Chamber-based continuous measurement of N2O fluxes in a winter wheat field: comparison of tillage treatments and identification of emission peak dynamic

François Broux (1), Margaux Lognoul (1), Nicolas Theodorakopoulos (2), Bernard Heinesch (1), and Marc Aubinet (1).
(1) TERRA, University of Liege - Gembloux Agro-Bio Tech, Gembloux, Belgium, (2) University of Liege - Gembloux Agro-Bio Tech, AgroBioChem Dept., Passage des Déportés, 2, B-5030 Gembloux, Belgium.

Introduction

Nitrous oxide (N_2O) :

- A major greenhouse gas with (GWP of 300)
- One of the main ozone-depleting substance in the stratosphere.
- Its concentration increased worryingly by 20 % since 1750.

Agriculture importance:

- First anthropogenic source of N2O emissions.
- Accounts for more than 20 % of total emissions, mainly through fertilized soils.

Soil emissions leading processes:

- Nitrification.
- Denitrification.

Identified factors affecting emissions:

- Climate through temperature, rainfalls, droughts events, or freezing/thaw cycles.
- Farming practices such as fertilization, tillage, intercropping and residues management.

Uncertainty

- Despite numerous studies on the subject, there is still no agreement between authors about the exact effect of tillage on N_2O emissions from croplands.

Objective

- What is the impact of soil tillage on N2O fluxes?
- What is the influence of fertilization events, climate on N2O emission dynamics?

Figure 1. Gas measurement device: one set consisting of 8 chambers.

Method

Experimental site

The experience was held in two plots located within the same silt loam winter wheat field in Gembloux, Belgium. Since 2008, the parcels have been treated with crop residue return and a differentiated tillage.

One parcel was under surface tillage (ST) while the other one was under conventional tillage (CT). Stubble breaking (15 cm) was done in both parcels, but winter ploughing (25 cm) was performed only in the CT parcel.

Fertilization was done with three fractions of UAN solution (04/02: 59 kg N ha^{-1} – 04/22: 66 kg N ha^{-1}– 05/19 : 75 kg N ha^{-1}).

Gas Fluxes Measurements

In each parcel, CO_2 and N_2O fluxes were measured with a set of 8 homemade automated closed chambers (figure #1) connected to CO_2 and N_2O analyzers . The 8 chambers close consecutively, allowing gas accumulation in their headspace and, hence, flow measurement. The full cycle lasts 4 hours, providing 6 mean flows measurement a day per plot.

Additional measurements

In addition to gas fluxes, soil water content at various depths and surface temperature were measured continuously.

Soil samples were taken every fortnight to determine soil pH, soil organic carbon and nitrogen pools (total, NO3 and NH4) and study microbial diversity and nitrification/denitrification gene expression.

At chamber withdrawal time, soil samples were taken beneath every chambers to measure nitrogen pools.

