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REGIONAL ASSESSMENT OF A REGIONAL BOTTOM-UP CATTLE AIR POLLUTANTS EMISSIONS INVENTORY AGAINST EUROPEAN EMISSIONS INVENTORIES

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Abstract: Cattle production has a significant contribution to the total GHGs emissions, particularly, CH_4 and N_2O. Also, other air pollutants, as NH_3 and NMVOC, are emitted. As a European region with significant dairy and beef farms, Galicia (NW of Spain) is suitable to assess the contribution of cattle production to the regional livestock air pollutants emissions (namely, EMEP S10 in SNAP classification), considering up to date activity data. Therefore, the objective of this study is to update the annual emissions by dairy and beef cattle in Galicia, according to the different bottom-up methodologies: IPCC (Tier 1 and Tier 2) and EMEP/CORINAIR. This inventory is compared to both EMEP and E-PRTR emissions inventories: NH_3 cattle emissions are around half of EMEP S10, taking into account that EMEP S10 also includes other agriculture sources. NMVOCs cattle emissions are strongly higher than EMEP S10 emissions; moreover, there is no agreement in this region between S10 EMEP emissions and cattle farms geographical distributions. Besides E-PRTR does not include cattle farms emissions, CH_4 and NH_3 cattle emissions are 900 and 8 times higher than total current E-PRTR declared emissions at the same region: to add cattle farms in E-PRTR activities is highly recommended.

Key words: *Cattle air emissions, Emissions factors, IPCC, EMEP/CORINAIR, E-PRTR.*

INTRODUCTION

Ruminants are the most important livestock producers of greenhouse gases (GHGs), due to their larger mass, large population and rumen fermentation (USDA, 2004). Methane is mainly produced as a product of enteric fermentation in feed, and from decomposition of manure under anaerobic conditions (Moss et al., 2000). N_2O is emitted from manure and mineral fertilization as an intermediate product of nitrification/denitrification (Fabbri et al., 2007).

Local agricultural emissions significantly contribute to atmospheric reactive nitrogen loads in terrestrial ecosystems. This contribution is due to deposition of dry ammonia gas phase resulting from local cattle production (Hertel et al., 2012). Emissions of NH_3 and NMVOCs arise from excreta of agricultural livestock deposited and collected as liquid slurry, solid manure or litter-based farmyard manure, in stables, yards and pastures, during storage and deposition as fertilizer.

Because of its high cattle density, feeding and productivity, and undersized manure storage (PXRAG, 2001), Galicia (NW of Spain) is a region with potential cattle atmospheric emissions problems. This study is focused in establishing the ruminant emissions production in Galicia, in order to obtain a regional emissions inventory. Also, an assessment of this regional inventory is done by comparison against both EMEP and E-PRTR (European Pollutant Release and Transfer Register inventory).

METHODOLOGY AND EMISSIONS FACTORS ESTIMATION

Ruminant production emissions inventories are based in the emissions factors derived from the process analysis. Different methodologies were proposed, depending on the complexity of the processes considered in a typical ruminants farm. About GHGs emissions, IPCC (IPCC, 2006) provides guidelines for CH_4 and N_2O emissions estimations from ruminant production, following two different methodologies. Tier 1, is based in the use of an average emission factor per animal for every type of animal. Tier 2 is a more complex methodology, derived from a comprehensive process analysis of different cattle farms.

About none-GHGs emissions, NH_3 and NMVOC emissions estimation follows EMEP/CORINAIR methodology, with updated emissions factors for animal husbandry and manure management (EEA, 2009). This methodology distinguishes four main sources of cattle emissions: shelter livestock, manure storage, manure application in field, and manure deposited during grazing.

RESULTS

Table 1 shows the calculated CH_4 and N_2O *EF*s in Galicia for year 2009 applying Tier 1 and Tier 2 methodologies. About CH_4 production, when manure is either stored or processed as a liquid, it decomposes anaerobically and produces significant amounts of CH_4.

Table 1. CH_4 *EF*s (kg $hd^{-1}yr^{-1}$) and emissions (Emiss, Gg yr^{-1}) from enteric fermentation (ef) and manure management (mm), and N_2O *EF*s (kg $hd^{-1}yr^{-1}$), emissions (Gg yr^{-1}) and N excretion (Nexc, kg N $hd^{-1}yr^{-1}$) in Galicia, year 2009, calculated following Tier 1 and Tier 2 (IPCC, 2006).

