.7
	5.9	2.8	3.7	3.4	4.0	4.3	4.5	4.6	4.9	5.1	4.9	4.7	4.9
	34.3	37.1	38.2	37.9	41.3	47.0	50.3	53.8	58.4	62.7	66.5	70.2	74.8
	4,067.1	3,861.7	3,576.4	3,818.0	4,060.8	4,485.9	4,637.8	4,644.4	4,996.6	5,198.4	5,980.4	6,095.2	6,313.5
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	4,067.1	3,861.7	3,576.4	3,818.0	4,060.8	4.485.9	4,637.8	4,644.4	4,996.6	5,198.4	5,980.4	6,095.2	6,313.5
	34,894.5	34,821.8	35,879.9	35,881.7	40,075.6	65,971.8	69,818.3	55,810.0	45,459.9	41,737.2	43,552.8	21,977.9	20,231.4
	48,781.2	**48,153.7**	**48,427.8**	**48,248.8**	**53,076.9**	**79,455.0**	**83,764.6**	**69,671.5**	**59,294.9**	**55,789.0**	**58,454.5**	**35,951.8**	**35,050.4**
	1.3	1.1	0.9	1.1	0.9	0.8	1.1	1.2	1.0	0.9	1.2	1.0	1.1
	1.3	1.1	0.9	1.1	0.9	0.8	1.1	1.2	1.0	0.9	1.2	1.0	1.1
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
		Gg											
	2,235.5	2,296.3	2,273.3	2,300.7	2,285.2	2,249.1	2,345.6	2,346.4	2,334.3	2,423.6	2,555.9	2,439.0	2,567.1
	2,235.5	2,296.3	2,273.3	2,300.7	2,285.2	2,249.1	2,345.6	2,346.4	2,334.3	2,423.6	2,555.9	2,439.0	2,567.1
	341.0	388.5	395.0	416.3	382.1	415.2	449.8	479.8	491.0	501.9	584.0	557.4	577.5
	201.5	218.0	222.7	223.2	227.2	229.5	236.3	242.9	255.5	278.2	271.6	270.7	286.6
	10.4	10.4	11.1	10.5	10.8	10.6	10.6	12.1	11.8	11.9	11.4	9.8	12.0
	191.1	207.6	211.6	212.7	216.4	218.9	225.7	230.8	243.7	266.3	260.2	260.9	274.6
	1,497.5	1,485.5	1,457.4	1,447.9	1,462.4	1,391.5	1,447.4	1,414.0	1,375.5	1,420.6	1,456.5	1,373.8	1,459.7
	1,387.7	1,373.2	1,355.3	1,334.7	1,348.2	1,279.6	1,323.4	1,287.4	1,252.3	1,274.8	1,298.9	1,222.4	1,290.6
	109.8	112.3	102.1	113.2	114.2	111.9	124.0	126.6	123.2	145.8	157.6	151.4	169.1

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SECTOR	1990	1991	1992	1993	1994	1995	1996	1997
Residential Subsector	29.2	29.3	29.6	27.8	27.4	26.3	26.5	26.8
Other Sectors	122.1	126.8	129.2	142.3	152.7	162.1	166.3	173.0
Industrial Processes	42.1	42.5	41.8	48.9	52.9	53.2	59.4	66.5
Production of metals	36.0	35.8	34.3	40.9	44.3	44.5	50.4	57.3
Other Productions	6.1	6.7	7.5	8.0	8.6	8.7	9.0	9.2
Agriculture	98.6	97.5	100.5	89.4	106.2	109.9	107.8	107.5
Cotton crop residues burning	3.5	3.1	2.2	0.9	0.5	0.0	0.0	0.0
Sugarcane burning	95.1	94.4	98.3	88.5	105.7	109.9	107.8	107.5
Land use, Land-Use Change and Forestry	526.7	531.9	582.2	597.6	593.1	1,196.0	979.2	898.9
TOTAL	**2,307.2**	**2,377.6**	**2,468.4**	**2,536.6**	**2,622.2**	**3,336.6**	**3,244.8**	**3,227.9**
For information purposes only								
Bunker fuels	1.6	1.4	1.5	1.8	1.7	2.1	2.5	2.7
Air Transport	1.3	0.9	1.0	1.1	1.0	1.3	1.6	1.7
Shipping	0.3	0.5	0.5	0.7	0.7	0.8	0.9	1.0

