

# Modelling N<sub>2</sub>O emissions from tile-drained winter-wheat fields

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## Introduction

Tile drainage is a common practice to alleviate soil aeration problems associated with water accumulation. Excess water is rapidly transported away from the fields through enhanced infiltration rather than run off, avoiding erosion and long periods of saturated conditions in topsoil. The presence of tile drains significantly increases crop yields (Bolton et al. 1982; Buscaglia et al. 1994) and soil NO<sub>3</sub><sup>-</sup> leaching (Bolton et al. 1970; Milburn et al. 1990; McIsaac and Hu 2004) but also influences SOC storage and bioavailability (Jacinthé et al. 2001) thereby limiting the microbial competition for N and C substrates. Gu et al. (2011, 2013) reported that tile drainage can impact on N<sub>2</sub>O emissions through modifying soil hydrology. However, a research in grazed peat soils indicated that tile drains reduced the seasonal fluctuations in groundwater level but did not contribute to the reduction of N<sub>2</sub>O emissions (van Beek et al. 2010). Considering that tile drainage is widespread in humid region, we argue the importance of understanding the N<sub>2</sub>O emissions from tile-drained soils.

Compared to the costly measurements in situ, mathematic models are one alternative tool to synthesize N<sub>2</sub>O emissions from tile-drained soils. The process-based DNDC model has been validated for N<sub>2</sub>O emissions and regulated variables under a broad range of climate, soil types and land uses with promising results (Li et al. 1992; Beheydt et al. 2007; Rafique et al. 2011). Though the model was tested for crop yields, soil water drainage and NO<sub>3</sub><sup>-</sup> leaching in tile-drained croplands (Li et al. 2006; Tonitto et al. 2007a, 2007b), applying DNDC to tile-drained soils for predicting N<sub>2</sub>O flux is still challenging.

The non-linear empirical Nitrous Oxide Emission (NOE) model simulates nitrification and denitrification follows the first-order kinetics and accounts N<sub>2</sub>O emission as the sum of both processes (Hénault et al. 2005). NOE is developed for temperate soils. Theoretically, the model is applicable for most agricultural soils since all the input variables are measured either in situ or in laboratory incubation with site-specific soils.

The aims of this study were to evaluate DNDC and NOE for modelling N<sub>2</sub>O emission from tile-drained soils and suggest the directions of future model development.

## Material and methods

### Study sites

The study area was located in the valley of the Loir river (48°23'N, 1°13'E), Chartres, France. Seventeen sites (N1-9 and T1-8) cropped with winter wheat were selected across a tile-drained landscape between 2009 and 2010 (Gu et al. 2011, 2013). Soil N<sub>2</sub>O flux was measured using static chambers once or twice a week at sites T1-5 during February to May 2009, at sites T1-5 during February to May 2010, and at sites T6-8 during October 2009 to June 2010.



The map is taken from Gu et al. 2013

### DNDC95

DNDC represents the effect of tile drainage on soil hydrology by a virtual water pool between the bottom of the modeled soil profile and the depth of the tile pipes (Li et al. 2006). Water excess the soil holding capacity is drained through the pipes.

We ran DNDC95 continuously for three years using the same climate and agricultural practices and tested the simulation in the third year. We also ran an old version of DNDC (8.9) for the simulation of soil temperature and WFPS.

### NOE development

We modified NOE by incorporating the effects of soil WFPS and NO<sub>3</sub><sup>-</sup> content on the N<sub>2</sub>O reduction through denitrification (Weier et al. 1993). Two dimensionless parameters, r<sub>w</sub> and r<sub>NO3</sub><sup>-</sup>, were applied to regulate r<sub>max</sub> at a daily step.

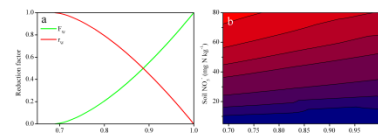
$$N_2O = z \cdot N_{NH_4^+} \cdot N_T, WFPS < 0.689$$

$$N_2O = r_{max} \cdot r_w \cdot r_{NO_3^-} \cdot D_p \cdot F_N \cdot F_W \cdot F_T, WFPS > 0.8$$

$$N_2O = r_{max} \cdot r_w \cdot r_{NO_3^-} \cdot (D_p \cdot F_N \cdot F_W \cdot F_T + z \cdot N_W \cdot N_{NH_4^+} \cdot N_T), 0.689 \leq WFPS \leq 0.8$$

