The Significance of Subsoil Denitrification in an Agricultural Landscape

Iurii Shcherbak and G. Philip Robertson

W.K. Kellogg Biological Station, Great Lakes Bioenergy Research Center, and Department of Crop and Soil Sciences, Michigan State University

Introduction

- Denitrification is the only process capable of returning active nitrogen to dinitrogen, closing the nitrogen cycle.
- Denitrification in agricultural fields is responsible for a substantial fraction of the anthropogenic nitrous oxide emitted globally.
- Most studies concentrate on denitrification from surficial depths and subsoil (below plow layer) denitrification is poorly understood.

How large is denitrification at depth in the soil profile and how does denitrification vary with land-use, and more specifically, with agricultural practices?

Objective

To examine the ***importance of denitrification at depth*** and whether patterns change significantly along the soil profile and with land use because of predictable underlying changes in primary controls:

- nitrate and soluble organic carbon (SOC) availability,
- soil temperature, and soil redox potential.

Hypotheses

- Significant denitrification occurs at depth in arable soils as subsoils have significant levels of nitrate and higher average moisture content compared to surface soils, with SOC a limiting factor.
- The importance of N_2O as a denitrification end product decreases with depth (mole ratio N_2O : N_2 decreases) due to longer residence times of N_2O in the soil.
- Subsurface denitrification differs by crop and land use, because of agricultural disturbances, e.g. plowing and compaction of the overlying surface soils, as well as additions of nitrogen and carbon.

Materials and Methods

- Field plots (Fig. 3) established at the Kellogg Biological Station (KBS) in 1986 to study nitrogen supply and tillage effects on soil-plant interactions
- Monolith lysimeters in plots 2, 13 (tilled) and 6, 9 (no-till) enclose intact soil profiles in stainless steel boxes (Fig. 1: 1.5m x 2m x 2m depth)
- Plots were fertilized at 13.3 g/m2 with 40% ^{15}N-Ammonium nitrate to enable subsoil N_2 measurements
- Inert tracer (hexafluoride SF_6) allows us to estimate diffusion in the soil
- Sampling is performed at 6 depths (20, 25, 50, 55, 75, and 100 cm) representing boundaries of major horizons.
- Flux from the surface of the soil (weekly)
- Gravimetric drainage water (weekly)
- Soil temperature (every 15 min)
- Soil solution (weekly)

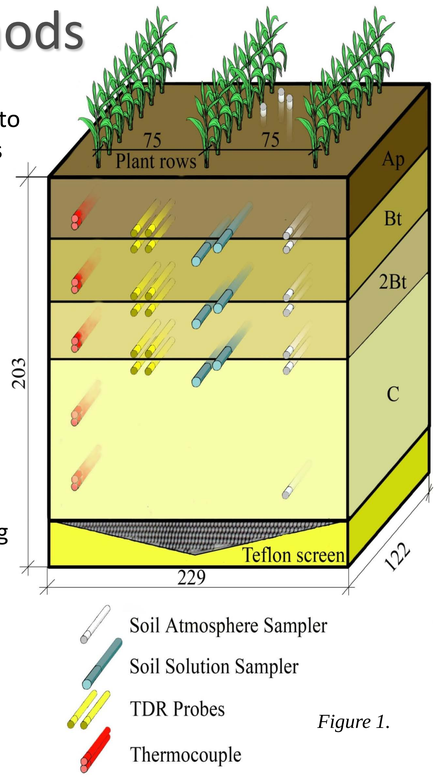


Figure 1.

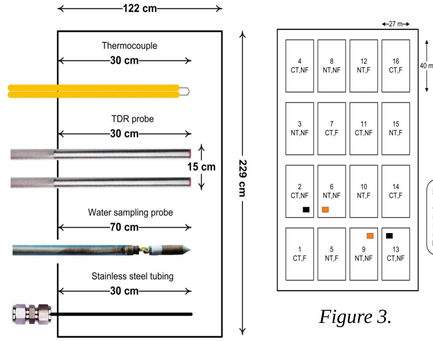


Figure 2.

Figure 3.

- Soil moisture (every 15 min)
- Soil atmosphere
  - Sample for concentrations of N_2O, CO_2, and CH_4 (weekly)
  - Sample for stable isotope ratios of N_2O and N_2 (twice a month at three layers per lysimeter)
- Fig. 2 shows a top of nondestructive samplers in a layer of soil profile in monolith lysimeter.

Preliminary results

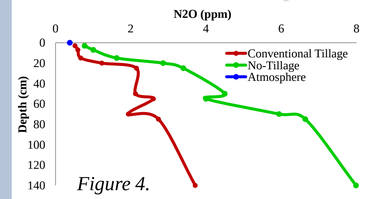


Figure 4.

- Graph (Fig. 4) shows high average growing season concentrations of N_2O in the soil air by horizon depth
- Tillage seems to have a profound effect on subsoil nitrous oxide concentrations

Figure 6. Graph for simulated vs. measured temperature at 20 cm depth

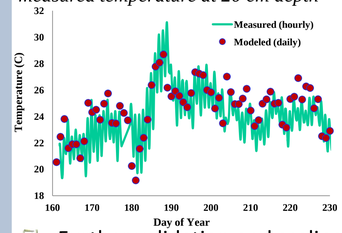
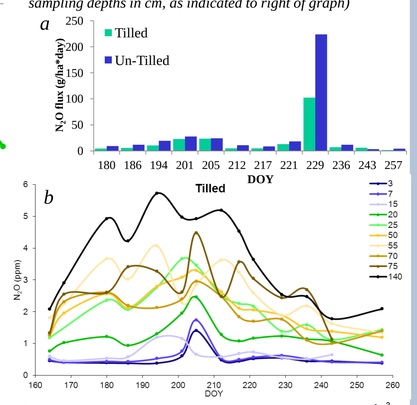
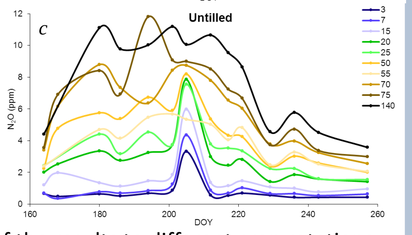


Figure 5. Average N_2O flux (a) and concentrations in tilled (b) and un-tilled (c) treatment (different colors refer to different sampling depths in cm, as indicated to right of graph)





- Further validation and scaling of the results to different crop rotations will be performed at the KBS Long-Term Ecological Research site and with the SALUS model, which works well at the KBS conditions (Fig 6).

Conclusion and Next Steps

- High subsoil N_2O concentrations and declines in concentration at depth coinciding with highest recorded fluxes suggest significance of subsoil denitrification (Fig 5.a compared to Fig 5.b and Fig 5.c).
- N_2O and N_2 production and N_2O consumption will be established precisely with ^{15}N measurements.

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