	CH_4						N_2O					
	Tier 1			Tier 2			Tier 1			Tier 2		
Livestock category	EF_{ef}	EF_{mm}	Emiss.	EF_{ef}	EF_{mm}	Emiss.	Emiss.	EF_{mm}	Nexc	Emiss.	EF_{mm}	Nexc
Mature Dairy Cow	109	27	50.69	82.65	45.59	30.82	8.25	22.13	79.72	0.969	2.6	69.62
Other Mature Cattle	57	8	22.28	65.18	28.99	22.36	33.56	97.9	84.65	17.22	50.2	54.01
Growing Cattle	57	8	16.52	52.75	33.94	13.42	67.29	26.47	22.89	15.5	61	65.56
TOTAL			89.5			66.6	48.54			33.7		

In Galicia the main CH_4 emission source is enteric fermentation, contributing 83% (using Tier 1) and 65% (using Tier 2) of total CH_4 emissions in 2009. However, the largest differences between Tier 1 and Tier 2 emissions (Table 1) are mainly due to the detailed modelling of manure management in Tier 2. Nutritional factors affecting the enteric CH_4 production rate in ruminants are mainly the level of digestible matter (DM) intake and the animal productivity; the feed concentrate composition, the maturity of harvested forages, and the use of maize silage as a complement of grass silage, are also considered.

For N_2O, Tier 2 Galician emissions are lower than Tier 1 (Table 1) although differences are lower than in the case of CH_4 emissions. The amount of excreted nitrogen depends on dry matter intake and protein concentration diet digestibility, which can reduce CH_4 emissions, GHGs Global Warming Potential (GWP) can be offset by increased emissions of N_2O and CO_2 (Doreau, et al. 2011).

Considering Tier 2 methodology, dairy cattle farms in Galicia have a CH_4 *EF* of 82.65 kg CH_4 $hd^{-1}yr^{-1}$, which is lower than other farms in previous studies: Vermorel et al. (2008) reported 118 kg CH_4 $hd^{-1}yr^{-1}$, with 5000-10000 kg milk $hd^{-1}yr^{-1}$ milk yield (in Galicia, 5400 kg milk $hd^{-1}yr^{-1}$); Berra et al. (2009) reported an average emission of CH_4 per animal in dairy cattle much higher than in beef cattle: 91.79 and 51.78 kg CH_4 $hd^{-1}yr^{-1}$, respectively. DeRamus et al. (2003) provided values ranged from 83 (beef cows) to 95 (dairy cows) kg CH_4 $hd^{-1}yr^{-1}$; Merino et al. (2011) obtained 107 (dairy cattle) and 60 (beef cattle) kg CH_4 $hd^{-1}yr^{-1}$, under similar conditions to Galicia. Those differences can be explained by specific Galicia conditions: First, *EF* calculated values (Table 1) from Tier 2 are higher than Tier 1, except to dairy cattle *EF* from enteric fermentation (EF_{ef}), since these animals are mainly fed with high concentrated diets with high digestibility, which results in lower enteric CH_4/hd emission. About manure management, estimated Tier 2 dairy cattle CH_4 *EF* in Galicia is higher than default Tier 1 *EF*, because in this region some beef cattle farms manage manure in a liquid form, resulting in an *EF* increase.

For N_2O, Tier takes into account that 6.2% of dairy cattle farms in Galicia manage manure based on solid systems, resulting in higher N_2O EF from manure management, as aerobic conditions in manure storage can increase N_2O losses (Gac, et al., 2007). When the beef cattle farms graze all year, it increases the risk of higher N_2O losses. Apart from manure storage, estimated N excretion also affects *EF* calculation. As a result, the contribution of beef cattle to N_2O emissions in this region has become important in recent years, as many farmers have changed from dairy to beef cattle production.

*EF*s based in Hobbs et al. (2004) (Table 2) were applied over the Galician region cattle, considering separately both dairy and none-dairy cattle. Although NMVOC *EF* for dairy cattle is twice the none-dairy cattle *EF*, the corresponding NMVOC emissions are quite similar in Galicia, showing the strong weight of none-dairy cattle in this region.

Table 2. *EF*s (kg $hd^{-1}yr^{-1}$) and emissions (Gg yr^{-1}) for NMVOC and NH_3 in Galicia, year 2009.

