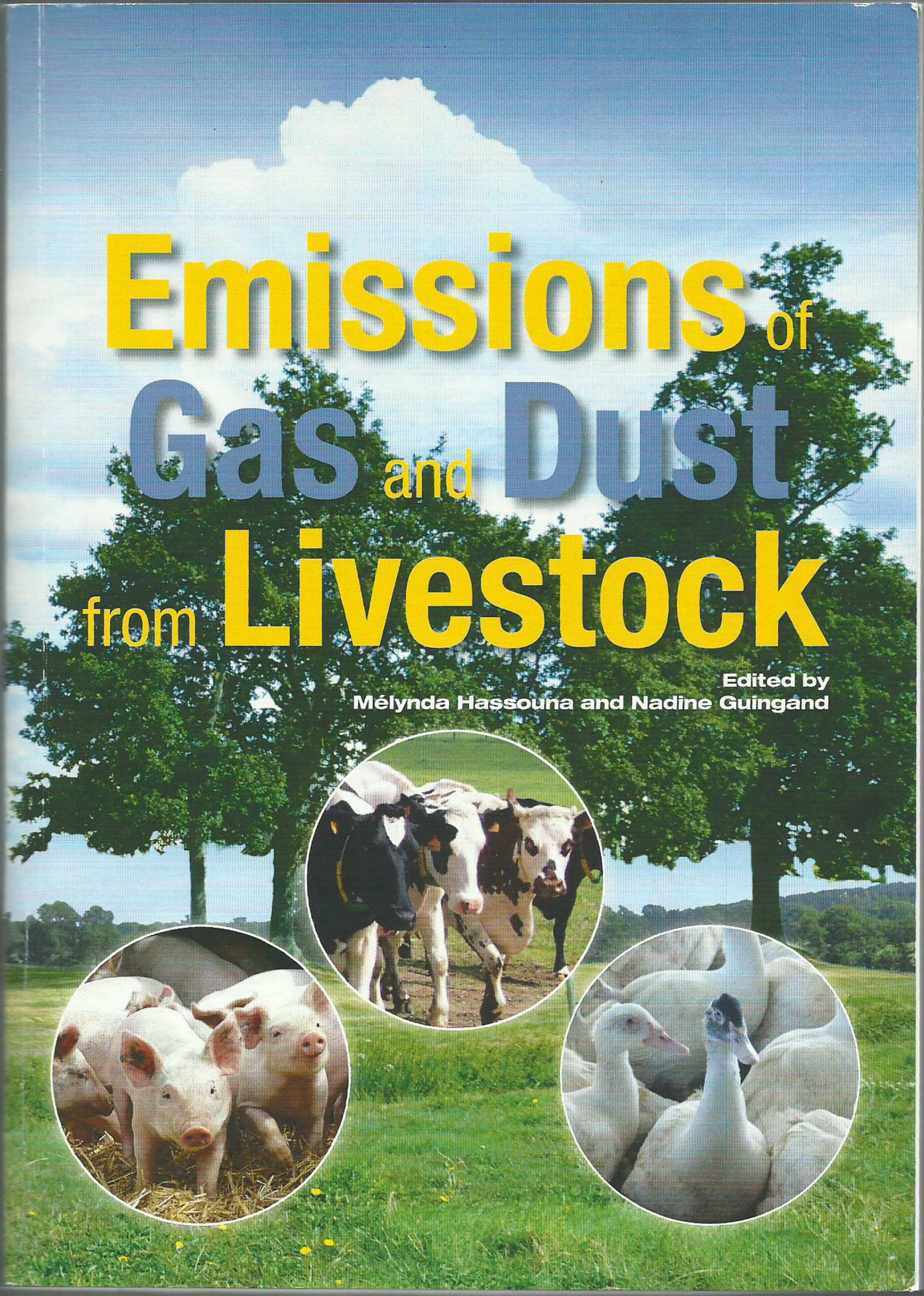

# Emissions of Gas and Dust from Livestock

Edited by
Mélynda Hassouna and Nadine Guingand

# $N_2O$ EMISSIONS FROM SOIL AMENDED WITH CATTLE SLURRY UNDER MEDITERRANEAN CONDITIONS

CARNEIRO, J. P.[1], COUTINHO, J.[2], TRINDADE, H.[3]

