Measurement and modeling of denitrification in poorly drained soils of the lower coastal plain

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1. Objectives

- Provide field measurement references for soil budget modeling using DRAINMOD
- Calculate Denitrification constants and provide field measured values for Water Free Pore Space (WFPS) thresholds

2. Methods

- Collect undisturbed soil cores in agricultural and forested soils down to 1.50 m deep
- Four sites: Forested and agricultural; DRY (water table below 1.2 m) and WET (water table within 30 cm of the surface) ; 3 replicates at each site
- Monitoring N_2O accumulation in incubation chamber headspace (acetylene inhibition technique)

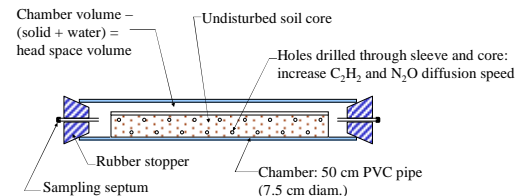## 3. Collection of undisturbed soil cores

- Probe truck with hydraulic pump for smooth soil core probing

- Undisturbed soil cores preserved in clear plastic sleeves before incubation

4. Soil cores incubations

- Acetylene inhibition technique
- Cores incubated at controlled temperature (on site T°C)
- Head space sampled at regular intervals for analysis using GC

5. Different types of N_2O accumulation in incubation chambers
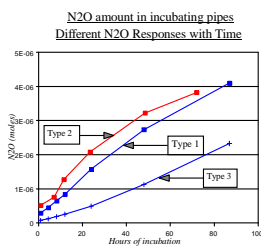
- Denitrification rates usually measured after 24 hours of incubation
- Data show that N_2O production can be non linear and may reveal limiting factors:
  - Diffusion of C_2H_2 in denitrifying sites 6 hours after injection
  - Nitrate and carbon depletion near denitrifying sites
- Denitrification rates taken as the maximum slope of the accumulation curves

6. Calculating denitrification rates

- Requires an accurate measurement of chamber head space: used a self made gas picnometer
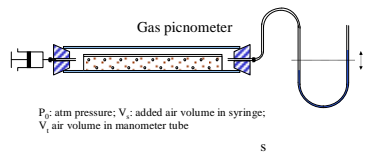
P_0: atm pressure; V_s: added air volume in syringe; V_t air volume in manometer tube

$$V = (P_0/h - 1) \times (V_s - h \times S/2) - V_t$$

- Evaluation of N_2O amounts in gas and liquid phase using Bunsen coefficients
- Final rates expressed in kg NO_3/ha/day/layer using soil bulk density, core diameter and dry weight

7. Denitrification rate results
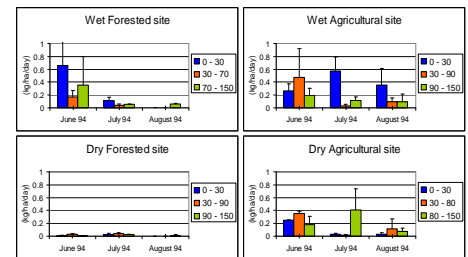
- Dry forest soil: very low rates
- Seasonal pattern for all sites: usually higher in June
- Surface horizon denitrifies most for wet sites
- Not negligible denitrification rates deep in the soil profile for agricultural sites
- Higher heterogeneity for wet sites than for dry ones

8. Denitrification modeling scheme used

- **Determination of denitrification rates**
  - Denitrification rate computed in Drainmod (Brevé et al. 1997):

$$\Gamma_{den} = k_{den} \times e_m(i) \times e_t(i) \times [NO_3^-]$$

  - where K_{den} denitrification constant, e_t temperature factor

$$e_m = \left[\frac{\theta - \theta_d}{\theta_s - \theta_d}\right]^2$$

θ soil water content
θ_s saturated water content
θ_d Threshold water content

Site		K_{den}	extreme bounds	θ_d
Wet Forested site	Layer 1	2.33 [0.2 - 5.1]	[0.23 - 16.4]	0.81
	Layer 2	0.55 [0.03 - 1.07]	[0.02 - 2.12]	0.6
	Layer 3	0.5	-	0.39
Dry Forested site	Layer 1	0.38		0.68
	Layer 2	0.17 [0.07 - 0.34]	[0.06 - 0.61]	0.4
	Layer 3	0.06 [0.01 - 0.07]	[0.01 - 0.08]	0.39
Wet Agricultural site	Layer 1	3.75 [0.14 - 15.5]	[0.09 - 352]	0.47
	Layer 2	1.87 [0.49 - 1.87]	[0.39 - 6.93]	0.37
	Layer 3	0.14 [0.01 - 0.19]	[0.007 - 0.4]	0.41
Dry Agricultural site	Layer 1	7.10^{-8} [1.10^{-3} - $1.74.10^{-1}$]	[0 - $2.39.10^{-2}$]	0.53
	Layer 2	$1.44.10^{-2}$ [$6.4.10^{-4}$ - $2.46.10^{-3}$]	[5.10^{-4} - $4.7.10^{-1}$]	0.5
	Layer 3	0.19 [0.01 - 0.62]	[$6.9.10^{-3}$ - $6.3.10^{-1}$]	0.43

9. Determination of moisture threshold values θ_d
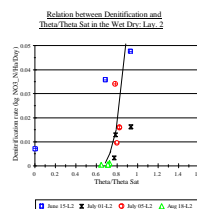
- Graphical determination of the threshold point
- Example in figure corresponds to layer 2 of dry forested site
- Relatively high values compared to the literature

Site	Wet Forested site	Dry Forested site	Wet Agricultural site	Dry Agricultural site
Layer 1	0.8	0.6	0.6	0.4
Layer 2	0.85	0.7	0.75	0.7
Layer 3	0.8(?)	0.7	0.8	0.8

10. Conclusions

- Incubation method used to measure denitrification rates revealed unreported kinetics
- Reported rate values may thus be often underestimated
- Obvious seasonal pattern of denitrification
- Higher denitrification in agricultural soils than in forested ones
  - Nitrate concentration in soils may be the main factor
- Sizable denitrification down to 1.5 m under the soil surface

- Denitrification constant and threshold values estimated but with large range of values
- Punctual field measurements:
  - Large spatial heterogeneity
  - What do they really represent?
  - pertinent as a support for conceptual and calibration factors in modeling?