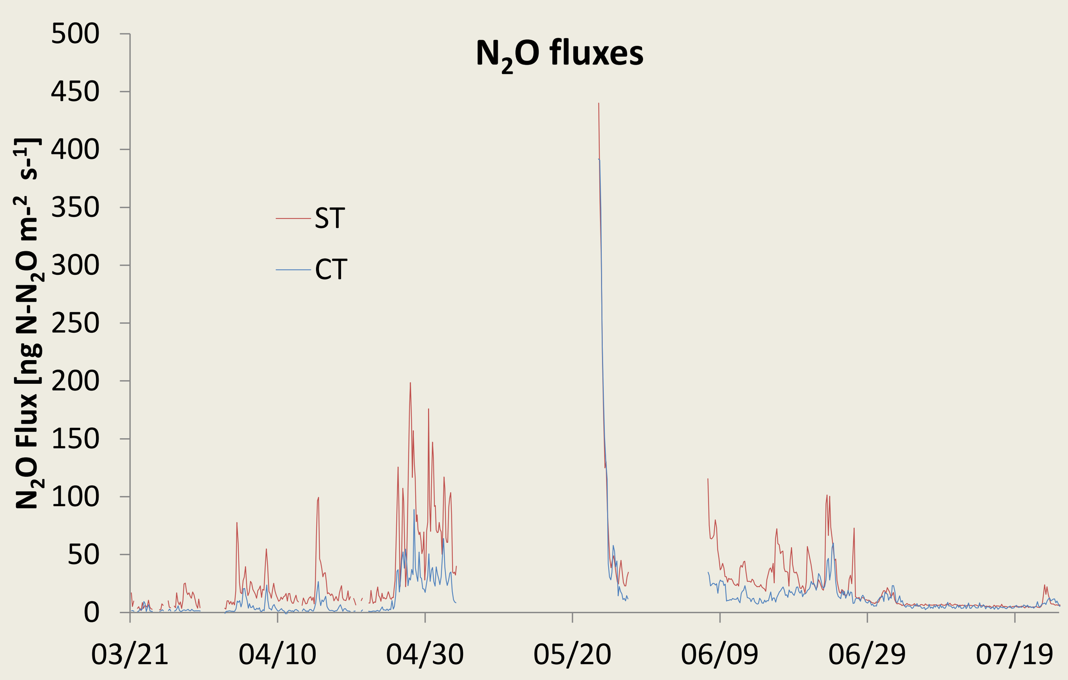

Figure 2 . Time series of N_2O emissions in both treatments: shallow tillage (ST) and conventional tillage (CT).

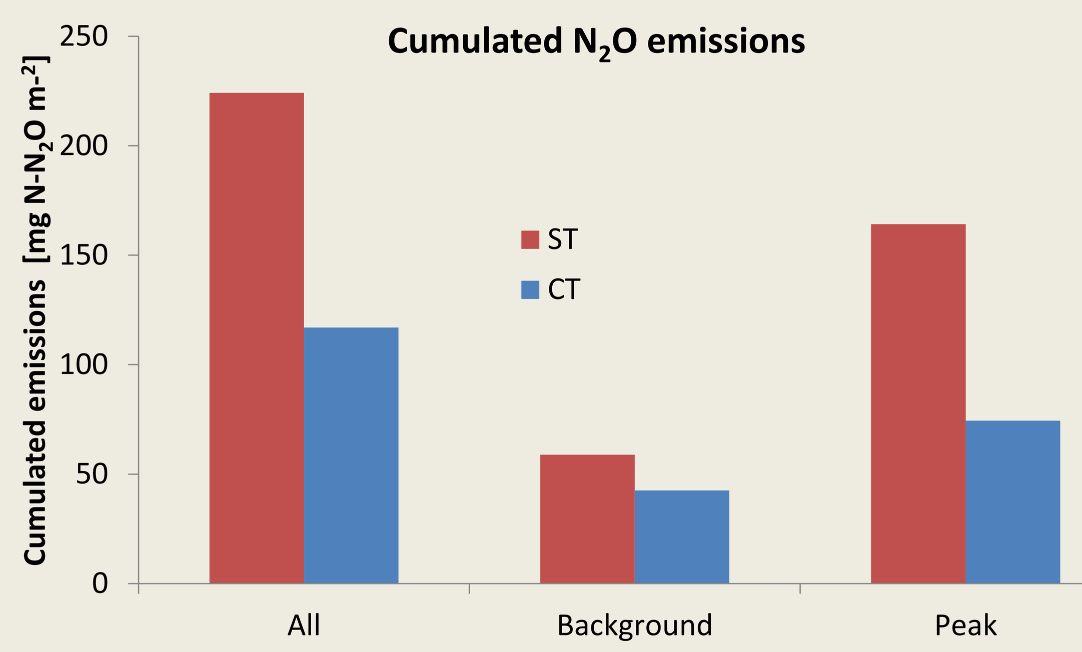

Figure 3. Cumulated N_2O emissions in both treatments: shallow tillage (ST) and conventional tillage (CT).

