Reducing uncertainties on carbon emissions from tropical deforestation: Brazil Amazon study case

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Abstract

In the last year, Brazil announced the voluntary commitment to reduce its greenhouse gas emissions from 36.1% to 38.9% by 2020 and, to this end, such a commitment requires cutting down 80% of the deforestation in the Amazon rainforest until that year. Much of the uncertainty on the role of forests for carbon emissions is due to the lack of reliable deforestation data. The Brazilian's National Institute for Space Research (INPE) carries on, since 1988, annual surveys of deforestation in the Amazon, an area of about 5 million km2. The existence of historic data on deforestation allows us to constrain the contribution of land cover change to greenhouse gases emissions since 40 years.

Our work estimate the carbon emission rates for the Brazilian Amazon, combining annual maps of new clearings and spatial information on biomass distribution for different vegetation types. The model also incorporates the temporal dynamics related to the deforestation process and its intraregional heterogeneity, including the percentage emitted by successive burning along the years and biological decay, the percentage of biomass used as timber, contribution of bellow ground emissions by root decay, and secondary vegetation growth.

Introduction

The increase rate of global green house gases concentration in the atmosphere has no parallel in the last one million year of the Earth history. From 1958 to 2004 the mean global CO_2 emissions increased at the rate of approximately 1.3% per year, whilst the last 5 years

(2004 to 2009) changes in emissions observed an increasing rate at the order of 3% per year (Global Carbon Project, www.globalcarbonproject.org). The IPCC AR4 [1] states that the tropical deforestation accounts to 10-20% of the global CO_2, with the uncertainly on this range mostly due to biomass estimates and regional heterogeneity. The pattern of biomass burning emission follows different trajectory in recent years when compared to fossil fuel emissions, which shows an increasing curve. Because of that, and due to recent reduction in deforestation rates worldwide, the relative contribution of the land use component in the global carbon budget is decreasing [2]. In spite of this, the standing forests are major carbon stocks and play an important role in the climate, carbon sequestration, biodiversity, and local resources for indigenous communities [3].

The Amazon region in South America, as the largest continuous area of remaining rainforest in the World, has a critical role in the global carbon budget. The Brazilian Amazon alone contains more carbon stored in its biodiversity than the amount of global human-induced CO_2 emissions of an entire decade [4]. A major question posed to the fate of this ecosystem is how the carbon balance of tropical forests responds to rapid, on-going changes in climate and atmospheric composition [5], [6], [7]. [8] showed that the Eastern Amazon forest takes 70 years to recover the nitrogen dynamic back to its original state, after deforestation for agricultural purpose, with direct implications to the carbon balance in the ecosystem. Other important points to take in consideration are the deforestation rate, and biomass burning, in this region for the past 30 years. The use of well developed remote sensing techniques (INPE, Brazil) to monitor and calculate the extent of tropical deforestation has considerably improved our ability to estimate rates of this process in these regions, what is certainly going to become an indispensable auditing tool for implementation of mitigation strategies.

This paper brings the results of a mathematical model proposed in order to systematize the calculation of annual green house gases emission from deforestation in the Brazilian Amazon. The auspice of this effort was construct under the voluntary compromise of emission reduction that the Brazilian Government has committed up to 2020 (see Figure 1), once land use change and deforestation are the main sources of GHG in the Brazilian emissions profile. According to [9] and the Brazilian Ministry of Science and Technology (MCT), the contribution of the Amazon deforestation to the country total emissions reaches 55%, summing to 75% when considering agriculture and cattle ranching.

The model here described considers, first, the biomass distribution according to vegetation maps overlapping with the deforestation-monitoring maps, produced annually by the National Institute for Space Research (PRODES System, [10]); the dynamic of the deforestation process, as well as its interregional peculiarities. Other components of the model logic are: the speed and frequency that trees are cut and burned; the percentage of timber extracted; equations of organic matter decay in soils; root decomposition; and emissions factors for different gases species (CH_4, N_2O, CO_2) which are associated to fire intensity and quality of organic matter. The secondary vegetation re-growth and its dynamic are also considered.

