PRE-HARVESTING BIOMASS BURNING FOR SUGARCANE CROP: COMPARING EMISSION FACTORS FOR REALIST RESULTS

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ABSTRACT

In Brazil, burning of residues as an agricultural practice occurs mainly in sugarcane cultivation, which accounts for about 98% of greenhouse gas emissions resulting from the burning of agricultural waste. Emission factors for this specific agricultural management practice came from the combustion processes, were the emission of non-CO_2 gases CH_4, CO, NO_x and N_2O were recorded, and the emission rates for these gases depend on the type of biomass and burning conditions. In the combustion with flame phase, N_2O and NO_x gases are generated, and CO and CH4 gases are formed under burning conditions with a predominance of flame. Thus, the use of specific emission factors for sugarcane, within the Brazilian context, in National Inventories is more appropriate than the use of default emission factors, in addition to increasing the level of refinement of emission estimates. In this context, this work aims to present a comparative analysis of the emission estimates of the non-CO_2, CO and NO_X gases, using the default emission factors presented in the IPCC Guidelines (2006) and those proposed by França et al. [4], for São Paulo State as a test area.

Key words* — *Emission factors; burning of sugarcane; National Inventories; State of São Paulo.

1. INTRODUCTION

Countries that are signatories United Nations Framework Convention on Climate Change (UNFCCC) have committed to prepare and regularly update the from time to time the National Inventory Report (NIR), containing detailed descriptive and numerical information about all greenhouse gas (GHG) emissions and removals, implied emission factors and activity data. The fourth edition scheduled to be disclosed in 2019, covers the period between 1990 to 2017.

These series of documents is provided by a law decree (no 7,390/2010), which regulates the National Policy of Climate Change. This law was held out to monitor compliance with the voluntary national commitment to reduce GHG emissions in 39 % by 2020, as a result of the initiative assumed voluntarily by Brazil at the 15th United Nations Conference on Climate Change (COP 15), held in 2009 in Copenhagen.

Five thematic axes compose the National Inventory: Agriculture; Energy; Land Uses, Land and Forests Use Change; Industrial processes; and Waste Treatment. Thematic sub-axes, such as Rice cultivation; Enteric Fermentation and Handling of Animal Waste; Burning of Agricultural Wastes; and Waste Management account for estimates of GHG emissions for agricultural activities. In the last reference report, Agriculture was responsible for the emission of 30% of the total Brazilian GHG emission. However, in 2015 the emissions were below the voluntary commitment, and the Agriculture sector was responsible by the decrease in 19 %.

In Brazil, burning of residues as an agricultural practice occurs mainly in sugarcane cultivation, which accounts for about 98% of greenhouse gas emissions resulting from the burning of agricultural waste [7].

Emissions estimates from agricultural waste are calculated, basically, by the product of the amount of biomass burned by an emission factor [2]. The amount of biomass burned is estimated based on the biomass density above the soil (harvested area), on the combustion factor (fraction of the biomass that was actually burned) and the burned area [2]. The emission factor (EF) represents the amount of a compound emitted by the amount of dry fuel consumed (g kg-1) [3;4].

The GHG emission values for burning of agricultural residues presented in the Brazilian inventories have adopted reference values presented in the IPCC-1996 (1st and 2nd inventories) [5] and IPCC-2006 (Third Inventory) [6] guidelines as emission factors. The IPCC-2006 Guideline takes as reference the values proposed by Andreae and Merlet [3]. However, in addition to being default values, they are general values for burning agricultural waste rather than for a specific agricultural crop.

Calculations for estimating GHG emissions can be classified into three levels of refinement, termed TIER. In Tier 1, the default method and factors are used. In Tier 2, the methods used are the same as Tier 1, but with biomass factors and data available for each country. In Tier 3, there is even greater refinement, with more comprehensive models [6].

In the *Reference Report - Agricultural Sector, Burning of Agricultural Residues*, of the *Third Brazilian Inventory of Anthropogenic Greenhouse Gas Emissions and Removals* [1], although burning residues releases a large quantity of CO_2, these emission are not considered in the Inventory, because the same amount of CO_2 is necessarily absorbed during plant growth through photosynthesis. However, during the combustion processes, the non-CO_2 gases emissions were recorded (CH_4, CO, NO_x and N_2O) from the burning of agricultural waste. In the combustion with flame phase, N_2O and NO_x gases are generated, and CO and CH_4 gases are formed under burning conditions with a predominance of flame. However, emission rates for these gases depend on the type of biomass and burning conditions [6].

Among the GHG emissions default presented by Packer et al. [1] for the Third Inventory, França et al. [4] estimated emission factors for the CO and NO_X gases emitted by the pre-harvesting burning of sugarcane biomass. Thus, the use of specific emission factors for pre-harvesting burning of sugarcane, within the Brazilian context, in National Inventories is more appropriate than the use of default emission factors, in addition to increasing the level of refinement of emission estimation.

