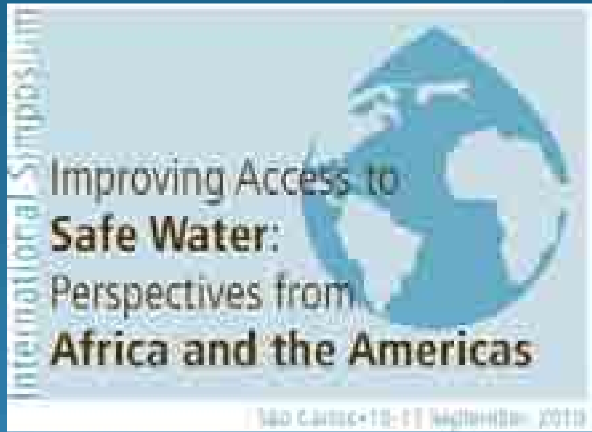


Greenhouse gas emission in reservoirs of Brazil

Donato Seiji Abe

International Institute of Ecology

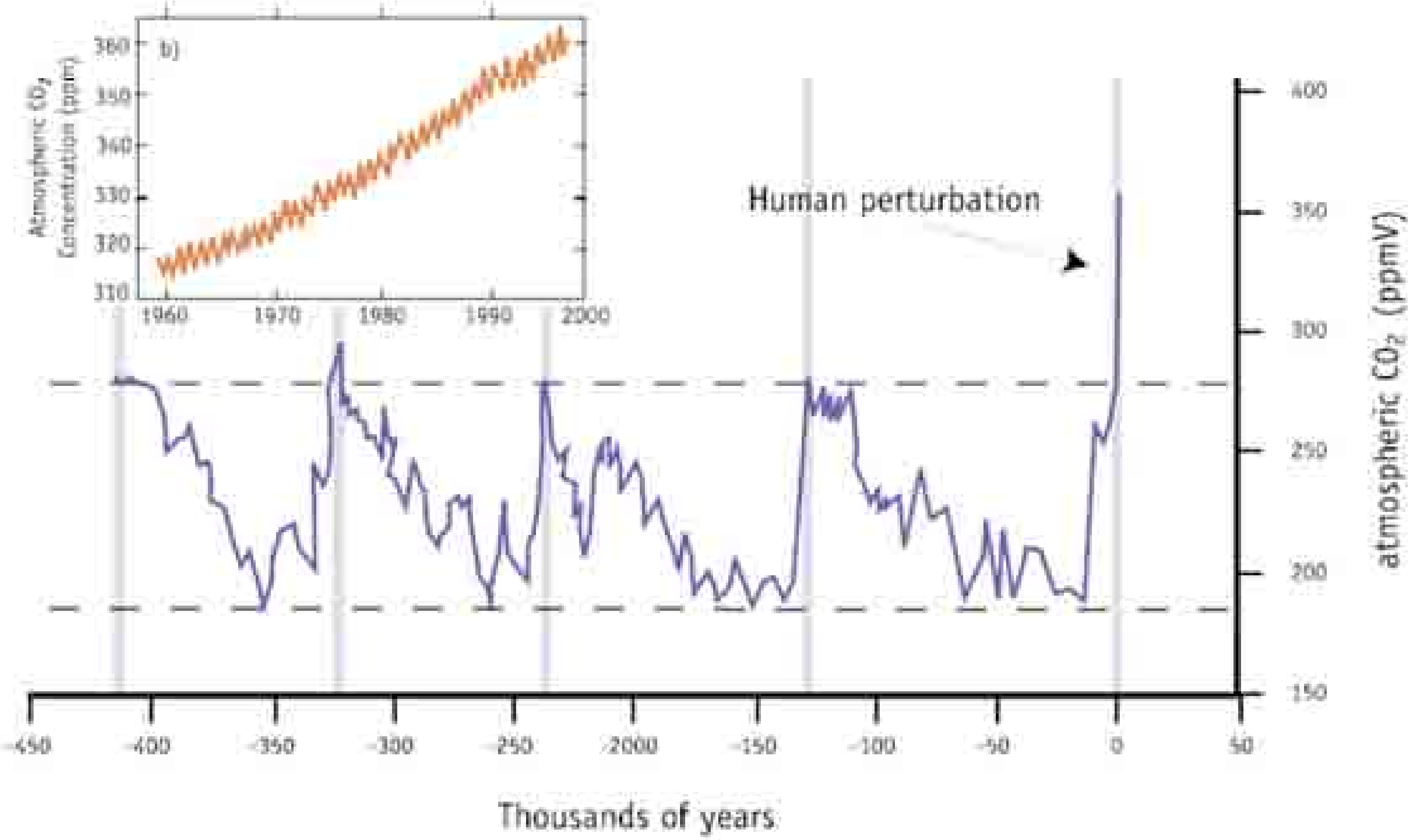
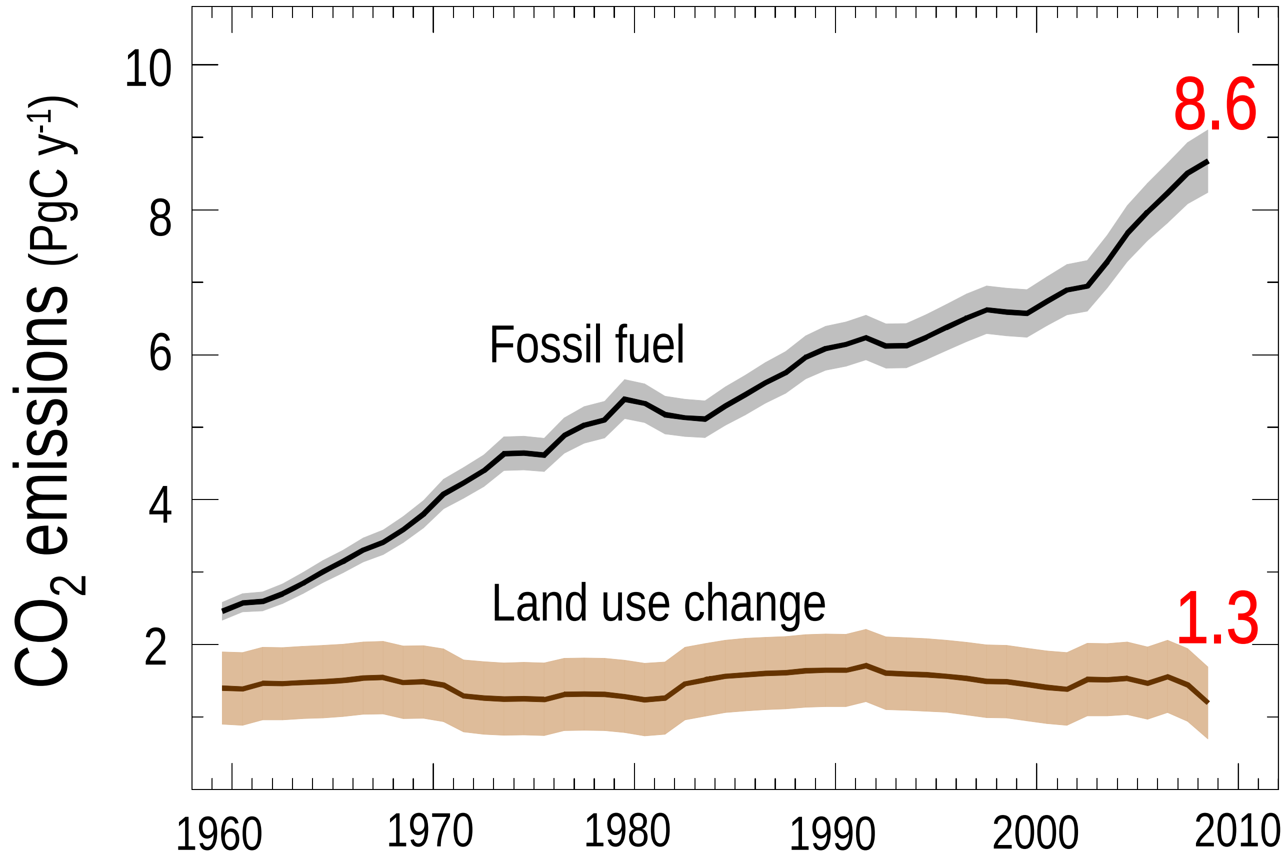


Figure 2. Atmospheric CO_2 concentration from the Vostok ice core record with the recent human perturbation superimposed. The inset shows the observed contemporary increase in atmospheric CO_2 concentration from the Mauna Loa (Hawaii) Observatory.

Sources: Petit et al. (1999) Nature 399, 429–436 and National Oceanic and Atmospheric Administration (NOAA), USA

in IGPB Executive Summary, 2004

Anthropogenic emissions of greenhouse gases



9.9 PgC

12% of total anthropogenic emissions

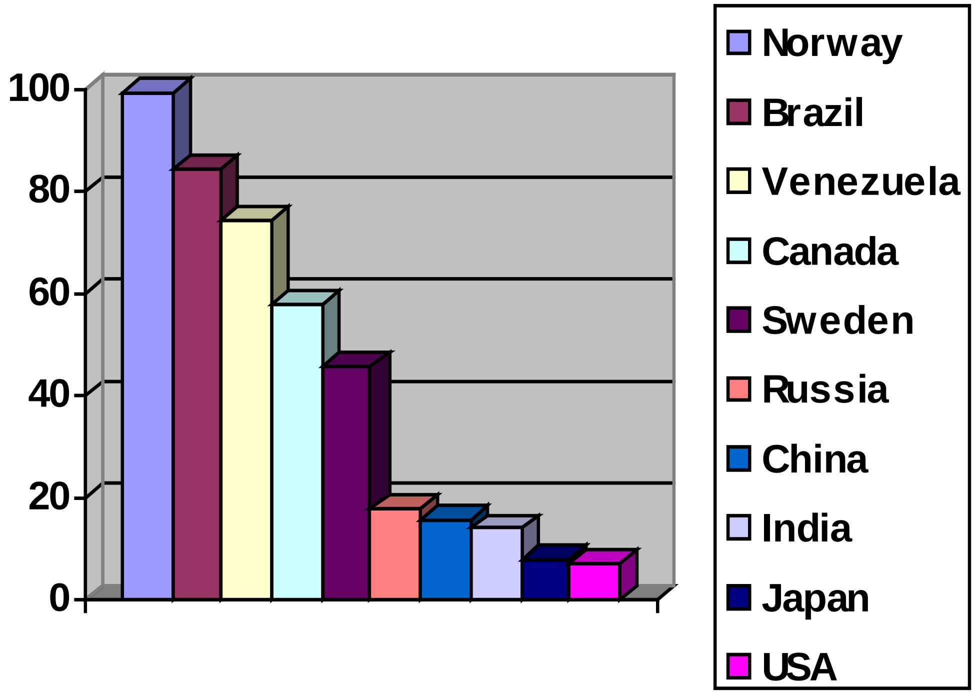
Le Quéré et al. 2009, Nature-geoscience; Data: CDIAC, FAO, Woods Hole Research Center 2009

(From Ometto, 2010)

Until the beginning of the 90th Century: hydroelectricity was perceived as one of the most ecologically sound means of energy production.

Serra da Mesa Reservoir, Central Brazil

Top countries with the highest percentage of hydropower in their electricity generation (%)



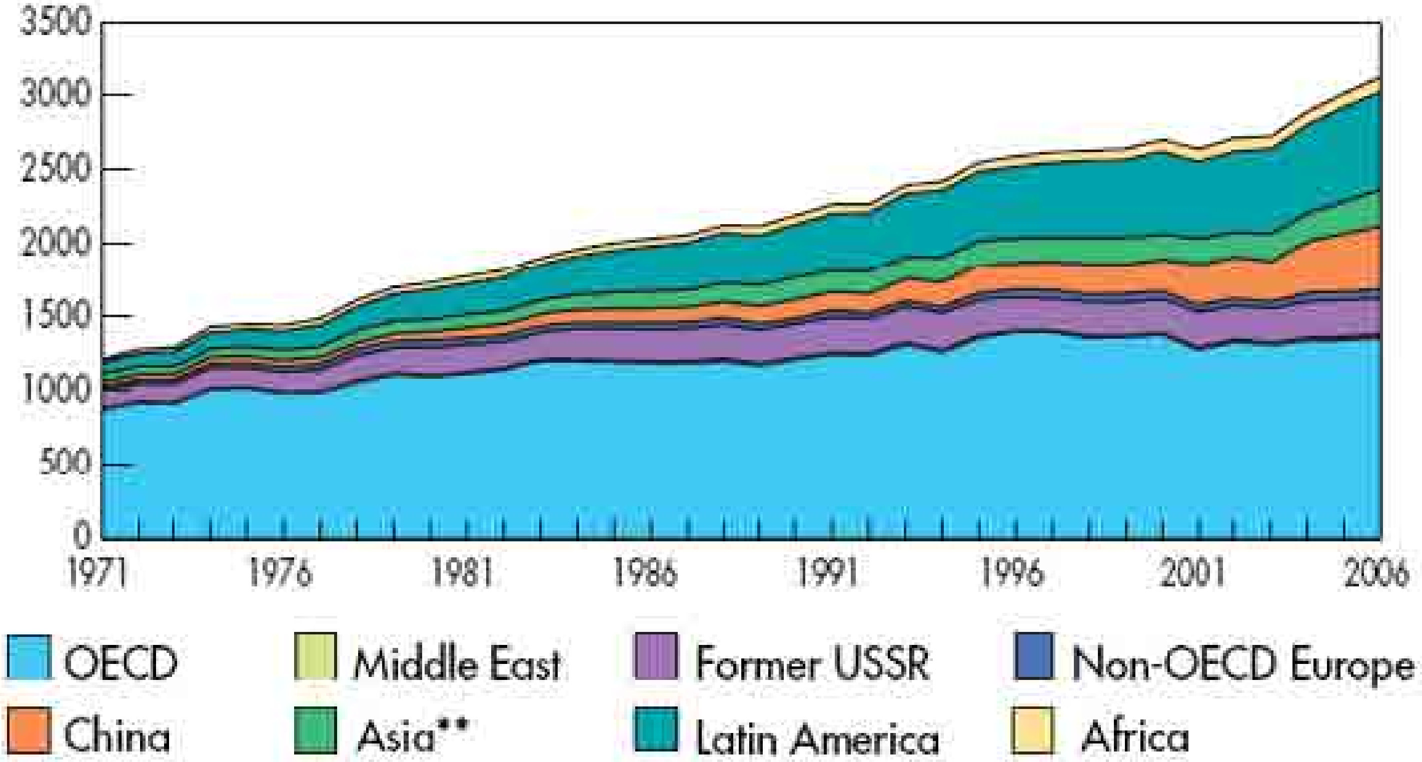
Source: IEA, 2006

Countries with higher hydro capacity – 2005 data (Rosa, 2010)

Country	Installed capacity (MW)
China	100000
USA	77354
Canada	71978
Brazil	71060

Hydro Production

Evolution from 1971 to 2006 of hydro* production by region (TWh)



*Includes pumped storage.
**Asia excludes China.

source: IEA, 2008

Rudd et al. (1993) and Kelly et al. (1994): suggested that reservoirs are potential net emitters of greenhouse gases (GHG), and can even be compared, by unit of energy produced, to the GHG production level of conventional fossil fuel power plants.

≈

CH4 Measured Emissions from Flooded Land
Diffusive Emission - kg CH4 / ha / day

Climate	Median	Minimum	Maximum
Polar/boreal	0.086	0.011	0.3
Cold temperate	0.061	0.001	0.2
Warm temperate moist	0.150	-	1.1
Warm temperate dry	0.044	0.032	0.09
Tropical, wet	0.630	0.067	1.3
Tropical, dry	0.295	0.070	1.1

Source: IPCC (2006).

When Brazil ratified the United Nations Framework Convention on Climate Change (1992), it made a commitment to develop and maintain updated information about its emission sources, as well as about the sinks of the main greenhouse gases: CO_2, CH_4 and N_2O.