Land-use activities—whether converting natural landscapes for human use or changing management practices on human-dominated lands—have transformed a large proportion of the planet's land surface. By clearing tropical forests, practicing subsistence agriculture, intensifying farmland production, or expanding urban centres, human actions are changing the landscape in pervasive ways [11]. In Brazil the National Institute for Space Research (INPE) has a historical series of satellite mapping of deforestation in the 5 million km^2 of the Brazilian Amazon region, identifying 16% of forest loss until 2007 [10], [12], [13]. The annual data, produced since 1988, show a decreasing rate from 2004 (Figure 1), however the total area deforested in the 2005-2009 periods is still important, reaching 65,000 km^2.

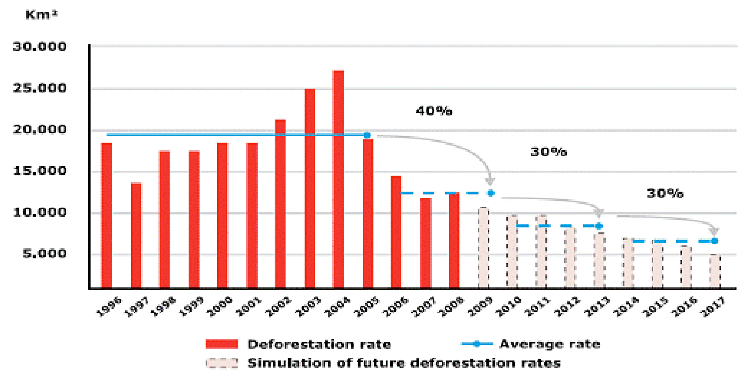

Figure 1: Deforestation rate and reduction simulation (Brazilian Ministry of Science and Technology, 2009)

Most of the degradation processes are concentrated in the southern and eastern parts of Amazonia (Figure 2). Central and other less accessible areas are still relatively well protected, opening great possibilities for conservation initiatives and carbon fluxes monitoring activities. Recent plans from the Brazilian Government for paving roads and developing infrastructure, with increasing presence of highly capitalized agribusiness companies, can pose a high threat to central areas in a very near future. In fact, an increase of 25–40% in Amazon deforestation due to projected road paving could counterbalance nearly half of the reductions in C emissions that would be achieved with the Kyoto Protocol [4]. Typical Amazon forests contain, on average, around 250 tons of biomass per hectare, thus deforestation in Amazonia alone, can release from 500 to 900 Mton of CO_2 annually, 2–4% of world emissions, according to [14], [15], [16]. [17] observed that depending if the regrowth dynamic of the secondary vegetation is considered the total carbon emission might vary significantly. Complimentary, [6], analysing data produced for the Amazon region, showed a broad range of values of emissions estimates, depending on the region, vegetation, or estimate method considered.

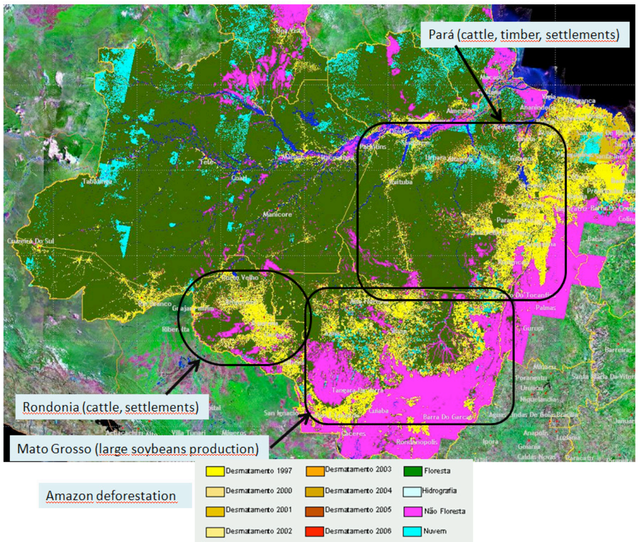

Figure 2: Brazilian Amazon map indicating (i) non forested areas (pink); (ii) deforestation after 1997 through 2004 (yellow and orange); (iii) forest; clouds (light blue).