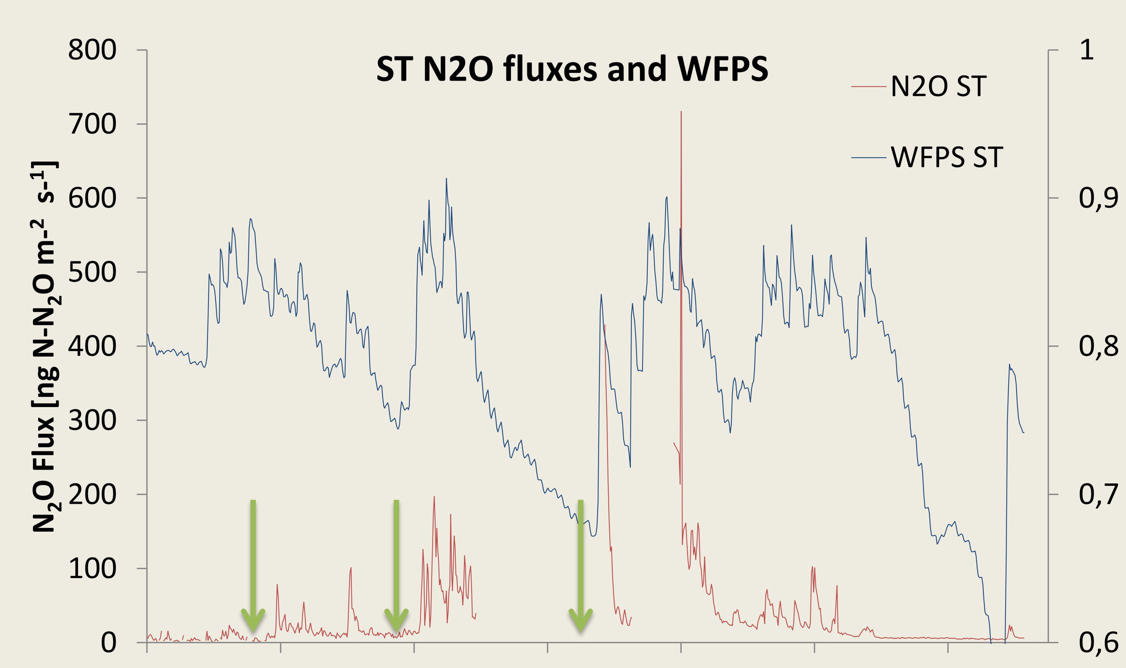

Figure 5. Time series of N_2O emissions under shallow tillage (ST) and soil water filled pore space (WFPS). Green arrows indicate fertilization events.

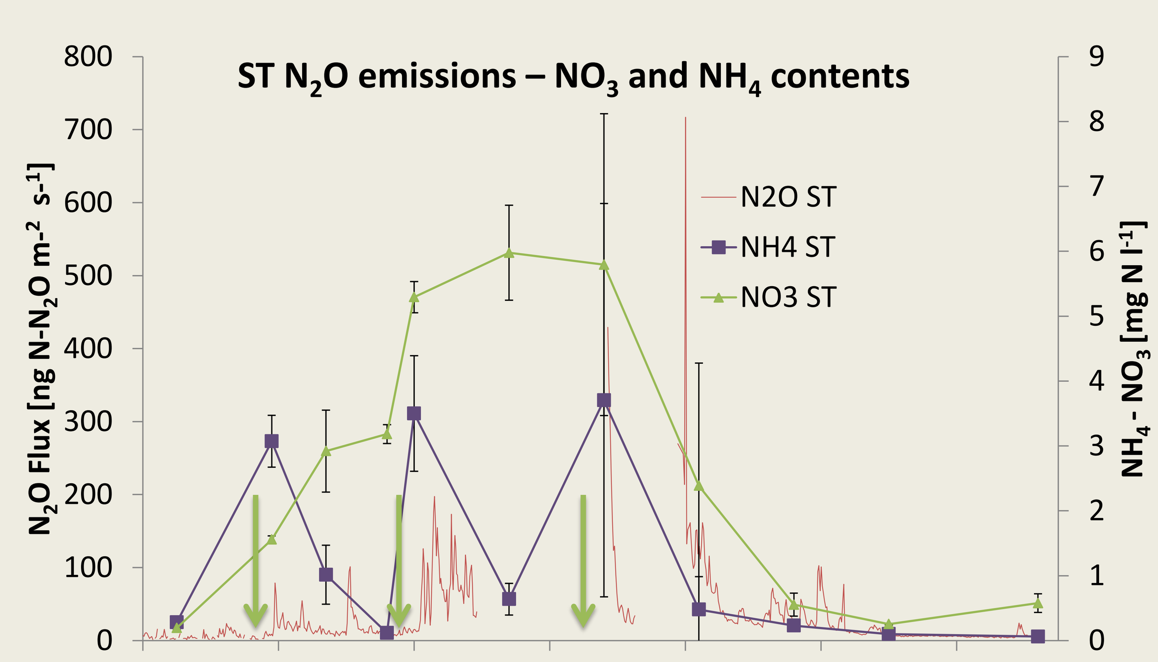

Figure 6. Time series of N_2O emissions under shallow tillage (ST) and NO_3, NH_4 soil content. Green arrows indicate fertilization events.

