Measurement strategy to quantify the effect of management practices on soil $\text{N}_2\text{O}$ emissions.

Philippe Rochette
Summary

• Background

• Strategy for quantifying the impact of management practices
  – Set realistic objectives
  – Minimize “noise”
  – Identify changes to N₂O production and transfer
  – Adapt chamber design and deployment

• My Examples
  – N fertilization
  – Tillage

• Your Examples...
Background

Chambers

• Micromet studies were “method-oriented”
• Chamber studies were “results-oriented”
• Lack of rigor for chamber use
• Low confidence in many datasets
• Consensus for the need for a Standard methodology

Micromet

– Standard methodology
– Mostly CO$_2$ and H$_2$O
Background

Micromet

- Energy budget closure
- Horizontal homogeneity
- Same fields

≈40 papers on N₂O since 2008
  - Fast-response sensors
  - Eddy covariance

Value your chamber measurements;
They have been/are/will be important
Methodology for addressing Impacts of Farming Practices on Soil $\text{N}_2\text{O}$

Three Steps

1- Set realistic objectives

2- Minimize the "Noise"

3- Anticipate impact and adapt chamber design and deployment
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1-

Set realistic objectives

Chamber limitations
NSS Chamber Techniques

• **Strengths**
  - Small spatial scale
  - Scale closer to that of $N_2O$ processes
  - High sensitivity
  - Few assumptions (WYSIWYG)
  - Adaptability
  - Simple
  - Low costs
  - Comparison of situations

• **Weaknesses**
  - Intrusive
  - Labor-intensive
  - Small spatial scale
  - Short duration (non automated)
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1-

Set realistic objectives

Chamber limitations

- Are NSS chambers the adequate tool?
  - Situation that is too complex?
    - Spatial and temporal variability
    - Grazing animals
  - Snow-covered or saturated soil conditions

Resources

- Do I have enough resources?
  - # replicates (4)
  - # treatments vs # sites
  - Site location

Success or failure of an experiment often depends on decisions made prior to field work
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Minimize the "Noise"

Site selection
N$_2$O controls - Conceptual Model

**Autotrophic Nitrification**

**Anaerobic Denitrification**

**Distal factors**

**Proximal factors**

**Substrates**

**Practices**
- tillage
- C inputs
- liming
- cover crop
- irrigation
- drainage
- crop type
- fallow
- fertilization

**Physics & Chemistry**
- redox
- temp.
- H$_2$O
- pH

**Soil & Climate**
- texture
- landscape
- climate
- organic matter
- porosity

N$_2$O Production & transfer
Environment often has a dominant impact on soil $N_2O$

**Summary of Canadian Data**

- **Cumulative $N_2O$ emissions** ($n=1300$)
  - Soil organic C
  - Precipitations
  - Air temperature
  - Sand %
  - Soil pH
  
  71% of the variability in $N_2O$ emissions

Variations in soil environmental conditions may mask practice-induced emissions

- Climate
- Soil Type

64% of the variability in EF
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Minimize the “Noise"

Site selection

- Is the site too heterogeneous?
  - Texture
  - Drainage

Previous management may mask practice-induced emissions by raising baseline emissions

- Perennials tilled in the year before?
- No-till that was plowed?
- Heavy manure applications?
- Recently tile drained?
- Any previous practice that could still impact?
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Minimize the “Noise”

- Site selection
- Chamber Size
- Field operations

- Can I include sites with contrasting soil types?
- What is the smallest scale at which I need information?

At each experimental site, remove as much noise as possible in order to isolate the treatment effect.
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Anticipate impact and adapt chamber design and deployment

Substrate & Environment

- How does the practice impact on:
  - C and N amounts, type and location?
  - Soil bulk density, water content, temperature, etc.?
- Ties up N in soil organic matter
- Decreases C availability
- Lowers temperature
- Keeps substrates closer to surface

Conventional tillage

No tillage

- Because substrates are located at different depths, they are exposed to different diurnal temperature cycles and N₂O transfer time to the surface is also different
- Diurnal pattern in surface emissions may differ between no-till and conventional tillage
Are diurnal pattern of emissions in phase?

- Substrate located at different depths
- Substrate exposed to different temperatures
- Temporal patterns of $\text{N}_2\text{O}$ production and diffusion to the soil surface could be affected
- **Determine the diurnal pattern**

- This also has an impact on where in the soil profile to measure pertinent variables (temperature, water content, microbial activity, etc.)
Efficient Use of Organic N Sources

Does organic N result in greater $\text{N}_2\text{O}$ emissions than synthetic N?

• Input of available organic C for denitrification

• Anoxic hotspots

• Lower mineral N content

• May decrease soil bulk density

• C substrates
  - Soil exceptionally rich in SOM?
  - Previous practices that may confound the $\text{N}_2\text{O}$ response?

• N substrates
  - Different timing of release?
Are seasonal emissions patterns in phase?

- Plan sampling schedule so that both emission curve is equally described.
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Anticipate impact and adapt chamber design and deployment

- Substrate & environment
- Chamber geometry
- Chamber deployment

- How does the practice impact on spatial pattern of emissions?
  - Adapt chamber geometry

- ... and on spatial variability?
  - Consider decreasing air samples per chamber deployment
  - ... but check linearity
  - Using a linear model may bias comparison between treatments...

- Does the practice impact on chamber performance?
  - Seal?
  - Soil-Headspace gas transfer?
  - Others?
No-Till vs Molboard plow

- Moldboard Plow (20 cm)
- Creates preferential flow
- Potential leaks
- Deeper collars on conventional tillage than on no-tillage shortly after tillage
Conclusions

• Start with realistic goals
• Minimize noise
• Account for impacts of practice on spatial and temporal patterns of N$_2$O emission
  - C and N substrates
  - Environment
• Account for impact of practice on chamber performance
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3-

Anticipate impact and adapt chamber design and deployment

Substrate & Environment

- How do differences in substrate placement depth can impact on the temporal pattern of emissions?