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Nitrous oxide and carbon dioxide emission responses to litter incorporated in a grassland soil

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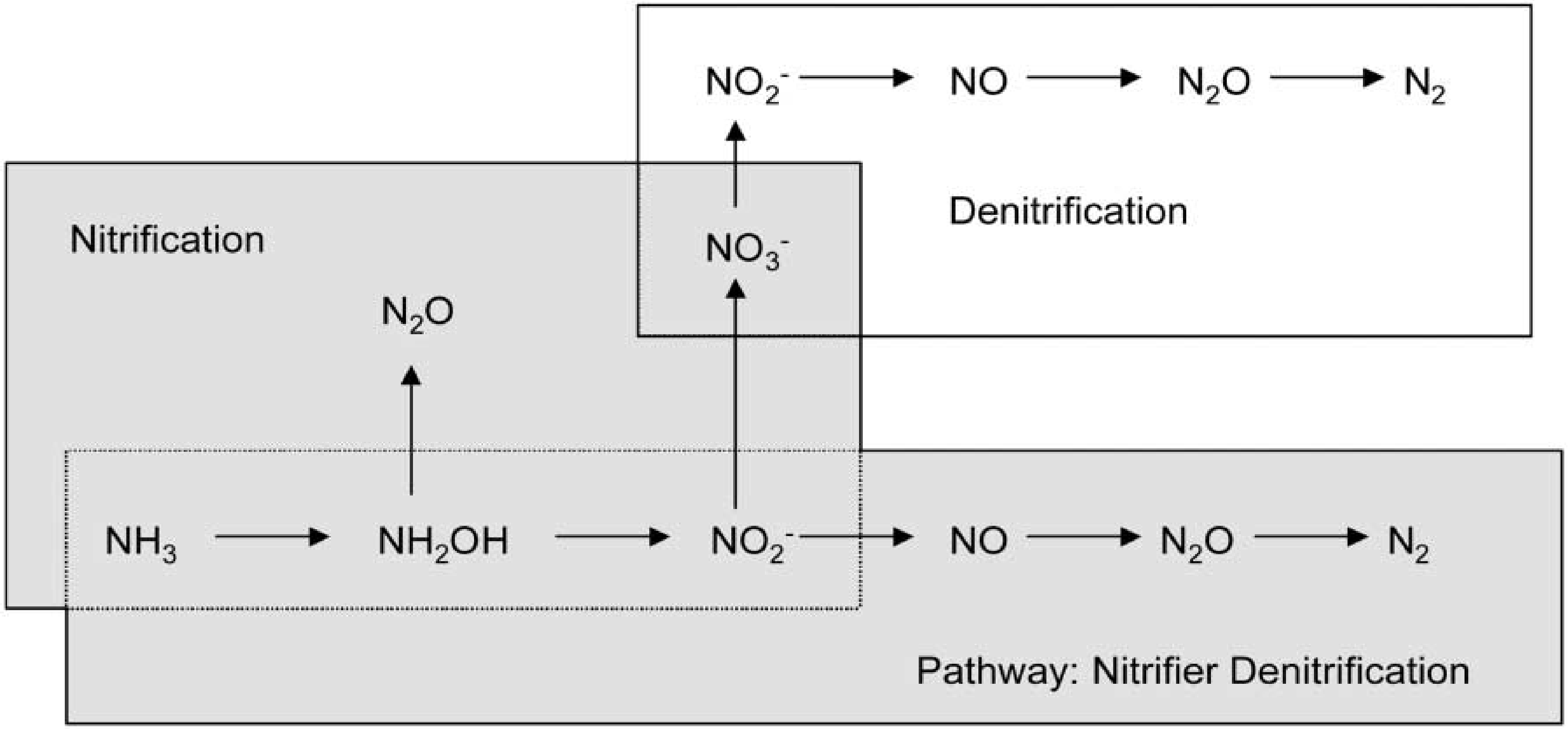
Outline

- Introduction
  - *N transformations*
  - *Nitrous oxide (N_2O)*
  - *Factors affecting N_2O emissions*
  - *Sources of N_2O*
- Objectives of the experiment
- Experimental setup and methodology
- Results and conclusion

Introduction

- Nitrogen (N) is a major element of all organisms: 6.25% body mass
- N transformations: denitrification and nitrification (cause N_2O)



Transformations of mineral N in soil (Wrage et al. 2001)

Introduction (contd.)