Aside to the Amazon, the central savanna in Brazil, named Cerrado, represents 23% of the land surface, spreading across 2,031,990 km² of the central Brazilian Plateau. The most extensive woodland/savanna region in South America and second major Brazilian biome, after the Amazon (Figure 2), the Cerrado is also the only hotspot that consists largely of savanna, woodland/savanna and dry forest ecosystems. Within the region, there is a mosaic of different vegetation types, including tree and scrub savanna, grassland with scattered trees, and occasional patches of a dry and closed canopy forest. The biome, however, has been subjected to rapid rates of land conversion to agriculture and pasture, with important consequences to local change in microclimate and carbon fluxes. Moderate Resolution Imaging Spectroradiometer (MODIS) composite vegetation index has being used in the region to analyse the seasonal patterns of photosynthetic vegetation activity and examine the potential separation of Cerrado formations. The Cerrado formations exhibited a high seasonality contrast with a pronounced dry season from June through August and wet season from November to March. The converted agricultural areas had a higher contrast than the native Cerrado, and the forest formation had the lowest seasonal contrast, showing a potential use of remote imagery to monitor and quantify the carbon stocks and dynamic in the region. In spite of emissions data from deforestation in Cerrado not being presented in this paper, the structure of the model can be adjusted to different regions; land use and land cover characteristics.

Results

The metodology was based on previous work by [14], [18], [19], [20], [21], however including new components looking to incorporate a better representation of the deforestation process itself. Inter-regional differences were represented by biomass and deforestation maps [10], [22], the structure of the agriculture production and the economical development frontier.

The modelled results indicate a reduction of emission from primary forests in recent years, from a mean value of 864 Mton CO_2 per year (in the period from 1995 to 2006) to 631 Mton CO_2 per year (2007-2009), a reduction of 27%. The dynamic of the secondary vegetation needs to be better understood and regionalized. According to our calculation the the re-growth of deforested vegetation does not contribute significantly to the emissions reduction (mean annual sequestration of 58 Mt CO_2 in the 1995-2009 period, representing 7% of the annual emissions from primary forest of that same period), overall because, according to [23], the residence time of the secondary vegetation is relatively short (circa of 5 years), after which the vegetation is cut and burned again. Figure 3 presents the amount of emissions by: (i) model results (red line) and (ii) the emissions without the dynamic processes represented by the model (blue line); as well as, (iii) the differences among carbon sequestration by the secondary vegetation (green line) and (iv) the emissions due to the deforestation of this vegetation (yellow line). The model predicted, over the deforestation reduction target Brazil has proposed, an average of 563 Mton CO_2 of avoided emissions per year until 2020 (compared to 1995-2006). However on considering a non-managed re-growth of secondary vegetation (and no deforestation of secondary vegetation) these numbers can get up to 757 Mton of CO_2.

The model results highlight the importance of regional differences on estimating emissions from tropical forests deforestation, as well as including the secondary forest dynamic as potential to recuperate regional ecosystem, but also to mitigate historical emissions from

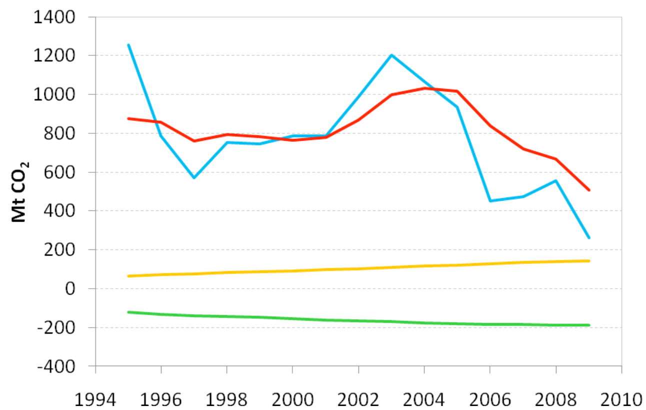

Figure 3: Emission Model results

deforestation. The dynamic of the deforestation process itself is also critical to be considered in emissions models, once depending on the activity replacing the original forest the clear cut deforestation might be concluded in few months or years. Information's of this nature are critical to mitigation mechanisms as REDD, for instance. Considering the global balance published by [2], our results place deforestation in the Brazilian Amazon contributing to 1.1% to 1.9% of the total global carbon emissions.

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