The First Brazilian Inventory of Anthropogenic Greenhouse Gas Emissions was published in 2002 by the Ministry of Science and Technology and prepared by the Federal University of Rio de Janeiro (COPPE/UFRJ).

The main conclusions of the 1st Brazilian Inventory:

- Hydroelectric generation is not free of atmospheric emissions, as was stated in environmental studies from the 1990s.
- Hydroelectric reservoirs emit biogenic gases, including CO2, CH4. However, a comparative study of emissions from the surface of reservoirs with the emissions from thermoelectric plants shows that in most of the cases analyzed hydroelectric plants perform better.
- Exceptions: reservoirs constructed in the Amazon region (rain forest bioma, like Balbina Reservoir).

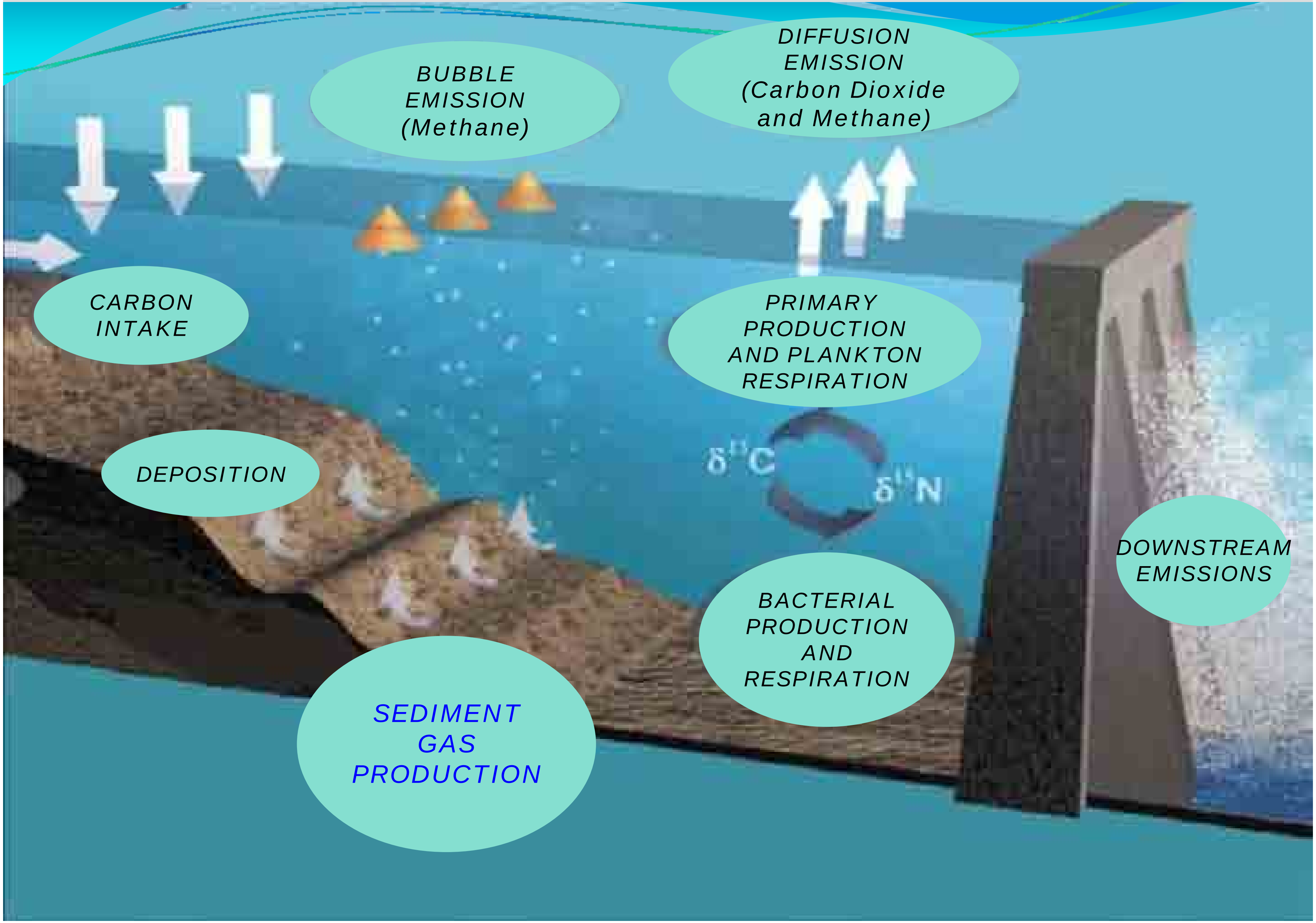
2003-2007: Project “Carbon Budget in FURNAS Hydroelectric Reservoirs”

Sponsor: FURNAS Centrais Elétricas S.A. (major state-owned company in electricity generation and transmission)

Period: 2003 – 2005.

Reservoirs studied: 8 (most in cerrado savanna biome).

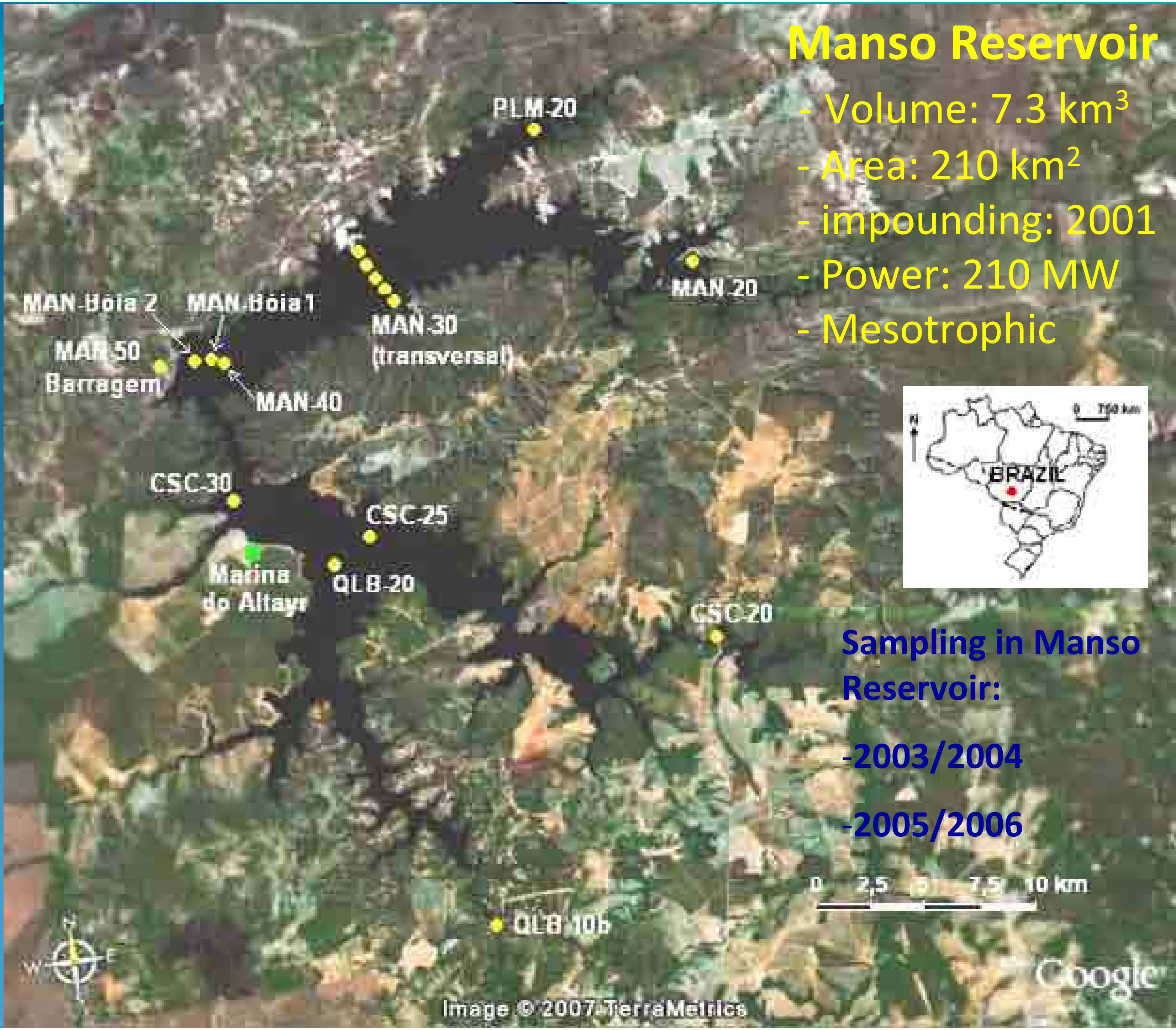
CARBON BUDGET IN FURNAS HYDROELECTRIC RESERVOIRS




Brasil
Bolivia
APM Manso
UHE Serra da Mesa
Brasilia
UHE Corumba
UHE Itumbiara
UHE L.C.B. Barreto (Estreito)
UHE Mascarenhas de Moraes
UHE Furnas
UHE Funil
© 2008 Europa Technologies
Image NASA
© 2008 MapLink/Tele Atlas
© 2008 DMapas
Google
Ponteiro lat 14.673533° lon -56.132139°
Fluxo 100%
Altitude do ponto de visão 4026,18 km

Manso Reservoir

- Volume: 7.3 km^3
- Area: 210 km^2
- impounding: 2001
- Power: 210 MW
- Mesotrophic



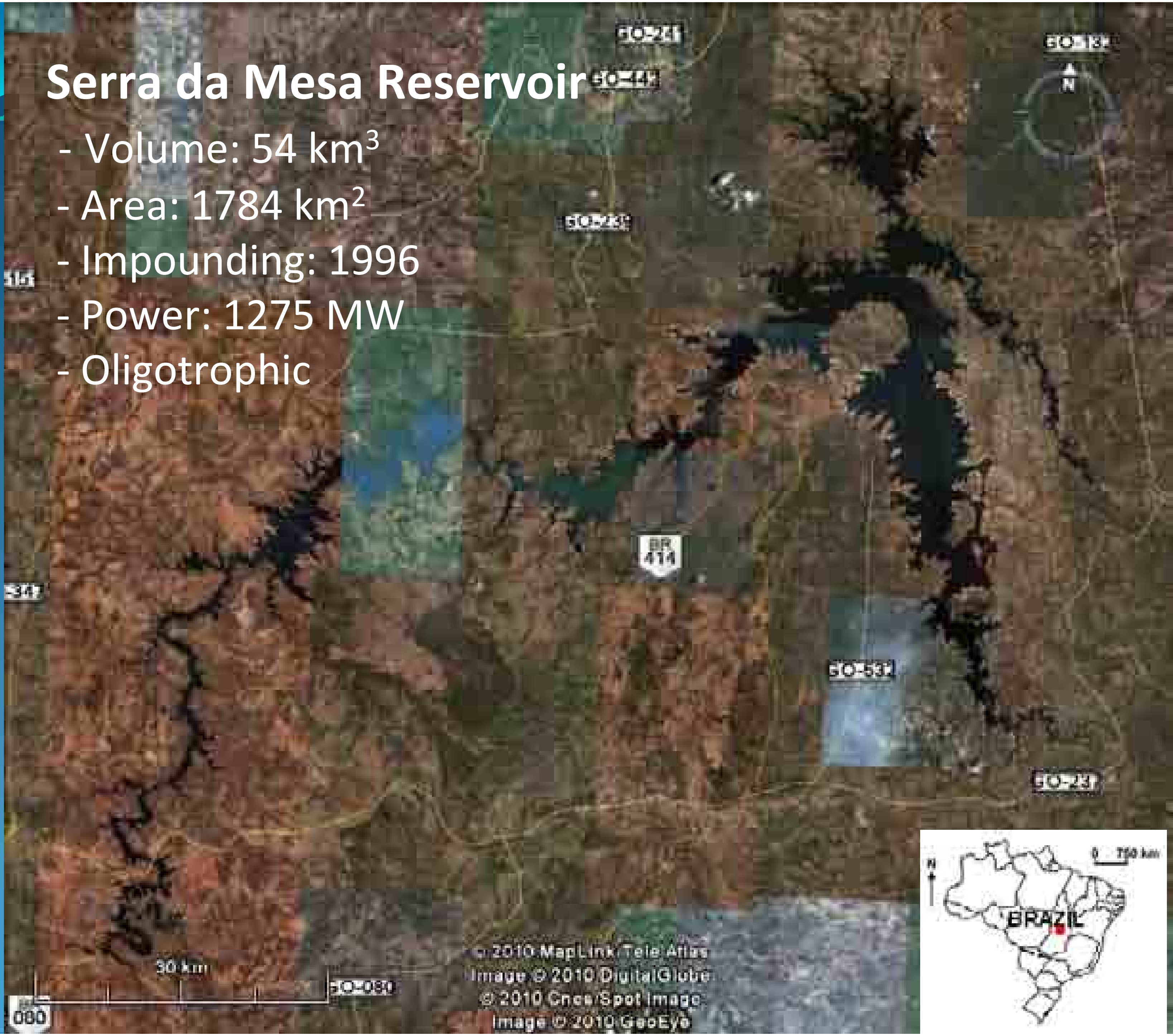
Sampling in Manso Reservoir:

-2003/2004

-2005/2006

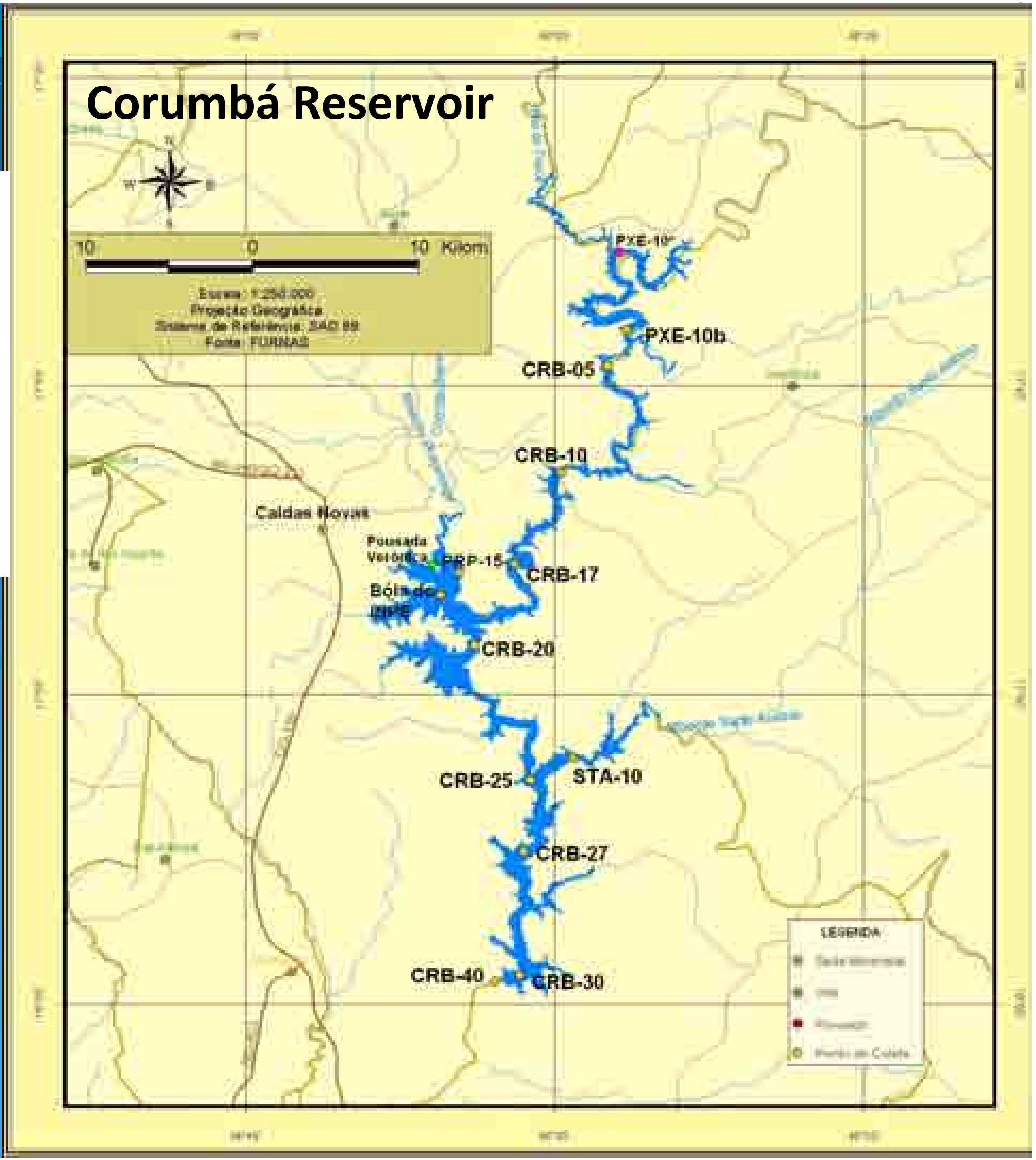
Serra da Mesa Reservoir

- Volume: 54 km^3
- Area: 1784 km^2
- Impounding: 1996
- Power: 1275 MW
- Oligotrophic