$$r_w = 1 - \left[ \frac{WFPS - 0.689}{0.311} \right]^{1.53}$$

$$r_{NO_3^-} = \frac{[NO_3^-]}{km_1 + GSWC + [NO_3^-]}$$

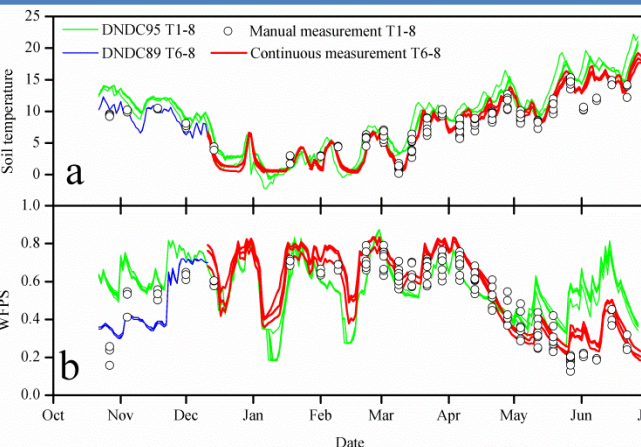
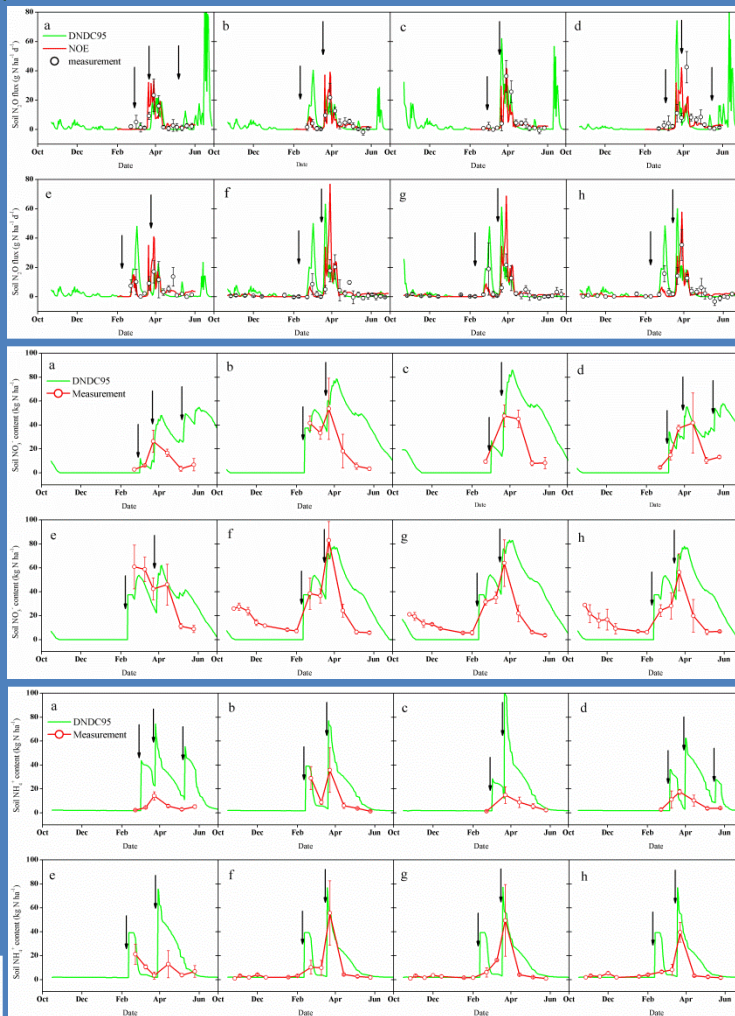


## Results

- DNDC95 well reproduced the temporal variations in soil temperature and WFPS. However, the overestimation during the low range of WFPS is evident.
- The predictions of DNDC95 for soil NH<sub>4</sub><sup>+</sup> and NO<sub>3</sub><sup>-</sup> contents were not optimal. The model overestimated the NO<sub>3</sub><sup>-</sup> during the post-fertilization period at all sites.
- Both DNDC95 and NOE simulated the fertilizer-induced emission peaks during the experimental period. NOE yielded positive model efficiency at four sites and DNDC95 did so only at one site.
- DNDC95 slightly overestimated (3%) the cumulative N<sub>2</sub>O emissions across the landscape while NOE underestimated by 15%.

## Conclusions

- Our validation indicates that the prediction of DNDC95 for nitrogen biogeochemistry (especially soil NH<sub>4</sub><sup>+</sup> and NO<sub>3</sub><sup>-</sup> contents) was not optimal in the studied soils. The overestimation of NH<sub>4</sub><sup>+</sup> and NO<sub>3</sub><sup>-</sup> during the post-fertilization period could be a result of mistreating the N application method. The crop leaves can intercept an apparent part of N when spraying UAN water solution over the canopy. While DNDC accounts all the N into the soil N pool. Interestingly, the overestimation of soil N substrates did not impact on the simulations of N<sub>2</sub>O flux at all sites during the experimental period.
- We suggest that dynamic fractions of N<sub>2</sub>O production through denitrification should be used in NOE. The effects of soil WFPS and NO<sub>3</sub><sup>-</sup> content on the N<sub>2</sub>O reduction through denitrification is common and can be applied at other sites. More validations therefore are needed.



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