Nitrous oxide (N_2O):

- *Laughing gas* & greenhouse gas
- 298 times higher GWP than CO_2, 60% of the total GHG emissions
- Residence time 114 years in the atmosphere
- Also precursor of stratospheric ozone depletion

***Factors affecting N_2O emissions*:**

- Energy source: Presence of easily available C sources
- Inorganic-N supply
- Soil pH: 6-8 optimum
- Anoxic conditions: ideally for denitrification
- Soil moisture: 55-65% WFPS: nitrification, 70-90% WFPS: denitrification
- Temperature

Introduction (contd.)

Sources of N_2O → Oceans (30%)

Sources of N_2O → Land (65%)

↓

Grazed Pastures (~90%)

- **Fertilizer N inputs** (1.25% as N_2O) (IPCC, 2001)
- **Livestock Excretions** (Urine/Faeces) (NZ=1%, MAFF)

NZ pastures are dominated by perennial clover-ryegrass systems and silage supplements

Rationale

To examine how plant litter of clover, ryegrass and maize (dried, ground and incorporated residues), affect N_2O emissions and decomposition at different moisture levels.

Hypotheses

- Readily decomposable plant material with a lower C: N ratio (e.g. clover) would have higher decomposition rates and higher N_2O fluxes;
- Higher soil moisture (86% WFPS) would accelerate litter decomposition and enhance the N_2O emissions.

Materials and methods

Collection of samples

Temuka silt loam soil (0-10 cm) → 4 mm sieved → Analysis

Herbage samples

Leaves of white clover, ryegrass & maize plucked → Dried@ 65^{o}C → Ground (<200 μm) → Stored & analyzed

Materials and methods (contd.)

Methodology

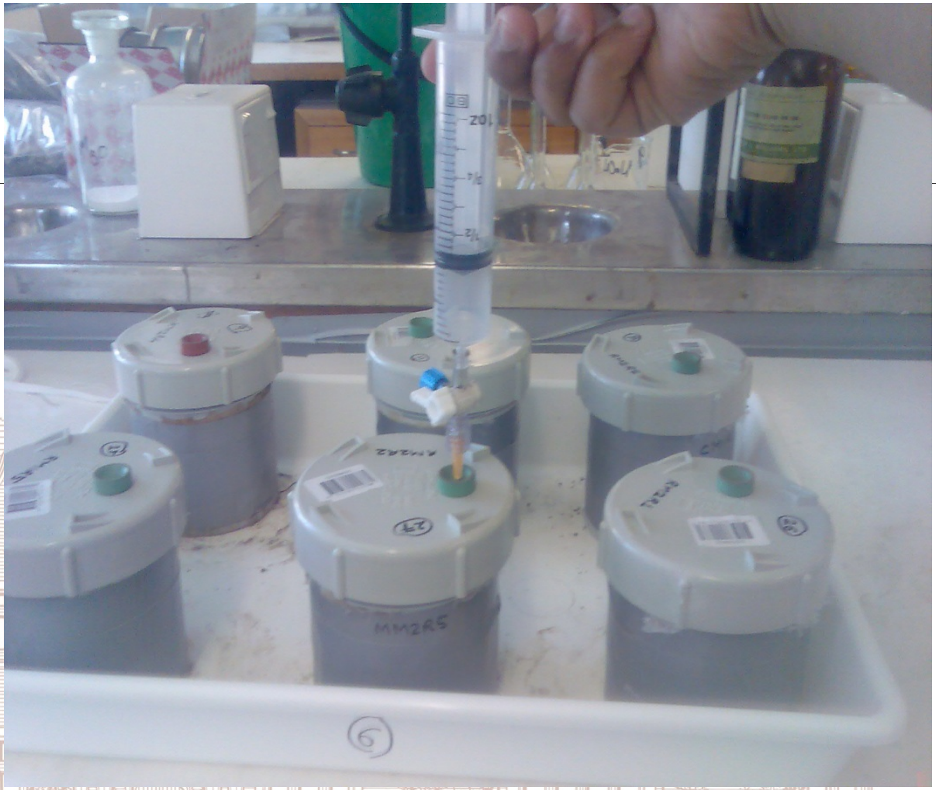
- Plant material = 5 g 165 g soil^{-1} (Kelliher et al. 2007) = 3% by mass
- Mixed with pre-weighed soil & again repacked into PVC containers.
- Deionised water: 54% (sub-field capacity) or 86% WFPS (FC) and maintained
- The treated soil cores were incubated at 20

Contrasting soil moisture level &
Soil moisture deficit during summer

Experimental design

- Factorial randomized block design
- Factor 1: Crop residue type: clover, ryegrass, maize and a control
- Factor 2: Moisture levels: 54% (sub-FC) & 86% WFPS (FC)
- Replicates: 5
- Total soil cores: 4 x 2 x 5 = 40

Materials and methods (contd.)