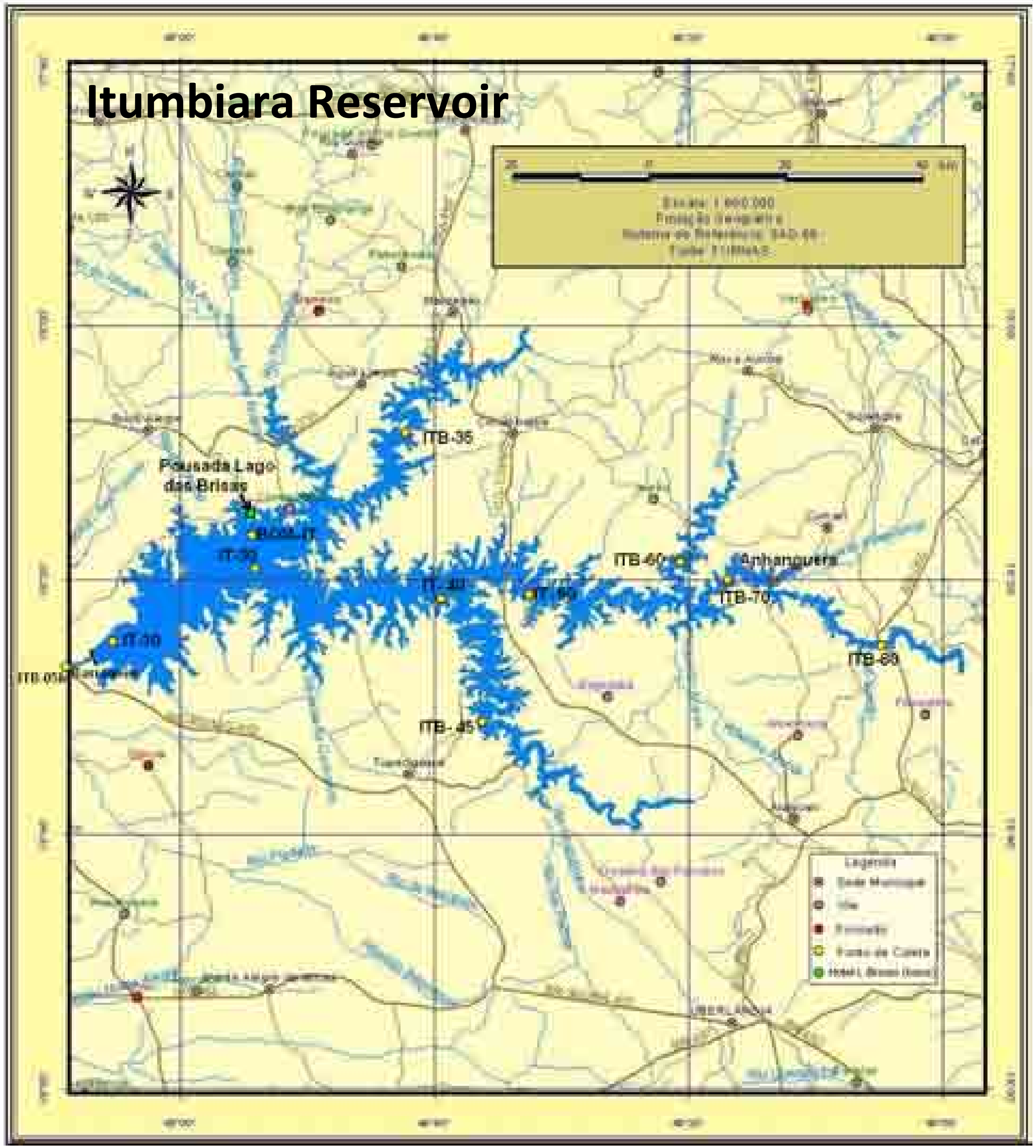
Corumbá Reservoir

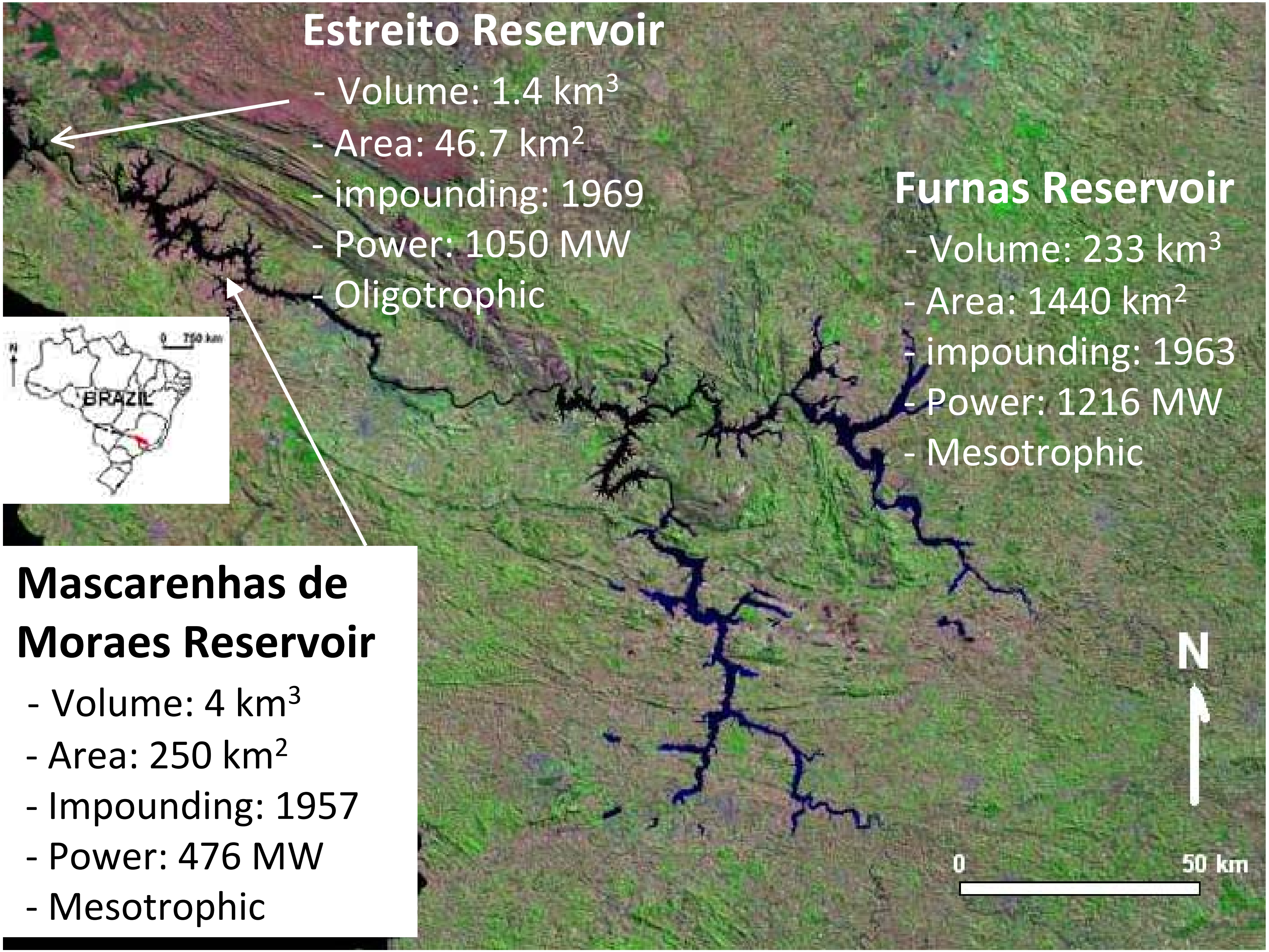
- Volume: 1.5 km^3
- Area: 65 km^2
- Impounding: 1997
- Power: 375 MW
- Mesotrophic

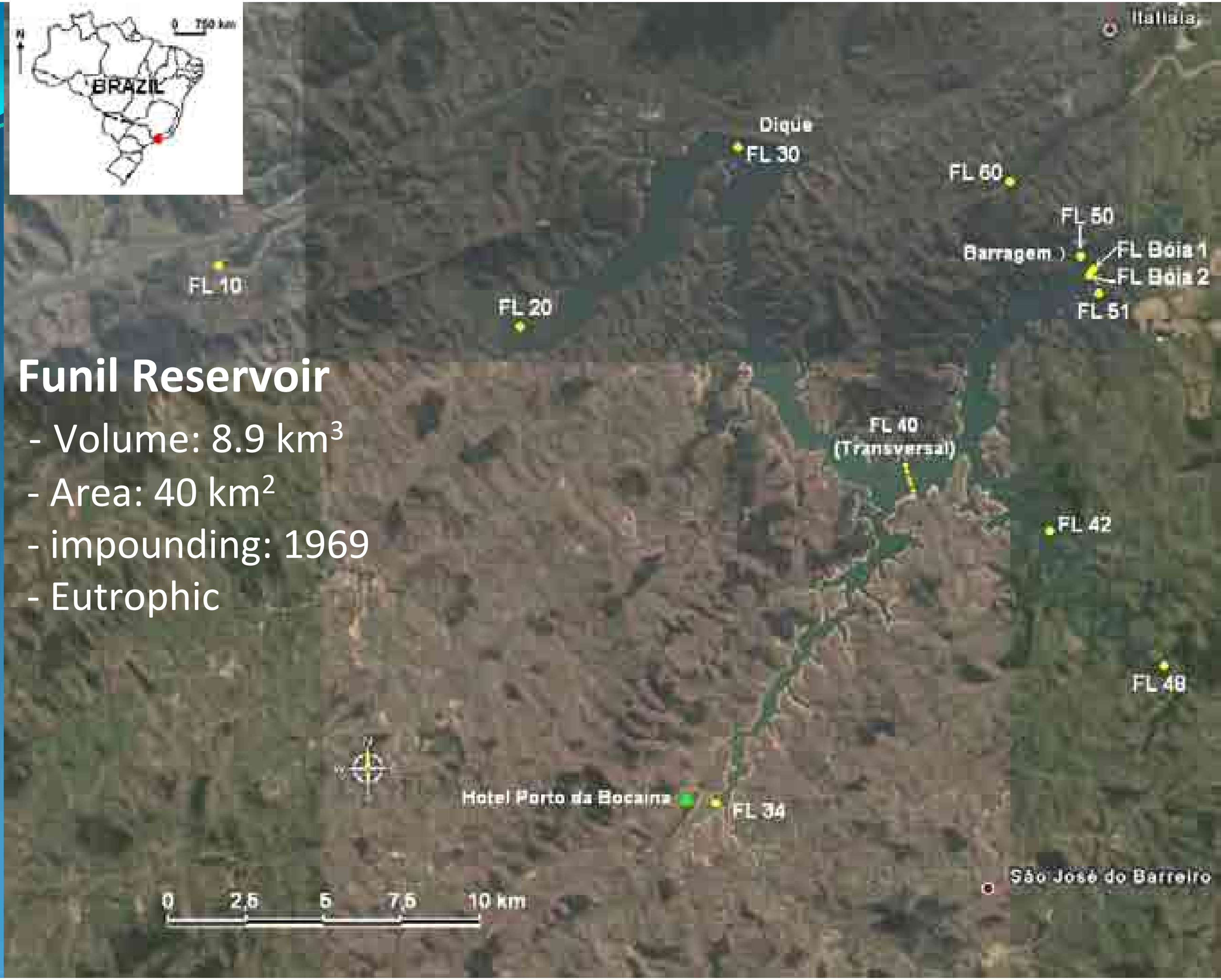


Itumbiara Reservoir

- Volume: 17 km^3
- Area: 778 km^2
- Impounding: 1980
- Power: 2082 MW
- Oligotrophic




Estreito Reservoir
- Volume: 1.4 km³
- Area: 46.7 km²
- impounding: 1969
- Power: 1050 MW
- Oligotrophic
Furnas Reservoir
- Volume: 233 km³
- Area: 1440 km²
- impounding: 1963
- Power: 1216 MW
- Mesotrophic
BRAZIL
Mascarenhas de Moraes Reservoir
- Volume: 4 km³
- Area: 250 km²
- Impounding: 1957
- Power: 476 MW
- Mesotrophic
N
0
50 km



Funil Reservoir

- Volume: 8.9 km^3
- Area: 40 km^2
- impounding: 1969
- Eutrophic

Sampling periods:

- In the beginning of the rainy season;

- In the end of the rainy season;

- In the dry season;

Participants:

International Institute of Ecology - IIEGA

Has estimated fluxes of CO_2, CH_4 and N_2O and concentrations of carbon and nutrients in the sediment-water interface.

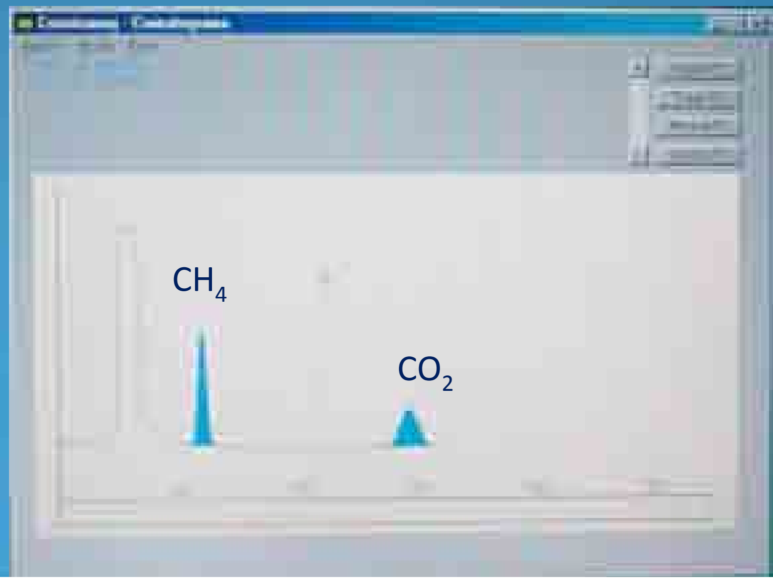
Sediment sampling - IIEGA

Gravity corer (UWITEC, Austria).