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SECTOR	1990	1991	1992	1993	1994	1995	1996	1997
Energy	1,167.5	1,149.7	1,113.8	1,102.1	1,120.9	1,104.8	1,091.9	1,056.4
Burning of Fossil Fuels	1,167.5	1,149.7	1,113.8	1,102.1	1,120.9	1,104.8	1,091.9	1,056.4
Energy Subsector	337.4	299.6	276.0	289.1	293.9	271.6	243.8	238.0
Industrial Subsector	31.2	30.8	29.7	29.8	31.7	31.2	30.5	30.2
Steel Industry	1.1	1.2	1.2	1.3	1.3	1.3	1.2	1.3
Food and Beverage	9.2	9.4	8.9	8.9	9.4	9.2	9.4	9.4
Other industries	20.9	20.2	19.6	19.6	21.0	20.7	19.9	19.5

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	Gg												
	27.2	27.9	28.5	29.2	30.6	30.6	31.1	31.3	31.3	30.8	31.0	30.9	30.6
	168.3	176.4	169.7	184.1	182.9	182.3	181.0	178.4	181.0	192.1	212.8	206.2	212.7
	75.3	86.3	94.9	91.8	102.4	117.0	125.0	125.2	125.3	134.7	136.9	113.5	100.8
	65.5	75.7	84.0	81.0	90.7	103.8	110.9	110.1	109.0	117.3	118.3	93.9	80.1
	9.8	10.6	10.9	10.8	11.7	13.2	14.1	15.1	16.3	17.4	18.6	19.6	20.7
	110.5	104.9	97.2	103.8	110.3	121.9	126.0	126.2	135.8	141.3	162.5	165.6	171.6
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	110.5	104.9	97.2	103.8	110.3	121.9	126.0	126.2	135.8	141.3	162.5	165.6	171.6
	978.8	978.6	993.8	994.7	1,060.5	1,631.8	1,692.9	1,470.3	1,304.5	1,243.5	1,273.8	659.0	589.9
	3,400.1	**3,466.1**	**3,459.2**	**3,491.0**	**3,558.4**	**4,119.8**	**4,289.5**	**4,068.1**	**3,899.9**	**3,943.1**	**4,129.1**	**3,377.1**	**3,429.4**
	3.0	3.3	3.2	3.6	3.6	3.2	3.3	3.4	3.5	3.8	4.6	3.7	4.3
	1.9	1.6	1.4	1.6	1.3	1.2	1.3	1.4	1.4	1.5	1.7	1.6	1.8
	1.1	1.7	1.8	2.0	2.3	2.0	2.0	2.0	2.1	2.3	2.9	2.1	2.5

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	Gg												
	1,031.0	1,014.6	987.4	955.3	1,003.1	1,025.3	1,072.8	1,061.5	1,020.9	1,017.4	1,019.5	864.4	900.5
	1,031.0	1,014.6	987.4	955.3	1,003.1	1,025.3	1,072.8	1,061.5	1,020.9	1,017.4	1,019.5	864.4	900.5
	216.7	232.7	249.5	234.2	245.1	287.6	330.8	328.9	322.9	332.9	337.7	228.3	251.6
	33.6	38.8	41.7	43.5	42.9	44.8	46.1	48.6	52.5	56.9	59.7	58.9	67.3
	1.3	1.2	1.2	1.2	1.2	1.4	1.4	1.4	1.4	1.4	1.4	1.3	1.6
	9.9	10.2	9.7	10.0	10.3	10.4	10.9	11.1	11.9	12.6	12.8	13.2	14.5
	22.4	27.4	30.8	32.3	31.4	33.0	33.8	36.1	39.2	42.9	45.5	44.4	51.2