In this context, this work aims at a comparative analysis of the emission estimates of the non-CO_2, CO and NO_X gases, by the emission factors presented in the IPCC Guidelines [6] and those proposed by França et al. [4], for the São Paulo State as a test area.

2. MATERIALS AND METHOD

2.1. Study area

The State of São Paulo, located in the southeastern region of Brazil, has a total area of 248,222,362 km², of which 70% are occupied by agricultural uses, 24% by forest remnants and 6% by other uses [6]. According to the climatic classification of Köppen-Geiger, in the territory of São Paulo, climates predominate: Cfa - humid temperate climate with hot summer (Planalto Paulista); Aw - tropical climate with dry winter season (northern portion of the State and Ribeira Valley); and Af - Tropical humid (littoral).

2.2. Materials

For the comparative analysis of emission factors used the value presents as default in the Guidelines IPCC (2006) and the data estimated by França et al. [4]. Production areas and yield data for sugarcane cultivation in São Paulo State were used for the years 1990 and 2012. These data were compiled from the Reference Report - Agriculture and Livestock Sector, [1]. In addition, the results of this study are presented in Table 1. The authors, in turn, obtained this data from the Brazilian Institute of Geography and Statistics (IBGE). In addition to these data, we also used the data from the straw / stem ratio, field burned fraction and combustion factor, used by Packer et al. [1].

2.3. Methodological procedures

For calculations of the emission estimates of CO and NO_x gases from the burning of sugarcane residues, Equation 2.27 of the Guidelines, 2006 (IPCC, 2006, volume 4, chapter 2) was applied (Equation 1):

$$L_{fire} = A * MB * Cf * Gef * 10\text{-}3 \qquad \text{(Eq. 1)}$$

At where:
L_{fire} = quantity of CO and NO_x gas emissions in tonnes (t);
A = burned area in hectares (ha);
MB = biomass available for combustion, in t / ha;
Cf = combustion factor, dimensionless (Table 2.6, IPCC 2006, vol.4);
Gef = emission factor, in g kg-1 of burnt dry matter (IPCC 2006, vol.4; FRANÇA et al. [4].

The emission factor values presented in the IPCC Guidelines (2006) are those proposed by Andreae and Merlet [3] for agricultural residues. In the paper by Andreae and Merlet [3], the authors do not present the means by which they reached the values of the emission factors for agricultural residues, only highlight *value is best guess*.

Already, França et al. [4] estimated the emission factors for the CO and NO_x gases emitted by the burning of biomass sugarcane. To do so, the actors performed thirteen experiments under controlled laboratory conditions. In these experiments, nine samples of sugarcane of the Saccharum spp were burned. The authors encourage the application of the estimated emission factors for the CO and NO_x gases emitted during the burning of the sugar cane straw for the generation of more realistic emission inventories.

The Table 1 shows the emission factors proposed by Andreae and Merlet [3] and França et al. [4].

Table 1. Emission factors proposed by Andreae and Merlet (2001) and França et al. (2012).

Greenhouse Gases	Emission factors (g kg^{-1})	
	Andreae et al. (2001)	França et al. (2012)
CO	92 ± 84	65 ± 20
NO_x	2.5 ±1.0	1.5 ± 0.4

After calculating emissions using the aforementioned factors, a comparative analysis was performed between them, subtracting the emission values obtained by the factors of França et al. [4] of emission values obtained using the factors of Andreae and Merlet [3].

3. RESULTS

The Table 2 shows the emission values estimated from the use of Equation 1, using the factors proposed by Andreae and Merlet [3] and França et al [4], in addition to the absolute difference between the emission values estimated using the factors of emission presented in each work.

Table 2. Emission values obtained using SFs proposed by Andreae and Merlet (2001) and França et al. (2012).