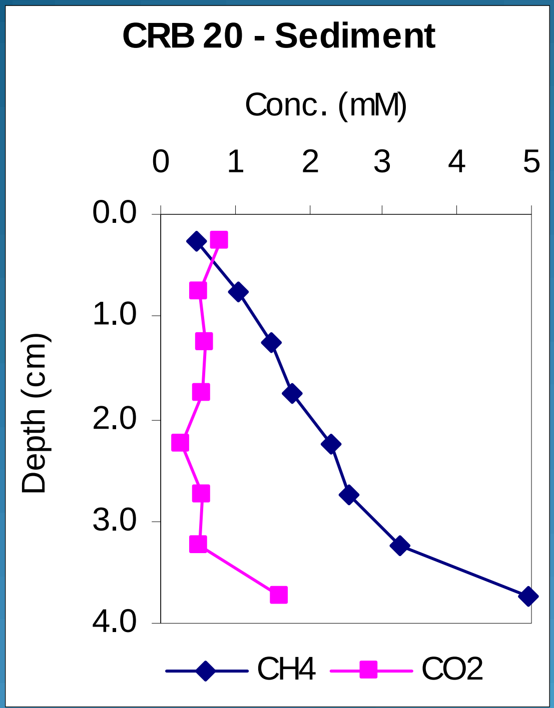
Sediment processing for gas analysis

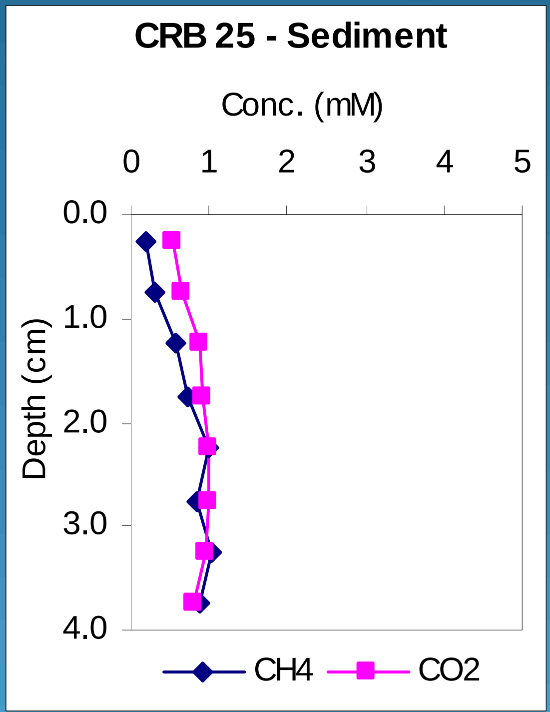
A-N gas sampling system (UWITEC, Austria) and specially-machined bottles (30 mL, having O-rings, pistons and built-in septa) at 5-mm depth intervals.

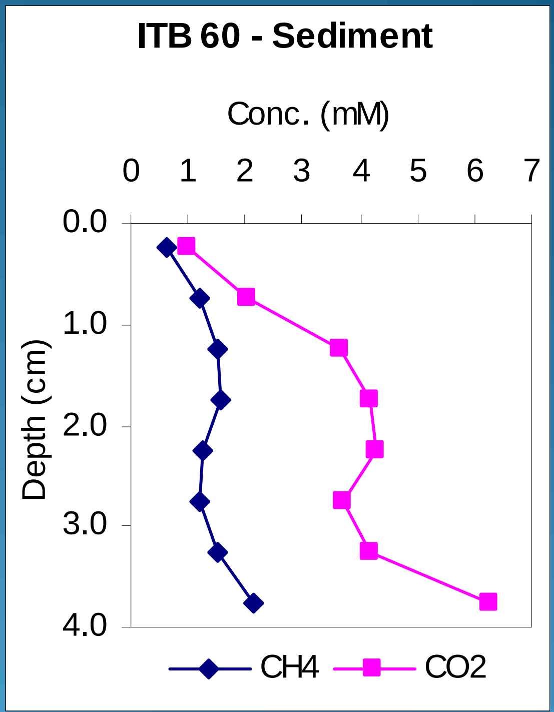
Gas measurements: Carried out by gas chromatography (TCD and ECD).



Typical profiles of CH4 and CO2 in the sediments.







Other participants:

Federal University of Rio de Janeiro (COPPE/UFRJ)

- Has estimated the GHG fluxes (CO_2, CH_4 and N_2O) in the water-atmosphere interface;

- has measured the input and sedimentation rates of carbon in the reservoirs.

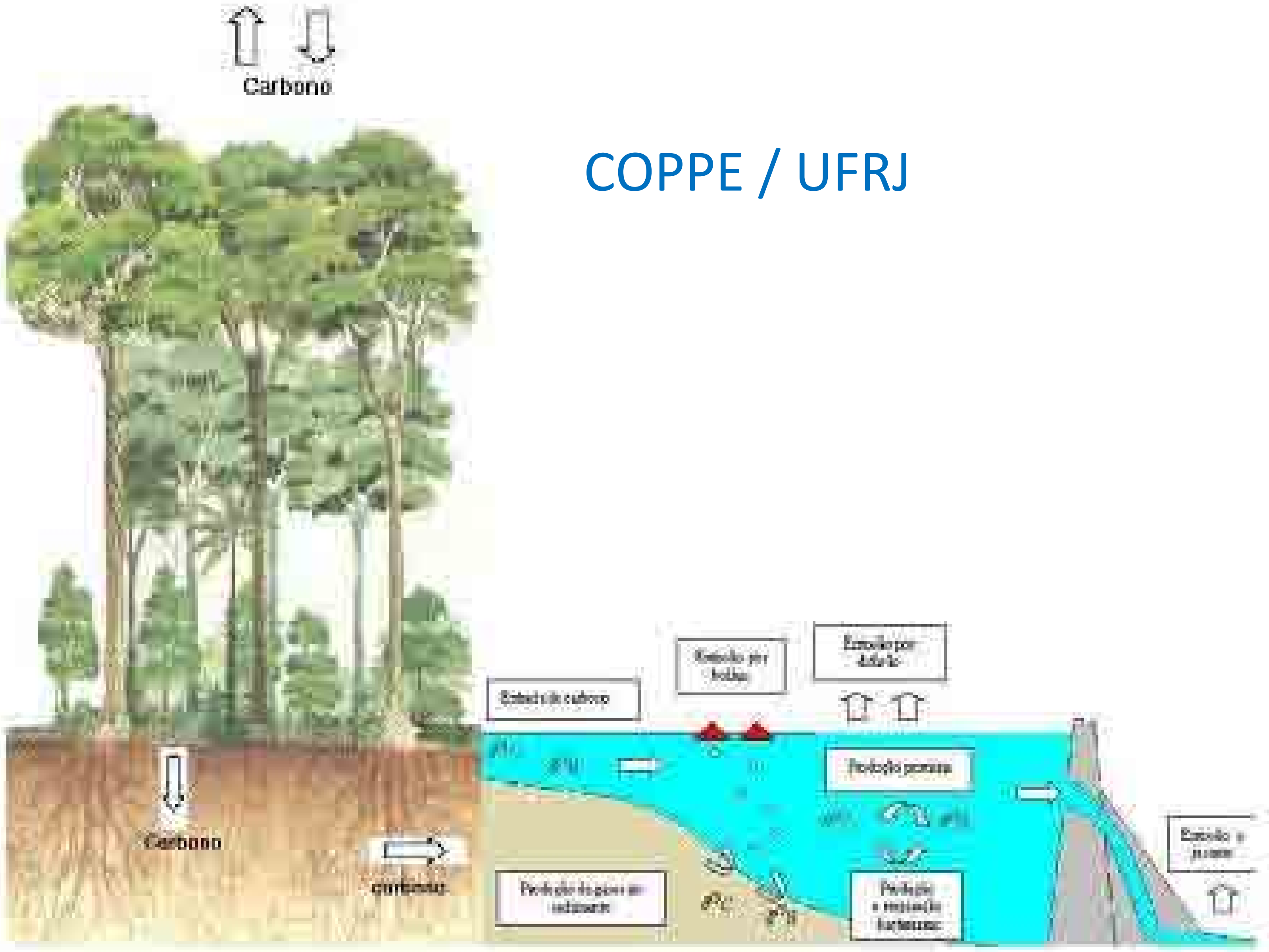
Emissions from Reservoirs – COPPE/UFRJ

Funnel Bubble Collector Coupled to a Gas Collecting Bottle

COPPE / UFRJ

Group of Collecting Funnels Placed in a Shallow Region

COPPE / UFRJ



Diffusion chambers - COPPE / UFRJ

Small-volume diffusion chambers: 5 cm diameter, 5 cm height and 100 mL vol.

Dynamic chamber (Santos, 2006).

Other participants:

Federal University of Juiz de Fora (UFJF)

Has estimated the primary production, bacterial metabolism, nutrient concentrations and the biomass of the organisms (bacteria, phytoplankton and zooplankton) in the water column .

Other Participants:

National Institute for Space Research (INPE)

•Organized the project database;

•Installed telemetric platforms in the reservoirs for environmental acquisition data;

• Estimated GHG flows in real time on the water-atmosphere interface.

National Institute for Space Research (INPE)

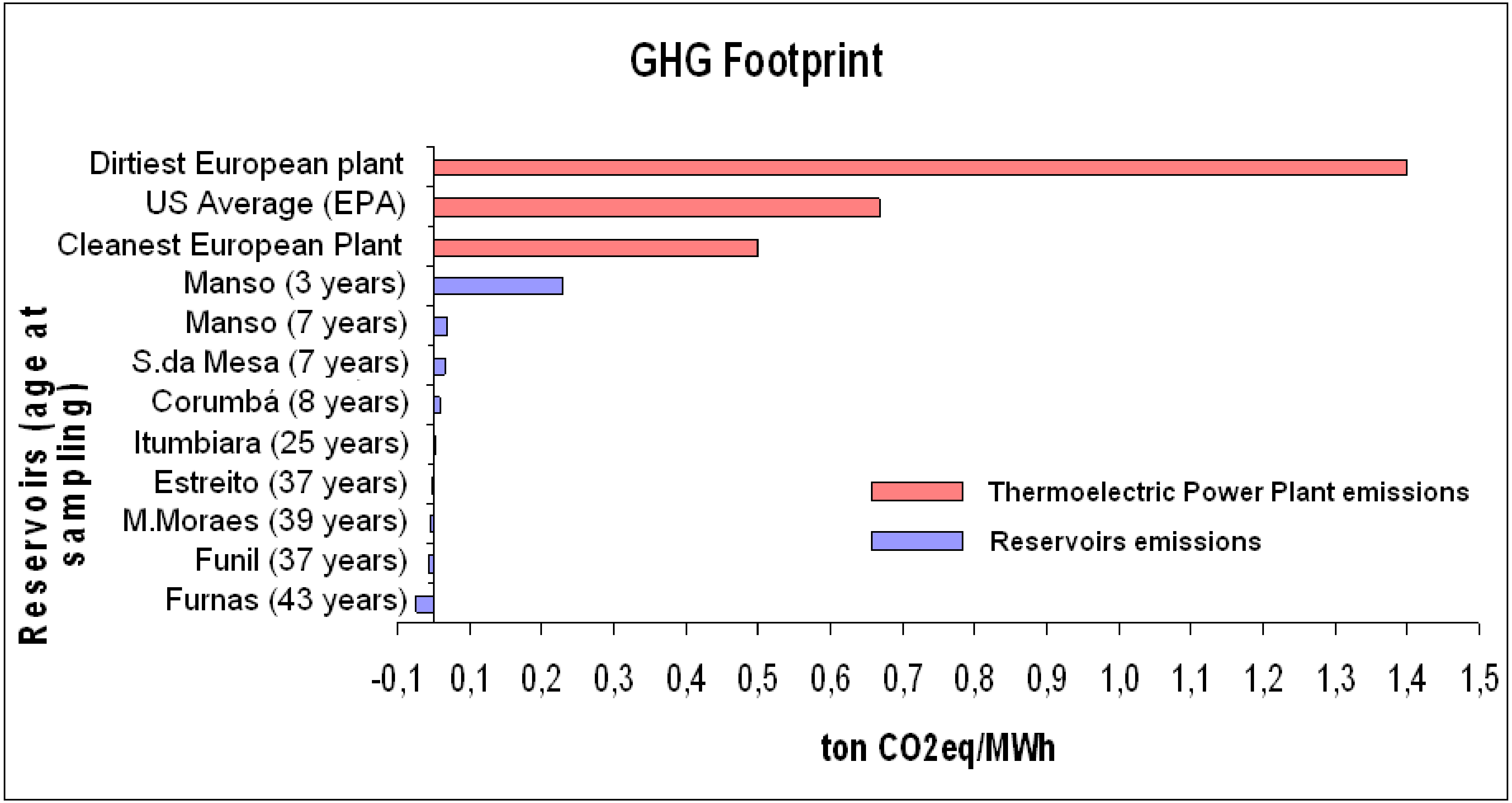
Telemetric platform for environmental acquisition data (climatology and water quality).

National Institute for Space Research (INPE)

Photoacoustic infrared trace gas analyzer (TGA) for real time measurements of GHG emissions (Photos: Ivan Lima, INPE)

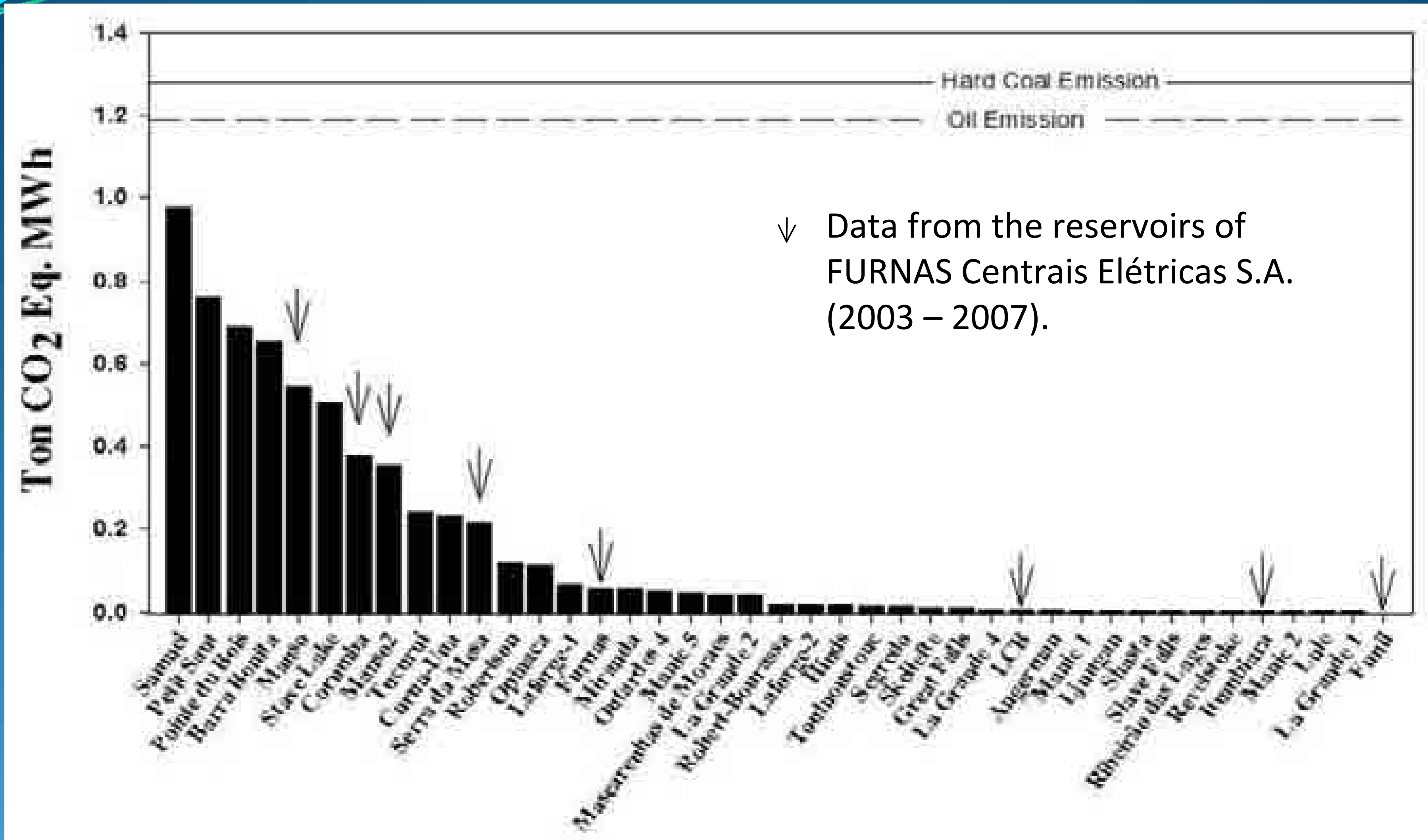
RESULTS

Comparison between GHG emissions by thermoelectric power plants and reservoirs of FURNAS Centrais Elétricas S. A.



