Brazilian greenhouse gas emissions: the importance of agriculture and livestock

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Abstract
Tthe aims of this study were (i) to update estimates of the GHG emissions for the Brazilian territory, (ii) estimate the sinks to provide calculations of the GHG net emissions to the 1990-2005 period, (iii) to calculate the actual and estimated shares of agriculture and livestock activities, and (iv) to discuss in the light of the new figures and patterns the best mitigation options for Brazil. Total emissions in CO_2-eq increased by 17% during the 1994-2005 period. CO_2 represented 72.3% of the total, i.e. a small decrease, in favour of non-CO_2 GHG, in relation to 1994 when its share was 74.1%. The increase of all GHG excluding LUCF was 41.3% over the period 1994-2005. CAIT-WRI estimated a higher increase (48.9%) that classified Brazil at the 69th position. Using our estimates Brazil will fall to the 78th position. But in both cases Brazil increased in clearly lower values than the tendency calculated for China and India, two major emitters, with increases of 88.8% and 62.1%, respectively. Besides effort to curb emissions from the energy and deforestation sectors, it is now a top priority to implement a national program to incentive mitigation efforts concerning the agricultural and livestock sectors.

Key Words
Soil, livestock, CO_2-equivalent (CO_2-eq), inventory, land use change and forestry.

Introduction
It is widely recognized that the Land Use, Land-Use Change and Forestry (LULUCF) is a key sector of Climate Change. The agricultural sector alone is responsible for about 14% of total global anthropogenic GHGs emissions and is expected to have high emission growth rates, driven mainly by population and income increases. Deforestation is responsible for an additional 17%, setting the total contribution of the LULUCF sector to nearly one third of the current total global emissions (IPCC 2007). Brazil is one of the top world greenhouse gas (GHG) emitters and a majority of Brazil's GHG emissions, which contribute to global warming, come from burning linked to deforestation of the Amazon biome, and not from fossil fuels which are the main culprit in most countries. Brazil suffered and still regularly suffers pressure to curb destruction of the Amazon rainforest. The latest official Brazilian data on GHG emissions and sinks were published in 2004 in the report entitled "Brazil's Initial National Communication to the United Nation Framework Convention on Climate Change" (Brazil 2004). The second part of this report included the first GHG inventory but included only the period from 1990 to 1994. This report showed that the sub-sector "Forest conversion" from the bulk LULUCF Sector was the main contributor in 1994, representing 55% of the total GHG sources, which totalised 1728 Mt CO_2-eq (CO_2 equivalent), and nearly 82% of the sole emissions of CO_2. This last percentage is reduced to 75% when considering the net result, which includes a CO_2 sink of 251 Mt. The agricultural sector is now facing a crossroads of issues linked with food security, rural livelihoods, environmental sustainability, bio-energy, climate change adaptation and mitigation, in a context of important and difficult negotiations for a future regime for LULUCF under the United Nation Framework Convention on Climate Change in a post-2012 international agreement. Our understanding is that the main focus of the majority of the National Inventories is on GHG emissions. However, in Brazil we do include sinks in our net GHG emissions. The sinks are mainly due to carbon fixation in soils and phytomass resulting from advanced agricultural management practices, reforestation and land abandonment. Thus, the objectives of this paper are (i) to update estimates of the GHG emissions for the Brazilian territory, (ii) to estimate the sinks to provide calculations of the GHG net emissions to the 1990-2005 period, (iii) to calculate the actual and estimated share of agriculture and livestock activities, and (iv) to discuss the best mitigation options for Brazil in light of the new figures and patterns.

Methods

Actual and recent data and forecasted values (from 2005 to 2020) were obtained from two main internationally recognized sources: i) Climate Analysis Indicators Tool (CAIT) from the World Resources Institute (WRI 2009), available on line at http://cait.wri.org; ii) Emission Databases for Global Atmospheric Research (EDGAR) from the Netherlands Environmental Assessment Agency (http://www.mnp.nl/edgar/model/). Specifically for Brazil, data of the CAIT from WRI were derived from individual sectors. For the CO_2 emission, fossil fuel emissions for the period 1971-2005 were obtained from IEA (2007). The emissions from cement manufacture and gas flaring were included for the year 1980 and subsequent years. CO_2 emissions for the period 1950-2000 were calculated from Houghton (2003). Finally CH_4 and N_2O emissions each 5 years for the period 1990-2005 were estimated using EPA (2006).

