STATE COMMUNICATION

1ST DIRECT AND INDIRECT GREENHOUSE GASES ANTHROPOGENIC EMISSIONS INVENTORY OF SAO PAULO STATE

EMISSIONS FROM LAND USE, LAND-USE CHANGE, AND FORESTRY SECTOR

SAO PAULO STATE GOVERNMENT • ENVIRONMENT SECRETARIAT
CETESB - SAO PAULO STATE ENVIRONMENT AGENCY

STATE COMMUNICATION

1st Direct and Indirect Greenhouse Gases Anthropogenic Emissions Inventory of Sao Paulo State

EMISSIONS FROM LAND USE, LAND-USE CHANGE, AND FORESTRY SECTOR

Sao Paulo State Government

Environment Secretariat

CETESB - Sao Paulo State Environment Agency

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Sao Paulo State Government

Geraldo Alckmin

Environment Secretariat

Bruno Covas

CETESB – Sao Paulo State Environment Agency

Otavio Okano

REFERENCE REPORT

EMISSIONS FROM LAND USE, LAND-USE CHANGE, AND FORESTRY SECTOR

Coordination:

Sao Paulo State Environment Agency – CETESB

Sao Paulo State Program on Climate Change – PROCLIMA

Foundation for Space Science, Technology and Applications – FUNCATE

Support:

British Embassy

ANALYSIS TOOL

The Sao Paulo State environmental actions and policies show its commitment to the environment preservation. This publication “Emissions from Land Use, Land-use Change, and Forestry Sector”, part of 1st Direct and Indirect Greenhouse Gases Anthropogenic Emissions Inventory of Sao Paulo State, released in 2010 by the Sao Paulo State Environment Agency – CETESB, which is an institution linked to the State Secretariat for Environment (SMA), is an example of this commitment.

The inventory identifies areas that remained under the same category of land use inventory for the analyzed period and those that have been converted to other use categories during it. The document provides necessary information to estimate changes in carbon stocks and anthropogenic emissions and removals of greenhouse gases associated with the data of land use activities. Thus, it is possible to estimate areas where there are evidences of significant changes in vegetation.

Considering those facts, the publication shows a first estimate of regions with strong evidence of significant changes in the native vegetation area.

The book is a tool for the major emissions sources and removals of greenhouse gases analysis, monitoring over time, identification of sectors and key categories to define strategies to reduce the emissions.

This publication is an important part of the State Communication and a tool for managing GHG emissions and as such should be used within a strategy for mitigating climate change and sustainability. The document will be updated periodically in order to generate information that is comparable, nationally and internationally, and that allows the quantification of the state emissions in the global context.

Curbing emissions is an indispensable task, and it is important to impose the necessity to create and implementation of measures of compensation and adaptation. To participate actively in efforts to protect the global climate system and to promote the transition to a low carbon economy in the state is a fundamental part of the commitment made by Sao Paulo.

Bruno Covas

Environment Secretary

PRESENTATION

The 1st Direct and Indirect Greenhouse Gases Anthropogenic Emissions Inventory of Sao Paulo State is the result of three years of preparation and synthesis of 22 reference reports, made possible through the partnership with the British Embassy in Brazil, through the "Sao Paulo State Policy on Climate Change Support Project".

Prepared under the coordination of the Sao Paulo State Program on Climatic Change (PROCLIMA) of CETESB, the inventory meets the determinations of the State Policy on Climate Change (PEMC), established by the State Law 13,798/2009 and regulated by the State Decree 55,947/2010. Working together with the Ministry of Science, Technology and Innovation (MCTI) in the coordination process of the inventory, the PROCLIMA is also responsible for the reference report of the Waste Sector in the National Inventory.

The development of the Sao Paulo Inventory on the whole, counted on the participation of more than 120 partner institutions and over 320 people, among authors, reviewers and collaborators. The reference reports will be presented for all five sectors defined by the IPCC, for the accounting of the GHG emissions: Energy, Industrial Processes, Agriculture, Waste, and Land Use, Land-use Change, and Forestry.

This publication refers to the Reference Report of the Land Use, Land-use Change, and Forestry Sector, result of the partnership between the Sao Paulo State Environment Agency (CETESB) and the Foundation for Space Science, Technology and Applications (FUNCATE), with the support of the National Institute on Space Research (INPE). The end result shows that this sector is not responsible for net emissions, but for the carbon dioxide removals, which is one more important reason for the continuity and increasing efforts for the conservation of the biodiversity and reforestation in the Sao Paulo State.

Otavio Okano

President Director of CETESB

President Director

Otavio Okano

Vice President Director

Nelson Roberto Bugalho

Environmental Impact Assessment Directory - I

Ana Cristina Pasini da Costa

Process Assessment Department – IP

Alfredo Carlos Cardoso Rocca

Sustainability Division – IPC

José Wagner Faria Pacheco

Climate and Energy Sector – IPCE

Josilene Ticianelli Vannuzini Ferrer

State Communication – Coordination

Sao Paulo State Program on Climate Change – PROCLIMA

Technical Team of the Publication

Coordination of the Contract between CETESB and FUNCATE

João Wagner Silva Alves

Josilene Ticianelli Vannuzini Ferrer

Coordination

FUNCATE – Foundation for Space Science, Technology and Applications

Clotilde Pinheiro Ferri dos Santos

Elaboration

FUNCATE – Foundation for Space Science, Technology and Applications

Adriana dos Santos Siqueira Scolastrici

Aline Yukari Naokazu

Andrea Daleffi Scheide

Camila Capassi Malagodi (CETESB)

Célia Regina Pandolphi Pereira

Charlles Jefferson de Miranda

Claudio Henrique Bogossian

Clotilde Pinheiro Ferri Santos

Daniel Soler Huet (CETESB)

Dayane de Carvalho Oliveira

Ederson Rodrigues Profeta

Elpídio Sgobbi Neto

Eric Silva Abreu

Fernanda Cristina Baruel Lara

Filipe Leme Lopes

Flávia Cristina Aragão

Gabriela Ribeiro

Giane Fátima Valles

Glauco Turci

Jacqueline de Oliveira Souza

Lidia Harue Hanada

Marcelo Francisco Sestini

Marcelo Rodolfo Siqueira

Márcia Cristina Passos F. Santos

Mário Rocco Pettinati

Patrícia dos Santos Mancilha

Paula de Melo Chiste

Paulo César Ferreira Alves

Rafael Fonseca da Cruz

Rafael Notarangeli Fávaro

Roberto Wilson Oliveira Dias

Rodnei Cassiano Todorow

Rubens Lopes Saraiva

Sérgio Lopes Dousseau

Sônia Beatriz Machado Alves

Taiana Nunes dos Santos

Talita dos Santos Esturba (CETESB)

Tassiana Yeda Faria Segantine

Tiago Massao Matsumoto

Ubirajara Moura de Freitas

Vagner Cruz

Vanildes Oliveira Ribeiro

Verônica Fernandes Gama

Technical Review – INPE

Thelma Krug

Technical Review – CETESB / SMA

Daniel Soler Huet

João Wagner Silva Alves

Oswaldo dos Santos Lucon

Executive Coordination of the Publication (Portuguese Edition)

Daniel Soler Huet

Josilene Ticianelli Vannuzini Ferrer

Ligia Prangutti Orlandi (support)

Executive Coordination of the Publication (English Edition)

Omar de Almeida Cardoso

Ligia Prangutti Orlandi (support)

Desktop Publishing

Eduardo Shimabokuro

Wilson Issao Shiguemoto

Cover

Vera Severo

Collaborators of CETESB

Bruna Patrícia de Oliveira (consultant)

Camila Bernardo de Faria

Camila Capassi Malagodi

Carlos Alberto Sequeira Paiva

Eliane Aparecida Milani de Queiróz Lopes da Cruz (consultant)

Ligia Prangutti Orlandi

Isabela Maria Rodrigues Silva

Maria Fernanda Pelizzon Garcia

Matheus Fernando Kelson Batinga de Mendonça (consultant)

Natacha Nogueira Britschka

Neuza Maria Maciel

Omar de Almeida Cardoso

Rafael Takayama Garrafoli

Renata Monteiro Siqueira

Talita dos Santos Esturba

Toshiko Ueda

Translation

Equipol Tradução e Consultoria

José de Arimatéa Maciel Ferreira – Director

Expedito Calixto – Interpreter

CETESB Project (PSF LGHG CCE 0195) "Support to Sao Paulo State Policy on Climate Change", GHG Inventory of Sao Paulo State, 1990–2008, by coordination to PROCLIMA – Sao Paulo State Program on Climate Change

Institutional Coordination of the Project

Fátima Aparecida Carrara – International Cooperation Department

Luciana Morini (support)

Executive Coordination of the Project

Josilene Ticianelli Vannuzini Ferrer – Executive Secretary of PROCLIMA

Eliane Aparecida Milani de Queiróz Lopes da Cruz (support)

Technical Coordination of the Project

João Wagner Silva Alves – Coordinator of PROCLIMA

Publishing CETESB – Sao Paulo State Environment Agency

For other information:

Sao Paulo State Program on Climate Change – PROCLIMA

Professor Frederico Hermann Junior Avenue, 345, ZIP 05459-900, Sao Paulo – SP

Phone: +55 (11) 3133 3156, +55 (11) 3133 3563, Fax: +55 (11) 3133 4058

E-mail: proclima@cetesbnet.sp.gov.br

www.cetesb.sp.gov.br/geesp

www.cetesb.sp.gov.br/proclima

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EXECUTIVE SUMMARY

Executive Summary

The State Policy on Climate Change

Due to increasing atmospheric concentrations of greenhouse gases (GHG) and their relationship with the warming of the climate system, not only national governments that are part of the United Nations Framework Convention on Climate Change (UNFCCC) (BRASIL, 1992), but also local governments (states, provinces and municipalities), have tried to make estimates of net anthropogenic emissions of greenhouse gases in order to support the society in identifying local priorities and adopting suitable measures to reduce those emissions.

In that sense, the Government of Sao Paulo State, in November 09, 2009, published the Law 13,798 (SÃO PAULO, 2009), establishing the State Policy on Climate Change (PEMC), regulated by Decree 55,947 , June 24, 2010 (SÃO PAULO, 2010). In Article 6 of the Law are set the guidelines for the preparation, periodic updating and publication of GHG anthropogenic emissions inventories by sources and removals through sinks, for gases not controlled by the Montreal Protocol, with the employment of both nationally and internationally comparable methods.

The Inventory

This publication "Emissions from Land Use, Land-use Change, and Forestry Sector" is a product of the contract established in 2009, between the Foundation for Space Science, Technology and Applications (FUNCATE) and the Sao Paulo State Environment Agency (CETESB), with support from the National Institute on Space Research (INPE) and resources from the contract with the British Embassy, through the "Sao Paulo State Policy on Climate Change Support Project". Several meetings were held involving researchers, specialists and institutions so this document would be possible.

This publication presents the estimates of net anthropogenic emissions of carbon dioxide, and the emissions and removals balance from Land Use, Land-use Change, and Forestry Sector (LULUCF) in Sao Paulo State, for the periods: 1994-2002, 2002-2005, and 2005-2008. This is one of the Reference Reports that, once reviewed and consolidated, resulted in the 1st Direct and Indirect Greenhouse Gases Anthropogenic Emissions Inventory of Sao Paulo State (CETESB, 2011).

Developed by institutions of excellence and experts, this report fulfills its role, following with clarity and transparency the methodological principles established by the Good Practice Guidance for Land Use, Land-use Change, and Forestry (GPG/LULUCF) of the Intergovernmental Panel on Climate Change (IPCC, 2003).

In addition, it has been in Public Consultation on the website of CETESB for a period of six months, starting in November 2010.

Estimates

The preparation of this inventory was guided by the Good Practice Guidance for Land Use, Land-use Change, and Forestry (IPCC, 2003) of the Intergovernmental Panel on Climate Change (IPCC), from which methodologies and methodological approaches were used following the principles of transparency, consistency and accuracy recommended by the Panel, in the preparation of national inventories of greenhouse gases.

The estimates of net anthropogenic emissions from this sector involved an extensive work of collection and interpretation of remote sensing data. The state's territory was divided into spatial units in polygons, which resulted from the integration of various data sources such as: municipal borders; limits of Brazilian biomes contained in Sao Paulo State; map of the original vegetation; map of the ground; maps of land use and land cover in different dates, makes possible the analysis of changes in carbon stocks, occurred between the analyzed time periods.

Results of Net Anthropogenic Emissions Associated with Land Use, Land-use Change, and Forestry Sector

In this publication were mapped 24,823,681 ha for the three inventoried periods (1994-2002, 2002-2005, and 2005-2008). Figure 1 below, shows the CO_2 emissions and removals balance for these analyzed periods, showing the extent of the CO_2 removals in the State.

In the period between 1994 and 2002, the net anthropogenic emissions totaled -10,663.29 Gg_{CO2} (negative result indicates a CO_2 net removals), and from the mapped area, there was land-use change on 62,480 ha (0.25%).

In the period between 2002 and 2005, the net anthropogenic emissions totaled -11,753.35 Gg_{CO2}, and from the mapped area, there was land-use change on 46,426 ha (0.19%).

In the period between 2005 and 2008, the net anthropogenic emissions totaled -9,846.08 Gg_{CO2}, and from the mapped area, there was land-use change on 64,618 ha (0.26%).

From the estimates of net anthropogenic emissions, was calculated the CO_2 annual average removals, shown in Table 1.

Figure 1. CO_2 Balance in the Periods: 1994-2002, 2002-2005, and 2005-2008, in Sao Paulo State (Gg_{CO2})

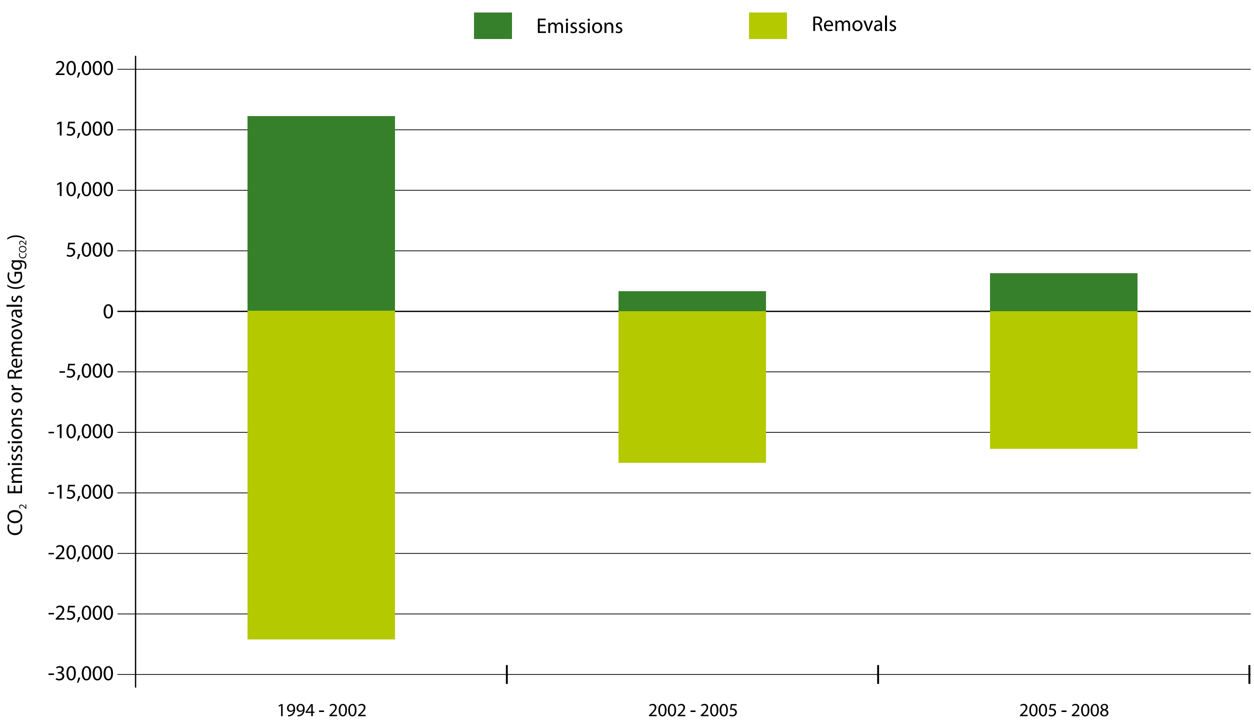


Table 1. CO_2 Annual Average Removals in the Period 1990-2008 in Sao Paulo State

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg_{CO2}.year^{-1}]									
LULUCF	NE	NE	NE	NE	NE	1,333	1,333	1,333	1,333	1,333

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg_{CO2}.year^{-1}]									
LULUCF	1,333	1,333	1,333	3,918	3,918	3,918	3,282	3,282	3,282	

Note – NE: Not Estimated;
Source: CETESB (2011).

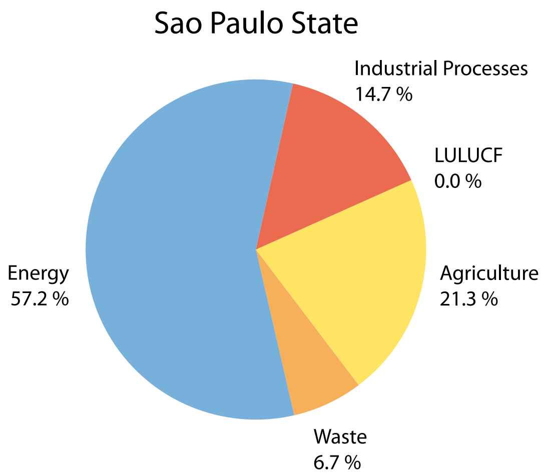
Profile of the National and Sao Paulo State Net Anthropogenic Emissions Related to the LULUCF Sector

The analysis of the net anthropogenic emissions in national level (BRAZIL, 2010) and state level (Sao Paulo), allows identify the profile of those emissions and the categories where the mitigation actions of greenhouse gases may be concentrated. Figure 2 and Figure 3 show the percentage contribution of the analyzed sectors (Energy, Waste, Industrial Processes, Agriculture, and Land Use, Land-use Change, and Forestry).