[1] CERNAS - Center for the Study of Natural Resources, Environment and Society - Instituto Politécnico de Castelo Branco – Escola Superior Agrária, Castelo Branco, Portugal;
[2] Chemistry Center, Dep. Biologia e Ambiente, ECVA - Universidade de Trás-os-Montes e Alto Douro, Vila Real, Portugal;
[3] CITAB – Centre for the Research and Technology of Agro-Environment and Biological Sciences, Universidade de Trás-os-Montes e Alto Douro, Vila Real, Portugal.

**ABSTRACT** $N_2O$ emissions are affected by several factors, including type of fertilizer, edafo-climatic conditions and mitigation measures applied. A field experiment was carried out in central Portugal for two consecutive years, to evaluate the effect over soil $N_2O$ emissions originated from the application of cattle slurry (CS) to a double-cropping system producing maize and oats. The use of a nitrification inhibitor (DCD) was evaluated as emission mitigation measure. A mineral fertilizer treatment (MIN) and a Control were included and the DCD effects were tested together with MIN (MIN+DCD) and CS (CS+DCD). Total N input was equal for all fertilizing treatments (oat 80 kg N $ha^{-1}$; maize 170 kg N $ha^{-1}$). $N_2O$ fluxes were measure on 165 sampling dates, using a photo-acoustic spectroscopic infrared gas analyzer. The most important fluxes were observed 8-10 days after fertilizer incorporation and during the following 20-40 days. Annual $N_2O$-N losses were higher in the first year, with a wettest autumn and a warmer summer than usual. The highest values were measured with the use of mineral fertilizers (4.65 and 4.21 kg N $ha^{-1}$ in MIN+DCD and MIN, respectively), which were 60-70% higher than those measured with slurry application or without fertilization (1.85, 1.55 and 1.33 kg N $ha^{-1}$ in CS+DCD, CS and Control, respectively). Mean annual values of emission factor based on N application (EF) were 0.76, 0.63, 0.12 and 0.07%, in MIN+DCD, MIN, CS and CS+DCD, respectively. The DCD use, namely with mineral fertilizer, didn't produce an evident effect on total $N_2O$ losses.

**Keywords:** GHG emissions, soil fertilization, nitrogen, nitrification inhibitor

**INTRODUCTION** Nitrous oxide ($N_2O$) is involved in global warming and destruction of stratospheric ozone (Bouwman, 1990). According to greenhouse gas inventory reports published this year, during 2010 $N_2O$ emissions were responsible for 7.2 % of total EU-27 GHG emissions (excluding LULUCF). In Portugal, they represented 6.7% of total GHG emissions, 90.4% of which associated with direct and indirect emissions from agricultural soils. Microbial nitrification and denitrification are the two mechanisms responsible for $N_2O$ emissions from soil, being seasonal dynamics in those emission largely regulated by the N-input in the soil and soil moisture status (Verma et al., 2006).

The default IPCC emission factor, i.e. the percentage of applied N emitted as $N_2O$, is 1% (IPCC, 2006). However, $N_2O$ emissions are affected by several factors, including edafoclimatic conditions (Dobbie and Smith, 2003), type of fertilizer incorporated to the soil (Jones et al. 2007) and use of nitrification inhibitors (Di and Cameron, 2012).

Carneiro, J. P., Coutinho, J., Trindade, H. (2013). $N_2O$ emissions from soil amended with cattle slurry under Mediterranean conditions. In Mélynda Hassouna and Nadine Guingand (Ed.), *Emissions of Gas and Dust from Livestock* (pp. 109-112). INRA & IFIP - Institut du Porc, France (ISBN: 978-2-85969-221-6).