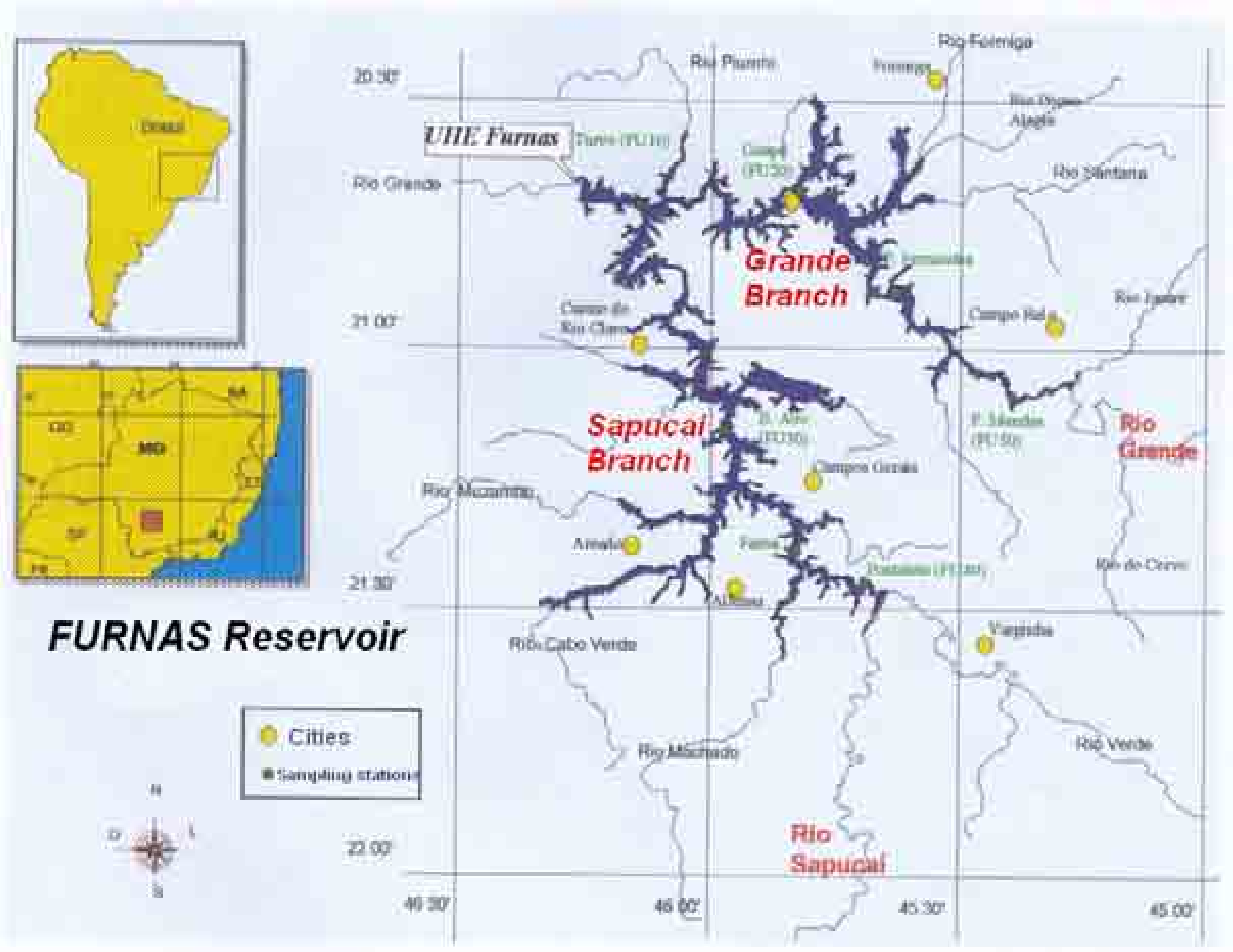
Brum (2008). Hydrovision Workshop 2008, Sacramento, CA

Emissions of CO_2-eq MWh^{-1} in hydroelectric reservoirs



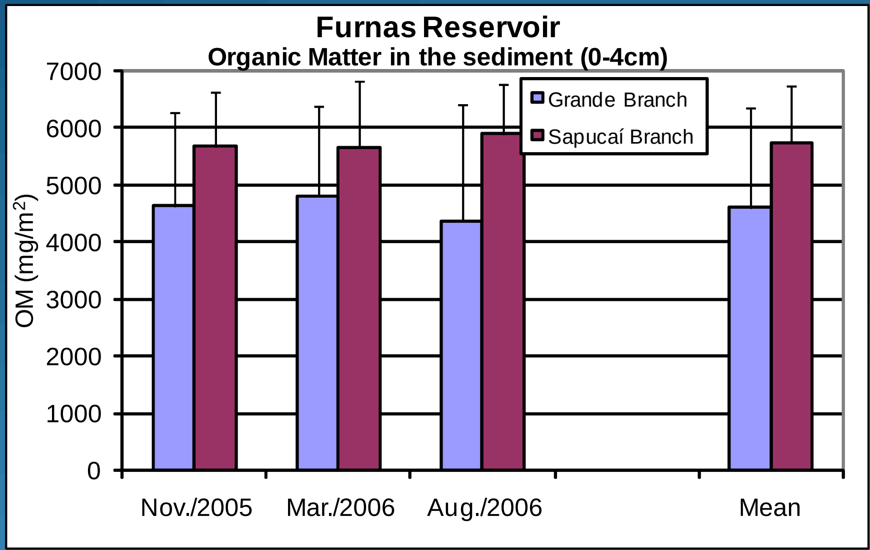
Abril et al. 2005; Bergstrom et al. 2004; Guerin et al. 2006 ; Kelly et al. 1994; Rosa et al. 2004; Santos et al. 2004; Soumis et al. 2004; St Louis et al. 2000; Tremblay et al. 2004;

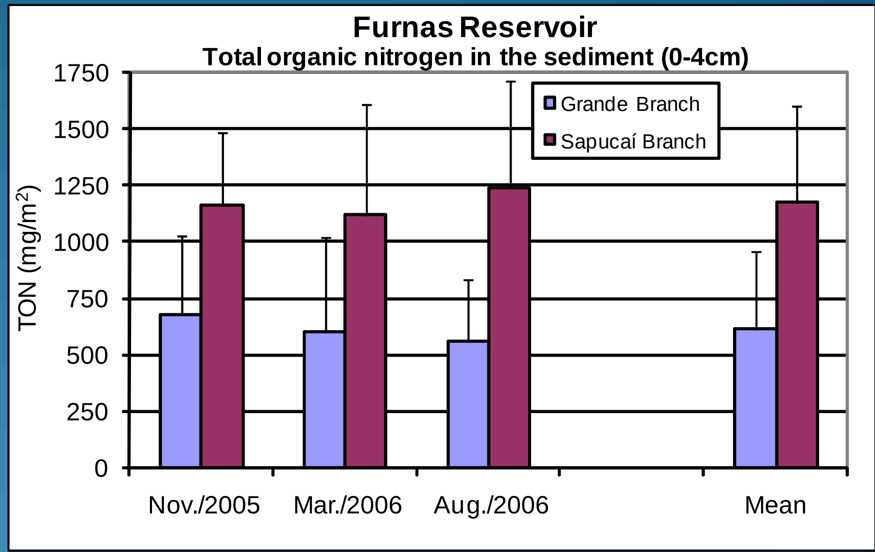
Impact of the watershed land use to greenhouse gas emission in Furnas Reservoir

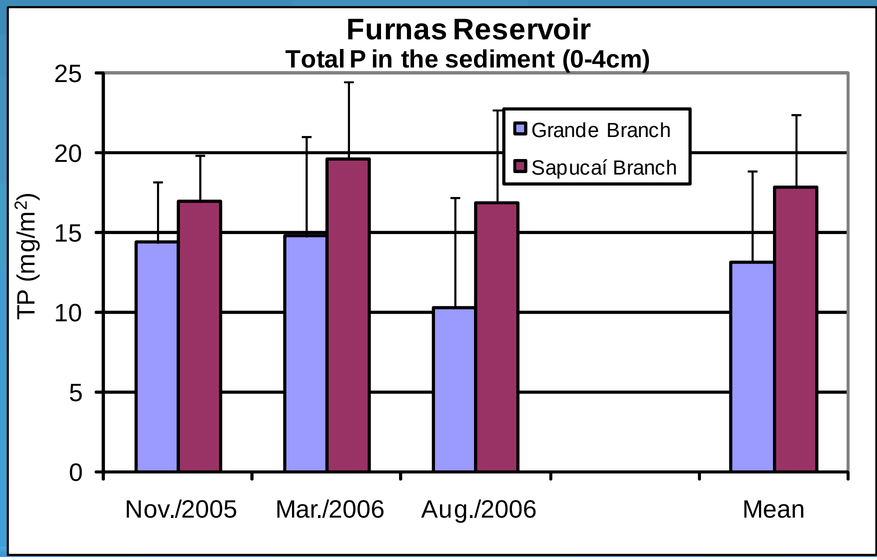


Furnas Reservoir

The concentrations of carbon, nitrogen and phosphorus in the sediments of the Sapucai branch were higher than in the Grande branch.

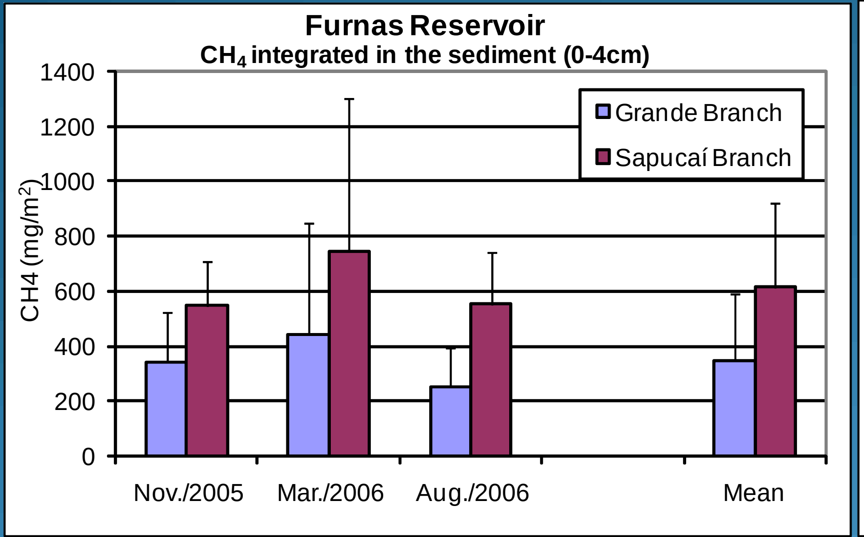


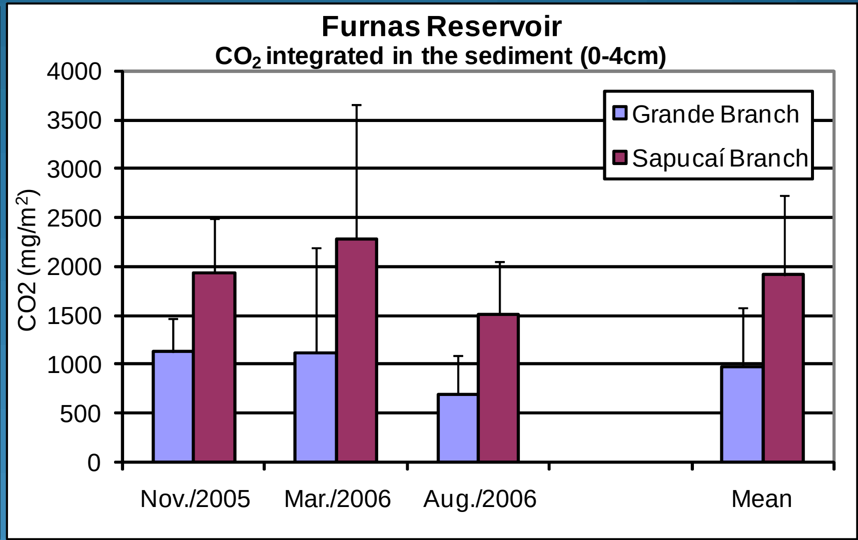


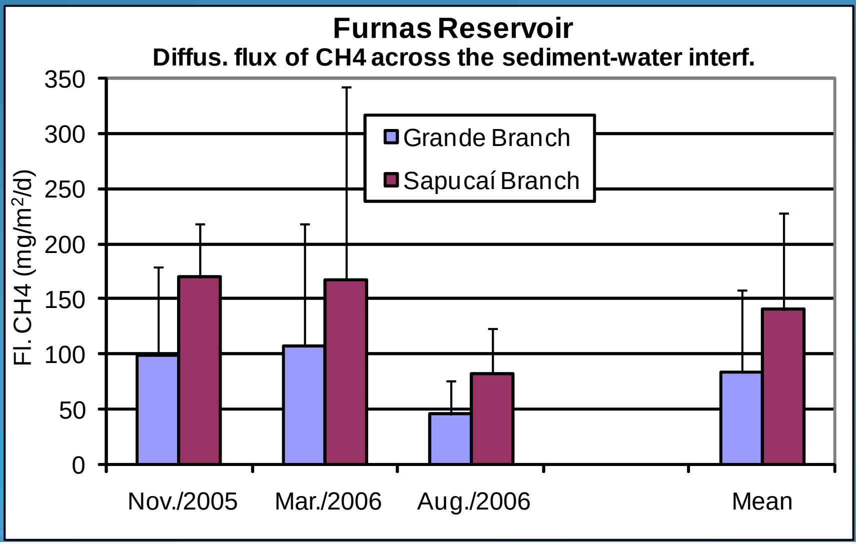


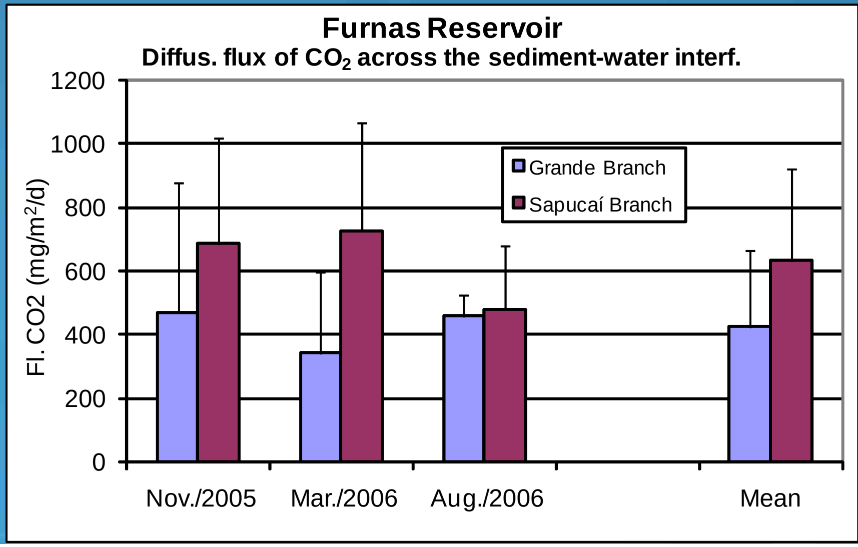
Furnas Reservoir

The concentrations and diffusive fluxes of CH4 and CO2 in the Sapucai branch were higher than in the Grande branch.