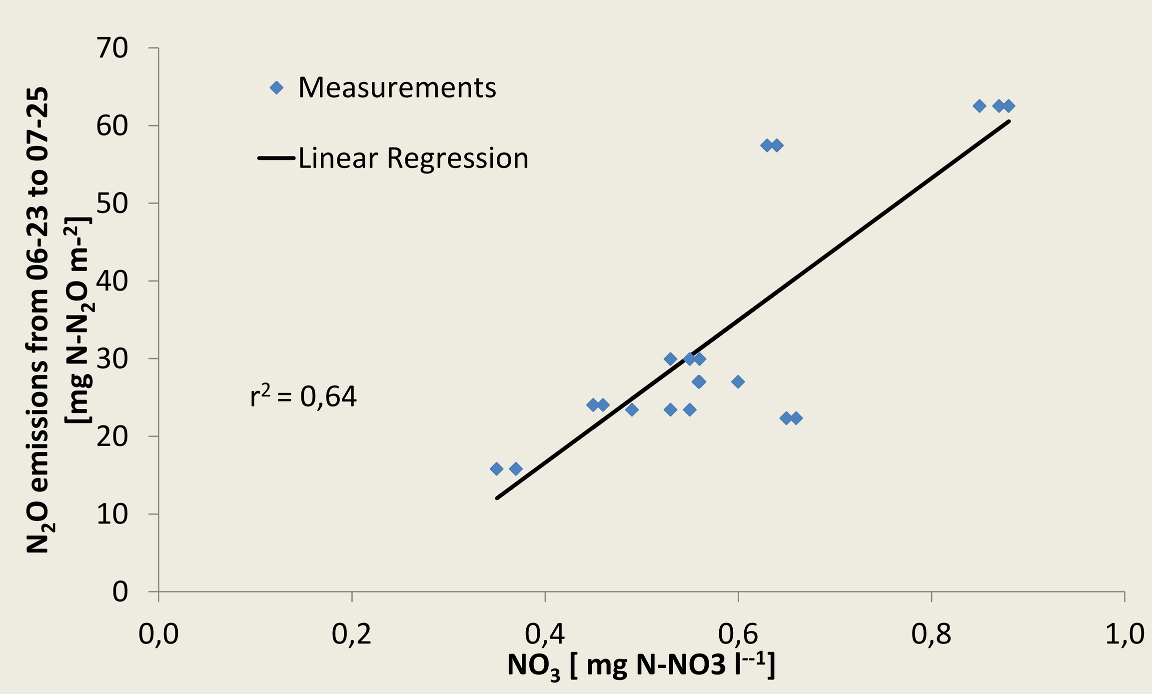

Figure 7. Linear regression relation between chamber N_2O emissions (from 06-23 to 07-25) in the shallow tillage parcel and soil NO_3 content measured in the soil samples taken beneath the chambers at withdrawal time (07-25).