The use of the nitrification inhibitor dicyandiamide (DCD) together with the nitrogen fertilizers applied to crops is usually associated to a reduction of $N_2O$ emissions from soils. However, there are also reports of no or contradictory effects from the use of DCD on N losses, particularly through $N_2O$ emissions (Merino et al., 2001).

A field experiment was carried out from May 2006 to May 2008, in central Portugal, to evaluate the effect over soil $N_2O$ emissions originated from cattle slurry applied to a double-cropping system producing oats and maize. The use of DCD, added to the organic effluent or incorporated in a mineral fertilizer, was also studied as mitigation measure.

**1. MATERIAL AND METHODS** A field experiment, using a double-cropping system producing oats and maize, was conducted over a 2 year period (May 2006 to May 2008), on a farm in central Portugal (Castelo Branco). The Castelo Branco region has a Mediterranean influence (average annual rainfall, 821 mm; mean annual temperature, 15.6 ◦C) with 90% of the annual rainfall concentrated in an 8-month period (October–May). Temperature and rainfall data were recorded daily at an on-site weather station during experiments, and important differences were observed between years. On July 2006, very high temperatures were recorded (maximum daily-values above 36 ◦C between days 8 and 18). Autumn 2006 was the third most rainy since 1931, while 2007/2008 (year 2 of the experiment) was one of the driest years of the last decade.

The soil was a Cambisol, with 0.81% organic C, pH ($H_2O$) 6.2, and high $P_2O_5$ and $K_2O$ levels (>120 mg $kg^{-1}$). The treatments (Table 1) consisted on the application of cattle slurry (CS) and implementation of traditional mineral fertilization (MIN). A Control treatment (with no fertilization) was included, and the DCD effects were tested together with MIN (MIN+DCD) and CS (CS+DCD). Nitrogen forms applied using conventional mineral fertilizers were: ammonium sulphate at sowing and ammonium nitrate in the top-dressing applications (February/March for oats and early July for maize). For treatment MIN+DCD, a commercial fertilizer with DCD (Nitrotop®) was used, which contained 20% of N (urea and ammonium sulphate) and about 1.4% of DCD. DCD (12 kg active ingredient $ha^{-1}$) was diluted and mixed well with the slurry just before the spring and autumn applications. Slurry was incorporated to the soil just before crop sowing. Total N input was equal for all fertilizing treatments (oats 80 kg N $ha^{-1}$; maize 170 kg N $ha^{-1}$), but application time differed (Table 1).

The field was divided in plots of $45m^2$ (5.6m x 8m), and the experimental design was randomized blocs, with 3 replications. $N_2O$ fluxes were measure on 165 sampling dates. The measuring frequency was diary in the first 15 days after fertilizers application, and 3-5 days during remaining culture growing season. Measurements took place always between 11 AM and 1 PM. $N_2O$ concentrations were measure using photo-acoustic spectroscopic infrared gas analyser (1412 Photoacoustic Field Gas-Monitor, Innova Air-Tech Instruments), in the headspace of PP chambers with a diameter of 24cm and a height of 16.5cm, inserted into the soil to a depth of 5cm; the chambers were kept in fixed places throughout all season. Two chambers per plot (6 per treatment) were used. Gas samples were taken when chambers were closed (t0) and 1h latter (t1), and fluxes were calculated based on changes in headspace concentrations at t1 and t0. The concentrations were corrected by the analyser to a temperature of 20°C and taking into account relative humidity in the sample taken. The calculated hourly emissions were integrated over time to estimate the total daily emission and the emission over the measurement period during each season. The emission factor based on N application (EF) was calculated using $EF(\%) = 100 \times ((N_2O_{fert} - N_2O_{Control}) / Nap)$, where $N_2O_{fert}$ represent the cumulative $N_2O$

flux (kg N ha$^{-1}$) in the fertilized plot, $N_2O_{Control}$ the cumulative flux in the zero-N treatment, and Nap the amount of applied N (kg N ha$^{-1}$).

