A new method for estimating ammonia volatilization from slurry in small fields using diffusion samplers

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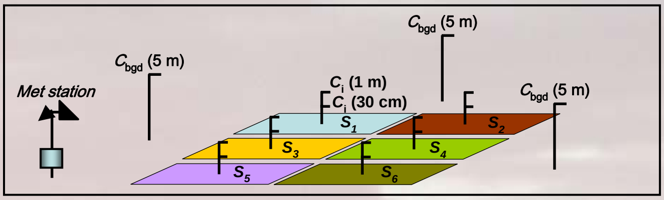
Context & objectives

- Tropospheric ammonia is mainly emitted by agriculture and has great environmental impacts (atmospheric pollution, eutrophication, biodiversity) which are increasingly taken into account in European regulation.
- The increasing price of mineral fertilizers and the concern regarding the nitrogen cascade ask for improvements in the efficiency of nitrogen fertilization, and especially of organic fertilization. Indeed, volatilization following application of manure and slurry is an important source of ammonia emission in France (CITEPA 2011).
- Therefore, reducing ammonia losses from this sector is a major objective for applied research. However, characterising these emissions at the field scale often requires heavy experimental designs and simpler methods are challenged.
- In this study we extend the inverse modelling approach of Loubet et al. (2010) to estimate NH_3 emissions from multiple fields with multiple concentration sensors. Such methods have been applied for longer range transport , and have been shown to be very dependent on the source-sensor geometry .

Scheme of the experimental set up



Results

- All inversion strategies gave the largest NH_3 emissions occurred from the surface application for both cattle and pig slurry.
- NH_3 emissions were not significantly different from zero in plots without application and with incorporation.
- Strategies 3 and 4 generally gave larger background concentrations and lower emissions than the strategies 1 and 2.
- The strategy 4 led to a reduced confidence interval.
- On average, the differences between the two replicate plots were smaller than 21% for the surface application plots with high fluxes and larger than 42% for the two other treatments with low fluxes (e.g. Table 1 for cattle slurry).

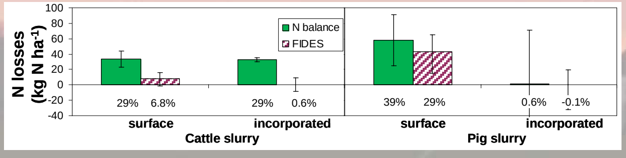


Figure 1. Comparison of nitrogen losses estimated with the nitrogen balance method (N-balance) and the inverse modelling approach (FIDES). The ratio of the losses to the total nitrogen applied is given in percentages.

- overall, the cattle slurry surface application was always found to be a significant source of NH3. The pig slurry was found to lead to NH3 emissions up to 29% of the applied nitrogen, while the cattle slurry led to NH3 emissions of around 7% of the applied nitrogen. The incorporation was found to lead to non significant NH3 emissions and seemed to be as such an efficient method to reduce NH3 emissions whatever the NH3 emission magnitude. The inversion method was in broad agreement with the N balance method in ranking the emissions but gave lower losses than the N balance in the Cattle slurry experiment in particular (La Jaillière).

Material and methods

- Two experiments were carried out, one with **pig slurry** (Bignan) and the other with **cattle slurry** (La Jaillière). Three treatments were compared: ***no application***, ***surface application*** and ***incorporation*** into bare soil. Two replicates for each treatment performed.
- The dimensions of each field ranged from 20 × 20 m to 40 × 20 m. Soil mineral N content was measured in the 0-0.3 m soil layer allowing indirect estimation of mineral N loss from slurry application using the soil mineral N balance (Cohan et al., 2012).
- Two diffusion samplers (alpha-badges, Sutton et al., 2001) were placed in the middle of each field at 0.3 and 1.0 m above the ground and sampled from 2 hours to 20 days.
- Three masts were placed around the field at 3 m height to catch the background concentration.
- A meteorological station recorded hourly averages of global radiation, air temperature, relative humidity, wind speed and wind direction.
- The inversion method consisted in three steps:

  (1) the surface **energy balance** of the **Volt'Air model** was used to retrieve the surface layer parameters (friction velocity u* and Obukhov length L) from the hourly meteorological data;

  (2) the **three-dimensional FIDES dispersion model** was then used to estimate the hourly transfer coefficient from each plot to each alpha-badge location (including background masts);

  (3) the sources from each field were then estimated by **optimizing** (by linear least square) the difference between the modelled and measured concentrations.

Inversion strategies

- In the first strategy, the sources S_i were estimated as

$$S_i = \frac{C_i(30cm) - C_{bgd}}{h_i^i(30cm)}$$

where C_i(30cm) is the concentration measured at 30 cm height in the middle of the i^{th} field, C_{bgd} is the measured background concentration, and is the transfer coefficient between the i^{th} field and the concentration sensor at 30 cm height in the same field.

- In the second strategy, the sources S_j were estimated by minimising by linear least square the difference between measured C_i(meas) and modelled C_i(mod) concentrations at all locations, where the modelled concentration was estimated as

where is the transfer coefficient from the j^{th} field to the i^{th} sensor, and C_{bgd} was fixed.

$$C_i(\text{mod}) = h_i^j \times S_j + C_{bgd}$$

- The third strategy is similar to the second one, but in this case C_{bgd} was considered as a fitting parameter and was estimated together with the sources S_j. Seven parameters were estimated in the minimising procedure.
- The fourth strategy was identical to the third one, but in this case the sources S_j were considered equal in the two replicates of each treatment. Only four parameters were estimated in the minimising procedure.

Table 1. Estimated NH_3 emissions with the four strategies for the cattle slurry trial. The confidence interval is given under brackets. In La Jaillière. N applied: Ntot: 114, N-NH_3 39 kg N ha^{-1}

	Emissions (kg N-NH_3 ha^{-1})				average difference between replicates
	Method 1	Method 2	Method 3	Method 4	
No application	0.7	-0.6 [-9 : 8]	-1.8 [-9 : 5]	-1.2 [-7 : 4]	49% [38% : 69%]
Cattle slurry (surface)	7.4	7.1 [-1 : 16]	5.7 [-1 : 13]	5.9 [0 : 12]	4% [1% : 8%]
Cattle slurry (incorporated)	1.0	0.3 [-8 : 9]	-0.6 [-8 : 7]	-0.6 [-5 : 4]	149% [39% : 252%]
C_{bdg}	5.7	5.7	7.9 [5 : 11]	8.1 [5 : 11]	-

Conclusions - perspectives

- The inversion method with multiple plots is challenging because of the small size of the plots and because all these plots are located near to each other: a strong NH_3 emission in one plot will influence the concentration measured in the other plots. Furthermore, the concentration measurements integrate over several stability conditions, which have very different transfer coefficients. In this context, the role of the replicates was found essential to validate the estimated flux
- Overall, the inversion method was found to give sound results with several inversion strategies. The inferred NH_3 emissions were similar between replicated plots giving confidence in this method. The NH_3 emissions were found to be 6.8% and 29% of the applied nitrogen for surface applied cattle and pig slurry and were found to be non significantly different from zero for the incorporated slurry.
- This study does not account for oasis effects and does not integrate corrections induced by time integration over correlated sources and concentrations (Loubet et al., 2011).

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Acknowledgement. This study was funded by CASDAR-NH_3 (FR) and ECLAIRE IP (EU).