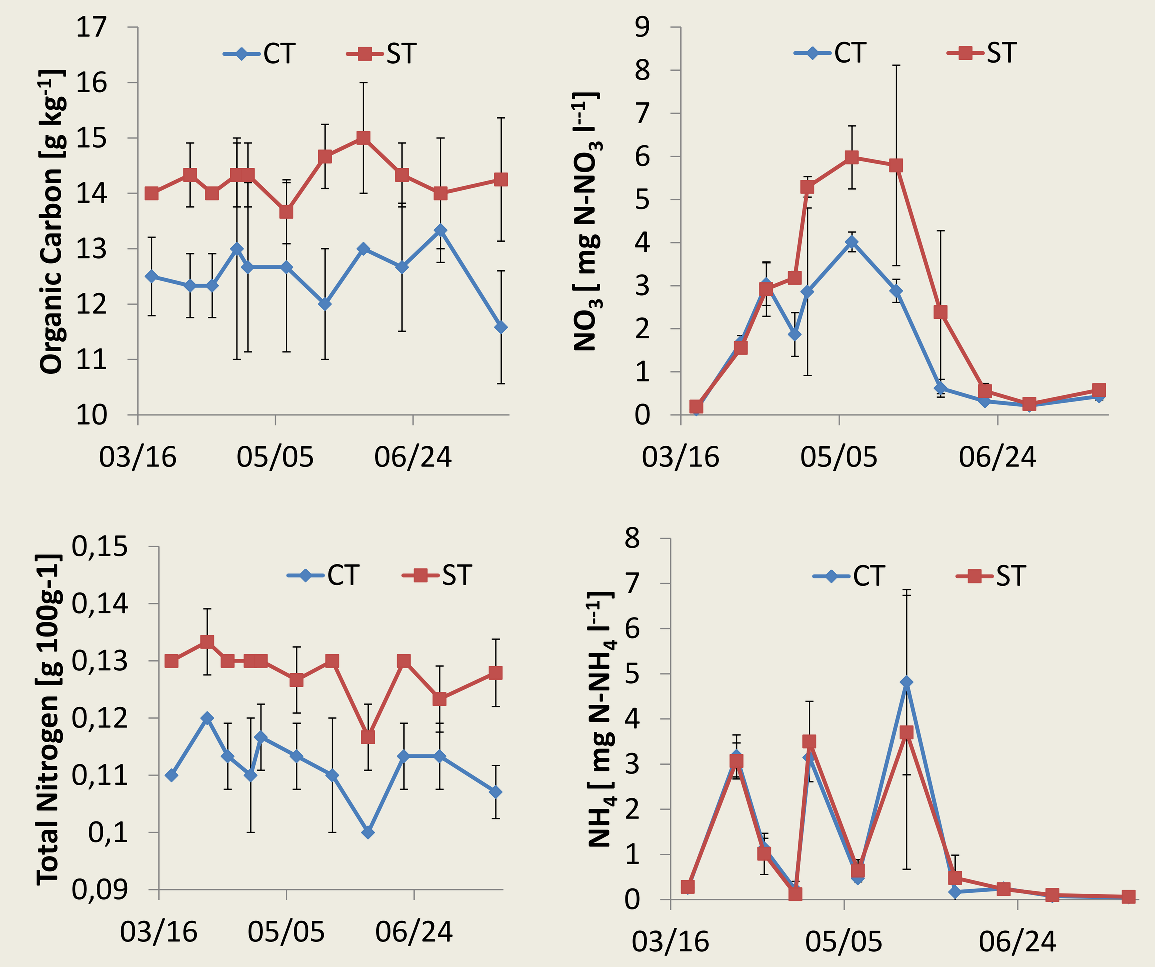

Figure 4. Time series of soil organic carbon (up left), nitrate (up right), total nitrogen (low left) and ammonia (low right) in both treatments: shallow tillage (ST) and conventional tillage (CT).

Results and discussion

N_2O emissions in the ST treatment are about two times higher than those of the CT treatments (figure #2 and #3). This trend is mainly due to larger emissions peaks in ST while the background emissions are more comparable between both plots.

This difference can be connected with higher soil organic carbon, total nitrogen and nitrate content in the ST parcel (figure #4). These differences most likely translate into greater microbial activity.

In the ST treatment, fertilization events predate emission bursts. The starts of the later seem to coincide with high values of soil Water Filled Pore Space (WFPS) (figure #5). After the first two fertilizations, high emissions occured simultaneously with a diminution in soil NH_4-N and a rise in soil NO_3-N (figure #6). Nevertheless, no increase in NO_3-N happened during emissions bursts following the third fertilization. But the rather low background emissions in July coincided with a slight growth of nitrate content. The same pattern can also be observed in the CT plot, though less pronounced as emissions are lower.

At chamber scale in the ST parcel, N_2O emissions during last month (from 06-23 until 07-25) were also positively correlated with NO_3-N measured in the soil samples taken beneath the chambers at withdrawal time (07-25) (figure #7).

Results from figure #6 and #7 suggest that emissions are due to nitrification activity. In the spring, both organic nitrogen from previous crop residues and ammonia nitrogen pool could be used as nitrogen supply for the process. In late June and July, process probably uses residues-N as source of electron as there is almost no ammonia left in the soil.

The uptake of NO_3-N by the crop for its development during late spring could explain the absence of NO_3-N rise in soil samples during last emissions peaks.

Conclusion

The results of the study shows larger emissions in the shallow tillage parcel than in the conventional tillage plot, particularly during emission peaks.

In both tillage treatments, emissions follow a pattern of relatively low background emissions interrupted by larger peaks

Temporal evolution of fluxes and soil nitrogen pools as well as spatial variability within the ST parcel suggest nitrification process as a major source of emission in the field.

Acknowledgements

The authors acknowledge the French Community of Belgium for funding this research through a Concerted Research Action (ARC 13/17-11). Special thanks to Gino Mancini and Frederic Wilmus for their technical assistance.