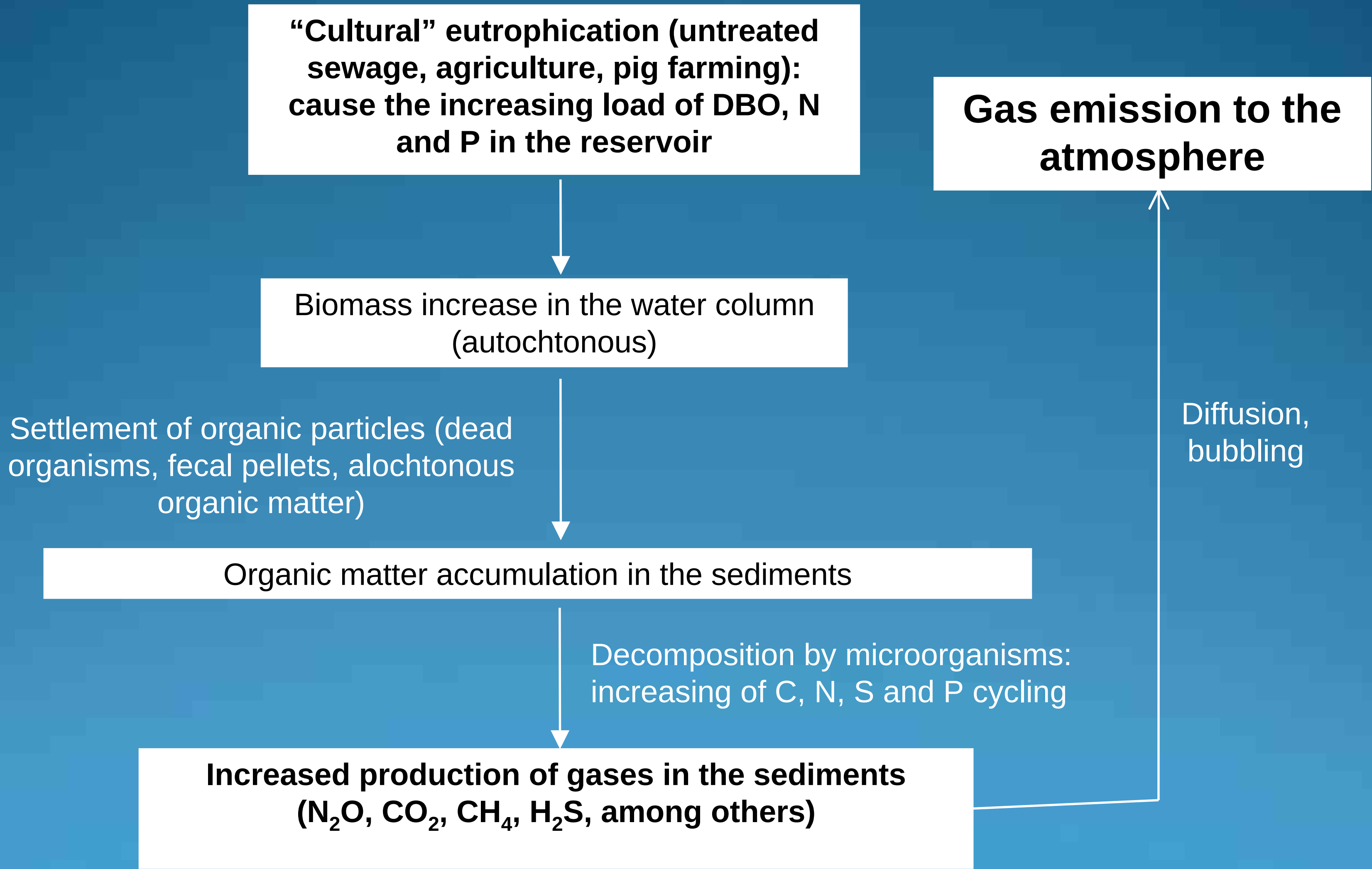




Today there is enough knowledge to discriminate between “good” and “bad” dams in terms of GHG emissions.

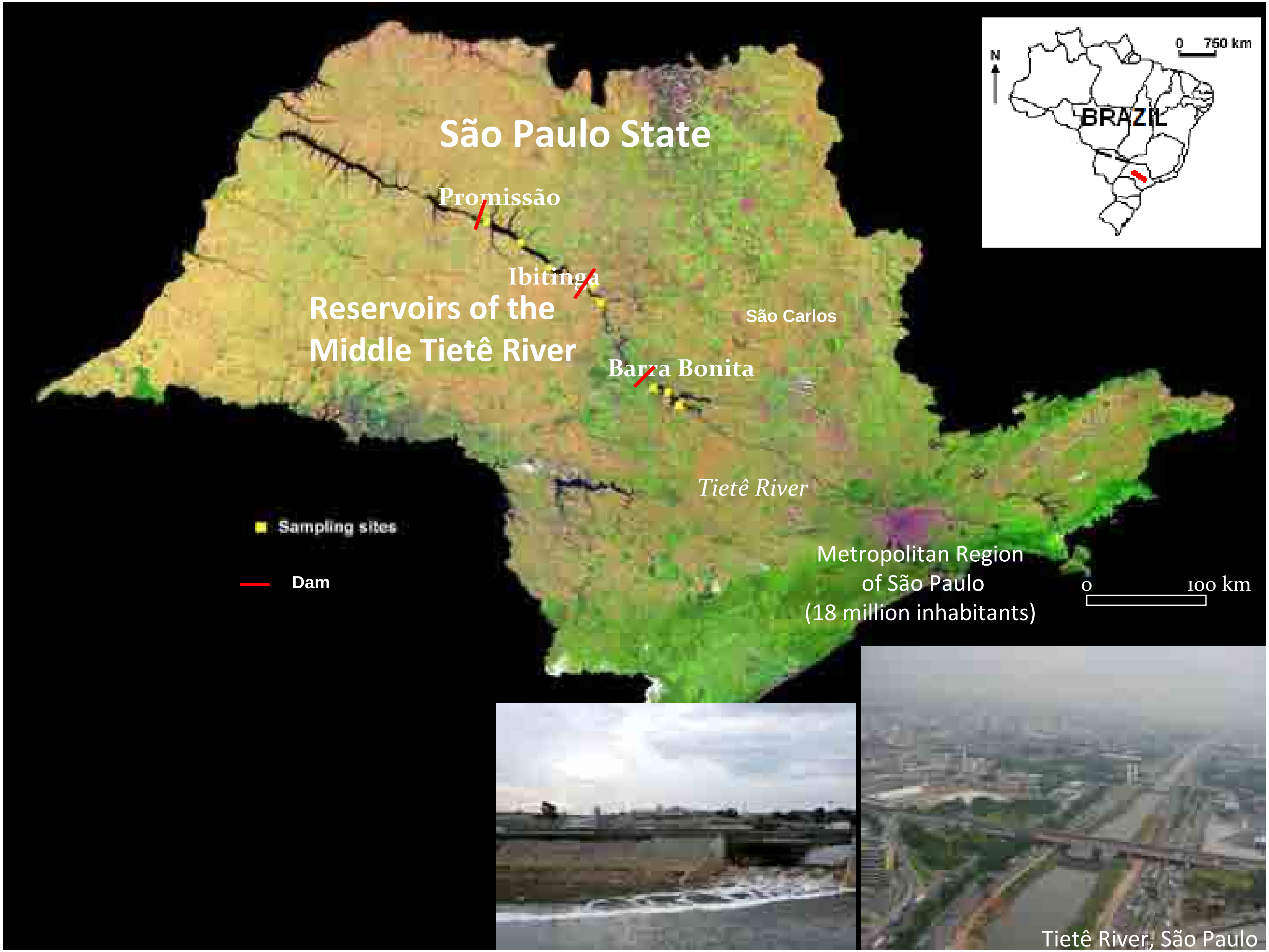
Ex: type of the drowned vegetation, organic matter content in the submerged soil, input of alochtonus organic material and nutrients from the watershed, morphometry, mean depth, residence time, the depth of the reservoir outlet, etc.

Eutrophication: has a strong influence on GHG accumulation in the sediments and emission to the atmosphere.

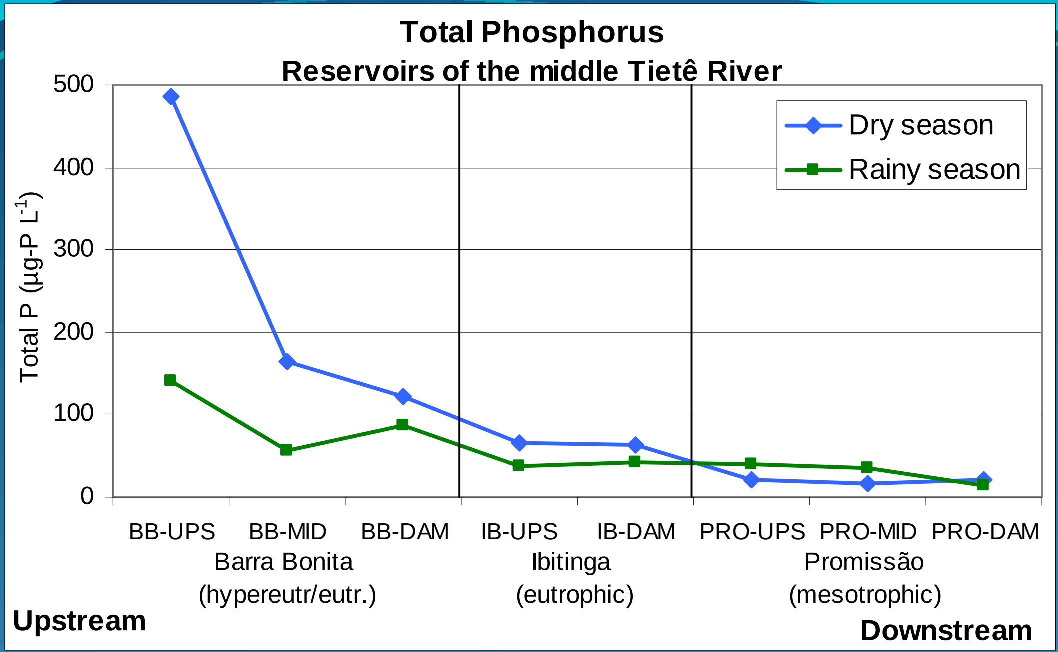

“Cultural” eutrophication (untreated sewage, agriculture, pig farming): cause the increasing load of DBO, N and P in the reservoir
Biomass increase in the water column (autochtonous)
Settlement of organic particles (dead organisms, fecal pellets, alochtonous organic matter)
Organic matter accumulation in the sediments
Decomposition by microorganisms: increasing of C, N, S and P cycling
Increased production of gases in the sediments (N_2O, CO_2, CH_4, H_2S, among others)
Diffusion, bubbling
Gas emission to the atmosphere

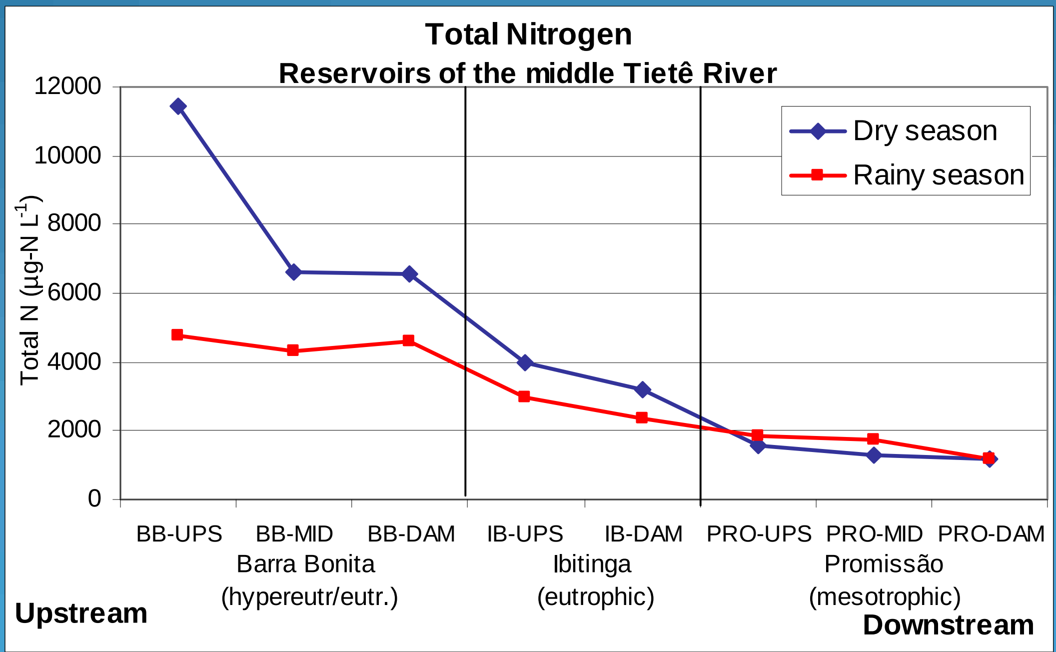
2005-2007: Project “Study of the relationship between trophic state and emission of greenhouse gases in the reservoirs of the middle Tietê River”.

Sponsor: State of São Paulo Research Foundation – FAPESP.


São Paulo State
Promissão
Ibitinga
Reservoirs of the
Middle Tietê River
São Carlos
Barra Bonita
Tietê River
Sampling sites
Dam
Metropolitan Region
of São Paulo
(18 million inhabitants)
0 100 km
N
0 750 km
BRAZIL
Tietê River, São Paulo