It is observed that the contribution of the LULUCF Sector to CO_2 total state emissions are null, although this is the sector that contributes the most to the total national emissions (60.6%).

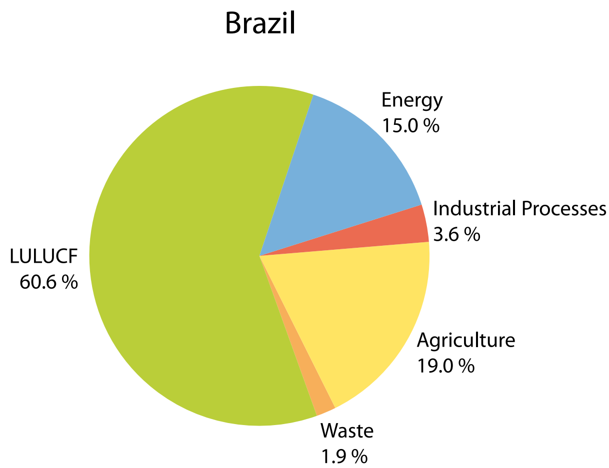
Figure 2 shows the Sao Paulo State emissions that resemble an emission standard of more industrialized states, in which the largest emitter is derived from the Energy Sector, while the emissions of Brazil, presented in Figure 3, represent a country profile with large territorial extensions and forest, where the biggest emissions are coming from the LULUCF Sector.

Figure 2. GHG Emissions in 2005 in Sao Paulo State



Source: CETESB (2011).

Figure 3. GHG Emissions in 2005 in Brazil



Source: CETESB (2011).

LIST OF ABBREVIATIONS AND ACRONYMS

A – Rivers and Lakes (Unmanaged Wetland)

ABRAF – Brazilian Association of Forest Plantation Producers (*Associação Brasileira de Produtores de Florestas Plantadas)*

Ac – Cropland Area

Ap – Planted Pasture

AvAgr – Average Carbon Stock in Cropland

AvFsec – Fraction of Carbon in Secondary Forest Relative to Carbon in Mature Forest

AvGsec – Fraction of Carbon in Secondary Grassland Relative to Carbon in Mature Grassland

AvRef – Average Carbon Stock in Reforestation Area

BRACELPA – Brazilian Pulp and Paper Association (*Associação Brasileira de Celulose e Papel*)

CC – Cropland Remaining Cropland

CETESB – Sao Paulo State Environment Agency (*Companhia Ambiental do Estado de São Paulo*)

Cm – Montane Deciduous Seasonal Forest

Cs – Submontane Deciduous Seasonal Forest

Da – Alluvial Dense Humid Forest

Db – Lowland Dense Humid Forest

DBMS - Database Management System

Dl – High Montane Dense Humid Forest

Dm – Montane Dense Humid Forest

Ds – Submontane Dense Humid Forest

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

Fa – Alluvial Semi Deciduous Seasonal Forest

FBDS – Brazilian Foundation for Sustainable Development (*Fundação Brasileira para o Desenvolvimento Sustentável*)

fc – Soil Carbon Change Factor

FF – Forest Land Remaining Forest Land

fI – Carbon Change Factor for Input of Organic Matter

fLU – Carbon Change Factor for Land Use

Fm – Montane Semi Deciduous Seasonal Forest

FM – Managed Forest

fMG – Carbon Change Factor for Management Regime

FNM – Unmanaged Forest

Fs – Submontane Semi Deciduous Seasonal Forest

FSec – Secondary Forest

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

GG – Grassland Remaining Grassland

GHG – Greenhouse Gases

GIS – Geographic Information System

GM – Managed Grassland

GNM – Unmanaged Grassland

GPG/LULUCF – Good Practice Guidance for Land Use, Land-use Change, and Forestry

GSec – Grassland with Secondary Vegetation

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

IncrAgr – Annual Average Carbon Increment in Cropland Still in Development

IncrRef – Annual Average Carbon Increment in Reforestation Areas Still in Development

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

IPCC – Intergovernmental Panel on Climate Change

LC – Land Converted to Cropland

LF – Land Converted to Forest Land

LG – Land Converted to Grassland

LO – Land Converted to Other Land

LS – Land Converted to Settlements

LULUCF – Land Use, Land-use Change, and Forestry

LW – Land Converted to Wetland

MCT – Ministry of Science and Technology (current MCTI)

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

Ml – Montane Mixed High Humid Forest

Mm – Montane Mixed Humid Forest

NASA – National Aeronautics and Space Administration

NO – Not Observed

O – Other Uses

OO – Other Land Remaining Other Land

Pa – Fluvial and/or Lacustre Influenced Vegetation

Pec – Average Carbon Stock in Planted Pasture

Pf – Pioneer Formation Fluviomarine Influenced (Mangroves)

Pm – Pioneer Formation Marine Influenced (Sand Banks)

PROCLIMA – Sao Paulo State Program on Climate Change (*Programa de Mudanças Climáticas do Estado de São Paulo*)

R/S – Root-to-shoot or Ratio of Root Biomass and Aboveground Biomass

Rebf – Annual Average Carbon Increment in Secondary Forests

Reb(G) – Annual Average Carbon Increment in Secondary Grasslands

Ref – Reforestation

Remf – Native Vegetation with Forest Physiognomy in Managed Land

Remg – Native Vegetation with Non-forest Physiognomy in Managed Land

Res – Reservoirs (Managed Wetland)

Rl – High Montane Vegetation Refuge

Rm – Montane Refuge

RPPN – Private Reserve of Natural Heritage (*Reserva Particular do Patrimônio Natural*)

S – Settlements

Sa – Wooded Savanna

Sd – Forested Savanna

Sg – Woody-grass Savanna

SIBCS – Brazilian System of Soil Classification (*Sistema Brasileiro de Classificação de Solos*)

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

Sp – Park Savanna

SS – Settlements Remaining Settlements

WW – Wetland Remaining Wetland

LIST OF SYMBOLS

C – Carbon

CO_2 – Carbon Dioxide

Gg – Gigagram

ha – Hectare

kg – Kilogram

m – Meter

T – Period

t – Time

t – Tonne

SUMMARY

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1

INTRODUCTION

1. Introduction

The Sao Paulo State Program on Climate Change (PROCLIMA) of the Sao Paulo State Environment Agency (CETESB) is responsible for the coordination of the 1st Direct and Indirect Greenhouse Gases Anthropogenic Emissions Inventory of Sao Paulo State, the State Communication (CETESB, 2011).

This State Communication counted on the support of the British Embassy through the "Sao Paulo State Policy on Climate Change Support Project", and consists of the emission estimates of the follow sectors: Energy, Industrial Processes, Agriculture, Land Use, Land-use Change, and Forestry, and Waste.

Product of a contract between FUNCATE and CETESB, this publication was attended with a technical review of an expert from INPE who chairs the task force in national inventories of greenhouse gases of IPCC. It presents estimates of the anthropogenic emissions by sources and removals through sinks of carbon dioxide (CO_2), associated with the LULUCF Sector, in the periods: 1994-2002, 2002-2005, and 2005-2008, for Sao Paulo State.

The methodologies adopted in the preparation of this document are presented in the Good Practice Guidance for Land Use, Land-use Change, and Forestry (GPG/LULUCF) of the Intergovernmental Panel on Climate Change (IPCC, 2003), which complements the Revised 1996 IPCC Guidelines (IPCC, 1996), used in the Reference Reports of Land Use, Land-use Change, and Forestry (BRASIL, 2006a; BRASIL, 2006b; BRASIL, 2006c) of the National Communication (BRASIL, 2004). Brazil has used the GPG/LULUCF (IPCC, 2003) in the preparation of its Second National Communication (BRASIL, 2010). The estimates of the LULUCF Sector of the national and state inventories, therefore, are methodologically compatible.

The crossing of several sources of data such as: municipal borders; limits of the Brazilian biomes contained in the Sao Paulo State; map of the original vegetation; map of the ground; and maps of land use and cover for the years 1994, 2002, 2005 and 2008 resulted in 544,123 analyzed polygons that enabled the estimates of CO_2. The final results obtained demonstrate that in the Sao Paulo State not contributing with CO_2 emissions, and this sector is acting as sinks of that gas, presenting removals throughout the studied period.

2

METHODOLOGY

2. Methodology

The methodological approach of the IPCC to estimate changes in carbon stocks and emissions/ removals of GHG is normally the product between data of activities (ex., area converted to another use of the land, area under agriculture, amount of fertilizer applied, burned area, etc.) and emission factors (ex., biomass associated with certain plant physiognomy, carbon in the soil under native vegetation, carbon in dead organic matter etc.). This approach is not necessarily followed if the compilers of the inventory use more advanced methods or models. However, the use of such methods and models must be well justified, especially with respect to its validation and calibration.

THE GPG/LULUCF provides methodological alternatives (Tiers) that vary from the Tier 1 proving default data that can be used if there is no specific data generated in the country; Tier 2, which is based on data specific to the country; and the Tier 3, based on models and methods other than those proposed in the Guidance. The use of a higher Tier is usually indicated for more significant emission sources or removals, which can only be identified after the completion of a first inventory.

In this inventory were not used models or methods that are not contained in the GPG/LULUCF. Additionally, as a way to estimate only the emissions/removals of anthropogenic GHG, the IPCC proposes an approach based on hypothesis that all emissions/removals in managed lands are considered anthropogenic. The IPCC knows that this approach is not perfect, but it also recognizes that there are no currently methods that can be widely used to separate the effects directly and indirectly promoted by man of those naturally. So, there is a need to define managed and unmanaged lands in the inventoried territory, before the beginning of the elaboration of the inventory itself.

3

GENERATION OF INFORMATION

3. Generation of Information

The generation of information in this section focuses primarily on the identification of the areas under different land-use categories, characterizing them into two large classes: (1) those which remained under the same land-use category in the inventory period; and (2) those which were converted to other categories in the same period. This information is one of the elements necessary to estimate the changes in carbon stocks and the associated anthropogenic emissions and removals of GHG (data of activity), as mentioned. The generation of information for the representation of areas to the Land Use, Land-use Change, and Forestry Sector (LULUCF) was based on the following guidelines of the GPG/LULUCF (IPCC, 2003):

ORIENTATION A. Use of appropriate approaches (capable of representing the changes in carbon stocks and anthropogenic emissions and removals of GHG and their relations between land use and land-use change); consistent (capable of representing management practices and land-use change in a consistent manner over time, without being affected by seasonal discontinuities); complete (involving the inclusion of the entire land area of the State, with increments of area in some categories being offset by decreases in other); transparent (providing a clear description of data sources, definitions, methodologies and hypothesis adopted); and accurate (trying not to generate super or sub estimates, as much as possible).

ORIENTATION B. Identification of land-use categories with land-use changes and more relevant anthropogenic emissions and removals of GHG. The IPCC proposes six broad land-use categories: forest, grassland, cropland, wetland, settlements and other lands. The GPG/LULUCF recognizes that some of these categories refer to land cover (forest, wetland), while other to land use (cropland, settlements). For convenience, this work refers to all categories as land-use categories.

Note 1: In this report were defined the land-use categories, identified in Table 2.

Table 2. Land-use Categories

Acronym	Category	IPCC Category
FNM	Unmanaged Forest	Forest
FM	Managed Forest	
FSec	Secondary Forest	
Ref	Reforestation	
GNM	Unmanaged Grassland	Grassland
GM	Managed Grassland	
GSec	Grassland with Secondary Vegetation	
Ap	Planted Pasture	
Ac	Cropland Area	Cropland
S	Urban Area	Settlements
A	Rivers and Lakes (Unmanaged Wetland)	Wetland
Res	Reservoirs (Managed Wetland)	
O	Other Uses	Other Land
NO	Not Observed	

ORIENTATION C. Using of own national definitions for land-use categories. For the purposes of this report, the following definitions were adopted:

1. Forest Land: Land-use category with the following characteristics:

a) Minimum tree crown coverage: 10%;

b) Minimum area: 0.5 ha;

c) Minimum tree height: 5 meters.

Forest land category was divided in the following subcategories:

i) Primary forest: forests in which human action did not cause significant alterations in its original structure and species. It is also denominated as Climax Forest;

ii) Reforestation: includes planted areas or areas being prepared for the planting of forest essentials (Black Acacia, *Eucalyptus, Pinus*, etc.), and included the occupied areas by forest essential sapling nurseries.

Primary Forest

Reforestation

2. Grassland

i) Primary grassland vegetation: grassland where human actions did not cause significant alterations in its original structure and species;

ii) Pasture: includes designated areas for grazing and that have been established by planting.

Primary Grassland Vegetation

Pasture

3. Cropland

Include all areas cultivated with annual and perennial crops.

Cropland

4. Wetland

Extension of natural or artificial, permanent or temporary, stagnant or running, fresh, brackish or salted salt marshes, swamps, peat bogs or waters, including extensions of sea waters, whose depths at low tide do not exceed 6 (six) meters. Includes:

i) Rivers and lakes;

ii) Reservoirs.

Paraibuna River

Foto Guarapiranga

5. Settlements

Internal area of an urban perimeter of a city or village defined by municipal law and characterized by continuous construction and the existence of social equipment for basic functions such as housing, work, recreation and circulation.

Sao Paulo City

6. Other Land

(Example: rock formations, mining activities, dunes, etc.).

Laje de Santos

7. Not Observed

(Areas not assessed by remote sensing due to continuous cloud cover).

ORIENTATION D. The use of one of three approaches proposed for the representation of areas: approach 1, which refers to the basic data of the land use; approach 2, involves the assessment of land use and land-use change; and approach 3, which requires spatially explicit observations of land use and land-use change.

Note 2: This report adopted approach 3 The entire territory of Sao Paulo State was subdivided into spatial units in the form of polygons that resulted from the integration of the following sources of data (information layer): (A) Soil Map at a scale of 1:5,000,000 (IBGE, EMBRAPA, 2001); (B) Map of original vegetation at a scale of 1:5,000,000 (IBGE, 2004); (C) Municipal borders; (D) Limits of the two Brazilian Biomes in the Sao Paulo State (IBGE, 2004), and (E) Maps of land use and cover for the years 1994, 2002, 2005 and 2008 at a scale of 1:250,000.

ORIENTATION E. Report of carbon stocks changes and GHG anthropogenic emissions/ removals in unmanaged lands converted for other land-use categories. The difference of the managed and the unmanaged lands involves not only production, but also includes ecological and social functions; there is a need to treat this issue with transparency. The 2006 IPCC Guidelines for Agriculture, Forestry and Other Land Use (IPCC, 2006) provides a more specific definition for managed land, as follows: "managed land is land where human interventions and practices have been applied to perform production, ecological or social functions" Although countries do not need reporting GHG emissions and removals in an unmanaged land, it is good practice to quantify and monitor over time the unmanaged land to ensure consistency in the accounts of the area as the conversions of unmanaged lands for managed lands are happening.

Note 3: This report presents the net anthropogenic emissions of Sao Paulo State, in managed lands defined according to 2006 Guidelines (IPCC, 2006)

For this report we considered managed land all forest, and native non-forest vegetation (grassland) contained in Indigenous lands and in the National System of Protected Areas – SNUC (Law 9,985/2000) (BRASIL, 2000), except the Private Reserves of Natural Heritage (RPPN)[1]. The SNUC defines Protected Area as the "territorial space and its environmental resources, including the jurisdictional waters, with relevant natural characteristics, legally instituted by the Public Power, with objectives of conservation and defined limits, under special administration regime, to which apply adequate guarantees of protection". The Federal Constitution of Brazil (paragraph 1st of article 231) (BRASIL, 1998) conceptualizes Indigenous lands as the lands traditionally occupied by the Indians, defined as those "inhabited by them permanently, used for their productive activities, essential to the preservation of environmental resources necessary for their well-being and required for their physical and cultural reproduction, according to their habits, customs and traditions".

1. The RPPN were not considered due to the difficulty of obtaining the date of execution of each area.

4

ACTIVITY DATA

4. Activity Data

4.1. Database

For the compilation and interpretation of data, the system *TerraAmazon* was used, a tool designed for editing vector geographical databases, stored in a Database Management System (DBMS) model *TerraLib* (www.terralib.org), in a corporate environment, distributed and concurrent use. *TerraAmazon* is free software available at <www.terraamazon.org>. The images from the Landsat 5 satellite, used for interpretation of the images were georeferenced by comparison with images from NASA (*GeoCover*).