NFR	NFR Name	*EF* for NMVOC	NMVOC emissions	*EF* for NH_3	NH_3 emissions Tier 1	NH_3 emissions Tier 2
4.B.01.a	Dairy cattle	13.6	5.07	39.3	14.6	13.0
4.B.01.d	Non-dairy cattle	7.4	4.42	13.4	8.0	6.47
	TOTAL		9.50		22.65	19.50

About manure management, only Tier 2 considers different systems. In Galicia, the pits for manure storage are undersized in most farms, presenting in many cases permeability problems; also, the lack of covers causes the rainwater inlet (PXRAG, 2001). In addition, the most typical manure management system in Galicia is the liquid system. Therefore, *EFs* have been calculated assuming that manure is stored prior to surface application, without quick incorporation. As it is shown, the relative difference between Tier 1 and Tier 2 NH_3 emissions in the study region is low, but Tier 2 is more confident. On the other hand, NMVOC emissions uncertainty can drive to very different results.

Emissions geographical distribution

An analysis of the spatial distribution of the new calculated emissions is feasible to explain their relationship to the farms geographical distribution of the farms in the study region. In this case, emissions were analysed using ArcGIS 9.3 (ESRI, 2008), with a municipalities database (316 councils) as base map.

Fig. 1 shows the distribution of farms, and CH_4 and NH_3 emissions in the study region. Southern part of this region has less cattle farms (Fig. 1a), and most of them are not dairy farms (which represent 80.7% of the total), with a few of cattle per farm. Beef farms are mainly located in the Eastern-Northeastern part, with small-sized farms (20.68 hd/farm). Western part shows similar dairy and beef farms numbers, although dairy farms number is still higher. This irregular farms distribution is reflected in the pollutants emissions distribution (Fig. 1b and 1c), both in CH_4 and NH_3; with the highest values in the Northern half of the region, due to the higher density of farms and cattle. However, none significant differences are observed in the emissions distribution due to the different farms (dairy and beef) in the region. Comparing this bottom-up inventory to EMEP, only EMEP NH_3 emissions (Fig.1d) correspond to the animal distribution (Fig.1a), but not the EMEP NMVOC emissions (Fig.1e).

Bottom-up vs. standard European emissions inventories

The reliability of calculated emissions in Galicia is compared to the corresponding activities, namely sectors, those include animal farms in both EMEP and E-PRTR emissions inventories, when available. About CORINAIR S10–Agriculture sector (EMEP S10 in the SNAP classification), it includes different emission sources, but livestock contribution to NH_3 and NMVOC emissions is the largest one.

Fig. 2 shows a comparison of the emissions total amounts over the study region from 1998 to 2010, for NH_3 and NMVOC. Three different inventories were considered: original EMEP inventory, EMEP inventory updated in June-2012 (CEIP, 2012), and new calculated bottom-up emissions. Compared to the new calculated cattle emissions inventory, original EMEP NH_3 emissions are clearly underestimated (Fig. 2a). Updated EMEP S10 inventory provides higher emissions, in agreement to the additional EMEP S10 sources. However, EMEP emissions evolutions are not in agreement to the new calculated cattle emissions, because EMEP emissions are not proportional to the number of cattle. About NMVOC (Fig. 2b), the new bottom-up cattle emissions are systematically higher that both EMEP S10 emissions (original and updated): Only large differences in the activity parameters explain this result.

E-PRTR Category 7 activities cover livestock and intensive aquaculture; but, only pigs and poultry are included as gandery, so cattle farms are excluded (MARM, 2010). Comparing E-PRTR Category 7 emissions to the new calculated bottom-up emissions over the study region: (a) new CH_4 emission is 900 times of E-PRTR Category 7 emission; (b) NH_3 cattle contribution is 8 times higher than E-PRTR Category 7 emission. Therefore, it is clear that both CH_4 and NH_3 cattle emissions must be included in E-PRTR inventory.