Total P and total N – mean values in the water column

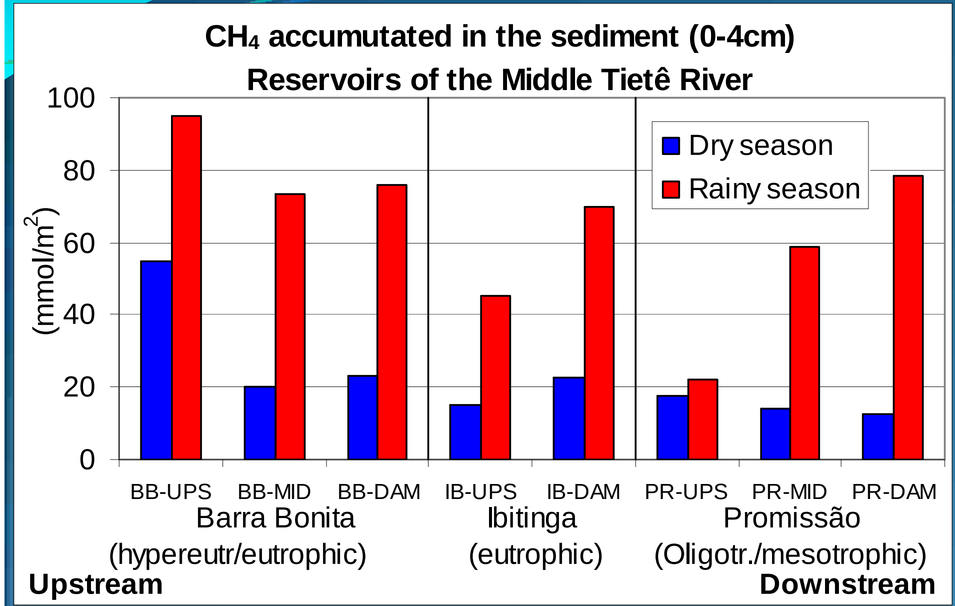


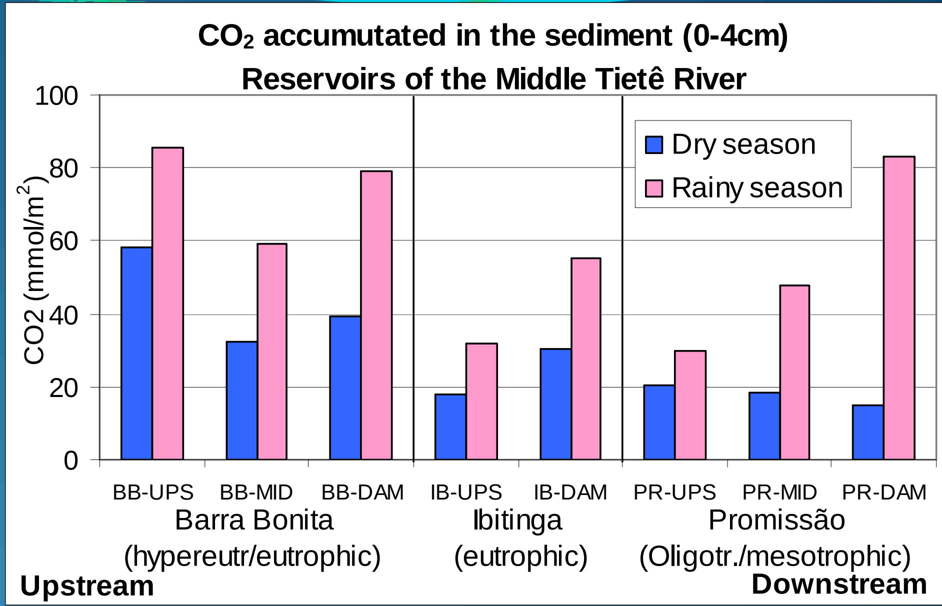


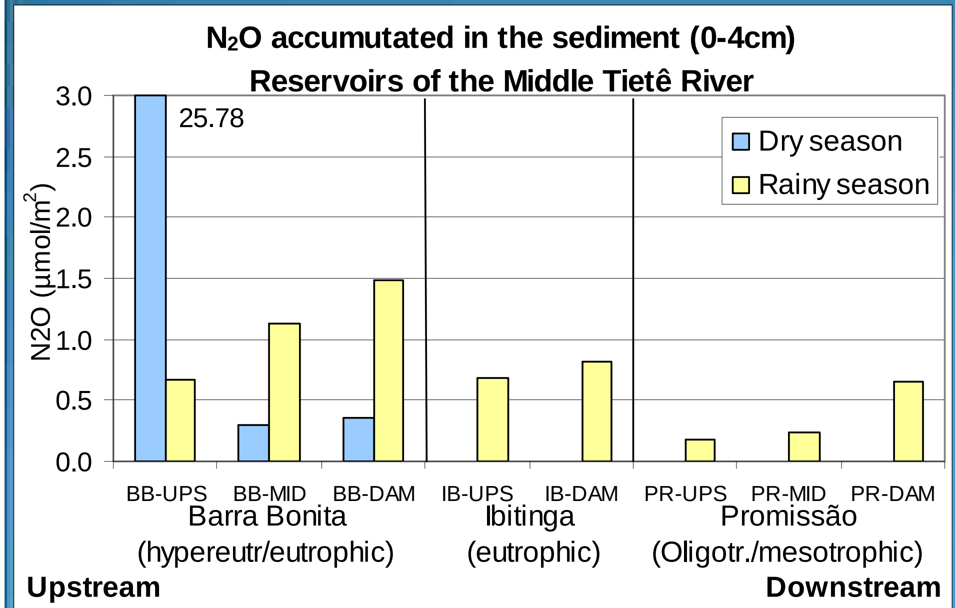
Dry season: October 2005

Rainy season: March 2006

CH_4 e CO_2 , N_2O accumulated in the sediments



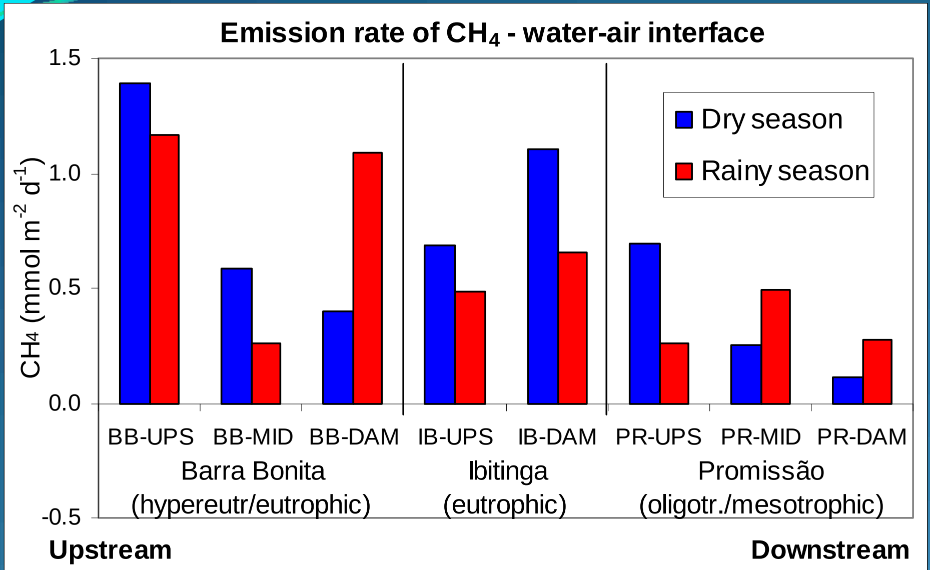


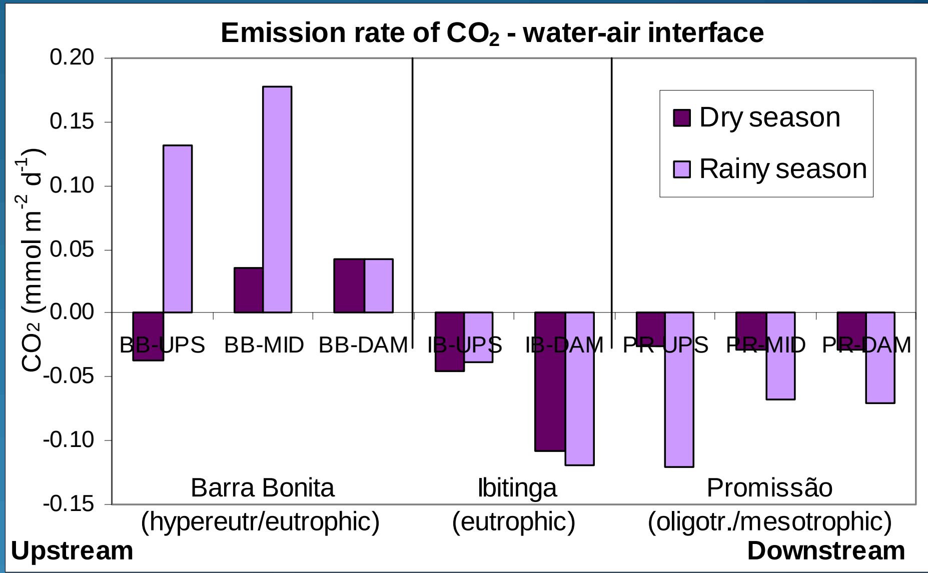


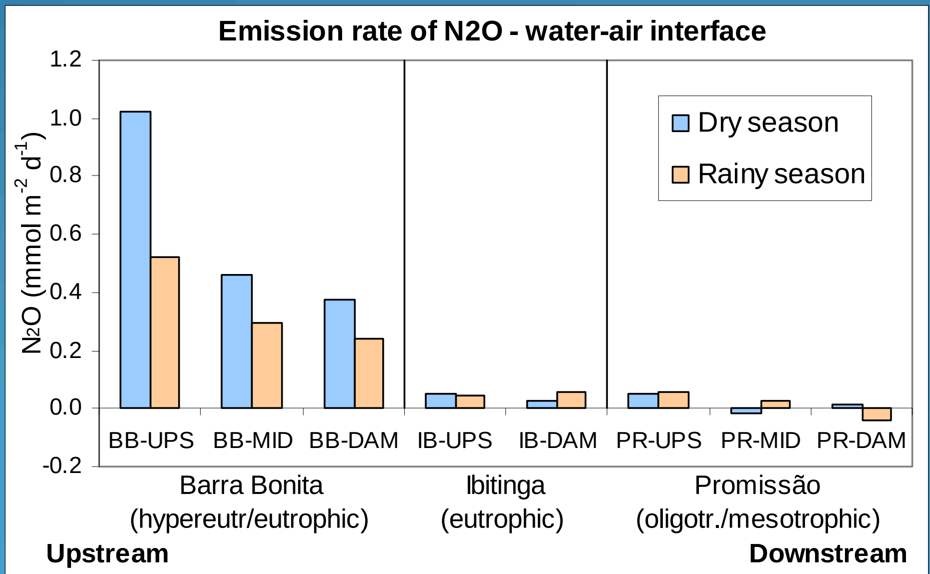
Dry season: October 2005

Rainy season: March 2006

Emission rates of CH_4, CO_2 e N_2O across the water-air interface in the Reservoirs of the Tietê RIver (measured with floating chambers)





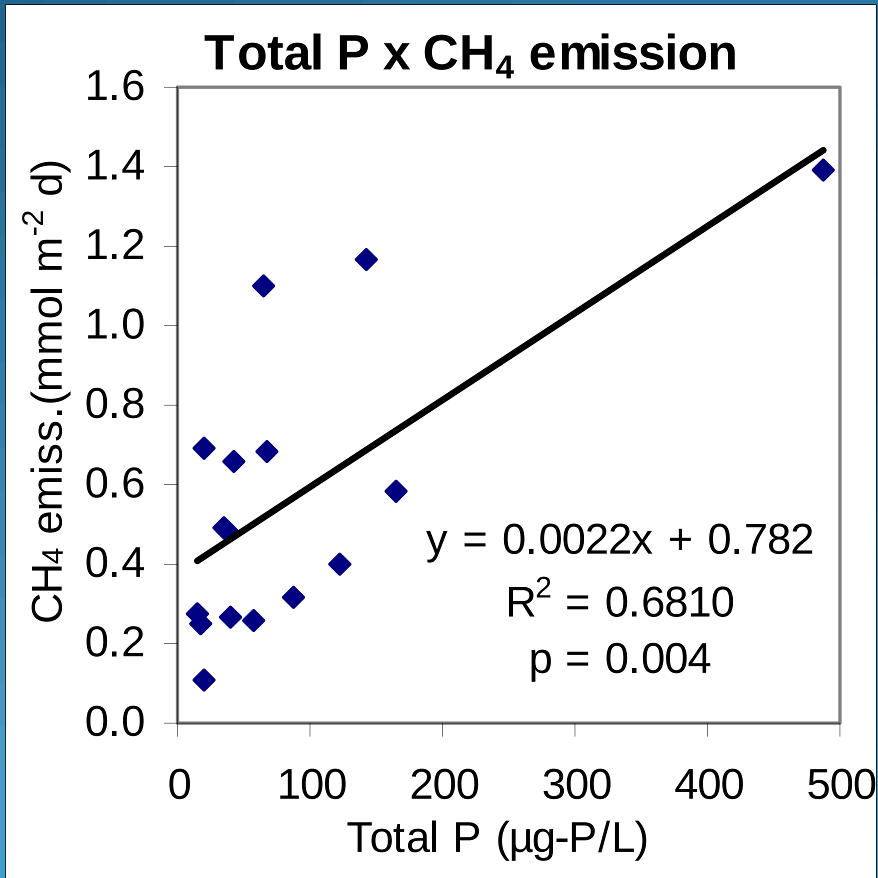


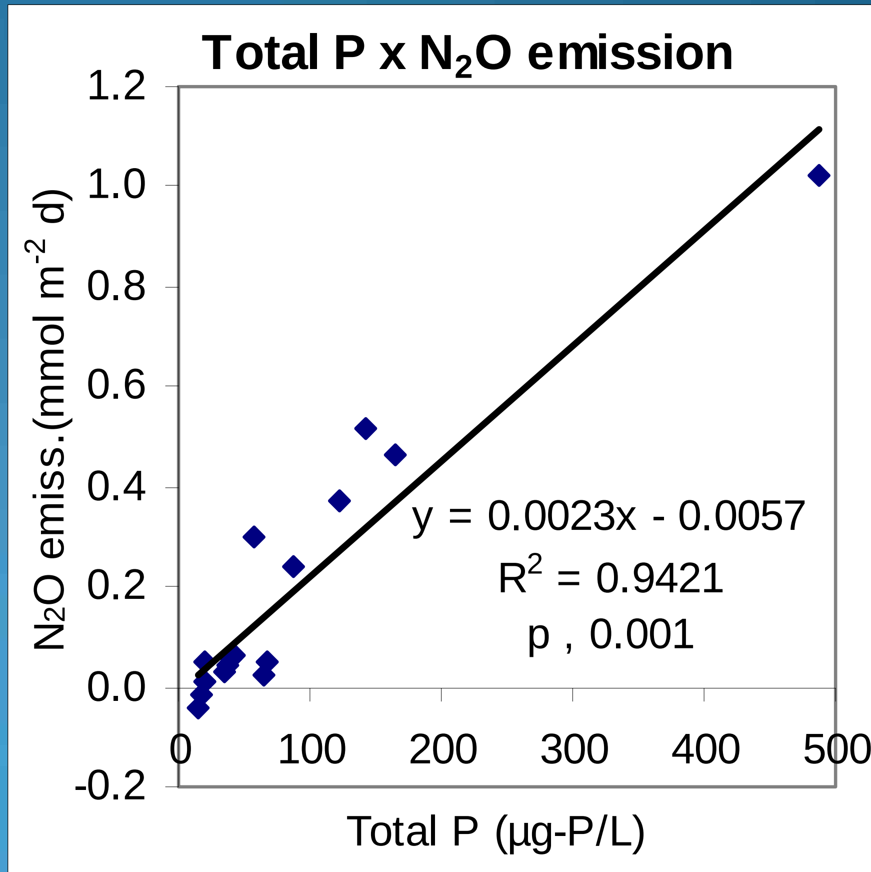
Dry season: October 2005

Rainy season: March 2006

Correlation between total P and gas emission

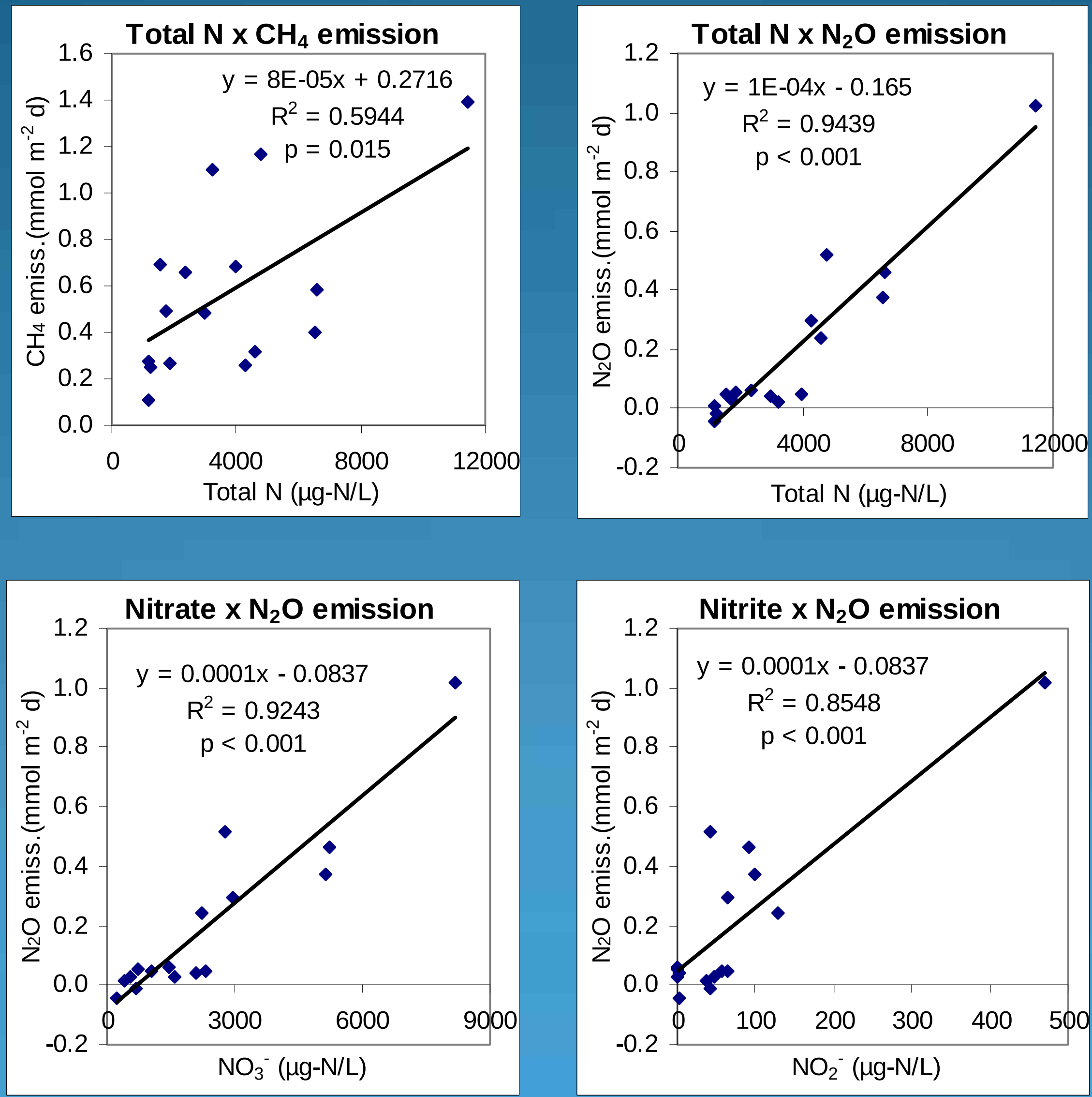
Total P in the water column x gas emissions across the water-air interface





Correlation between nitrogen and gas emission

Total N, nitrate and nitrite in the water column x gas emissions across the water-air interface



2010 – 2013: Continuation of the project on GHG emission in hydroelectric reservoirs in Brazil.