*Table 1. Amounts (kg ha$^{-1}$) of N applied in each culture and treatment, through organic and mineral fertilizers.*

| Treatment | Oats | | | Maize | | |
|---|---|---|---|---|---|---|
| | Organic fert. | Mineral fert. | | Organic fert. | Mineral fert. | |
| | | Initial | Cover | | Initial | Cover |
| Control | 0 | 0 | 0 | 0 | 0 | 0 |
| MIN | 0 | 30 | 50 | 0 | 90 | 80 |
| MIN+DCD | 0 | 80 | 0 | 0 | 170 | 0 |
| CS | 80 | 0 | 0 | 170 | 0 | 0 |
| CS+DCD | 80 | 0 | 0 | 170 | 0 | 0 |

**2. RESULTS AND DISCUSSION** In both cultural periods (spring-summer and autumn-winter) $N_2O$ fluxes (data not show) were greater between 8-10 and 30-40 days after crops sowing. The higher value (practically 300 g N-$N_2O$ ha$^{-1}$ day$^{-1}$) took place during the rainy autumn with mineral N fertilization, which confirm the importance of the simultaneity of precipitation and greater mineral N availability for the higher emissions of $N_2O$.

As observed in other field trials carried out in different conditions (e.g. Jones et al., 2007), differences in temperature and precipitation (soil water content) originated inequalities between the $N_2O$-N losses measured in each year (Table 2). In the first year, the highest values were measured in MIN+DCD and MIN (4.65 and 4.21 kg N ha$^{-1}$, respectively), which were 60-70% higher than those measured in CS+DCD, CS or in Control (1.85, 1.55 and 1.33 kg N ha$^{-1}$, respectively). During the second experimental year, the $N_2O$-N losses in the different treatments were much similar, ranging from 0.45 kg N ha$^{-1}$ year$^{-1}$ in Control to 0.92 kg N ha$^{-1}$ year$^{-1}$ in MIN+DCD.

*Table 2. Total cumulative $N_2O$-N losses and emission factor based on N application (EF) observed during the experiment. Values in parenthesis represent standard error of the mean; n=6.*

| Treatment | Year 1 | | Year 2 | |
|---|---|---|---|---|
| | Total $N_2O$-N losse (kg N ha$^{-1}$) | EF (%) | Total $N_2O$-N losse (kg N ha$^{-1}$) | EF (%) |
| Control | 1.33 (0.09) | | 0.45 (0.03) | |
| MIN | 4.21 (0.40) | 1.15 (0.15) | 0.70 (0.13) | 0.10 (0.05) |
| MIN+DCD | 4.65 (0.32) | 1.33 (0.12) | 0.92 (0.12) | 0.19 (0.06) |
| CS | 1.85 (0.21) | 0.21 (0.08) | 0.50 (0.08) | 0.02 (0.02) |
| CS+DCD | 1.55 (0.09) | 0.09 (0.05) | 0.58 (0.04) | 0.05 (0.02) |

With the use of CS, the $N_2O$-N annual losses did not exceed 2 kg N ha$^{-1}$, less than half of the maximum value reached with mineral fertilizers. This result could be explained by the addition of organic carbon, which would have stimulated $O_2$ demand, $N_2O$ consumption and a decreased in the $N_2O/N_2$ ratio (Vallejo et al., 2006). During the first autumn-winter period, the use of DCD in both fertilizers promoted important reductions in daily $N_2O$-N emissions (data not show), but not in the cumulative $N_2O$-N emitted in this period.

Carneiro, J. P., Coutinho, J., Trindade, H. (2013). $N_2O$ emissions from soil amended with cattle slurry under Mediterranean conditions. In Mélynda Hassouna and Nadine Guingand (Ed.), *Emissions of Gas and Dust from Livestock* (pp. 109-112). INRA & IFIP - Institut du Porc, France (ISBN: 978-2-85969-221-6).