Concerning the EDGAR database, two principal databases were used. Data for the years 1990 and 1995 were derived from the EDGAR 3.2 database (Olivier *et al.* 2002) that provides global annual emissions per country of Kyoto Protocol greenhouse gases CO_2, CH_4, N_2O, and F-gases (HFCs, PFCs and SF_6). Data for the year 2000 were obtained from the EDGAR 3.2 Fast Track 2000 dataset that incorporated updated values from EDGAR 3.2. Most data in EDGAR derived from IEA, FAO and UN databases. Emissions for the LULUCF sectors were calculated and updated for the years 2000 and 2005 using the same methodologies described in the background reports of the BINC. Details of the different methodologies are provided in each report, but they are all based on steps proposed by the Revised 1996 Guidelines for National Greenhouse Gas inventories. The estimates of GHG emissions associated with LULUCF sector were updated for the 2000-2005 time period according to data availability. The LULUCF sector was subdivided into the following two broad sub-sectors: Land-use change and Forestry, and Agriculture. The former represented the GHG emissions and removals due to deforestation of the native vegetation, changes in forest and other woody biomass stocks, abandonment of managed areas, and from soils. The agriculture sub-sector represented the emissions of GHG from the enteric fermentation, manure management, rice cultivation, field burning of agricultural residues, and agricultural soils. Agricultural soils include the emissions produced by the use of synthetic N fertilizers; organic N applied as fertilizer (e.g., animal manure, compost, sewage sludge, rendering waste); urine and dung deposited on pasture, range and paddock by grazing animals; crop residues, including from N-fixing crops. The GHG emissions from the agriculture sub-sector were estimated based on the procedures and parameters adopted in the Brazil's Initial National Communication. GHG emissions estimates associated with the Forest sub-sector for the 1990-1994 period were derived from the use of remote sensing, which mapped for this period the land cover situation in the main Brazilian biomes (Amazônia, Cerrado, Mata Atlântica, Caatinga, and Pantanal).

The CO_2 emissions from soils were estimated according to the approach proposed by the Revised 1996 Guidelines for National Greenhouse Gas Inventories and adapted by Bernoux *et al.* (2001). The estimate was based on the variations in soil C stocks due to the land-use changes for the time period of 1985-2005, assuming a linear change in C storage. The 20-year period, the soil depth (0-30 cm) and the units of measurement (Mha for land areas and Mg C/ha for soil C) suggested by the IPCC were used in the present study. The calculation was performed by state and more details about the parameters adopted and procedures can be found in Bernoux *et al.* (2001). CO_2 emissions due to the organic soils cultivation were also included, using the same methodology used in the Brazil's Initial National Communication, assuming as organic soils the lowlands cultivated with rice, and adopting the IPCC emission factor. All results are expressed in CO_2 equivalent (CO_2-eq) using the official global warming potential (GWP) considered for the 1st commitment period, i.e. 21 for methane and 310 for nitrous oxide. The latest IPCC assessment report provided revised values (25 for CH_4 and 298 for N_2O).

Results and discussion

Table 1 presents a tentative proposal for the Brazilian main greenhouse gas (CO_2, CH_4 and N_2O) emissions for the 2005-1990 period based on the above results for LUCF, amended with sectors estimated for the other categories (Energy, Industrial Processes and Waste). The most crucial sector to be estimated is the Energy because of the importance of its share. Our estimate is based on the results calculated for the national carbon balance in the energy sector (MCT 2007). The authors calculated the emission from fossil fuel combustion using both bottom-up and top-down approaches for the 1970-2005 period, and also compared their results to BINC values. They concluded that their results systematically underestimate the values from the BINC in 5%. Therefore, in our calculations, the estimates for the Energy sector for CO_2 and CH_4 derived from their proposed values for the year 2000 and 2005 were corrected by this coefficient (5%). For the other emissions of the Energy sector (Fugitive emissions, and N_2O emissions from fossil fuel combustion) a conservative approach was used considering the level unchanged in relation to 1994.