The database stores the spatial information using a Geographic Information System (GIS), inserting and integrating into single database, spatial information from cartographic data and satellite images. In this report is included data from the years 1994, 2002, 2005 and 2008 and the following complementary information:

a) Images from NASA (*GeoCover*) year 1999/2000:

GeoCover images obtained at NASA's website (2008), were used in the georeferencing of the TM/*Landsat* images. The registration of TM/*Landsat* images was done by associating the coordinates of the image (line and column) with the geographical coordinates (latitude and longitude) of *GeoCover* images.

b) TM/*Landsat* Images:

For each *GeoCover* scene that covers the Sao Paulo State, was made a selection of the Landsat images trough research on the INPE's website[2] (2008a), for the years 1994, 2002, 2005 and 2008, seeking to meet scenes obtained in dates near to minimize spatial variations especially those associated with the land use and land cover when the integration of scenes of different dates. The selection also considered other variables, as the clouds covering index and the presence of irreversible noises. These factors are preponderant to determination of the radiometric, spectral

Table 3. Scenes Used in the Land-use Mapping and Respective Acquisition Dates

Orbit/Point	Acquisition Date			
	1994	2002	2005	2008
218/76	9/9/1995	5/15/2002	6/16/2005	3/4/2008
218/77	7/20/1994	8/19/2002	6/16/2005	3/4/2008
219/75	2/1/1994	10/13/2002	9/11/2005	8/18/2008
219/76	2/1/1994	6/7/2002	9/11/2005	8/18/2008
219/77	2/1/1994	6/7/2002	6/23/2005	7/17/2008
220/74	9/20/1994	10/20/2002	8/1/2005	7/24/2008
220/75	7/20/1994	9/2/2002	8/1/2005	9/10/2008
220/76	7/18/1994	9/2/2002	8/1/2005	7/8/2008
220/77	7/18/1994	9/2/2002	2/22/2005	6/6/2008
221/74	7/25/1994	10/11/2002	5/4/2005	8/16/2008
221/75	7/25/1994	9/25/2002	5/4/2005	9/1/2008
221/76	7/9/1994	10/11/2002	5/4/2005	7/15/2008
221/77	7/9/1994	10/11/2002	5/4/2005	10/3/2008
222/74	11/21/1994	10/2/2002	7/14/2005	8/23/2008
222/75	8/1/1994	10/2/2002	7/14/2005	8/23/2008
222/76	7/16/1994	11/03/2002	7/14/2005	8/23/2008
223/74	5/4/1994	8/6/2002	8/22/2005	10/17/2008
223/75	8/8/1994	8/6/2002	8/22/2005	4/24/2008
223/76	8/8/1994	8/6/2002	8/22/2005	8/30/2008

Source: INPE (2008a).

2. <www.dgi.inpe.br/CDSR>.

and spatial quality of the used images. Table 3 shows the used scenes with the respective dates of acquisition.

c) Vegetation map from the Brazilian Institute of Geography and Statistics (IBGE, 2004):

The vegetation map of Brazil (IBGE, 2004) reconstitutes the situation of the vegetation in the Brazilian territory at the time of its discovery, emphasizing two major sets of vegetation: a forest, which occupies more than 60% of the national territory, and grassland formations.

The forest formations are constituted by Dense Humid Forests (typical of wetlands throughout the year) and Deciduous Seasonal Forests (typical of lands with deficiency of humidity during part of the year) located in the Amazon Region and outside areas as the Atlantic Forest.

The grassland formations are constituted by types of open vegetation, mapped as: Savanna (corresponding to the Cerrado that predominates in the Central Region of Brazil, also occurring in small areas in other regions of the country, including the Amazon Region); Steppe Savanna (includes the Caatinga in Northeast Region of Brazil, Grasslands of Roraima, Pantanal of Mato Grosso, and a small occurrence in the Extreme West of Rio Grande do Sul); Steppe (which corresponds to the Grasslands, Plateau and Prairies in the Extreme South of Brazil); and Campinarana (vegetation due to the lack of mineral nutrients in the soil and that occurs in the Amazon, in the Rio Negro basin).

The map also brings the indication of the areas of pioneer formations, as the Restingas, Mangroves and Wetlands, in addition to the areas of ecological tension (where are the contacts between vegetation types) and the so-called Vegetation refuges, where the vegetation in general is consisting of the relic's communities.

The digital data of the mosaic of vegetation map of the IBGE (2004) were obtained directly from the IBGE website. This map was cropped for Sao Paulo State, inserted in the database and used as a basis for the recognition of the predominance of vegetation in the area covered by the State (Map 1).

d) Map of the Biomes

In Sao Paulo State there are two of the six National Biomes: Atlantic Forest and Cerrado. Map 2 presents the Sao Paulo State and the delimitations of its biomes.

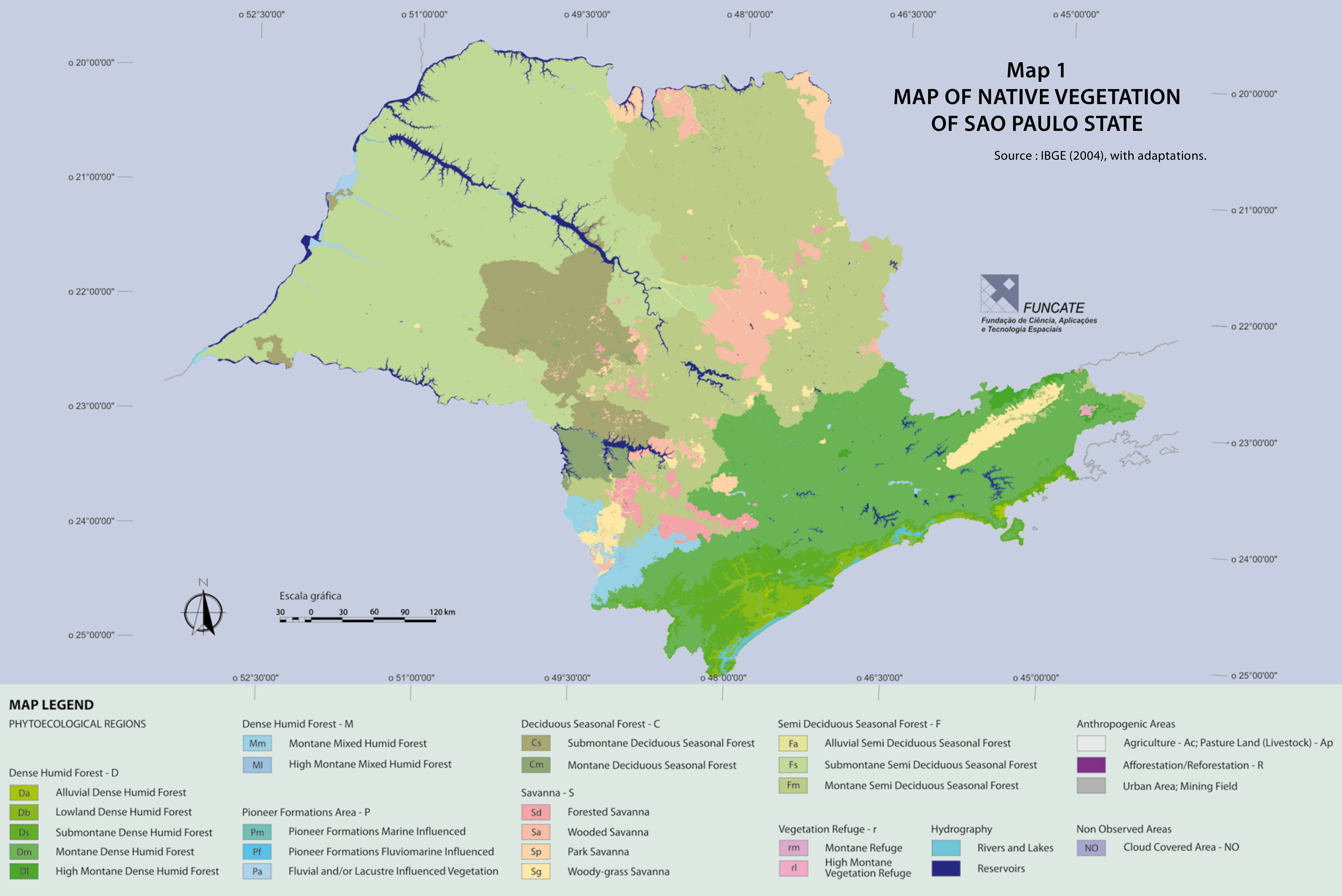
4.2. Identification of Land Use and Land-use Change

At this stage, has been created for each of the analyzed years (1994, 2002, 2005 and 2008) a map of the land use and land cover using the land-use categories indicated in Table 2. These land-use maps are presented in Map 3, Map 4, Map 5, and Map 6, for the years 1994, 2002, 2005 and 2008, respectively.

Maps of Land Use and Land Cover were generated from the interpretation of the images of the American satellite *Landsat* 5, identified in the Table 3. The maps of 1994 and 2002 are a crop of the Sao Paulo State from the maps generated for the Second National Communication (BRASZIL, 2010).

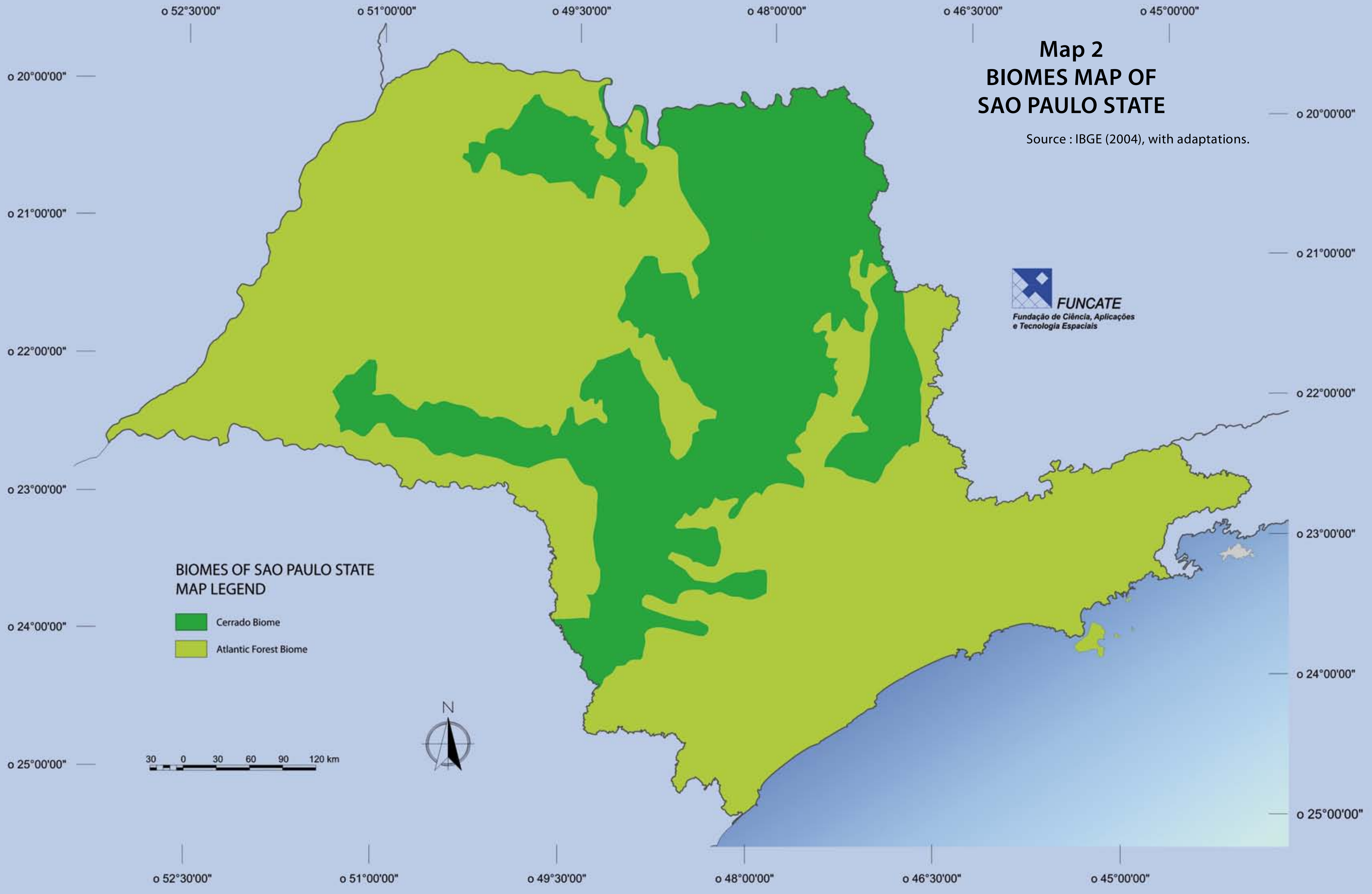
Map 1
MAP OF NATIVE VEGETATION OF SAO PAULO STATE

Source : IBGE (2004), with adaptations.

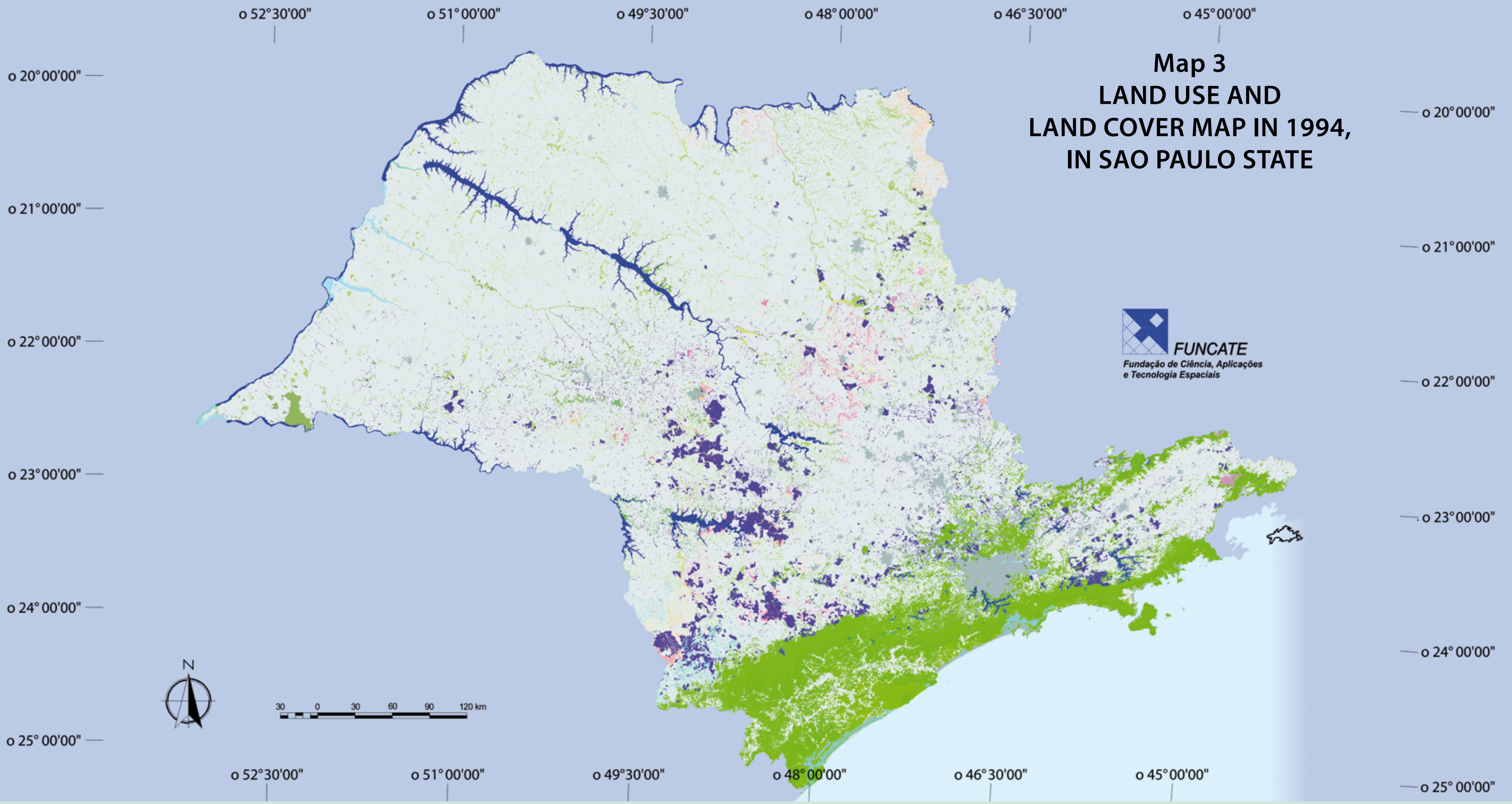


Map 2
BIOMES MAP OF SAO PAULO STATE

Source : IBGE (2004), with adaptations.