Gioacchini et al. (2002) suggested that DCD can have a priming effect in the net mineralization of organic N in soil, resulting in greater long-term nutrient loss.

Considering the results presented in Table 2, it can be seen that the $N_2O$ emission factor of 1% could be acceptable to estimate $N_2O$-N losses from soils where mineral fertilizers were applied, but clearly overestimate the losses from soils amended with cattle slurry. With application of mineral fertilizers the two years mean emission factors were 0.76 and 0.63% in MIN+DCD and MIN, respectively. Is important to note that in a year with a raining autumn an EF superior to 1% could be expected, while in drier years the EF will be significantly lower this value. With slurry application, EF annual value did not exceeded 0.12%.

**3. CONCLUSION** Concurrent conditions of high soil mineral-N content and high soil water content (precipitation) promoted important $N_2O$-N emissions, explaining the higher $N_2O$-N losses when mineral fertilizers were applied during a raining autumn. The $N_2O$ IPCC emission factor of 1% seems to be acceptable to estimate $N_2O$-N losses when mineral fertilizers were applied to soils. However it clearly leads to the overestimation of the losses in the case of soils amended with cattle slurry. In the experimental conditions under scrutiny, the use of DCD as a nitrification inhibitor added to mineral fertilizer or slurry did not influence annual $N_2O$-N losses.

## REFERENCES

Bouwman A.F., 1990. Exchange of green house gases between terrestrial ecosystem and atmosphere, in: Bowman AF (Eds.), Soils and the Greenhouse Effect, Wiley, Chichester, pp. 61-127.

Di H.J., Cameron K.C., 2012. How does the application of different nitrification inhibitors affect nitrous oxide emissions and nitrate leaching from cow urine in grazed pastures?. Soil Use Manage, 28, 54-61.

Dobbie K., Smith K., 2003. Nitrous oxide emission factors for agricultural soils in Great Britain: the impact of soil water-filled pore space and other controlling variables. Glob Change Biol, 204-218.

Gioacchini P., Nastri A., Marzadori C., Giovannini C., Antisari L. V., Gessa, C., 2002. Influence of urease and nitrification inhibitors on N losses from soils fertilized with urea. Biol Fertil Soils, 36, 129-135.

IPCC, 2006. Guidelines for National Greenhouse Gas Inventories. Eggleston S., Buendia L., Miwa K., Ngara T., Tanabe K. (Eds.), $N_2O$ Emissions from Managed Soils, and $CO_2$ Emissions from Lime and Urea Application. Pub. IGES, Japan, pp. 11.1-11.54.

Jones K., Rees M., Skiba M., Ball C., 2007. Influence of organic and mineral N fertiliser on $N_2O$ fluxes from a temperate grassland. Agric Ecosyst Environ, 121, 74-83.

Merino P., Estavillo J.M., Besga G., Pinto M., González-Murua C., 2001. Nitrification and denitrification derived $N_2O$ production from a grassland soil under application of DCD and Actilith F2. Nutr Cycl Agroecosys, 60, 9-14.

Vallejo A., García-Torres L., Arce A., López-Fernández S., Sánchez-Martín L., 2006. Nitrogen oxides emission from soils bearing a potato crop as influenced by fertilization with treated pig slurries and composts. Soil Biol Biochem, 38, 2782-2793.

Verma A., Tyagi L., Yadav S., Singh S.N., 2006. Temporal changes in $N_2O$ efflux from cropped and fallow agricultural fields. Agric Ecosyst Environ, 116, 209-215.

Carneiro, J. P., Coutinho, J., Trindade, H. (2013). $N_2O$ emissions from soil amended with cattle slurry under Mediterranean conditions. In Mélynda Hassouna and Nadine Guingand (Ed.), *Emissions of Gas and Dust from Livestock* (pp. 109-112). INRA & IFIP - Institut du Porc, France (ISBN: 978-2-85969-221-6).