Closed chamber technique following GC analyses for N_2O/CO_2

Materials and methods (contd.)

Portable chamber with an infrared gas analyzer

Results and discussion

Table 1. Chemical properties of the plant species' litter incorporated into the soil

Plant material	Lignin	Hemi-cellulose	Cellulose	Total N	Total C	C: N ratio	Class[a]
	(g kg^{-1})						
Clover	23[b]	83	203	50	439	8.8	I
Ryegrass	19	153	400	34	418	12.3	I
Maize	19	215	449	20	409	20.6	II

[a]According to a decision support system for organic residues (Palm et al. 2001).
[b]Mean of 3 replicates.

Results and discussion (contd.)

92-95 % of the total emissions during first 2 d

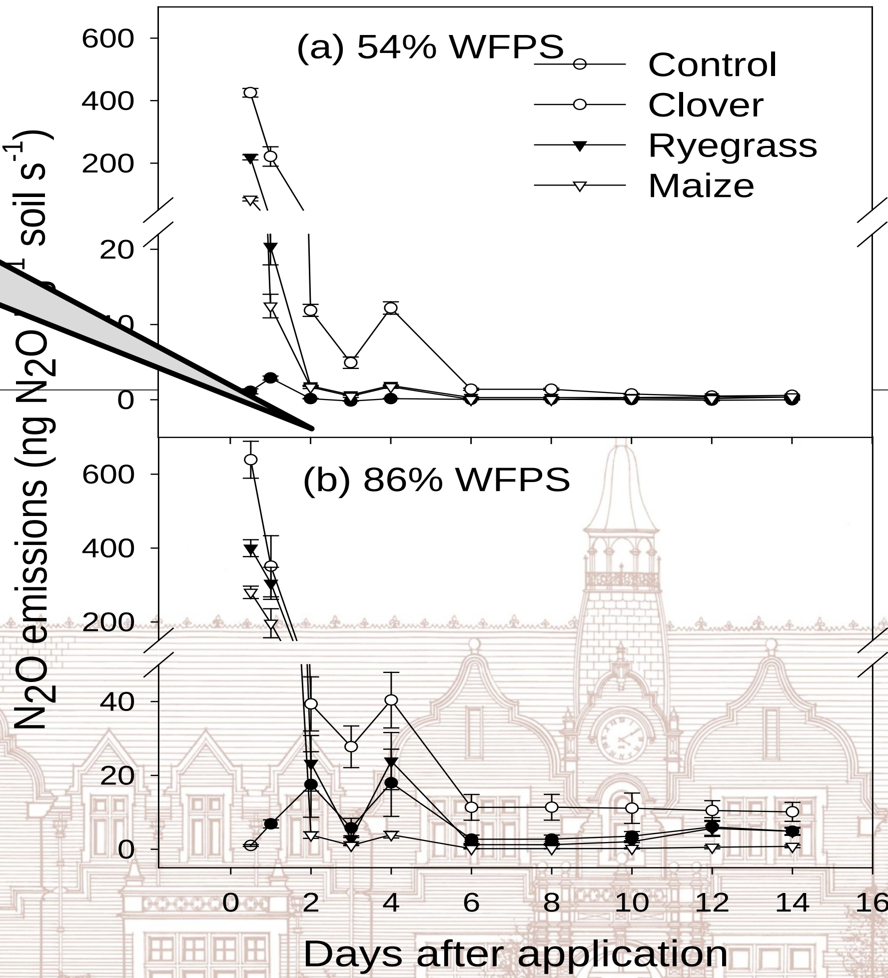
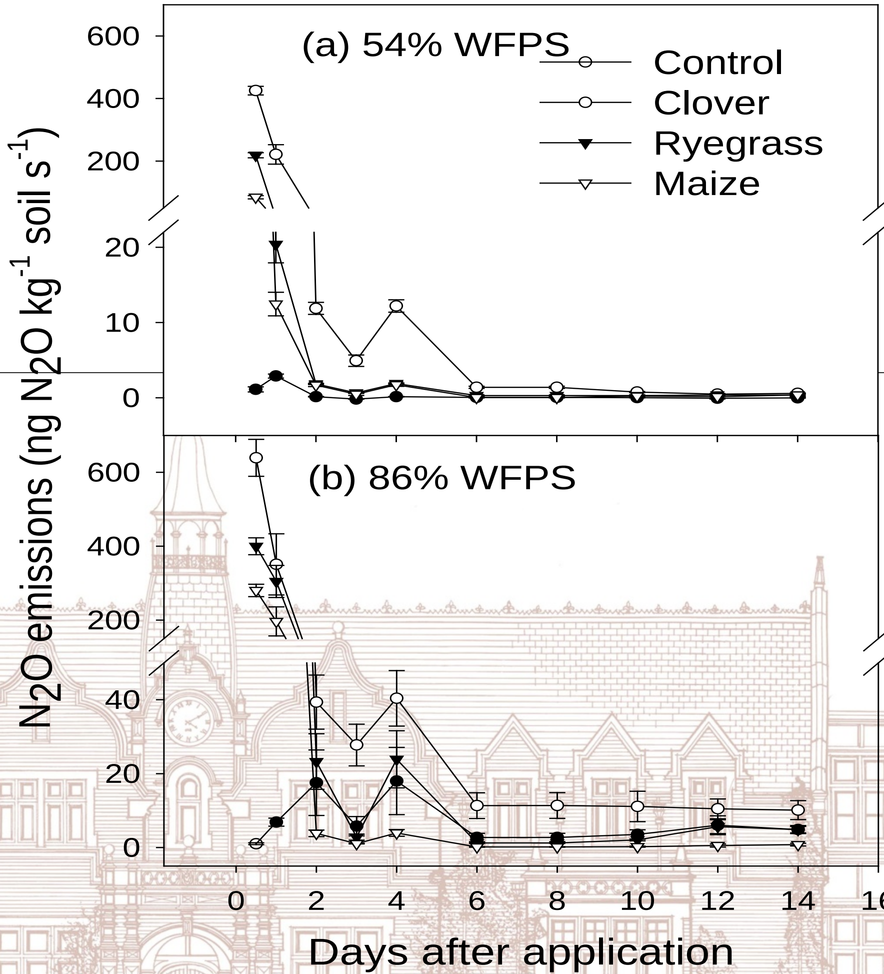