Table 1. Greenhouse gas emissions for 1990-2005 period for the Energy, Industrial Processes, Agriculture, Land Use Change and Forestry and Waste sectors.

SECTOR	1990	1994	2000	2005	2005-1994
	------------- Mt CO_2-eq ------------				%
Energy					
Fossil Fuel Combustion	207.4	240.4	324.9	347.0	44.4
Fugitive Emissions	7.6	7.4	7.3	7.3	-0.5
Total	*215.1*	*247.7*	*332.2*	*354.3*	*43.0*
Industrial Processes					
Cement Production	10.2	9.3	19.0	14.2	52,5
Other	6.7	7.5	9.0	14.6	94.2
Total	*19.5*	*21.3*	*34.1*	*36.9*	*73.6*
Agriculture					
Enteric Fermentation	184.9	196.9	204.8	248.4	26,1
Manure Management	13.0	13.9	*13.2*	*16.1*	15.7
Rice Cultivation	5.0	5.9	5.0	5.4	-8.4
Field Burning of Agricultural Residues	4.4	5.0	4.0	4.6	-7.9
Agricultural Soils	132.1	147.6	155.4	192.9	30.7
Total	*339.4*	*369.3*	*382.4*	*467.4*	*26.6*
Land Use Change and Forestry					
Forest and Grassland Conversion	919.8	993.5	1051.8	1074.2	8.1
Emissions and Removals from Soils	110.2	75.6	67.9	65.1	-13.8
Total	*1030.0*	*1069.1*	*1119.7*	*1139.3*	*6.5*
Waste					
Total	*19.2*	*20.6*	*22.7*	*24.4*	*18.5*
TOTAL	1623.2	1728.0	1891.1	2022.3	17.0

Cement production is the main contributor of the Industrial Processes. Emissions from this sub-sector were calculated according to the energy inputs in the processes (reported by MCT 2007). The total emissions for the Industrial Processes were estimated in the same manner, and emissions from Other Activities were calculated by difference. N_2O and CH_4 emissions from cement production were calculated using a linear trend. This last approach was also used in the case of the Waste sector. Table 1 does not include the CO_2 fixation by the phytomass from reforestation and abandoned lands. If these sinks are accounted in the calculations, the net emissions for the Land Use Change and Forestry decreases by about 26%, from 1189.5 to 936.7 Mt CO_2. Then, the total net emission for 2005, adjusted considering the mentioned removals, would be 1231.5 against 1461.7 Mt CO_2, which is about 19% lower in relation to the emission only scenario.

Global emissions in CO_2-eq increased by 17% during the 1994-2005 period. CO_2 represented 72.3% of the total, i.e. a small decrease, in favour of non-CO_2 GHG, in relation to 1994 when its share was 74.1%. The increase of all GHG excluding LUCF was 41.3% over the period 1994-2005. CAIT-WRI estimated a higher increase (48.9%) that classified Brazil at the 69th position. Using our estimates Brazil will fall to the 78th position. But in both cases Brazil increased in clearly lower values than the tendency calculated for China and India, two major emitters, with increases of 88.8%and 62.1%, respectively. It can also be noted that Brazil´s increase is lower than those for some Annex 1 country that are submitted to a quota of reduction, e.g. Spain with 55.6% of increase and New Zealand with 45.8%. Brazil also is below the average increase showed by non-Annex I countries, estimated to be 61.3%, but above the world average (28.1%).

Conclusion

In Brazil most mitigation efforts focused on the energy and LUCF, i.e. mostly reduction of deforestation in the Amazon. The later aspect succeeded since deforestation rates decreased. On the other hand, despite the intensification of ethanol use (increasing percentage of flex fuel cars), the energy sector showed the highest level of increase (+44%). However, it must be recognized that the energy-related programs and measures implemented in the 90's and after have provided a broad range of benefits for the Brazilian economy, and helped lower carbon emissions in relation to was considered business as usual in the yearly 90's. Besides effort to curb emissions from the energy and deforestation sectors, it is now a top priority to implement a national program to incentive mitigation efforts concerning the agricultural sectors (+27%). These mitigation options should not be only focused on emissions reduction, but also prone enhancement of the carbon sink. Such a program would be easy to implement, because several mitigation strategies have already proved to be efficient, simple to adopt and economically viable.

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