Map 3
LAND USE AND LAND COVER MAP IN 1994, IN SAO PAULO STATE



MAP LEGEND

PHYTOECOLOGICAL REGIONS

Dense Humid Forest - D
- Da — Alluvial Dense Humid Forest
- Db — Lowland Dense Humid Forest
- Ds — Submontane Dense Humid Forest
- Dm — Montane Dense Humid Forest
- Dl — High Montane Dense Humid Forest

Dense Humid Forest - M
- Mm — Montane Mixed Humid Forest
- Ml — High Montane Mixed Humid Forest

Pioneer Formations Area - P
- Pm — Pioneer Formations Marine Influenced
- Pf — Pioneer Formations Fluviomarine Influenced
- Pa — Fluvial and/or Lacustre Influenced Vegetation

Deciduous Seasonal Forest - C
- Cs — Submontane Deciduous Seasonal Forest
- Cm — Montane Deciduous Seasonal Forest

Savanna - S
- Sd — Forested Savanna
- Sa — Wooded Savanna
- Sp — Park Savanna
- Sg — Woody-grass Savanna

Semi Deciduous Seasonal Forest - F
- Fa — Alluvial Semi Deciduous Seasonal Forest
- Fs — Submontane Semi Deciduous Seasonal Forest
- Fm — Montane Semi Deciduous Seasonal Forest

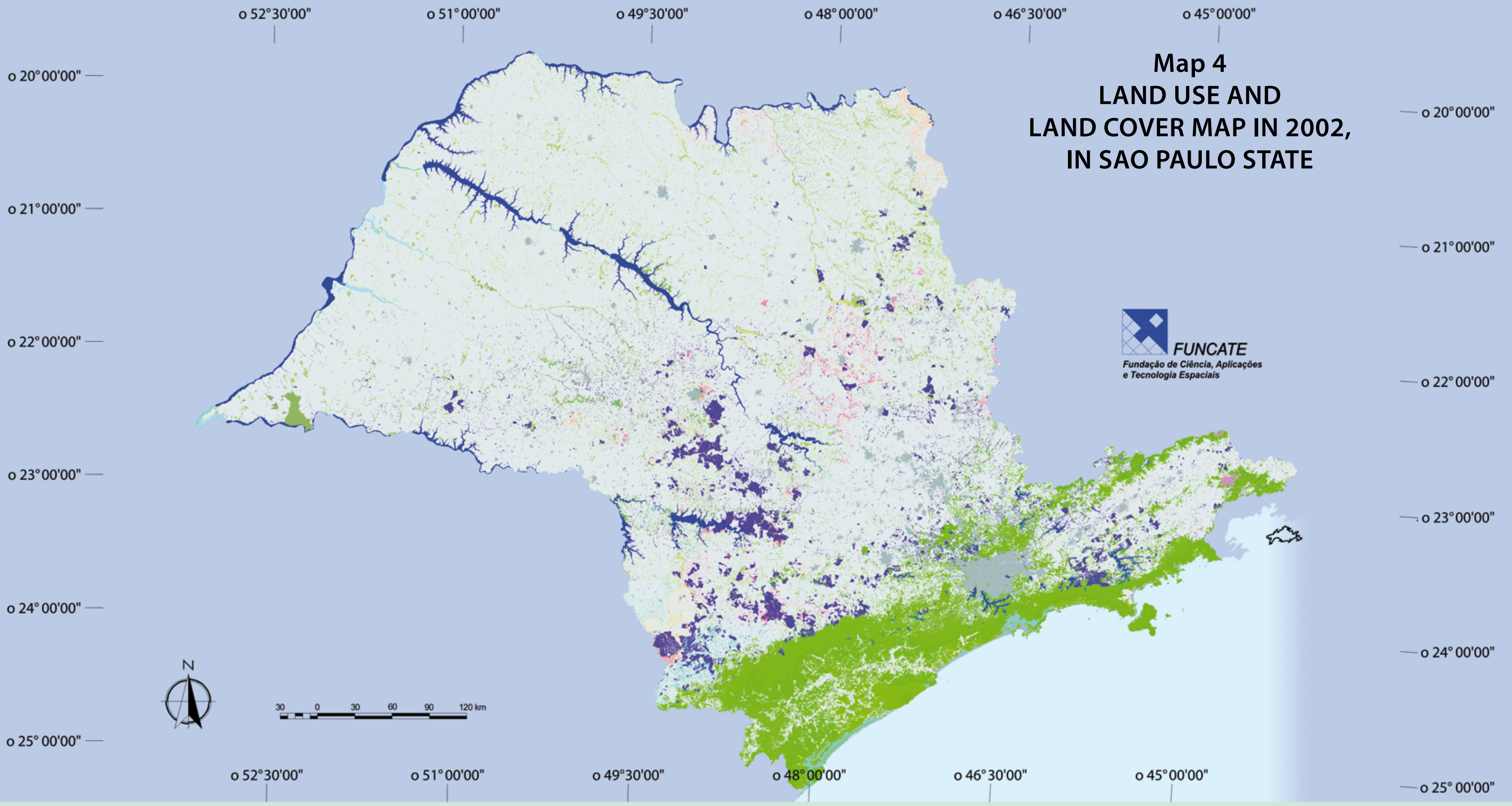
Vegetation Refuge - r
- rm — Montane Refuge
- rl — High Montane Vegetation Refuge

Hydrography
- Rivers and Lakes
- Reservoirs

Anthropogenic Areas
- Agriculture - Ac; Pasture Land (Livestock) - Ap
- Afforestation/Reforestation - R
- Urban Area; Mining Field

Non Observed Areas
- NO — Cloud Covered Area - NO

Map 4
LAND USE AND LAND COVER MAP IN 2002, IN SAO PAULO STATE



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MAP LEGEND

PHYTOECOLOGICAL REGIONS

Dense Humid Forest - D
- Da Alluvial Dense Humid Forest
- Db Lowland Dense Humid Forest
- Ds Submontane Dense Humid Forest
- Dm Montane Dense Humid Forest
- Dl High Montane Dense Humid Forest

Dense Humid Forest - M
- Mm Montane Mixed Humid Forest
- Ml High Montane Mixed Humid Forest

Pioneer Formations Area - P
- Pm Pioneer Formations Marine Influenced
- Pf Pioneer Formations Fluviomarine Influenced
- Pa Fluvial and/or Lacustre Influenced Vegetation

Deciduous Seasonal Forest - C
- Cs Submontane Deciduous Seasonal Forest
- Cm Montane Deciduous Seasonal Forest

Savanna - S
- Sd Forested Savanna
- Sa Wooded Savanna
- Sp Park Savanna
- Sg Woody-grass Savanna

Semi Deciduous Seasonal Forest - F
- Fa Alluvial Semi Deciduous Seasonal Forest
- Fs Submontane Semi Deciduous Seasonal Forest
- Fm Montane Semi Deciduous Seasonal Forest

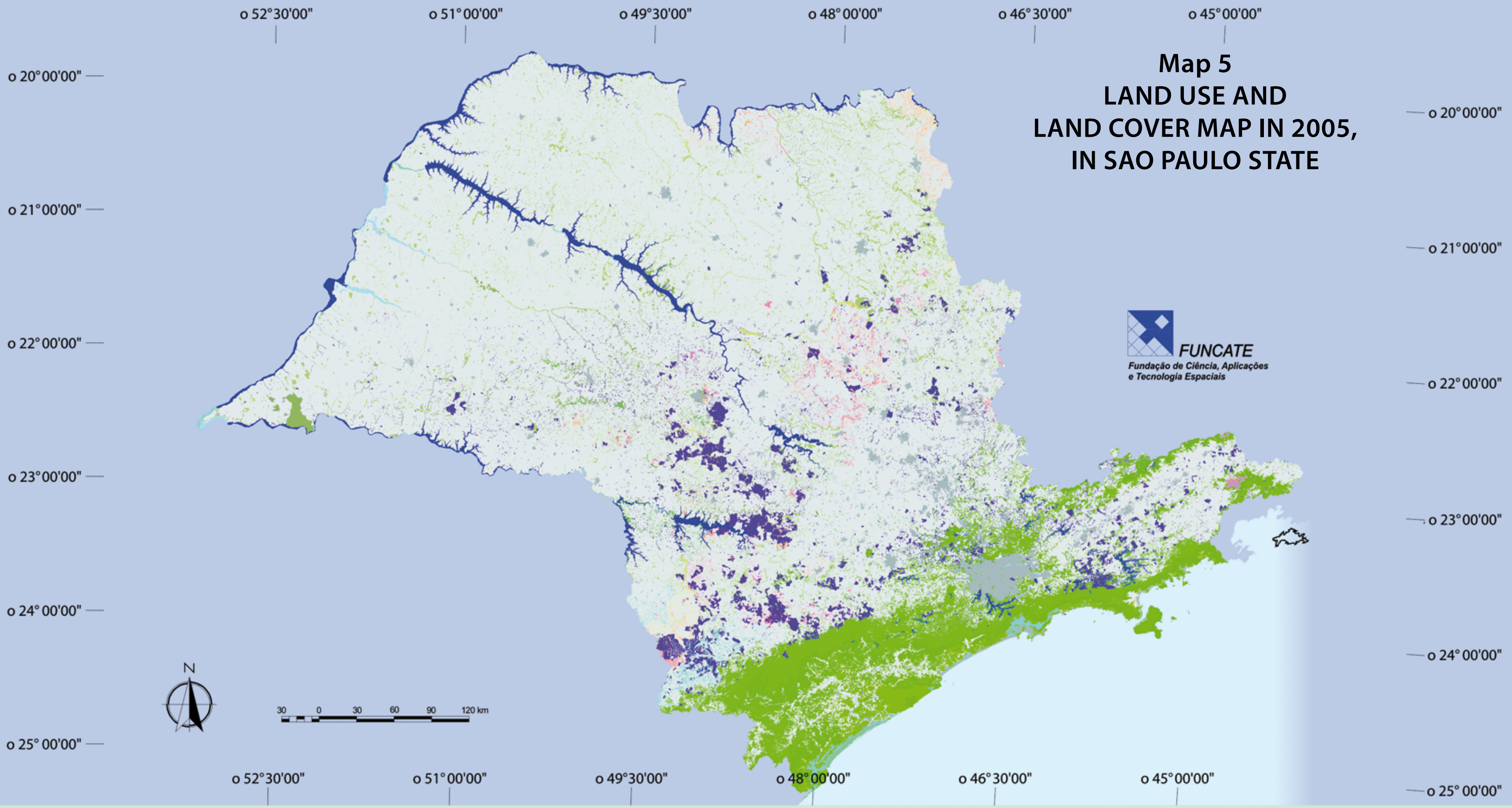
Vegetation Refuge - r
- rm Montane Refuge
- rl High Montane Vegetation Refuge

Hydrography
- Rivers and Lakes
- Reservoirs

Anthropogenic Areas
- Agriculture - Ac; Pasture Land (Livestock) - Ap
- Afforestation/Reforestation - R
- Urban Area; Mining Field

Non Observed Areas
- NO Cloud Covered Area - NO

Map 5
LAND USE AND LAND COVER MAP IN 2005, IN SAO PAULO STATE



MAP LEGEND

PHYTOECOLOGICAL REGIONS

Dense Humid Forest - D
- Da — Alluvial Dense Humid Forest
- Db — Lowland Dense Humid Forest
- Ds — Submontane Dense Humid Forest
- Dm — Montane Dense Humid Forest
- Dl — High Montane Dense Humid Forest

Dense Humid Forest - M
- Mm — Montane Mixed Humid Forest
- Ml — High Montane Mixed Humid Forest

Pioneer Formations Area - P
- Pm — Pioneer Formations Marine Influenced
- Pf — Pioneer Formations Fluviomarine Influenced
- Pa — Fluvial and/or Lacustre Influenced Vegetation

Deciduous Seasonal Forest - C
- Cs — Submontane Deciduous Seasonal Forest
- Cm — Montane Deciduous Seasonal Forest

Savanna - S
- Sd — Forested Savanna
- Sa — Wooded Savanna
- Sp — Park Savanna
- Sg — Woody-grass Savanna

Semi Deciduous Seasonal Forest - F
- Fa — Alluvial Semi Deciduous Seasonal Forest
- Fs — Submontane Semi Deciduous Seasonal Forest
- Fm — Montane Semi Deciduous Seasonal Forest

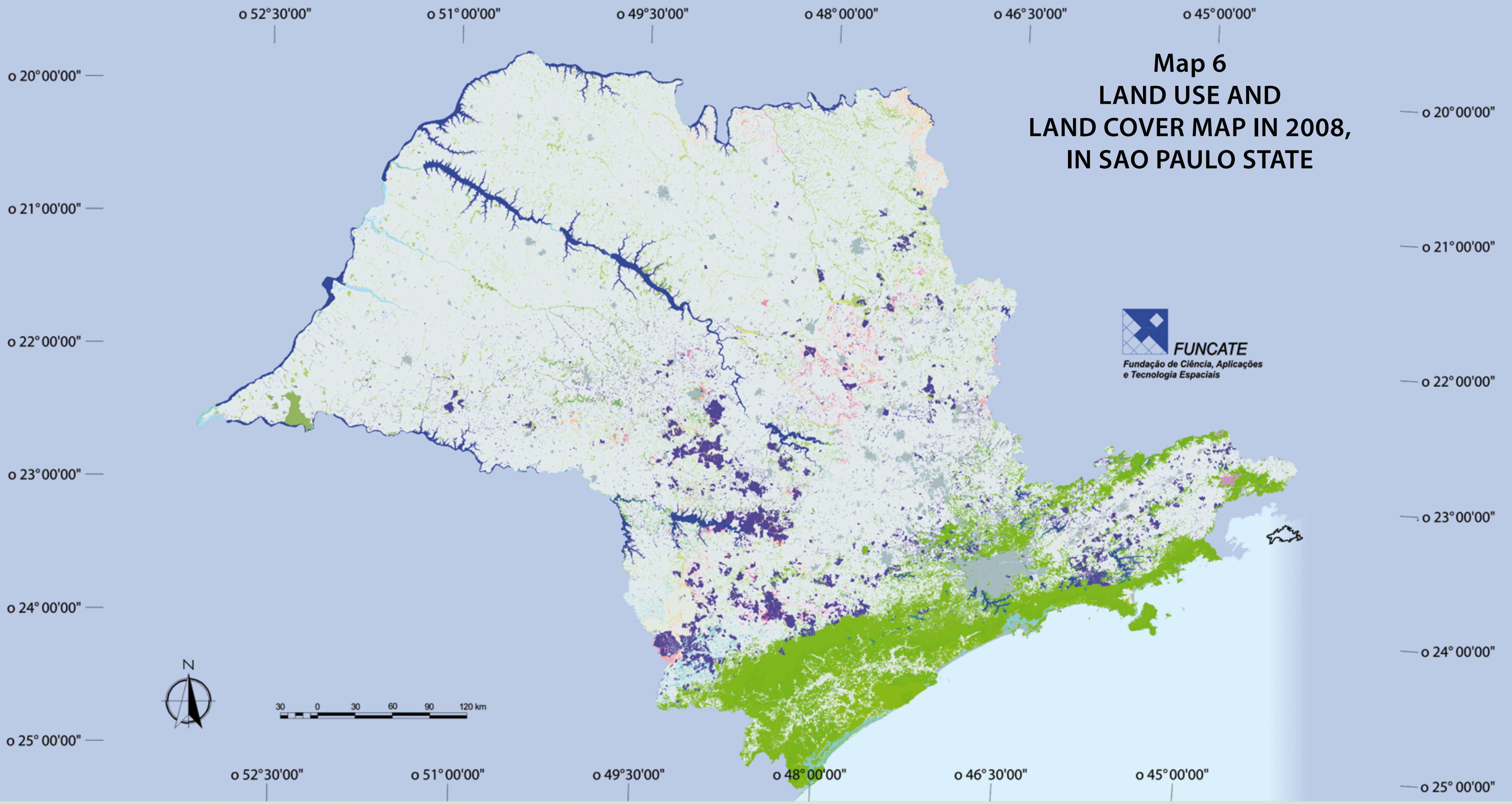
Vegetation Refuge - r
- rm — Montane Refuge
- rl — High Montane Vegetation Refuge

Hydrography
- Rivers and Lakes
- Reservoirs

Anthropogenic Areas
- Agriculture - Ac; Pasture Land (Livestock) - Ap
- Afforestation/Reforestation - R
- Urban Area; Mining Field

Non Observed Areas
- NO — Cloud Covered Area - NO

Map 6
LAND USE AND LAND COVER MAP IN 2008, IN SAO PAULO STATE



MAP LEGEND

PHYTOECOLOGICAL REGIONS

Dense Humid Forest - D
- Da Alluvial Dense Humid Forest
- Db Lowland Dense Humid Forest
- Ds Submontane Dense Humid Forest
- Dm Montane Dense Humid Forest
- Dl High Montane Dense Humid Forest

Dense Humid Forest - M
- Mm Montane Mixed Humid Forest
- Ml High Montane Mixed Humid Forest

Pioneer Formations Area - P
- Pm Pioneer Formations Marine Influenced
- Pf Pioneer Formations Fluviomarine Influenced
- Pa Fluvial and/or Lacustre Influenced Vegetation

Deciduous Seasonal Forest - C
- Cs Submontane Deciduous Seasonal Forest
- Cm Montane Deciduous Seasonal Forest

Savanna - S
- Sd Forested Savanna
- Sa Wooded Savanna
- Sp Park Savanna
- Sg Woody-grass Savanna

Semi Deciduous Seasonal Forest - F
- Fa Alluvial Semi Deciduous Seasonal Forest
- Fs Submontane Semi Deciduous Seasonal Forest
- Fm Montane Semi Deciduous Seasonal Forest

Vegetation Refuge - r
- rm Montane Refuge
- rl High Montane Vegetation Refuge

Hydrography
- Rivers and Lakes
- Reservoirs

Anthropogenic Areas
- Agriculture - Ac; Pasture Land (Livestock) - Ap
- Afforestation/Reforestation - R
- Urban Area; Mining Field

Non Observed Areas
- NO Cloud Covered Area - NO

4.3. Construction of Land-use Transitions Matrices for the Periods: 1994-2002, 2002-2005, and 2005-2008

At this stage, has been generated, for each period considered (1994-2002, 2002-2005, and 2005-2008) and from the data obtained in the phases above, land-use transition matrices, and identifying the areas that remained under the same category between the initial and final years of the period (diagonal of the matrix), and those who suffered land-use conversion in the same period (off the diagonal of the matrix).

Table 4 presents possible states of land-use categories identified in the GPC/LULUCF. Obviously, this table is adapted to include the possible states of the subcategories defined in Table 2.

For purposes of this report, the observed transitions are shown in Table 5. The filled cells indicate the unlikely states (permanence or transition) in the analyzed period.