Fig. 1. Soil N_2O emissions at 54% and 86% WFPS during incubation at 20^oC. Data are means ± SE (*n* = 5)

Results and discussion (contd.)

- ❑ N mineralization from litter: dried/ground
- ❑ pre-existing reduction enzymes-activated: readily available C (and N)
- ❑ Litter addition: ↑O_2 consumption: ↑C avail (directly), ↑metabolism (indirectly): Anaerobic condi. ↑
- ❑ biochemical composition
- ❑ microbial biomass: 'switch'–SOM to labile



Results and discussion (contd.)

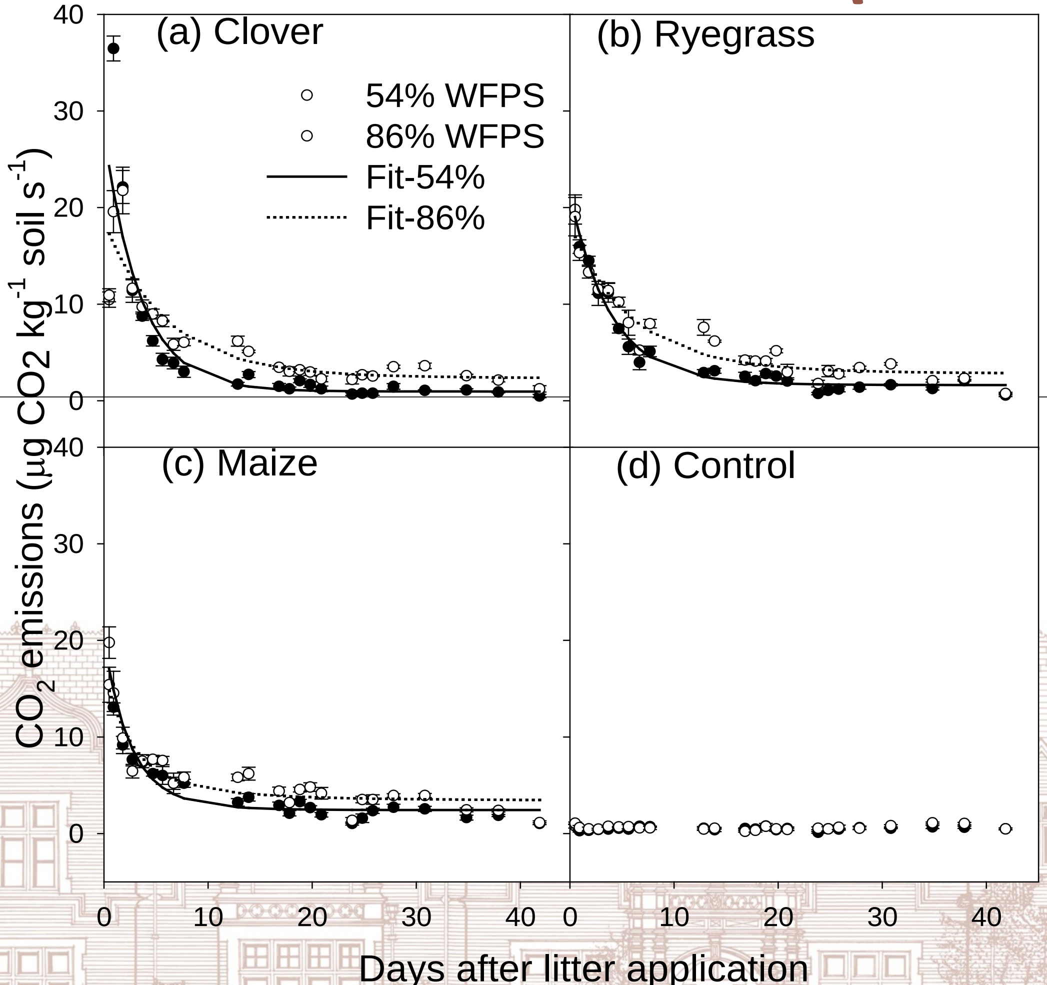
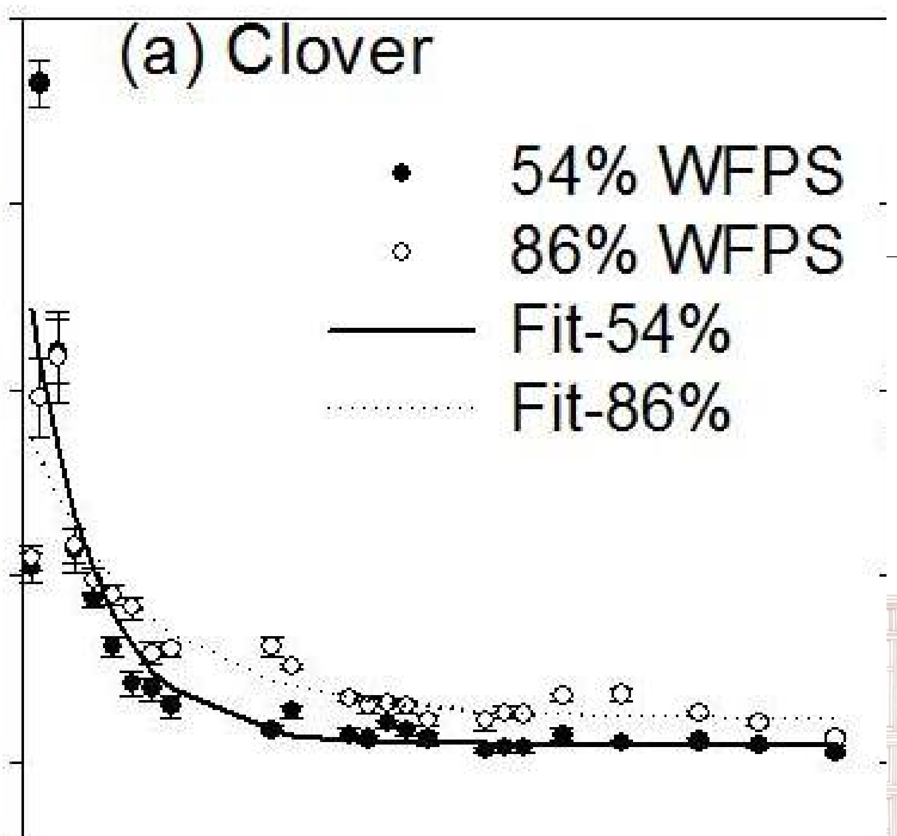