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(NMVOC continuing)

SECTOR	1990	1991	1992	1993	1994	1995	1996	1997	
Transport Subsector	541.5	563.7	555.5	555.9	572.9	596.2	615.5	583.8	
Road Transport	534.9	557.2	549.0	548.8	566.7	589.9	608.6	578.1	
Other Transports	6.6	6.5	6.5	7.1	6.2	6.3	6.9	5.7	
Residential Subsector	216.5	215.1	214.1	188.3	182.8	164.9	160.9	162.8	
Other Sectors	40.9	40.5	38.5	39.0	39.6	40.9	41.2	41.6	
Industrial Processes	345.0	340.9	347.7	369.4	370.8	426.2	437.4	457.0	
Chemical Industry	26.6	24.8	24.7	27.8	30.6	31.4	31.4	33.7	
Production of Metals	24.3	22.5	21.2	22.9	23.4	22.0	20.7	20.6	
Pulp and Paper	13.3	14.9	16.7	17.5	19.0	19.2	20.2	20.8	
Production of food	110.5	115.1	128.2	137.5	140.9	179.7	188.2	202.0	
Production of beverage	170.3	163.6	156.9	163.7	156.9	173.9	176.9	179.9	
Use of Solvents	2,338.9	2,138.8	2,057.7	2,115.7	2,299.1	2,286.9	2,516.8	2,633.9	
TOTAL	**3,851.4**	**3,629.4**	**3,519.2**	**3,587.2**	**3,790.8**	**3,817.9**	**4,046.1**	**4,147.3**	
For information purposes only									
Bunker fuels	2.9	4.4	4.7	5.9	6.8	7.3	7.8	8.3	
Air Transport	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	
Shipping	2.7	4.2	4.5	5.7	6.6	7.1	7.5	8.0	

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
		Gg											
	574.2	531.3	481.5	454.1	469.0	435.7	434.1	417.4	377.2	368.0	360.6	321.1	331.3
	567.9	525.0	475.3	447.4	462.3	429.0	426.8	410.4	370.4	360.6	352.6	313.4	322.0
	6.3	6.3	6.2	6.7	6.7	6.7	7.3	7.0	6.8	7.4	8.0	7.7	9.3
	166.2	171.4	175.9	183.3	204.3	212.9	215.9	220.3	221.0	209.7	207.4	204.3	196.1
	40.3	40.4	38.8	40.2	41.8	44.3	45.9	46.3	47.3	49.9	54.1	51.8	54.2
	463.4	507.2	532.8	501.8	542.1	590.5	629.5	616.6	745.8	695.3	724.2	717.9	736.8
	35.0	37.5	43.0	40.7	42.3	45.3	49.1	49.1	53.9	56.3	56.6	59.5	61.2
	19.4	21.1	23.3	21.5	22.8	25.8	29.8	29.1	28.1	29.5	29.1	18.9	23.0
	22.0	23.9	24.6	24.5	26.6	30.4	32.3	34.8	37.7	40.5	43.0	45.5	48.5
	204.0	238.8	252.8	223.1	255.5	291.3	317.4	338.8	331.0	374.8	386.6	386.8	407.2
	183.0	185.9	189.1	192.0	194.9	197.7	200.9	164.8	295.1	194.2	208.9	207.2	196.9
	2,879.5	2,976.0	3,154.0	2,899.6	2,958.8	2,657.0	3,032.2	2,982.2	3,722.6	2,475.0	4,135.7	4,317.4	4,749.9
	4,373.9	**4,497.8**	**4,674.2**	**4,356.7**	**4,504.0**	**4,272.8**	**4,734.5**	**4,660.3**	**5,489.3**	**4,187.7**	**5,879.4**	**5,899.7**	**6,387.2**
	9.1	14.4	14.9	17.0	19.2	16.9	16.9	16.9	17.9	19.2	24.2	17.1	21.4
	0.3	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	8.8	14.1	14.7	16.7	19.0	16.7	16.7	16.7	17.7	19.0	24.0	16.9	21.2

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