Table 4. Possible Land-use Categories between Initial and Final Dates of the Inventory, According to the GPG/LULUCF

State (permanence)	
FF	Forest Land Remaining Forest Land
GG	Grassland Remaining Grassland
CC	Cropland Remaining Cropland
WW	Wetland Remaining Wetland
SS	Settlements Remaining Settlements
OO	Other Land Remaining Other Land
State (transition)	
LF	Land Converted to Forest Land
LG	Land Converted to Grassland
LC	Land Converted to Cropland
LW	Land Converted to Wetland
LS	Land Converted to Settlements
LO	Land Converted to Other Land

Fonte: IPCC (2003), com adaptações.

Table 5. Observed Land-use Transitions Matrix

		Year 02											
		FNM	FM	Ref	GNM	GM	Ap	Ac	S	A	Res	O	NO
Year 01	FNM												
	FM												
	Ref												
	GNM												
	GM												
	Ap												
	Ac												
	S												
	A												
	Res												
	O												
	NO												

Legend:

FNM – Unmanaged Forest; **FM** – Managed Forest; **Ref** – Reforestation; **GNM** – Unmanaged Grassland; **GM** – Managed Grassland; **Ap** – Planted Pasture; **Ac** – Cropland Area; **S** – Settlements; **A** – Rivers and Lakes (Unmanaged Wetland); **Res** – Reservoirs (Managed Wetland); **O** – Other Uses; **NO** – Not Observed; "—" Not Applicable";
Unlikely transitions in the analyzed period. Areas in state of residence in the analyzed period.

4.4. Calculation of Anthropogenic Emissions and Removals for the Transitions Analyzed

For each of the biomes that compose Sao Paulo State, are presented specific data on biomass and other relevant parameters (Emission Factors - EF). It was tried to use, whenever possible, specific values generated for Sao Paulo State, instead of the default values (Tier 1) contained in the GPG/LULUCF.

The fundamental basis for the methodological approach of the IPCC (1996) is set in two hypotheses:

i) The CO_2 flow from the atmosphere, or to the atmosphere, is equal to changes in carbon stocks in existing biomass and in soils;

ii) The changes in carbon stocks can be estimated by determination of the rates of land-use change and the activity responsible for the change (burning, deforestation, selective logging, etc.). Next, the impacts of such activities in carbon stocks and the biological response of a particular land-use are evaluated.

The methodology of the GPG/LULUCF establishes that the estimate of the CO_2 emissions in a given period of time (T) is generated by the difference of carbon stocks observed at the beginning and end of the inventoried period for each of the transitions defined in Table 4. Two approaches are described for this calculation: (1) direct assessment of carbon stocks in two moments in time (beginning and end of the period); or (2) assessment of the annual gains (increments) and losses of carbon per unit area, in the period considered.

The carbon stock, or carbon losses and gains are calculated for the various carbon pool (above and belowground biomass, dead organic matter and soil carbon). In this report, three distinct periods were considered for the inventory: 1994-2002, 2002-2005, and 2005-2008. The two approaches above were used, depending on the type of land-use change observed.

The methodology used to estimate the changes in carbon stocks in the biomass in forest areas was based on the equations of the GPG/LULUCF, reproduced below.

Equation 1. Annual Carbon Stocks Change in a Given Pool, as a Function of Gains and Losses

$$\Delta C = \sum_{ijk} [A_{ijk} \cdot (C_I - C_L)_{ijk}]$$

where:

ΔC	Annual Average change in carbon stock	$[t_C.year^{-1}]$
A	Area	[ha]
ijk	Indexes that correspond to climate type "i", vegetation type "j" and management practice "k"	
C_I	Annual average gain of carbon per unit of area	$[t_C.(ha.year)^{-1}]$
C_L	Annual average loss of carbon per unit of area	$[t_C.(ha.year)^{-1}]$

Equation 2. Equation 2. Annual Carbon Stocks Change in a Given Pool

$$\Delta C = \sum_{ijk} \frac{(C_{t_2} - C_{t_1})}{(t_2 - t_1)_{ijk}}$$

where:

ΔC	Annual Average change in carbon stock	$[t_C.year^{-1}]$
C_{t_1}	Carbon stock at time t1	$[t_C]$
C_{t_2}	Carbon stock at time t2 (end of the period)	$[t_C]$
ijk	Indexes that correspond to climate type "i", vegetation type "j" and management practice "k"	
t_1	Beginning of the inventoried period	[year]
t_2	End of the inventoried period	[year]

Next, is described the methodology for calculation of the net annual anthropogenic emissions for each of the transitions observed, shown in Table 5.

4.4.1. Emissions and Removals on Stock Change in Living Biomass and Dead Organic Matter

In the sections below are presented the equations used in this report. The parameter T (time interval in the inventoried period) is identified below for each of the inventoried periods and is used in all equations:

- Between 1994 and 2002 is equal to 8 years;

- Between 2002 and 2005 is equal to 3 years;

- Between 2005 and 2008 is equal to 3 years.

A) Forest Land Remaining Forest Land

In this report were defined four subcategories of forests: Unmanaged Forest (FNM), Managed Forest (FM), Secondary Forest (FSec) and Reforestation (Ref). The possible transitions are according to Table 5.

A.1) Unmanaged Forest Remaining Unmanaged Forest (FNM–FNM)

It is assumed that there is no change in carbon stock, since the emissions or removals in unmanaged lands are not considered as being of anthropogenic nature.

A.2) Managed Forest Remaining Managed Forest (FM–FM)

Equation 3. CO_2 Emissions in Transition FM – FM

$$E_i = A_i \cdot Remf_i \cdot T$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
$Remf_i$	Annual average carbon removals in forest physiognomy of the polygon i	$[t_C.(ha.year)^{-1}]$
T	Interval of inventoried period	[year]

A.3) Secondary Forest Remaining Secondary Forest (FSec–FSec)

Equation 4. CO_2 Emissions in Transition FSec – FSec

$$E_i = A_i \cdot Rebf \cdot T$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
$Rebf$	Annual average carbon increment in secondary forest	$[t_C.(ha.ano)^{-1}]$
T	Interval of inventoried period	[year]

A.4) Reforestation Remaining Reforestation (Ref–Ref)

It is assumed that, on average, the annual change in carbon stock is null (loss-cut balanced by gains in growth).

A. 5) Unmanaged Forest Converted to Managed Forest (FNM–FM)

It is assumed that the transition (FNM–FM with the creation of a conservation unit) occurs, on average, in the middle point of the inventoried period.

Equation 5. CO_2 Emissions in Transition FNM – FM

$$E_i = A_i \cdot Remf_i \cdot (T/2)$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]

$Remf_i$	Annual average carbon removals in forest physiognomy of the polygon i	$[t_C.(ha.year)^{-1}]$
T	Interval of inventoried period	[year]

A.6) Unmanaged Forest Converted to Secondary Forest (FNM–FSec)

Equation 6. CO_2 Emissions in Transition FNM – FSec

$$E_i = A_i \cdot \{C_i - [Rebf \cdot (T/2)]\}$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
$Rebf$	Annual average carbon increment in secondary forest	$[t_C.(ha.year)^{-1}]$
T	Interval of inventoried period	[year]

A.7) Managed Forest Converted to Secondary Forest (FM–FSec)

Equation 7. CO_2 Emissions in Transition FM – FSec

$$E_i = A_i \cdot \{C_i - [Rebf \cdot (T/2)]\}$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
$Rebf$	Annual average carbon increment in secondary forest	$[t_C.(ha.year)^{-1}]$
T	Interval of inventoried period	[year]

A.8) Reforestation Converted to Secondary Forest (Ref–FSec)

Equation 8. CO_2 Emissions in Transition Ref – FSec

$$E_i = A_i \cdot \{Av(Ref) - [Rebf \cdot (T/2)]\}$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
$Av(Ref)$	Average carbon stock in reforestation area	$[t_C.ha^{-1}]$
$Rebf$	Annual average carbon increment in secondary forest	$[t_C.(ha.year)^{-1}]$
T	Interval of inventoried period	[year]

A.9) Unmanaged Forest Converted to Reforestation (FNM–Ref)

Equation 9. CO_2 Emissions in Transition FNM – Ref

$$E_i = A_i \cdot \{C_i - [Incr(Ref) \cdot (T/2)]\}$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
$Incr(Ref)$	Annual average carbon increment in reforestation	$[t_C.(ha.ano)^{-1}]$
T	Interval of inventoried period	[ano]

A.10) Managed Forest Converted to Reforestation (FM–Ref)

Equation 10. CO_2 Emissions in Transition FM – Ref

$$E_i = A_i \cdot \{C_i \cdot [Incr(Ref) \cdot (T/2)]\}$$

where:

E_i	Carbon emission associated with the polygon i in the period T	[t_C]
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	[t_C.ha^{-1}]
$Incr(Ref)$	Annual average carbon increment in reforestation	[t_C.(ha.year)$^{-1}$]
T	Interval of inventoried period	[ano]

A.11) Secondary Forest Converted to Reforestation (FSec–Ref)

Equation 11. CO_2 Emissions in Transition FSec – Ref

$$E_i = A_i \cdot \{[C_i \cdot Av\,(Fsec)] - [Incr(Ref) \cdot (T/2)]\}$$

where:

E_i	Carbon emission associated with the polygon i in the period T	[t_C]
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	[t_C.ha^{-1}]
$Av(Fsec)$	Fraction of carbon in secondary forest relative to carbon in mature forest	
$Incr(Ref)$	Annual average carbon increment in reforestation	[t_C.(ha.year)$^{-1}$]
T	Interval of inventoried period	[year]

B) Land Converted to Forest Land

B.1) Planted Pasture Converted to Secondary Forest (Ap–FSec)

Equation 12. CO_2 Emissions in Transition Ap – FSec

$$E_i = A_i \cdot \{Pec - [Rebf \cdot (T/2)]\}$$

where:

E_i	Carbon emission associated with the polygon i in the period T	[t_C]
A_i	Area of polygon i	[ha]
Pec	Average carbon stock in planted pasture	[t_C.ha^{-1}]
$Rebf$	Annual average carbon increment in secondary forest	[t_C.(ha.year)$^{-1}$]
T	Interval of inventoried period	[year]

B.2) Cropland Converted to Secondary Forest (Ac–Fsec)

Equation 13. CO_2 Emissions in Transition Ac – FSec

$$E_i = A_i \cdot \{Av(Agr) - [Rebf \cdot (T/2)]\}$$

where:

E_i	Carbon emission associated with the polygon i in the period T	[t_C]
A_i	Area of polygon i	[ha]
$Av(Agr)$	Average carbon stock in cropland	[t_C.ha^{-1}]
$Rebf$	Annual average carbon increment in secondary forest	[t_C.(ha.year)$^{-1}$]
T	Interval of inventoried period	[year]

B.3) Other Uses Converted to Secondary Forest (O–Fsec)

Equation 14. CO_2 Emissions in Transition O – FSec

$$E_i = A_i \cdot \{O - [Rebf \cdot (T/2)]\}$$

where:

E_i	Carbon emission associated with the polygon i in the period T	[t_C]
A_i	Area of polygon i	[ha]
O	Average carbon stock in other uses	[t_C.ha^{-1}]
$Rebf$	Annual average carbon increment in secondary forest	[t_C.(ha.year)$^{-1}$]
T	Interval of inventoried period	[year]

B.4) Grassland Converted to Reforestation (GNM–Ref) (GM–Ref)

Equation 15. CO_2 Emissions in Transition GNM e GM – Ref

$$E_i = A_i \cdot \{C_i - [Incr(Ref) \cdot (T/2)]\}$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
$Incr(Ref)$	Annual average carbon increment in reforestation	$[t_C.(ha.year)^{-1}]$
T	Interval of inventoried period	[year]

B.5) Grassland with Secondary Vegetation Converted to Reforestation (GSec–Ref)

Equation 16. CO_2 Emissions in Transition GSec – Ref

$$E_i = A_i \cdot \{[C_i \cdot Av(Gsec)] - [Incr(Ref) \cdot (T/2)]\}$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
$Av(Gsec)$	Fraction of carbon in secondary grassland relative to carbon in mature grassland	
$Incr(Ref)$	Annual average carbon increment in reforestation	$[t_C.(ha.year)^{-1}]$
T	Interval of inventoried period	[year]

B.6) Planted Pasture Converted to Reforestation (Ap–Ref)

Equation 17. CO_2 Emissions in Transition Ap – Ref

$$E_i = A_i \cdot \{Pec - [Incr(Ref) \cdot (T/2)]\}$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
Pec	Average carbon stock in planted pasture	$[t_C.ha^{-1}]$
$Incr(Ref)$	Annual average carbon increment in reforestation	$[t_C.(ha.year)^{-1}]$
T	Interval of inventoried period	[year]

B.7) Cropland Converted to Reforestation (Ac–Ref)

Equation 18. CO_2 Emissions in Transition Ac – Ref

$$E_i = A_i \cdot \{Av(Agr) - [Incr(Ref) \cdot (T/2)]\}$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
$AvAgr$	Average carbon stock in cropland	$[t_C.ha^{-1}]$
$Incr(Ref)$	Annual average carbon increment in reforestation	$[t_C.(ha.year)^{-1}]$
T	Interval of inventoried period	[year]

B.8) Other Uses Converted to Reforestation (O–Ref)

Equation 19. CO_2 Emissions in Transition O – Ref

$$E_i = A_i \cdot \{O - [Incr(Ref) \cdot (T/2)]\}$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]

O	Average carbon stock in other uses	$[t_C.ha^{-1}]$
$Incr(Ref)$	Annual average carbon increment in reforestation	$[t_C.(ha.year)^{-1}]$
T	Interval of inventoried period	[year]

C) Grassland Remaining Grassland

C.1) Unmanaged Grassland Remaining Unmanaged Grassland (GNM–GNM)

It is assumed that there is no change in carbon stock, since the removals in unmanaged lands are not considered anthropogenic.

C.2) Managed Grassland Remaining Managed Grassland (GM–GM)

It is assumed that, on average, the change in carbon stock is null.

C.3) Grassland with Secondary Vegetation Remaining Grassland with Secondary Vegetation (GSec–GSec)

Equation 20. CO_2 Emissions in Transition GSec – GSec

$$E_i = A_i \cdot Reb(G) \cdot T$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
$Reb(G)$	Annual average carbon increment in secondary grasslands	$[t_C.(ha.year)^{-1}]$
T	Interval of inventoried period	[year]

C.4) Planted Pasture Remaining Planted Pasture (Ap–Ap)

It is assumed that, on average, the change in carbon stock is null.

C.5) Unmanaged Grassland Converted to Managed Grassland (GNM–GM)

It is assumed that, on average, the change in carbon stock is null.

C.6) Unmanaged Grassland Converted to Grassland with Secondary Vegetation (GNM–GSec)

Equation 21. CO_2 Emissions in Transition GNM – GSec

$$E_i = A_i \cdot \{C_i - [Reb(G) \cdot (T/2)]\}$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
$Reb(G)$	Annual average carbon increment in secondary grasslands	$[t_C.(ha.year)^{-1}]$
T	Interval of inventoried period	[year]

C.7) Managed Grassland Converted to Grassland with Secondary Vegetation (GM–GSec)

Equation 22. CO_2 Emissions in Transition GM – GSec

$$E_i = A_i \cdot \{C_i - [Reb(G) \cdot (T/2)]\}$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
$Reb(G)$	Annual average carbon increment in secondary grasslands	$[t_C.(ha.year)^{-1}]$

T	Interval of inventoried period	[year]

C.8) Planted Pasture Converted to Grassland with Secondary Vegetation (Ap–GSec)

Equation 23. CO_2 Emissions in Transition Ap – GSec

$$E_i = A_i \cdot \{Pec - [Reb(G) \cdot (T/2)]\}$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
Pec	Average carbon stock in planted pasture	$[t_C.ha^{-1}]$
$Reb(G)$	Annual average carbon increment in secondary grasslands	$[t_C.(ha.year)^{-1}]$
T	Interval of inventoried period	[year]

C.9) Unmanaged Grassland Converted to Planted Pasture (GNM–Ap)

Equation 24. CO_2 Emissions in Transition GNM – Ap

$$E_i = A_i \cdot (C_i - Pec)$$

onde:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_{i_i}	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
Pec	Average carbon stock in planted pasture	$[t_C.ha^{-1}]$

C.10) Managed Grassland Converted to Planted Pasture (GM–Ap)

Equation 25. CO_2 Emissions in Transition GM – Ap

$$E_i = A_i \cdot (C_i - Pec)$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_{i_i}	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
Pec	Average carbon stock in planted pasture	$[t_C.ha^{-1}]$

C.11) Secondary Grassland Converted to Planted Pasture (GSec–Ap)

Equation 26. CO_2 Emissions in Transition GSec – Ap

$$E_i = A_i \cdot [C_i \cdot Av\,(Gsec) - Pec]$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
$Av(Gsec)$	Fraction of carbon in secondary grassland relative to carbon in mature grassland	
Pec	Average carbon stock in planted pasture	$[t_C.ha^{-1}]$

D) Land Converted to Grassland

D.1) Reforestation Converted to Grassland with Secondary Vegetation (Ref–GSec)

Equation 27. CO_2 Emissions in Transition Ref – GSec

$$E_i = A_i \cdot \{Av(Ref) - [Reb(G) \cdot (T/2)]\}$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
$Av(Ref)$	Average carbon stock in reforestation area	$[t_C.ha^{-1}]$
$Reb(G)$	Annual average carbon increment in secondary grasslands	$[t_C.(ha.year)^{-1}]$