Fig. 2. Soil CO_2 emissions at 54% and 86% WFPS. Also shown is the time-response model, $F_{CO2}(t) = a + br^t$, where *a*, *b* and *r* are parameters fitted to the CO_2 emissions over time (*t*). Data are means ± SE (*n* = 5)

Results and discussion (contd.)

$$F_{CO2}(t) = a + br^t$$

- ‘Sequential degradation’
- ***r***: r-strategist activity: equal at 86% WFPS: uniform decomposition rate
- ***a*** – asymptote: C-priming effect: positive & uniform at 86% WFPS compared to controls
- ***b*** – scaling factor
- At 54% WFPS, parameter values were different



Results and discussion (contd.)

Table 2. Nitrous oxide emission factor (EF_{N2O}) at 54% and 86% WFPS, as a % of N applied, over 14 d after incorporation of plant litter into soil samples

Plant species	g N kg^{-1} soil	(%)	
		54% WFPS	**86% WFPS**
Clover	1.5	1.7^{a}	2.9^{d}
Ryegrass	1.0	0.7^{b}	3.1^{d}
Maize	0.6	0.5^{c}	2.3^{d}

Significant differences are indicated by different letters in the same column or row (P <0.05)

Results and discussion (contd.)

Table 3. Carbon dioxide emission factor (EF_{CO2}) at 54% and 86% WFPS, as a % of C applied, over 42 d after incorporation of plant litter into soil samples

Plant species	**g C kg^{-1} soil**	**(%)**	
		54% WFPS	**86% WFPS**
Clover	13.3	18.9^{b}	30.4^{c}
Ryegrass	12.7	21.9^{a}	34.0^{c}
Maize	12.4	22.7^{a}	30.7^{c}

Significant differences are indicated by different letters in the same column or row (P <0.05)

Conclusions

N_2O emissions:

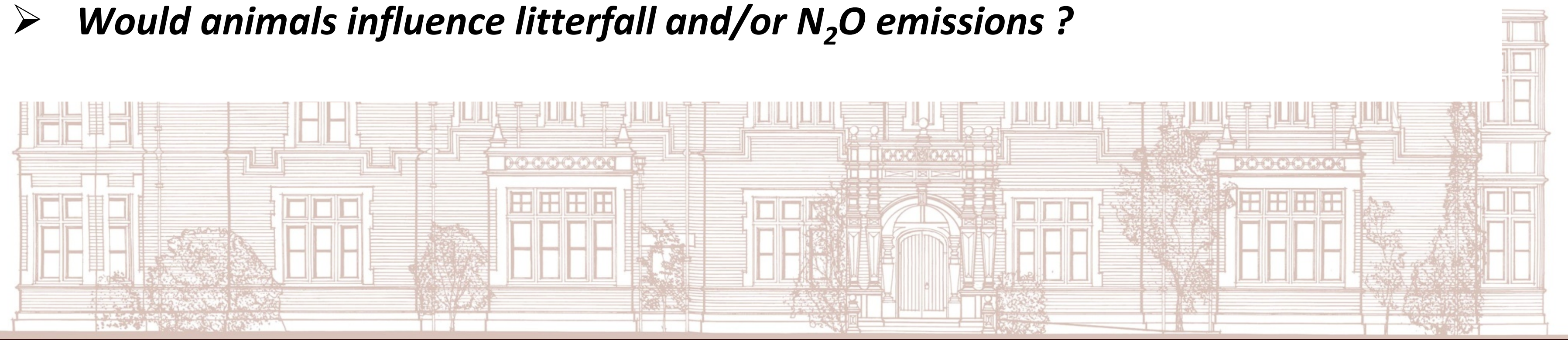
- Soil microbial community responded rapidly to litter.
- Maximum N_2O occurred at 0.5 d and virtually complete in 2 days.
- At 86% WFPS, EF_{N2O} was 2-3% of the applied N.
- Main reason for differences: Biochemical composition and C: N ratio.

CO_2 emissions:

- Higher CO_2 emissions at 86% WFPS
- EF_{CO2}: 32% at 86% WFPS and 21% at 54% WFPS
- Decomposition rates and the trend at 86% WFPS were similar

Future research

- ***Why did the clover treatment have higher N_2O emissions ?***
- ***How do these lab results translate to field conditions ?***
- ***Quantify the litterfall in field conditions ?***
- ***Would animals influence litterfall and/or N_2O emissions ?***



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Thank you!!!

Questions please