Year	Issue values (Gg)				Difference (Gg)	
	Andreae e Merlet (2001)		França et al. (2012)			
	CO	NO_x	CO	NO_x	CO	NO_x
1990	1,836.18	49.90	1,297.30	29.94	538.88	19.96
1991	1,814.40	49.30	1,281.91	29.58	532.49	19.72
1992	1,938.29	52.67	1,369.45	31.60	568.85	21.07
1993	1,980.22	53.81	1,399.07	32.29	581.15	21.52
1994	2,319.29	63.02	1,638.63	37.81	680.66	25.21
1995	2,330.75	63.34	1,646.72	38.00	684.02	25.33
1996	2,305.81	62.66	1,629.10	37.59	676.70	25.06
1997	2,124.64	57.73	1,501.11	34.64	623.54	23.09
1998	2,129.14	57.86	1,504.29	34.71	624.86	23.14
1999	2,040.61	55.45	1,441.74	33.27	598.88	22.18
2000	1,750.23	47.56	1,236.57	28.54	513.65	19.02
2001	1,881.57	51.13	1,329.37	30.68	552.20	20.45
2002	2,040.19	55.44	1,441.44	33.26	598.75	22.18
2003	2,247.43	61.07	1,587.86	36.64	659.57	24.43
2004	2,297.44	62.43	1,623.19	37.46	674.25	24.97
2005	2,444.02	66.41	1,726.75	39.85	717.27	26.57
2006	2,535.89	68.91	1,791.66	41.35	744.23	27.56
2007	2,341.10	63.62	1,654.04	38.17	687.06	25.45
2008	2,617.76	71.13	1,849.51	42.68	768.26	28.45
2009	2,415.90	65.65	1,706.89	39.39	709.01	26.26
2010	2,523.08	68.56	1,782.61	41.14	740.47	27.42
2011	1,981.23	53.84	1,399.78	32.30	581.45	21.54
2012	1,504.15	40.87	1,062.71	24.52	441.43	16.35
TOTAL	49,399.34	1,342.37	34,901.71	805.42	14,497.63	536.95

4. DISCUSSION

The results obtained show that CO and NO_x emission estimates from sugarcane burning, using the SF proposed in the IPCC Guidelines [6] for agricultural residues, overestimate the emission estimates of these gases by sugarcane burning (Figures 1 and 2). Since these EFs are general for any compendium of agricultural residues, it is natural to make a difference between the emission values obtained with the use of standard EF with specific EF for a particular crop, as could be observed when compared to the Specific FE for the burning of sugarcane residues [4].

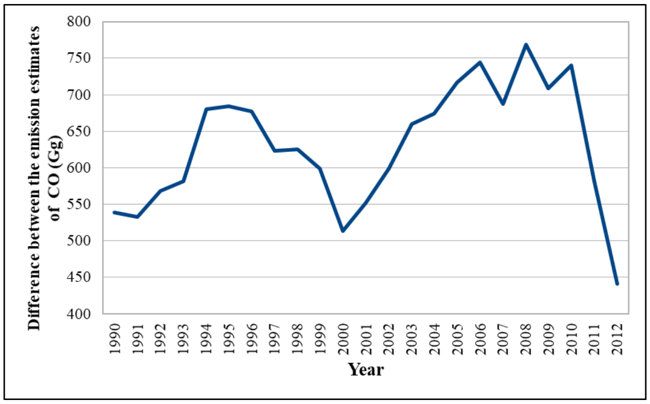

Figure 1. Difference between the CO emission estimates obtained using the SF proposed by Andreae and Merlet [3] and França et al. [4].

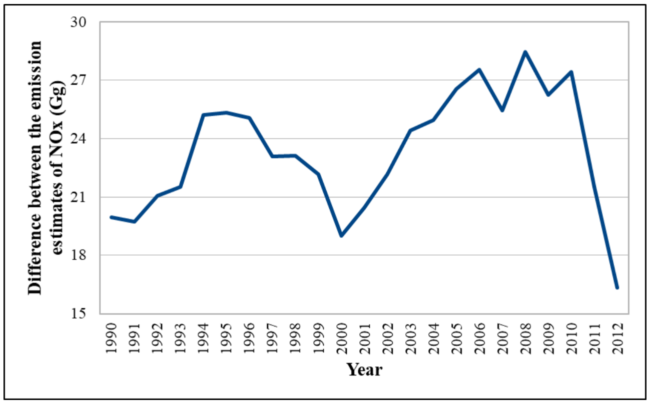

Figure 2. Difference between the NOx emission estimates obtained using the SF proposed by Andreae and Merlet (2001) and França et al. (2012).

Estimates of CO and NOx emission from sugarcane burning for São Paulo State with the use of SF proposed by França et al. [4] are more realistic. Adopting these SFs, cumulative CO emission estimates between 1990 and 2012 were 34.9 thousand Gg, against 49.4 thousand Gg estimated using the proposed SFs in the IPCC Guidelines [6], a difference / overestimation of 14.5 thousand Gg - 29%. Regarding the NOx emission estimates, between 1990 and 2012, emission estimates by the FE in comparison show a difference of 536.95 Gg, with an overestimation of 40% by the EF proposed by the IPCC Guidelines [6].

These results show the potential of EF presented by França et al. [4] in the estimation of CO and NOx emission from the burning of sugarcane.

5. CONCLUSIONS

Based on the results obtained, we encourage the broad use of emission factors for CO and NOx GHG proposed by França et al. [4], when estimating the emissions from the burning of sugarcane.

If these emission factors were adopted for the generation of emission inventories, the results obtained will be more realistic, and the estimated values will be less overestimated, thus bringing the emission values closer to the reduction commitment agreed by the Brazilian government.

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