T	Interval of inventoried period	[year]

D.2) Cropland Converted to Grassland with Secondary Vegetation (Ac–GSec)

Equation 28. CO_2 Emissions in Transition Ac – GSec

$$E_i = A_i \cdot \{Av(Agr) - [Reb(G) \cdot (T/2)]\}$$

where:

E_i	Carbon emission associated with the polygon i in the period T	[t_C]
A_i	Área do polígono i	[ha]
$Av(Agr)$	Average carbon stock in cropland	[t_C.ha^{-1}]
$Reb(G)$	Annual average carbon increment in secondary grasslands	[t_C.(ha.year)$^{-1}$]
T	Interval of inventoried period	[year]

D.3) Other Uses Converted to Grassland with Secondary Vegetation (O–GSec)

Equation 29. CO_2 Emissions in Transition O – GSec

$$E_i = A_i \cdot \{O - [Reb(G) \cdot (T/2)]\}$$

where:

E_i	Carbon emission associated with the polygon i in the period T	[t_C]
A_i	Area of polygon i	[ha]
O	Average carbon stock in other uses	[t_C.ha^{-1}]
$Reb(G)$	Annual average carbon increment in secondary grasslands	[t_C.(ha.year)$^{-1}$]
T	Interval of inventoried period	[year]

D.4) Unmanaged Forest Converted to Planted Pasture (FNM–Ap)

Equation 30. CO_2 Emissions in Transition FNM – Ap

$$E_i = A_i \cdot (C_i - Pec)$$

where:

E_i	Carbon emission associated with the polygon i in the period T	[t_C]
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	[t_C.ha^{-1}]
Pec	Average carbon stock in planted pasture	[t_C.ha^{-1}]

D.5) Managed Forest Converted to Planted Pasture (FM–Ap)

Equation 31. CO_2 Emissions in Transition FM – Ap

$$E_i = A_i \cdot (C_i - Pec)$$

where:

E_i	Carbon emission associated with the polygon i in the period T	[t_C]
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	[t_C.ha^{-1}]
Pec	Average carbon stock in planted pasture	[t_C.ha^{-1}]

D.6) Secondary Forest Converted to Planted Pasture (FSec–Ap)

Equation 32. CO_2 Emissions in Transition FSec – Ap

$$E_i = A_i \cdot [C_i \cdot Av(Fsec) - Pec]$$

where:

E_i	Carbon emission associated with the polygon i in the period T	[t_C]
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	[t_C.ha^{-1}]
$Av(Fsec)$	Fraction of carbon in secondary forest relative to carbon in mature forest	
Pec	Average carbon stock in planted pasture	[t_C.ha^{-1}]

D.7) Reforestation Converted to Planted Pasture (Ref–Ap)

Equation 33. CO_2 Emissions in Transition Ref – Ap

$$E_i = A_i \cdot [Av(Ref) - Pec]$$

where:

E_i	Carbon emission associated with the polygon i in the period T	[t_C]
A_i	Area of polygon i	[ha]
$Av(Ref)$	Average carbon stock in reforestation area	[t_C.ha^{-1}]
Pec	Average carbon stock in planted pasture	[t_C.ha^{-1}]

D.8) Cropland Converted to Planted Pasture (Ac–Ap)

Equation 34. CO_2 Emissions in Transition Ac – Ap

$$E_i = A_i \cdot [Av(Agr) - Pec]$$

where:

E_i	Carbon emission associated with the polygon i in the period T	[t_C]
A_i	Area of polygon i	[ha]
$Av(Agr)$	Average carbon stock in cropland	[t_C.ha^{-1}]
Pec	Average carbon stock in planted pasture	[t_C.ha^{-1}]

D.9) Other Uses Converted to Planted Pasture (O–Ap)

Equation 35. CO_2 Emissions in Transition O – Ap

$$E_i = A_i \cdot (O - Pec)$$

where:

E_i	Carbon emission associated with the polygon i in the period T	[t_C]
A_i	Area of polygon i	[ha]
O	Average carbon stock in other uses	[t_C.ha^{-1}]
Pec	Average carbon stock in planted pasture	[t_C.ha^{-1}]

E) Cropland Remaining Cropland

It is assumed that, on average, the change in carbon stock is null.

F) Land Converted to Cropland

F.1) Unmanaged Forest Converted to Cropland (FNM–Ac)

Equation 36. CO_2 Emissions in Transition FNM – Ac

$$E_i = A_i \cdot [C_i - Av(Agr)]$$

where:

E_i	Carbon emission associated with the polygon i in the period T	[t_C]
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	[t_C.ha^{-1}]
$Av(Agr)$	Average carbon stock in cropland	[t_C.ha^{-1}]

F.2) Managed Forest Converted to Cropland (FM–Ac)

Equation 37. CO_2 Emissions in Transition FM – Ac

$$E_i = A_i \cdot [C_i - Av(Agr)]$$

where:

E_i	Carbon emission associated with the polygon i in the period T	[t_C]
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	[t_C.ha^{-1}]
$Av(Agr)$	Average carbon stock in cropland	[t_C.ha^{-1}]

F.3) Secondary Forest Converted to Cropland (FSec–Ac)

Equation 38. CO_2 Emissions in Transition FSec – Ac

$$E_i = A_i \cdot [C_i \cdot Av(Fsec) - Av(Agr)]$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
$Av(Fsec)$	Fraction of carbon in secondary forest relative to carbon in mature forest	
$Av(Agr)$	Average carbon stock in cropland	$[t_C.ha^{-1}]$

F.4) Reforestation Converted to Cropland (Ref–Ac)

Equation 39. CO_2 Emissions in Transition Ref – Ac

$$E_i = A_i \cdot [Av(Ref) - Av(Agr)]$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
$Av(Ref)$	Average carbon stock in reforestation area	$[t_C.ha^{-1}]$
$Av(Agr)$	Average carbon stock in cropland	$[t_C.ha^{-1}]$

F.5) Unmanaged Grassland Converted to Cropland (GNM–Ac)

Equation 40. CO_2 Emissions in Transition GNM – Ac

$$E_i = A_i \cdot [C_i - Av(Agr)]$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
$Av(Agr)$	Average carbon stock in cropland	$[t_C.ha^{-1}]$

F.6) Managed Grassland Converted to Cropland (GM–Ac)

Equation 41. CO_2 Emissions in Transition GM – Ac

$$E_i = A_i \cdot [C_i - Av(Agr)]$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
$Av(Agr)$	Average carbon stock in cropland	$[t_C.ha^{-1}]$

F.7) Grassland with Secondary Vegetation Converted to Cropland (GSec–Ac)

Equation 42. CO_2 Emissions in Transition GSec – Ac

$$E_i = A_i \cdot [C_i \cdot Av(Gsec) - Av(Agr)]$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
$Av(Gsec)$	Fraction of carbon in secondary grassland relative to carbon in mature grassland	
$Av(Agr)$	Average carbon stock in cropland	$[t_C.ha^{-1}]$

F.8) Planted Pasture Converted to Cropland (Ap–Ac)

Equation 43. CO_2 Emissions in Transition Ap – Ac

$$E_i = A_i \cdot [Pec - Av(Agr)]$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
Pec	Average carbon stock in planted pasture	$[t_C.ha^{-1}]$
$Av(Agr)$	Average carbon stock in cropland	$[t_C.ha^{-1}]$

F.9) Other Uses Converted to Cropland (O–Ac)

Equation 44. CO_2 Emissions in Transition O – Ac

$$E_i = A_i \cdot [O - Av(Agr)]$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
O	Average carbon stock in other uses	$[t_C.ha^{-1}]$
$Av(Agr)$	Average carbon stock in cropland	$[t_C.ha^{-1}]$

G) Wetland Remaining Wetland

G.1) Rivers and Lakes Remaining Rivers and Lakes (A–A)

The change in carbon stock is null.

G.2) Reservoirs Remaining Reservoirs (Res–Res)

The change in carbon stock is null.

G.3) Rivers and Lakes Converted to Reservoirs (A–Res)

The change in carbon stock is null.

H) Land Converted to Wetland

H.1) Unmanaged Forest Converted to Reservoirs (FNM–Res)

Equation 45. CO_2 Emissions in Transition FNM – Res

$$E_i = A_i \cdot (C_i - Res)$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
Res	Average carbon stock in reservoirs	$[t_C.ha^{-1}]$

H.2) Managed Forest Converted to Reservoirs (FM–Res)

Equation 46. CO_2 Emissions in Transition FM – Res

$$E_i = A_i \cdot (C_i - Res)$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
Res	Average carbon stock in reservoirs	$[t_C.ha^{-1}]$

H.3) Secondary Forest Converted to Reservoirs (Fsec–Res)

Equation 47. CO_2 Emissions in Transition FSec – Res

$$E_i = A_i \cdot [C_i \cdot Av(Fsec) - Res]$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
$Av(Fsec)$	Fraction of carbon in secondary forest relative to carbon in mature forest	
Res	Average carbon stock in reservoirs	$[t_C.ha^{-1}]$

H.4) Reforestation Converted to Reservoirs (Ref–Res)

Equation 48. CO_2 Emissions in Transition Ref – Res

$$E_i = A_i \cdot [Av(Ref) - Res]$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
$Av(Ref)$	Average carbon stock in reforestation area	$[t_C.ha^{-1}]$

Res	Average carbon stock in reservoirs	$[t_C.ha^{-1}]$

H.5) Unmanaged Grassland Converted to Reservoirs (GNM–Res)

Equation 49. CO_2 Emissions in Transition de GNM – Res

$$E_i = A_i \cdot (C_i - Res)$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
Res	Average carbon stock in reservoirs	$[t_C.ha^{-1}]$

H.6) Managed Grassland Converted to Reservoirs (GM–Res)

Equation 50. CO_2 Emissions in Transition GM – Res

$$E_i = A_i \cdot (C_i - Res)$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
Res	Average carbon stock in reservoirs	$[t_C.ha^{-1}]$

H.7) Grassland with Secondary Vegetation Converted to Reservoirs (GSec–Res)

Equation 51. CO_2 Emissions in Transition GSec – Res

$$E_i = A_i \cdot [C_i \cdot Av(Gsec) - Res]$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
$Av(Gsec)$	Fraction of carbon in secondary grassland relative to carbon in mature grassland	
Res	Average carbon stock in reservoirs	$[t_C.ha^{-1}]$

H.8) Planted Pasture Converted to Reservoirs (Ap–Res)

Equation 52. CO_2 Emissions in Transition Ap – Res

$$E_i = A_i \cdot (Pec - Res)$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
Pec	Average carbon stock in planted pasture	$[t_C.ha^{-1}]$
Res	Average carbon stock in reservoirs	$[t_C.ha^{-1}]$

H.9) Cropland Converted to Reservoirs (Ac–Res)

Equation 53. CO_2 Emissions in Transition Ac – Res

$$E_i = A_i \cdot [Av(Agr) - Res]$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
$Av(Agr)$	Average carbon stock in cropland	$[t_C.ha^{-1}]$
Res	Average carbon stock in reservoirs	$[t_C.ha^{-1}]$

H.10) Other Uses Converted to Reservoirs (O–Res)

Equation 54. CO_2 Emissions in Transition O – Res

$$E_i = A_i \cdot (O - Res)$$

where:

E_i	Carbon emission associated with the polygon *i* in the period *T*	$[t_C]$
A_i	Area of polygon *i*	[ha]
O	Average carbon stock in other uses	$[t_C.ha^{-1}]$
Res	Average carbon stock in reservoirs	$[t_C.ha^{-1}]$

I) Settlements Remaining Settlements

The change in carbon stock is null.

J) Land Converted to Settlements

J.1) Unmanaged Forest converted to Settlements (FNM–S)

Equation 55. CO_2 Emissions in Transition FNM – S

$$E_i = A_i \cdot (C_i - S)$$

where:

E_i	Carbon emission associated with the polygon *i* in the period *T*	$[t_C]$
A_i	Area of polygon *i*	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon *i*	$[t_C.ha^{-1}]$
S	Average carbon stock in settlements	$[t_C.ha^{-1}]$

J.2) Managed Forest Converted to Settlements (FM–S)

Equation 56. CO_2 Emissions in Transition FM – S

$$E_i = A_i \cdot (C_i - S)$$

where:

E_i	Carbon emission associated with the polygon *i* in the period *T*	$[t_C]$
A_i	Area of polygon *i*	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon *i*	$[t_C.ha^{-1}]$
S	Average carbon stock in settlements	$[t_C.ha^{-1}]$

J.3) Secondary Forest Converted to Settlements (FSec–S)

Equation 57. CO_2 Emissions in Transition FSec – S

$$E_i = A_i \cdot [C_i \cdot Av(Fsec) - S]$$

where:

E_i	Carbon emission associated with the polygon *i* in the period *T*	$[t_C]$
A_i	Area of polygon *i*	[ha]
C_{i_i}	Average carbon stock in vegetation physiognomy of the polygon *i*	$[t_C.ha^{-1}]$
$Av(Fsec)$	Fraction of carbon in secondary forest relative to carbon in mature forest	
S	Average carbon stock in settlements	$[t_C.ha^{-1}]$

J.4) Reforestation Converted to Settlements (Ref–S)

Equation 58. CO_2 Emissions in Transition Ref – S

$$E_i = A_i \cdot [Av(Ref) - S]$$

where:

E_i	Carbon emission associated with the polygon *i* in the period *T*	$[t_C]$
A_i	Area of polygon *i*	[ha]
$Av(Ref)$	Estoque médio de carbono em reflorestamento	$[t_C.ha^{-1}]$
S	Average carbon stock in settlements	$[t_C.ha^{-1}]$

J.5) Unmanaged Grassland Converted to Settlements (GNM–S)

Equation 59. CO_2 Emissions in Transition GNM – S

$$E_i = A_i \cdot (C_i - S)$$

where:

E_i	Carbon emission associated with the polygon *i* in the period *T*	$[t_C]$
A_i	Area of polygon *i*	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon *i*	$[t_C.ha^{-1}]$

S	Average carbon stock in settlements	$[t_C.ha^{-1}]$

J.6) Managed Grassland Converted to Settlements (GM–S)

Equation 60. CO_2 Emissions in Transition GM – S

$$E_i = A_i \cdot (C_i - S)$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
S	Average carbon stock in settlements	$[t_C.ha^{-1}]$

J.7) Grassland with Secondary Vegetation Converted to Settlements (GSec–S)

Equation 61. CO_2 Emissions in Transition GSec – S

$$E_i = A_i \cdot [C_i \cdot Av(Gsec) - S]$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
$Av(Gsec)$	Fraction of carbon in secondary grassland relative to carbon in mature grassland	
S	Average carbon stock in settlements	$[t_C.ha^{-1}]$

J.8) Planted Pasture Converted to Settlements (Ap–S)

Equation 62. CO_2 Emissions in Transition Ap – S

$$E_i = A_i \cdot (Pec - S)$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
Pec	Average carbon stock in planted pasture	$[t_C.ha^{-1}]$
S	Average carbon stock in settlements	$[t_C.ha^{-1}]$

J.9) Cropland Converted to Settlements (Ac–S)

Equation 63. CO_2 Emissions in Transition Ac – S

$$E_i = A_i \cdot [Av(Agr) - S]$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
$Av(Agr)$	Average carbon stock in cropland	$[t_C.ha^{-1}]$
S	Average carbon stock in settlements	$[t_C.ha^{-1}]$

J.10) Other Uses Converted to Settlements (O–S)

Equation 64. CO_2 Emissions in Transition O – S

$$E_i = A_i \cdot (O - S)$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
O	Average carbon stock in other uses	$[t_C.ha^{-1}]$
S	Average carbon stock in settlements	$[t_C.ha^{-1}]$

K) Other Land Remaining Other Land

It is assumed that, on average, the change in carbon stock is null.