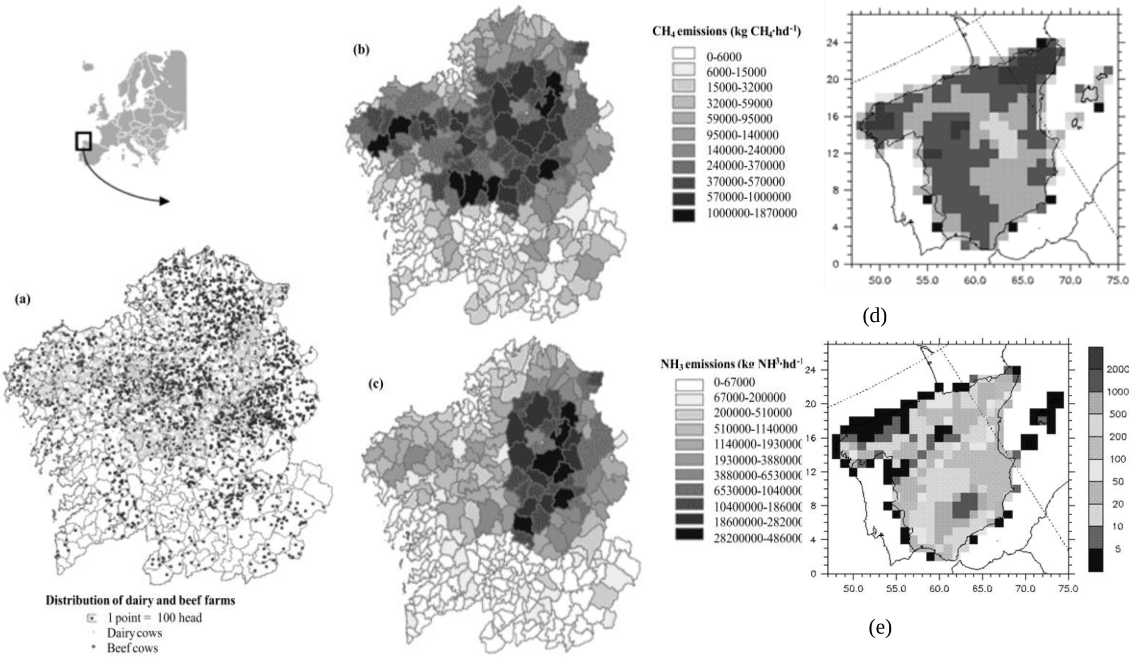

Figure 1. (a) Geographical distribution of dairy and beef farms, bottom-up inventory (b) CH_4 and (c) NH_3 emissions in 2009 in Galicia by municipalities, and EMEP emissions of (d) NH_3 and (e) NMVOC in tons (t) in 2009 for S10 – Agriculture sector (CEIP, 2012).

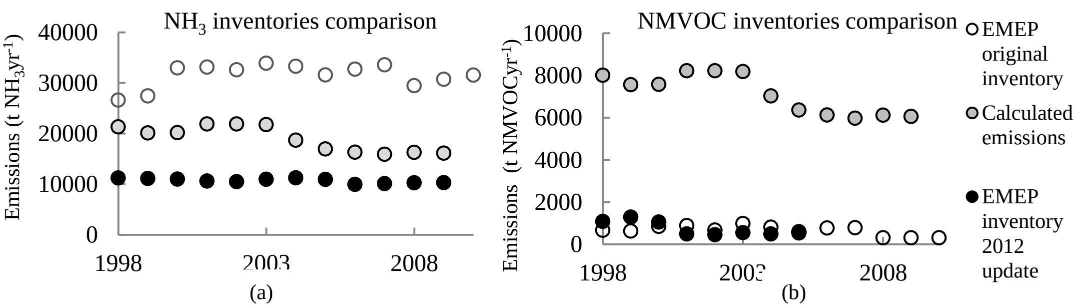

Figure 2. Comparison of calculated and EMEP S10 (a) sector NH_3 and sector NMVOC (b) emissions at Galicia, considering both original and updated EMEP inventories.

CONCLUSIONS

Cattle activities produce significant both GHGs and tropospheric pollutants emissions. Cattle emissions uncertainty is associated not only to the emissions factors, but also to the associated activity and environmental parameters, depending on the manure management system, climate conditions and cattle feeding. Particularly, in Galicia cattle feeding are based on the use of wet forage (grass and maize silos) and manure management has become mostly liquid slurry due to high rainfall resulting in higher CH_4 and NH_3 emissions. Considering GHGs emissions, Global Warming Potential (GWP) from CH_4 and N_2O cattle emissions represents 56% of the total GWP in this region. CH_4 emission estimated using Tier 2 is higher than using Tier 1, especially when manure management emissions are considered. Tier 2 results show that 65% of CH_4 livestock emissions come from enteric fermentation. About N_2O emissions, direct contribution (89%) is the largest component. These large contributions of cattle to GHGs emissions in this region is explained by the amount of produced manure, because of the large size of both dairy and beef cattle populations. Compared to EMEP inventory, NH_3 emissions value is twice the updated S10 EMEP sector emissions, even though S10 sector not only includes cattle. Differences are even higher when NMVOC emissions are considered, with extremely low S10 EMEP values respect to the calculated NMVOC emissions. Also, cattle activities are not included in the E-PRTR emissions inventory, even though they should be the main contribution to CH_4 and NH_3 emissions in the IPPC Category 7.

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