Number of reservoirs to be studied: 11

- 3 under construction (Santo Antonio and Belo Monte in the Amazon Basin, and Batalha in central Brazil (cerrado savanna bioma).

- 8 reservoirs in operation (2 in the Amazon Basin, 2 in the cerrado savanna, 1 in the caatinga (semi-arid), 3 in the Atlantic Forest (Funil, Segredo and Itaipu).

2010 – 2013: Continuation of the project on GHG emission in hydroelectric reservoirs in Brazil.

Sponsors: ELETRONORTE, FURNAS and CHESF (state companies of electric generation).

Participants:
- The Brazilian Electrical *Energy* Research (CEPEL)
- Federal University of Rio de Janeiro (UFRJ/COPPE);
- Federal University of Juiz de Fora (UFJF);
- National Institute for Space Research (INPE)
- International Institute of Ecology (IIEGA);
- University of Pará;
- Federal University of Paraná;

11 reservoirs in Brazil to be studied

Tucuruí Reservoir

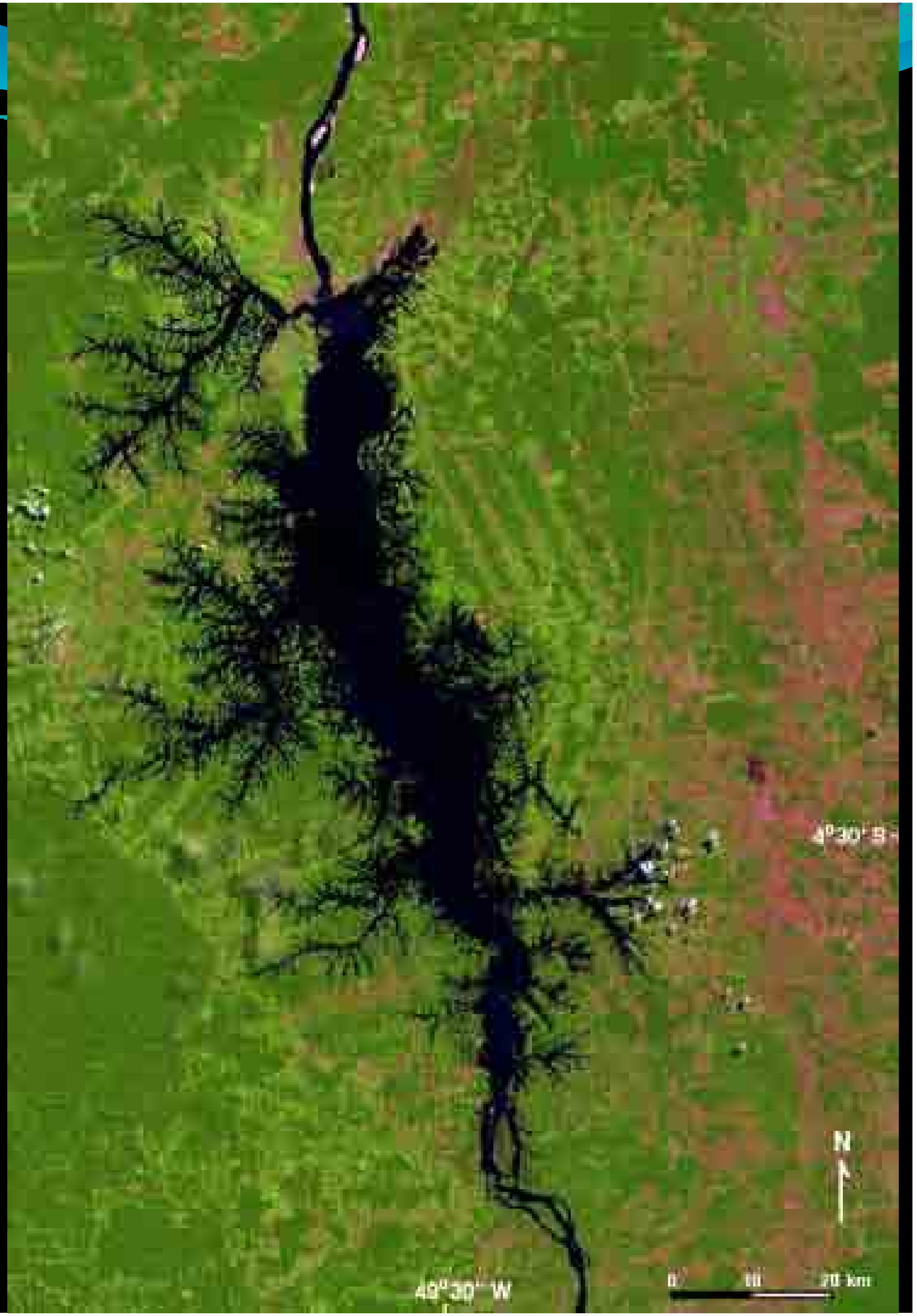
-Volume: 45.5 km^3

-Area: 2875 km^2

-Impounding: 1985

-Power: 3960 MW

-Bioma: rain forest



Balbina Reservoir

-Volume: 17.5 km^3

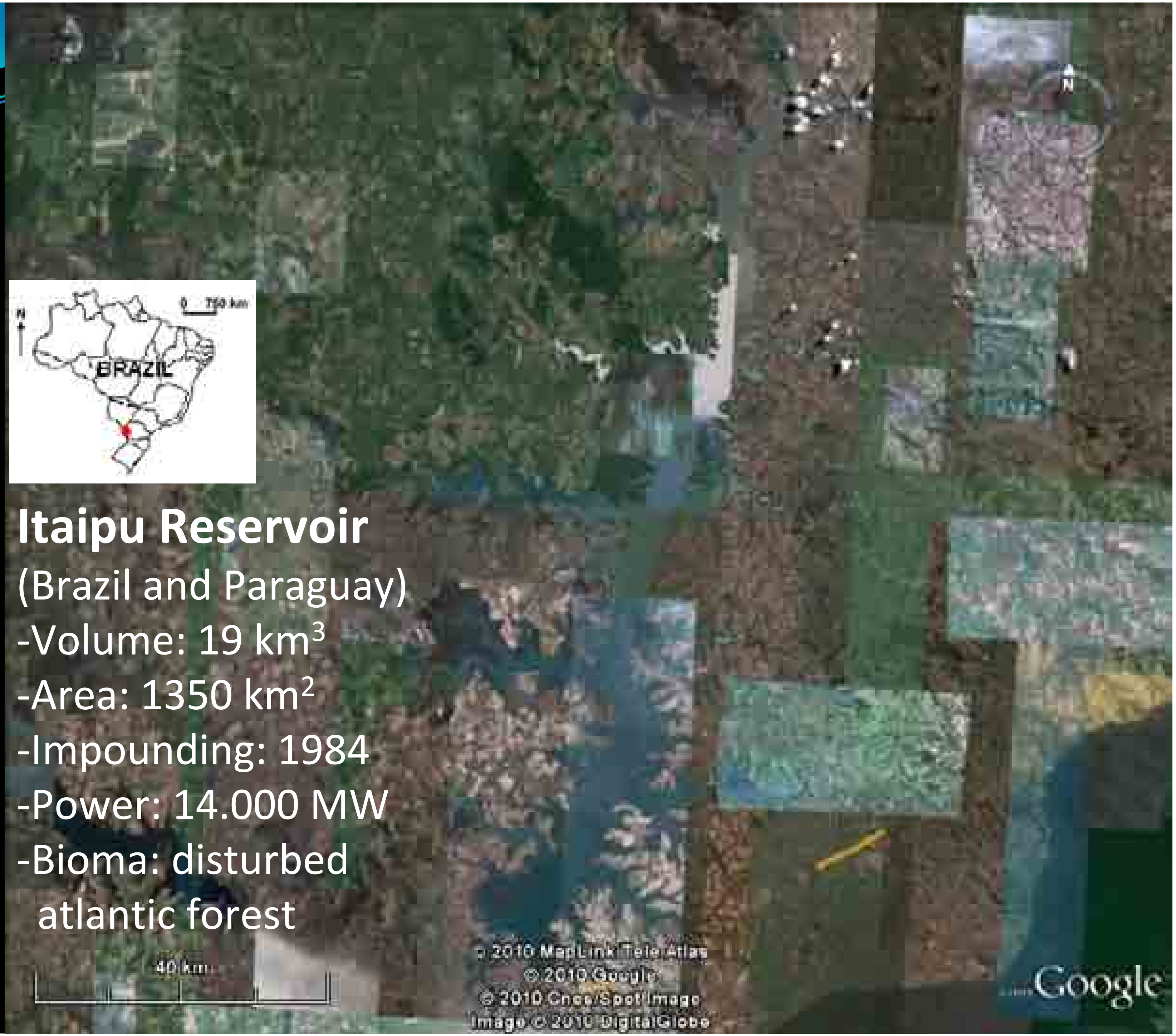
-Area: 2360 km^2

-Impounding: 1987

-Power: 250 MW

-Bioma: rain forest (Amazon Basin)

Balbina Reservoir



Itaipu Reservoir

(Brazil and Paraguay)

-Volume: 19 km^3

-Area: 1350 km^2

-Impounding: 1984

-Power: 14.000 MW

-Bioma: disturbed atlantic forest

New approaches to be applied in this project:

•Measurements of GHG emissions to be taken before the construction of the reservoir (Santo Antonio, Belo Monte and Batalha reservoirs): will enable quantification of net emissions in the future, after the creation of the reservoir.

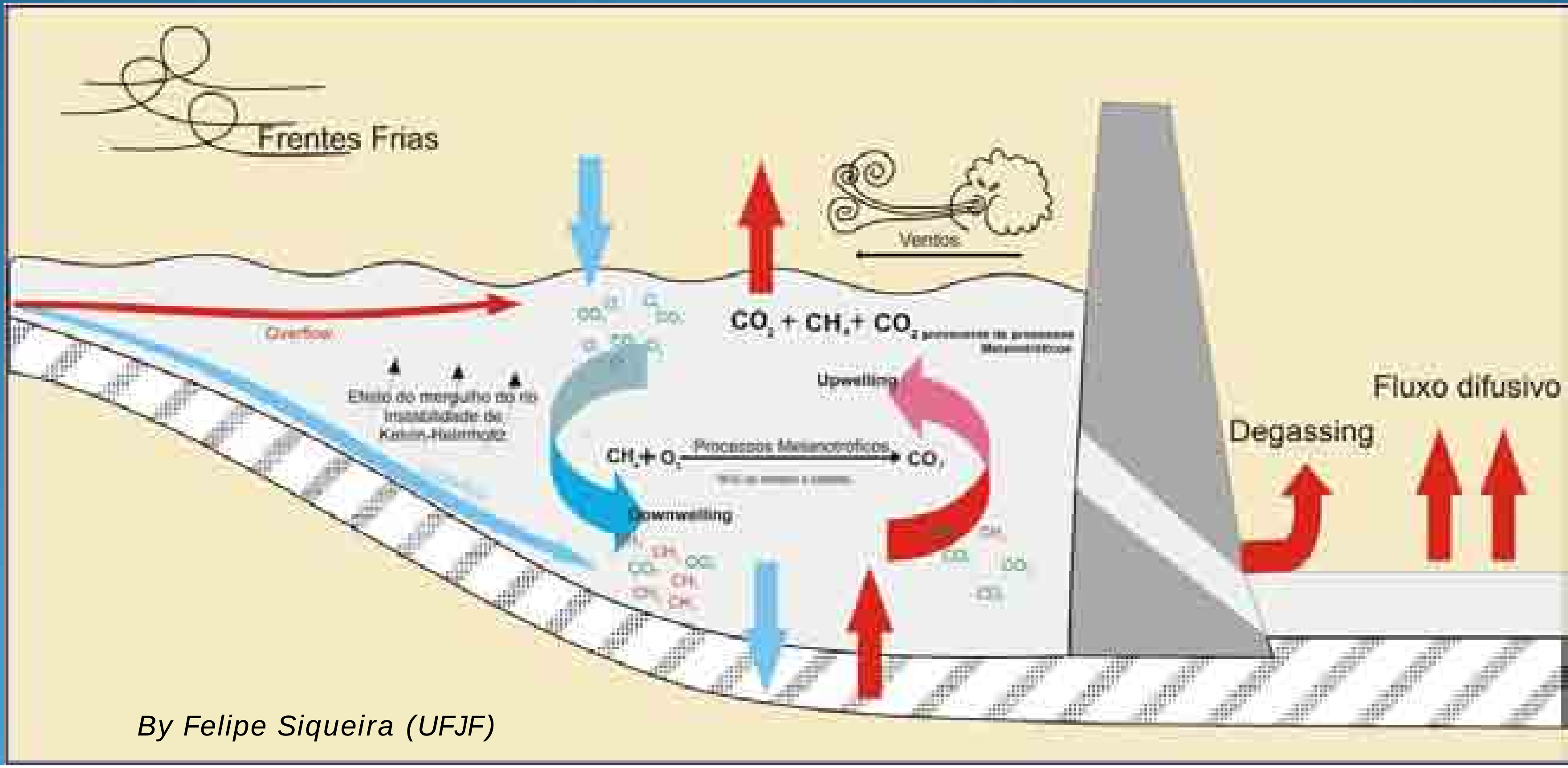
Net emission = emission after the reservoir construction – emission before the reservoir construction

Other new approaches to be applied:

- Measurement of production rates of CH_4, CO_2 and N_2O in the water and in the sediments;
- Measurement of CH_4 oxidation by methanotrophic bacteria;
- Identification of bacteria involved in the processes by molecular techniques (Federal University of Pará);

Other new approaches to be applied:

- Measurements of downstream methane emission below the dam, after the water passes through the turbines (degassing).



By Felipe Siqueira (UFJF)

Other new approaches to be applied:

- •Hydrodynamic modelling (University of Paraná);
- •GHG emissions modelling (CEPEL);
- •Carbon budget modelling (CEPEL).

Documents to be prepared

- •Guidelines of methodologies for greenhouse gas measurements.
- •Guidelines of good practices of management for mitigation of GHG emissions in hydroelectric reservoirs.

THANK YOU !

Contact: donatoabe@iie.com.br