L) Land Converted to Other Land

L.1) Unmanaged Forest Converted to Other Uses (FNM–O)

Equation 65. CO_2 Emissions in Transition FNM – O

$$E_i = A_i \cdot (C_i - O)$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
O	Average carbon stock in other uses	$[t_C.ha^{-1}]$

L.2) Managed Forest Converted to Other Uses (FM–O)

Equation 66. CO_2 Emissions in Transition FM – O

$$E_i = A_i \cdot (C_i - O)$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
O	Estoque médio de carbono em outros usos	$[t_C.ha^{-1}]$

L.3) Secondary Forest Converted to Other Uses (FSec–O)

Equation 67. CO_2 Emissions in Transition FSec – O

$$E_i = A_i \cdot [C_i \cdot Av(Fsec) - O]$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
$Av(Fsec)$	Fraction of carbon in secondary forest relative to carbon in mature forest	
O	Average carbon stock in other uses	$[t_C.ha^{-1}]$

L.4) Reforestation Converted to Other Uses (Ref–O)

Equation 68. CO_2 Emissions in Transition Ref – O

$$E_i = A_i \cdot [Av(Ref) - O]$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
$Av(Ref)$	Estoque médio de carbono em reflorestamento	$[t_C.ha^{-1}]$
O	Average carbon stock in other uses	$[t_C.ha^{-1}]$

L.5) Unmanaged Grassland Converted to Other Uses (GNM–O)

Equation 69. CO_2 Emissions in Transition GNM – O

$$E_i = A_i \cdot (C_i - O)$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
O	Average carbon stock in other uses	$[t_C.ha^{-1}]$

L.6) Managed Grassland Converted to Other Uses (GM–O)

Equation 70. CO_2 Emissions in Transition GM – O

$$E_i = A_i \cdot (C_i - O)$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
O	Average carbon stock in other uses	$[t_C.ha^{-1}]$

L.7) Grassland with Secondary Vegetation Converted to Other Uses (GSec–O)

Equation 71. CO_2 Emissions in Transition GSec – O

$$E_i = A_i \cdot [C_i \cdot Av(Gsec) - O]$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
C_i	Average carbon stock in vegetation physiognomy of the polygon i	$[t_C.ha^{-1}]$
$Av(Gsec)$	Fraction of carbon in secondary grassland relative to carbon in mature grassland	
O	Average carbon stock in other uses	$[t_C.ha^{-1}]$

L.8) Planted Pasture Converted to Other Uses (Ap–O)

Equation 72. CO_2 Emissions in Transition Ap – O

$$E_i = A_i \cdot (Pec - O)$$

where:

E_i	Emissão de carbono associada ao polígono i no período T	$[t_C]$
A_i	Area of polygon i	[ha]
Pec	Estoque médio de carbono em área de pastagem	$[t_C.ha^{-1}]$
O	Average carbon stock in other uses	$[t_C.ha^{-1}]$

L.9) Cropland Converted to Other Uses (Ac–O)

Equation 73. CO_2 Emissions in Transition Ac – O

$$E_i = A_i \cdot [Av(Agr) - O]$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
$Av(Agr)$	Average carbon stock in cropland	$[t_C.ha^{-1}]$
O	Average carbon stock in other uses	$[t_C.ha^{-1}]$

L.10) Settlements Converted to Other Uses (S–O)

Equation 74. CO_2 Emissions in Transition S – O

$$E_i = A_i \cdot (S - O)$$

where:

E_i	Carbon emission associated with the polygon i in the period T	$[t_C]$
A_i	Area of polygon i	[ha]
S	Average carbon stock in settlements	$[t_C.ha^{-1}]$
O	Average carbon stock in other uses	$[t_C.ha^{-1}]$

4.4.2. Emissions and Removals from Change in Soil Carbon Stock

For each of the transitions listed in Table 4, in addition to the emissions and removals by the change of carbon in the biomass of the vegetation as described in the Section 4.4. ("Calculation of Anthropogenic Emissions and Removals for the Transitions Analyzed"), must be accounted the losses or gains of soil carbon by the land-use change.

The methodology for estimating the range of variation of soil carbon takes as reference the average value of carbon in soil under primary vegetation for each of the soil-vegetation associations described in the Section 4.2. ("Identification of Land Use and Land-use Change"). According to IPCC (2003), was adopted as the losses or gains of soil carbon result of the land-use change occur during the period of 20 years.

The general equation for the calculation of the soil carbon change is described below and is consistent with the equation of the IPCC (2003):

Equation 75. Calculation of Soil Carbon Change

$$ES_i = A_i \cdot C_{solo} \cdot (fc_{(t0)} - fc_{(tf)}) \cdot \frac{(T/2)}{20}$$

where:

ES_i	Net emission of the polygon i in period T due to variation in soil carbon	[t_C]
A_i	Area of polygon i	[ha]
C_{solo}	Soil carbon stock under the soil-vegetation association of the polygons	[$t_C.ha^{-1}$]
$fc_{(t)}$	Soil carbon change factor at time t	
$_{(t0)}$	Initial time	
$_{(tf)}$	End time	

The factor of carbon change is defined by the equation:

Equation 76. Carbon Change Factor

$$fc_{(t)} = f_{LU} \cdot f_{MG} \cdot f_I$$

where:

$fc_{(t)}$	soil carbon change factor at time t	
f_{LU}	carbon change factor for land use	
f_{MG}	carbon change factor for management regime	
f_I	carbon change factor for inputs	

4.5. Definition of Emission Factors and Other Necessary Parameters for Estimating GHG Anthropogenic Emissions and Removals

4.5.1. Carbon Stock in Living Biomass and Dead Organic Matter

a) Cerrado Biome

The emission factors (EF) for the Cerrado biome, more specifically, of the carbon stocks in biomass for the savanna typologies, were obtained from the available scientific literature. To obtain the total values of biomass was applied the expansion factor R/S (root-to-shoot or ratio of root biomass and above-ground biomass), as shown in Table 3.4.3 in the GPG/LULUCF (2003).

Typical Physiognomy of Cerrado

Table 6 shows the carbon content values of different vegetation physiognomies of the Cerrado biome present in Sao Paulo State.

Table 6. Carbon Content of Cerrado Vegetation Physiognomies in the Sao Paulo State ($t_c.ha^{-1}$)

Vegetal Physiognomy	Forest/Cropland	Content of C ($t_C.ha^{-1}$)	Reference
Montane Deciduous Seasonal Forest (Cm)	Forest	104.95	BRITEZ, R. M. et al. (2006)
Submontane Deciduous Seasonal Forest (Cs)	Forest	116.27	BRITEZ, R. M. et al. (2006)
Montane Dense Humid Forest (Dm)	Forest	139.03	BRITEZ, R. M. et al. (2006)
Alluvial Semi Deciduous Seasonal Forest (Fa)	Forest	140.09	BRITEZ, R. M. et al. (2006)
Montane Semi Deciduous Seasonal Forest (Fm)	Forest	140.09	BRITEZ, R. M. et al. (2006)
Sub Montane Semi Deciduous Seasonal Forest (Fs)	Forest	140.09	BRITEZ, R. M. et al. (2006)
Montane Mixed High Humid Forest (Ml)	Forest	118.81	BRITEZ, R. M. et al. (2006)
Montane Mixed Humid Forest (Mm)	Forest	118.81	BRITEZ, R. M. et al. (2006)
Fluvial and/or Lacustre Influenced Vegetation (Pa)	Forest	105.64	BRITEZ, R. M. et al. (2006)
Wooded Savanna (Sa)	Forest	47.10	ABDALA, G. C. et al. (2006)
Forested Savanna (Sd)	Forest	77.80	ABDALA, G. C. et al. (2006)
Woody-grass Savanna (Sg)	Grassland	16.30	ABDALA, G. C. et al. (2006)
Park Savanna (Sp)	Grassland	24.10	ABDALA, G. C. et al. (2006)

b) Atlantic Forest Biome

The emission factors (EF) for the Atlantic Forest biome, more specifically, of the carbon stocks in biomass for the forest typologies, were obtained from available scientific literature.

For the other physiognomies that comprise the Atlantic Forest biome were obtained emission factors of the physiognomies of surrounding forests, such as Cerrado, Caatinga and Pampa.

Table 7 shows the carbon content values of different vegetation physiognomies of the Atlantic Forest biome present in Sao Paulo State.

Typical Physiognomy of Atlantic Forest

Table 7. Carbon Content of Atlantic Forest Vegetation Physiognomies in the Sao Paulo State ($t_c.ha^{-1}$)

Plant Physiognomy	Forest/Grassland	Content of C ($t_c.ha^{-1}$)	Reference
Montane Deciduous Seasonal Forest (Cm)	Forest	104.95	BRITEZ, R. M. et al. (2006)
Submontane Deciduous Seasonal Forest (Cs)	Forest	116.27	BRITEZ, R. M. et al. (2006)
Alluvial Dense Humid Forest (Da)	Forest	166.93	BRITEZ, R. M. et al. (2006)
Lowland Dense Humid Forest (Db)	Forest	135.76	BRITEZ, R. M. et al. (2006)
Montane Dense Humid Forest (Dm)	Forest	122.92	BRITEZ, R. M. et al. (2006)
High Montane Dense Humid Forest (Dl)	Forest	122.92	BRITEZ, R. M. et al. (2006)
Submontane Dense Humid Forest (Ds)	Forest	122.92	BRITEZ, R. M. et al. (2006)
Alluvial Semi Deciduous Seasonal Forest (Fa)	Forest	140.09	BRITEZ, R. M. et al. (2006)
Montane Semi Deciduous Seasonal Forest (Fm)	Forest	140.09	BRITEZ, R. M. et al. (2006)
Sub Montane Semi Deciduous Seasonal Forest (Fs)	Forest	140.09	BRITEZ, R. M. et al. (2006)
Montane Mixed High Humid Forest (Ml)	Forest	118.81	BRITEZ, R. M. et al. (2006)
Montane Mixed Humid Forest (Mm)	Forest	118.81	BRITEZ, R. M. et al. (2006)
Fluvial and/or Lacustre Influenced Vegetation (Pa)	Forest	105.64	BRITEZ, R. M. et al. (2006)
Pioneer Formation Fluviomarine Influenced (Pf)	Forest	98.16	CARVALHO L.C; FONSECA S.M, (2003)
Pioneer Formation Marine Influenced (Pm)	Forest	94.48	BRITEZ, R. M. et al. (2006)
High Montane Vegetation Refuge (Rl)	Grassland	6.55	BRITEZ, R. M. et al. (2006)
Montane Refuge (Rm)	Grassland	6.55	BRITEZ, R. M. et al. (2006)
Wooded Savanna (Sa)	Forest	47.10	ABDALA, G. C. et al. (1998)
Forested Savanna (Sd)	Forest	77.80	ABDALA, G. C. et al. (1998)
Woody-grass Savanna (Sg)	Grassland	16.30	ABDALA, G. C. et al. (1998)
Park Savanna (Sp)	Grassland	24.10	ABDALA, G. C. et al., 1998

4.5.1.1. Soil Carbon

The calculation of soil carbon stock followed the methodology adopted by the First Brazilian Inventory of Anthropogenic Emissions of Greenhouse Gases (BRASIL, 2006) and consisted of the following stages:

1) Adaptation of the soil map of Brazil (IBGE, EMBRAPA, 2001), at a scale of 1:5,000,000, cropped for Sao Paulo State;

2) Adaptation of the vegetation map of Brazil (IBGE, 2004), cropped for Sao Paulo State;

3) Generation of the soil-vegetation association map.

As in the First Brazilian Inventory, the 69 classes included in 18 orders of the Brazilian System of Soil Classification (SIBCS) were reclassified in six 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 reunification is considered adequate to evaluate the changes in carbon stock. However, since the Initial National Communication (BRASIL, 2004), there were changes in the system of classification of soils. In addition, some classes were not present in the regrouped map, requiring new compatibility to generate a new grouping for the categories defined above.

The vegetation classes were aggregated into categories according to the criteria suggested by the First Brazilian Inventory, based on vegetation map of Brazil (IBGE, 2004). The First Brazilian Inventory grouped the vegetation classes of 1988 IBGE map, adding them based on physiognomy and geographical distribution (BRASIL, 2006). There were obtained 15 categories. The contact areas were included in this grouping, linking them to each of 15 categories according to the dominance of vegetation and location. For this key of the classification, 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 Vegetation Refuge (V13), Pioneer Formation Areas (V14) and Woody Oligotrophic Vegetation of Swamps and Sandy Areas (V15).

In this inventory, was used the vegetation map of Brazil (IBGE, 2004), whose compatibility with the categories of the First Brazilian Inventory was added in a different way some of the types of vegetation due to changes in the mapping and classification in relation to the map of 1988, requiring new compatibility.

For each of the soil-vegetation associations, was adopted the same soil carbon stock under natural vegetation used in the First Brazilian Inventory. In this report was adopted the median value of the values reported in the First Brazilian Inventory (BRASIL, 2006), shown in Table 8.

Table 8. Soil Carbon Stock for Brazil ($kg_C.m^{-2}$).

Categories						
Vegetation	Soil					
	S1	S2	S3	S4	S5	S6
	$kg_C.m^{-2}$					
V1	5.09	4.75	4.89	4.11	4.36	–
V2	3.22	5.19	4.69	5.06	5.27	4.81
V3	5.83	5.23	4.29	6.33	3.58	41.78
V4	4.67	3.08	4	2.59	3.27	3.18
V5	4.09	4.43	3.74	2.7	5.36	3.16
V6	9.88	10.25	5.68	–	8.54	–
V7	6.42	9.09	5.16	–	7.42	3.28
V8	4.8	1.98	3.81	4.37	3.46	2.9
V9	2.44	4.31	3.6	1.92	6.65	3.29
V10	6.6	4.66	6.12	–	3.38	4.99
V11	2.42	2.58	2.62	1.51	2.51	2.09
V12	3.38		3.52	3.54	10.52	2.17
V13	3.41	5.041	3.99	–	–	–
V14	7.3	4.131	3.31	5.02	5.92	3.72
V15	5.09	4.68	4.81	6.17	9.05	12.09

Note: " – ": Non existing category.

1 In the absence of median used the average.

Source: BRASIL (2006), with adaptations.

4.5.1.2. Annual Removals of Carbon in Managed Lands

To estimate the annual removals of carbon in Managed Lands of Native Forest (Remf), was adopted the factor of $0.62t_C.(ha.year)^{-1}$ (PHILLIPS et al, 1998). For the managed lands with native vegetation with non-forest physiognomy (Remg), the value zero for Remg was adopted, because there is no information about the occurrence of removing in these physiognomies.

4.5.1.3. Carbon Stock in Reforestation Area

To obtain the average carbon stock in reforestation area (AvRef) and the annual average carbon increment in reforestation area still in development (IncrRef), it was necessary to differentiate the areas planted with *Pinus* from areas planted with *Eucalyptus*, dominant species in the country, using the statistical information for the participation of these cultures. From data from the statistical yearbook of the Brazilian Association of Forest Plantation Producers (ABRAF) the following values were obtained for Sao Paulo State, identified in Table 9.

Table 9. Planted Area in Reforestation (ha)

Area Planted with *Eucalyptus* and *Pinus* in 2005		
	(ha)	(%)
Eucaliptus	798,522	84
Pinus	148,020	16
Total	**946,542**	**100**

Fonte: ABRAF (2010).

For the reforestation with *Eucalyptus*, the value of $41m^3.(ha.year)^{-1}$ of net average annual increment in appropriate volume for industrial processing was adopted (BRACELPA, 2010). This corresponds to a value of IncrRef of $14.11t_C.(ha.year)^{-1}$, whereas the same parameters (wood density, crown/trunk ratio, root/trunk ratio) used in the Reference Report of the First Brazilian Inventory (BRASIL, 2006) using the equation 3.2.5 from IPCC (2003). For the calculation of the average carbon stock in reforestation areas (AvRef), a cycle of 7 years between harvestings was considered, obtaining a value of $49.385t_C.ha^{-1}$.

For the reforestation with *Pinus*, the value of $36m^3.(ha.year)^{-1}$ of net average annual increment in appropriate volume for industrial processing was adopted (BRACELPA, 2010). This corresponds to a value of $11.69t_C.(ha.year)^{-1}$ for IncrRef whereas the same parameters (wood density, crown/trunk ratio, root/trunk ratio) used in the Reference Report of the First Brazilian Inventory (BRASIL, 2006) and applying the Equation 3.2.5 from IPCC (2003). It was considered a cycle of 15 years between harvestings for the calculation of the average carbon stock, obtaining a value of $87.675t_C.ha^{-1}$ for AvRef.

Based on these data, the mean values of AvRef and IncrRef were calculated as presented in Table 10.

Table 10. Average Carbon Stock and the Annual Increment of Carbon in Reforestation, in 2005 in São Paulo State

Sao Paulo State	IncrRef	AvRef
	$[t_C.(ha.year)^{-1}]$	$[t_C.ha^{-1}]$
	13.7	55.4

4.5.1.4. Average Carbon Stock in Planted Pasture and Cropland

a) Average Carbon Stock in Planted Pasture

It was adopted the default value from IPCC (Table 3.4.9) equal to $8.05t_C.ha^{-1}$ for the average stock of carbon in established planted pasture (IPCC, 2003).

b) Average Carbon Stock in Cropland

To obtain the average stocks of carbon in cropland (AvAgr) and the average annual carbon gains in cropland still in development (IncrAgr), it was necessary to differentiate between areas of perennial crops and areas of annual crops.

The default value of $5t_C.ha^{-1}$ of IPCC (Table

3.3.8) was adopted for the carbon stock for annual croplands (IPCC, 2003). For the areas of perennial crops, the value of 21$t_C.ha^{-1}$ was adopted for the average carbon stock and 2.6$t_C.(ha.year)^{-1}$ for the annual increment in newly formed areas. These values are those IPCC default (Tables 3.3.2 and 3.3.9) for these parameters (IPCC, 2003).

The interpretation of satellite images does not distinguish between perennial and annual crops without a field work involved. It is known, however, that the ratio of perennial and annual crops varies per Unit of the Federation. Thus, this information was used to calculate specific values of AvAgr and IncrAgr for the Sao Paulo State (Table 11).

Table 11. Average Carbon Stock and the Annual Increment of Carbon in Cropland, in 2055 in Sao Paulo State ($t_c.ha^{-1}$)

IncrAgr	AvAgr	Percentage [%][1]	
[$t_C.(ha.year)^{-1}$]	[$t_C.ha^{-1}$]	Permanent Crops	Annual Crops
6.00	7.90	18	82

[1]Source: IBGE (2008).

4.5.1.5. Carbon Stock in Biomass in Reservoirs, Settlements and Other Uses Areas

It is assumed that the value of carbon in the biomass in areas of Reservoirs (Res), settlements (S), and other uses areas (O) is equal to zero.

4.5.1.6. Soil Carbon Change Factor

The carbon change factors for land use (fLU), for the management regime (fMG) and for the inputs (fI), defined in the Section 4.6. ("Emissions and Removals from Change in Soil Carbon Stock"), were selected from the values suggested by IPCC (2003) and in consultation with the specialists. These factors are presented in Table 12.

Table 12. Soil Carbon Change Factors for the 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
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

Note: "–" not applicable.

[1] GPG, 2003 - Table 3.3.4.

[2] GPG, 2003 - Table 3.4.5.

5

RESULTS

5. Results

5.1. Integration of Data and Generation of Net Anthropogenic Emissions Estimation Related to the Land Use, Land-use Change, and Forestry Sector

At this stage, the data are integrated, generating a land-use transition matrix for the whole State territory, and the estimation of the annual net average anthropogenic emissions between 1994 and 2002, 2002 and 2005, and 2005 and 2008.

5.1.1. Matrix of Transition: 1994-2002

Table 13 shows the estimated area of each of the transitions observed between 1994 and 2002 for Sao Paulo State. Table 14 shows the corresponding net CO_2 emissions. It is observed that from 1994 to 2002, there was land-use change in 62,480 ha (0.25%) in the total mapped (24,823,681ha). The net anthropogenic emissions totaled -10,663.29Gg_{CO2}. The negative number indicates that there was removal.

Table 13. Transitions Areas Identified in Sao Paulo State in the Period: 1994 - 2002 (ha)

Area (ha)		Land Use in 2002												
		FNM	FM	Ref	GNM	GM	Ap	Ac	S	A	Res	O	NO	Total 1994
Land Use in 1994	FNM	2,357,938	126,765				1,491	5,266	9,620		18,238	28		2,519,346
	FM		1,575,629					8	1,202		1			1,576,840
	Ref			871,844										871,844
	GNM				89,394	234	5	358			45			90,035
	GM					10,541		47						10,588
	Ap			18,022			4,747,253		60		379			4,765,714
	Ac							13,879,634	5,306		1,865	329		13,887,134
	S								550,461					550,461
	A									58,500	211			58,711
	Res										487,186			487,186
	O											3,655		3,655
	NO	7	10					767	1,378	4				2,166
Total 2002		2,357945	1,702,404	889,866	89,394	10,775	4,748,749	13,886,080	568,027	58,505	507,925	4,013	0	24,823,681

Table 14. Net CO_2 Emissions in Sao Paulo State in the Period: 1994 - 2002 (Gg_{CO2})

CO_2 (Gg)		Land Use in 2002											
		FNM	FM	Ref	GNM	GM	Ap	Ac	S	A	Res	O	NO
Land Use in 1994	FNM	—	-929.61				637.66	2,625.01	4,666.96		7,394.10	13.54	
	FM		-23,109.22					3.47	560.13		0.43		
	Ref			—									
	GNM			-	—	—	0.15	17.2			5.43		
	GM							2.24					
	Ap			-2,917.80			—		3.6		19.5		
	Ac							—	255.17		72.84	15.91	
	S												
	A									—	—		
	Res										—		
	O											—	
	NO	—	—					—	—	—			
	Total = -10,663.29												

Legend:

FNM – Unmanaged Forest; **FM** – Managed Forest; **Ref** – Reforestation; **GNM** – Unmanaged Grassland; **GM** – Managed Grassland; **Ap** – Planted Pasture; **Ac** – Cropland Area; **S** – Settlements; **A** – Rivers and Lakes (Unmanaged Wetland); **Res** – Reservoirs (Managed Wetland); **O** – Other Uses; **NO** – Not Observed; "—" Not Applicable";
Unlikely transitions in the analyzed period. Areas in state of residence in the analyzed period

5.1.2. Matrix of Transition: 2002-2005

Table 15 shows the estimated area of each of the transitions observed between 2002 and 2005 for Sao Paulo State. Table 16 shows the corresponding net CO_2 emissions. It is observed that from 2002 to 2005, there was land-use change in 46,426 ha (0.19%) in the total mapped (24,823,681ha). The net anthropogenic emissions totaled -11,753.35Gg_{CO2}. The negative number indicates that there was removal.

Table 15. Transitions Areas Identified in Sao Paulo State in the Period: 2002 - 2005 (ha)

Area (ha)		Land Use in 2005												
		FNM	FM	Ref	GNM	GM	Ap	Ac	S	A	Res	O	NO	Total 2002
Land Use in 2002	FNM	2,336,981	14,097					1,248			21		5,598	2,357,945
	FM		1,701,220				1						1,182	1,702,404
	Ref			89,866										889,866
	GNM				89,394									89,394
	GM					10,775								10,775
	Ap			22,079			4,726,160						510	4,748,749
	Ac							13,862,474	23,078				529	13,886,080
	S								568,027					568,027
	A									58,505				58,505
	Res										507,925			507,925
	O											3,684	329	4,013
	NO													0
Total 2005		2,336,981	1,715,317	911,945	89,394	10,775	4,726,161	13,863,722	591,104	58,505	507,945	3,684	8,149	24,823,681

Table 16. Net CO_2 Emissions in Sao Paulo State in the Period: 2002 - 2005 (Gg_{CO2})

CO_2 (Gg)		Land Use in 2005											
		FNM	FM	Ref	GNM	GM	Ap	Ac	S	A	Res	O	NO
Land Use in 2002	FNM	-	-38.77					373.56			10.56		-
	FM		-9,356.71				0.54						-
	Ref			-									
	GNM				-								
	GM					-							
	Ap			-3,573.72			-						-
	Ac							-	831.19				-
	S								-				
	A										-		
	Res										-		
	O											-	-
	NO												
Total = -11,753.35													

Legend:

FNM – Unmanaged Forest; **FM** – Managed Forest; **Ref** – Reforestation; **GNM** – Unmanaged Grassland; **GM** – Managed Grassland; **Ap** – Planted Pasture; **Ac** – Cropland Area; **S** – Settlements; **A** – Rivers and Lakes (Unmanaged Wetland); **Res** – Reservoirs (Managed Wetland); **O** – Other Uses; **NO** – Not Observed; "—" Not Applicable";

(light blue) Unlikely transitions in the analyzed period. (green) Areas in state of residence in the analyzed period

5.1.3. Matrix of Transition: 2005-2008

Table 17 shows the estimated area of each of the transitions observed between 2005 and 2008 for Sao Paulo State. Table 18 shows the corresponding net CO_2 emissions. It is observed that from 2005 to 2008, there was land-use change in 64,618 ha (0.26%) in the total mapped (24,823,681ha). The net anthropogenic emissions totaled -9,846.08Gg_{CO2}. The negative number indicates that there was removal.

Table 17. Transitions Areas Identified in Sao Paulo State in the Period: 2005 - 2008 (ha)

Area (ha)		Land Use in 2008												
		FNM	FM	Ref	GNM	GM	Ap	Ac	S	A	Res	O	NO	Total 2005
Land Use in 2005	FNM	2,278,773	54,631				94	813					2,670	2,336,981
	FM		1,714,968					348					1	1,715,317
	Ref			905,323					6,509		113			911,945
	GNM				89,394									89,394
	GM					10,775								10,775
	Ap			16,042			4,706,457		3,662					4,726,161
	Ac			2			0	13,827,746	35,841			132		13,863,722
	S								591,104					591,104
	A									57,444	886	175		58,505
	Res										507,945			507,945
	O									26		3,658		3,684
	NO	5,598	1,182	510				529				329		8,149
Total 2008		2,284,371	1,770,781	921,877	89,394	10,775	4,706,551	13,829,436	637,117	57,470	508,944	4,294	2,671	24,823,681

Table 18. Net CO_2 Emissions in Sao Paulo State in the Period: 2005 - 2008 (Gg_{CO2}).

CO_2 [Gg]		Land Use in 2008											
		FNM	FM	Ref	GNM	GM	Ap	Ac	S	A	Res	O	NO
Land Use in 2005	FNM	—	-150,23				44,22	402,60					—
	FM		-9.432,32					54,76					—
	Ref			—					1399,74		24,26		
	GNM				—								
	GM					—							
	Ap			-2583,56			—		147,42				
	Ac			-0,33			-0,01	—	246,41			0,96	
	S								—				
	A									—	—	—	
	Res										—		
	O									—		—	
	NO	—	—	—				—				—	
Total = -9.846,08													

Legend:

FNM – Unmanaged Forest; **FM** – Managed Forest; **Ref** – Reforestation; **GNM** – Unmanaged Grassland; **GM** – Managed Grassland; **Ap** – Planted Pasture; **Ac** – Cropland Area; **S** – Settlements; **A** – Rivers and Lakes (Unmanaged Wetland); **Res** – Reservoirs (Managed Wetland); **O** – Other Uses; **NO** – Not Observed; "—" Not Applicable";

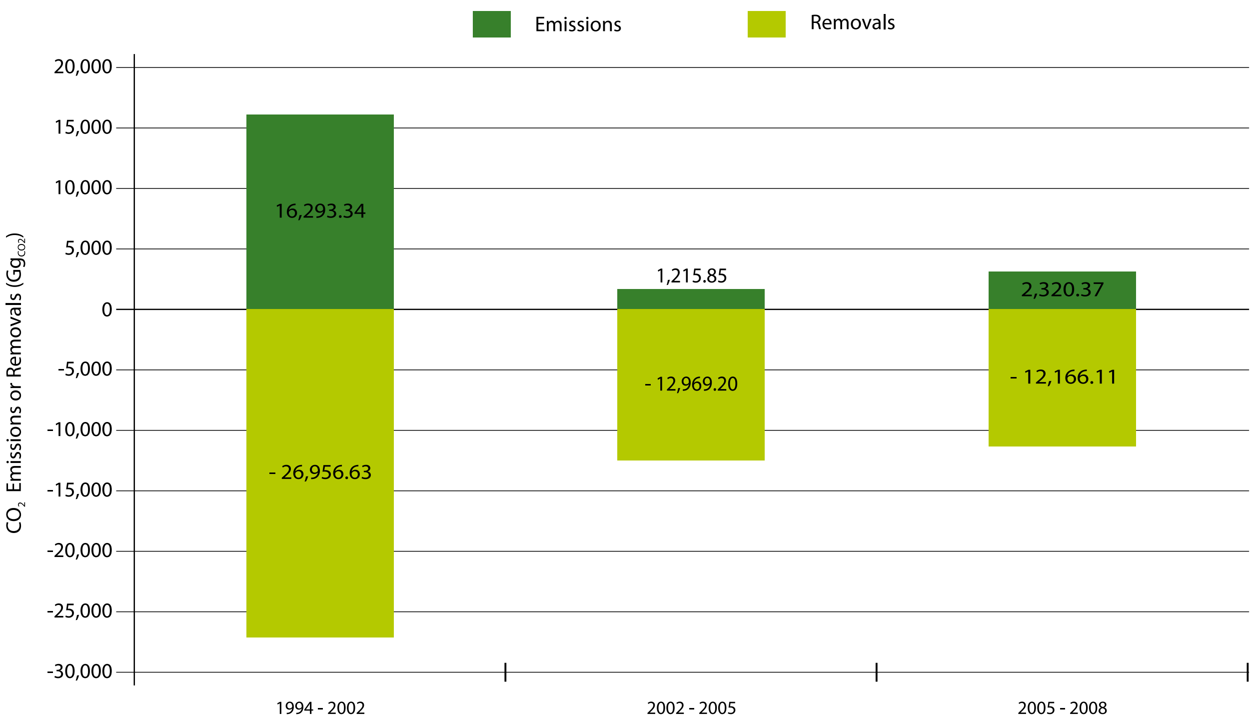
Unlikely transitions in the analyzed period. Areas in state of residence in the analyzed period

5.2. Balance of Emissions

From the data in Table 14, Table 16 and Table 18 was generated the Figure 4, below, which shows the CO_2 balance (emissions and removals) in the three analyzed periods. The result obtained for each period in Gg_{CO2}, was divided by the duration of each period, resulting in an average of the CO_2 balance per year.

In the Figure 4, it can be observing decreases of CO_2 emissions from 1994-2002 for the following period, increasing again in the 2005-2008. It is also noticed a decrease of CO_2 removals in the State, from the first to the second period, and from the second to the third period. It is meant to highlight the first period is longer than the others, and thus a higher emissions/removals is expected in such period.

Figure 4. CO_2 Balance in Periods: 1994-2002, 2002-2005, and 2005-2008, in the Sao Paulo State ($Gg.year^{-1}$)



5.3. Emissions and Removals by Category

The following figures show the CO_2 emissions from the periods: 1994-2002, 2002-2005, and 2005-2008. Figure 5 shows the land-use change that most influenced the CO_2 emissions in first period, was the transition of unmanaged forest to reservoir, followed by unmanaged forest converted to settlements, unmanaged forest converted to cropland and unmanaged forest converted to planted pasture.

Figure 5. CO_2 Emissions between 1994 and 2002 in Sao Paulo State (16,293 Gg)

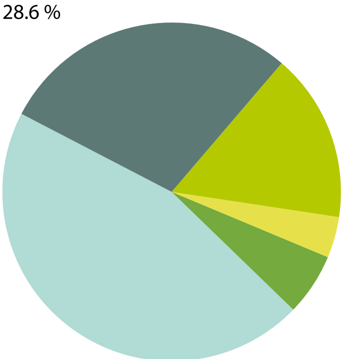


Figure 6 shows the land-use change that most influenced the CO_2 emissions in second period, was the transition of cropland converted to urban area, followed by unmanaged forest converted to cropland, unmanaged forest converted to reservoir and managed forest converted to planted pasture.

Figure 7 shows the land-use change that most influenced the CO_2 emissions in third period, was the transition of reforestation in settlements, followed by unmanaged forest converted to cropland, cropland converted to settlements and planted pasture converted to settlements.

Figure 6. CO_2 Emissions between 2002 and 2005 in Sao Paulo State (1,216 Gg)

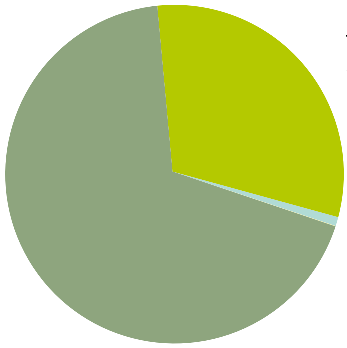


Figure 7. CO_2 Emissions between 2005 and 2008 in Sao Paulo State (2,320 Gg)

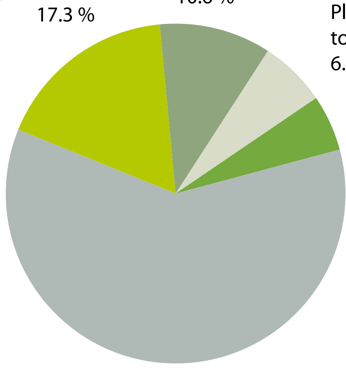


Figure 8, Figure 9, and Figure 10 below, show the CO_2 removals for the periods analyzed. The three figures show the same pattern, being the land-use category that most contributes to the CO_2 removals from the atmosphere was the permanence of managed forest, followed by the transition from planted pasture to reforestation and unmanaged forest converted to managed forest.

Figure 8. CO_2 Removals between 1994 and 2002 in Sao Paulo State (26,957 Gg)

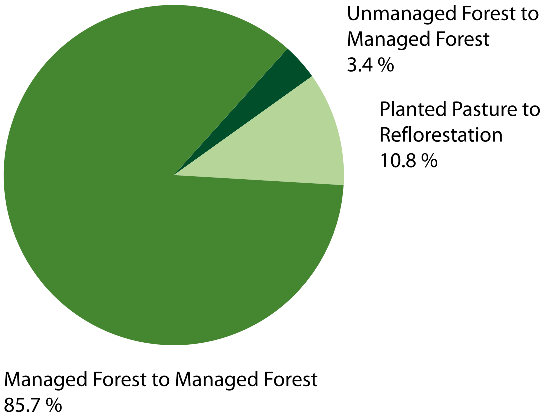


Figure 9. CO_2 Removals between 2002 and 2005 in Sao Paulo State (12,969 Gg)

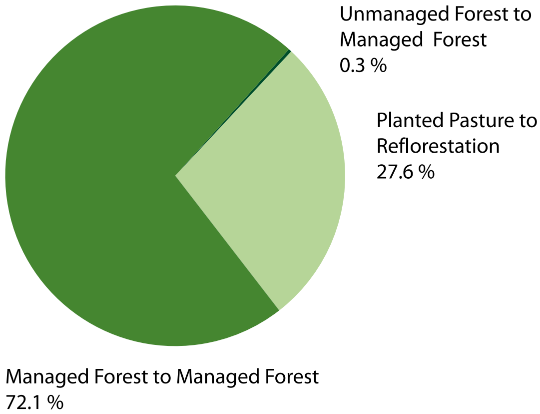
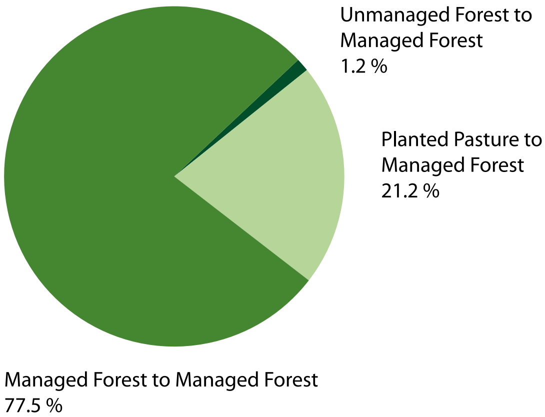


Figure 10. CO_2 Removals between 2005 and 2008 in Sao Paulo State (12,166 Gg)



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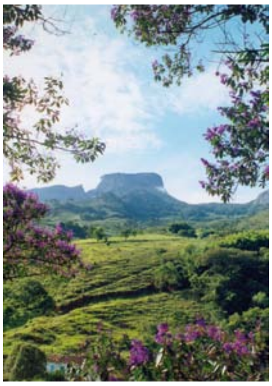

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