Denitrification in an Agro-ecosystem

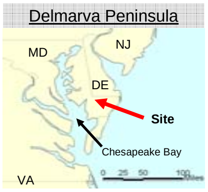
Michael Castellano[1], Charles Walker[1], John Schmidt[2], Jason Kaye[1], Curtis Dell[2], Henry Lin[1]

[1]The Pennsylvania State University, University Park, PA 16802 [2]USDA-ARS, University Park, PA 16802

Objective

To determine how different landscape positions along a hydrological gradient contribute to nitrogen transport & transformation during rapid, extreme water table fluctuations characteristic of an Atlantic Coastal Plain system.

Setting and Introduction

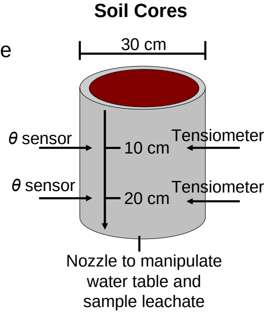


- Much of US agricultural production in the Midwest and the Atlantic Coastal Plain is dependent upon drainage systems.
- Artificial drainage systems transport excess water from agricultural soils; however, they can also transport harmful levels of biologically available nitrogen to open waters.

- On the Delmarva Peninsula, excess water is drained through croplands to man-made ditches and natural rivers ultimately reaching the eutrophication-prone Chesapeake Bay.
- Thus, these ditches have the potential to rapidly transport nutrient-rich agricultural drainage to surface waters.

Methods

- Large (30 x 30 cm), intact soil cores from each of 3 landscape locations were collected (n=4; see below).
- The water table was raised to the soil surface and then dropped within a period of 12h.
- N_2O & CO_2 emissions were measured; leachate was sampled for future analysis.
- Soil moisture and matric potential were measured at 10 cm and 20 cm below the surface.



Soil Cores

30 cm

θ sensor

10 cm

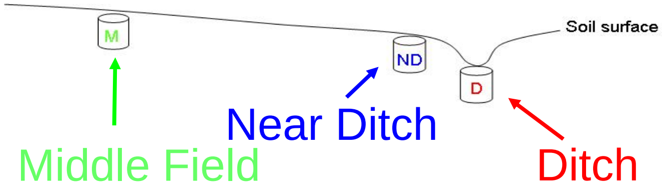
Tensiometer

θ sensor

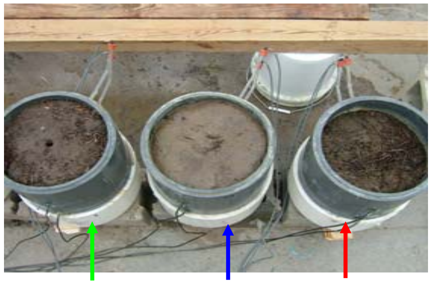
20 cm

Tensiometer

Nozzle to manipulate water table and sample leachate



Experimental Design

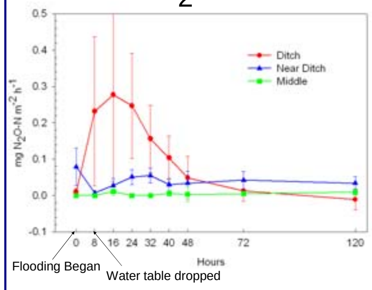


Left Photo: One soil core from each landscape position; tensiometers and volumetric moisture probes are inserted into the cores to measure matric potential and percent soil moisture.

Right Photo: gas flux measurements being made with a photoacoustic gas analyzer.

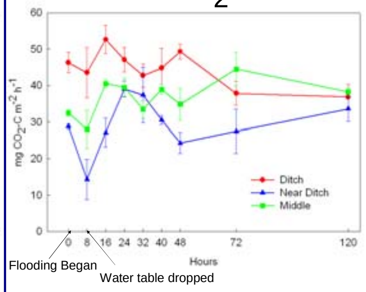
Results

N_2O



- Approximately 48 hours after flooding began, all landscape locations converged upon similar N_2O emissions.
- Prior to convergence, D soils consistently emitted more N_2O than ND or M soils.
- Although not significantly different, during the 48 hours prior to convergence, the D soils emitted 8.22 mg N_2O-N m^{-2} whereas the ND and M soils only emitted 1.82 mg N_2O-N m^{-2} and 0.15 mg N_2O-N m^{-2}, respectively.

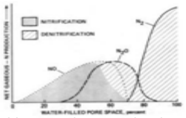
CO_2



- Approximately 120 hours after flooding began, all landscape locations converged upon similar CO_2 emissions.
- During the 120 hours prior to convergence, the D soils emitted significantly more CO_2 (5975.80 mg CO_2-C m^{-2}) than ND soils (4147.79 mg CO_2-C m^{-2}). The M soils' emissions (5720.63 mg CO_2-C m^{-2}) were between D and ND.

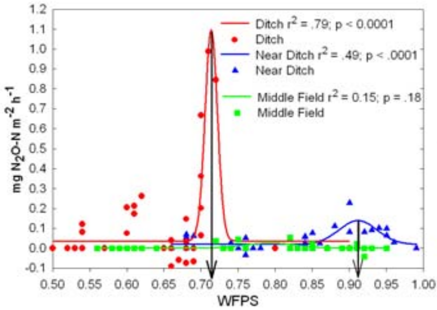
Denitrification

- Davidson *et al.* (2000) proposed the following relationship between gaseous N emissions and water filled pore space (WFPS), suggesting that denitrification is a function of WFPS and biologically available N.

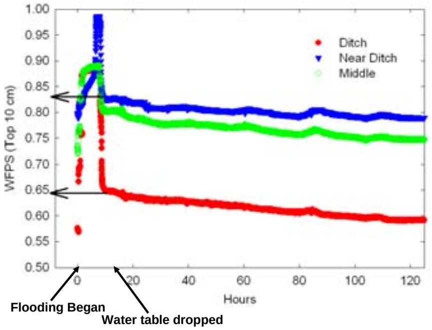


Davidson *et al.* 2000, Bioscience

- *We empirically evaluated the relationship by regressing N_2O emissions against Water Filled Pore Space (WFPS).*



- **D and ND N_2O emission data significantly fit a Gaussian distribution, supporting Davidson *et al.*'s model.**
- **M data did not significantly differ from zero, suggesting low biologically available soil N.**

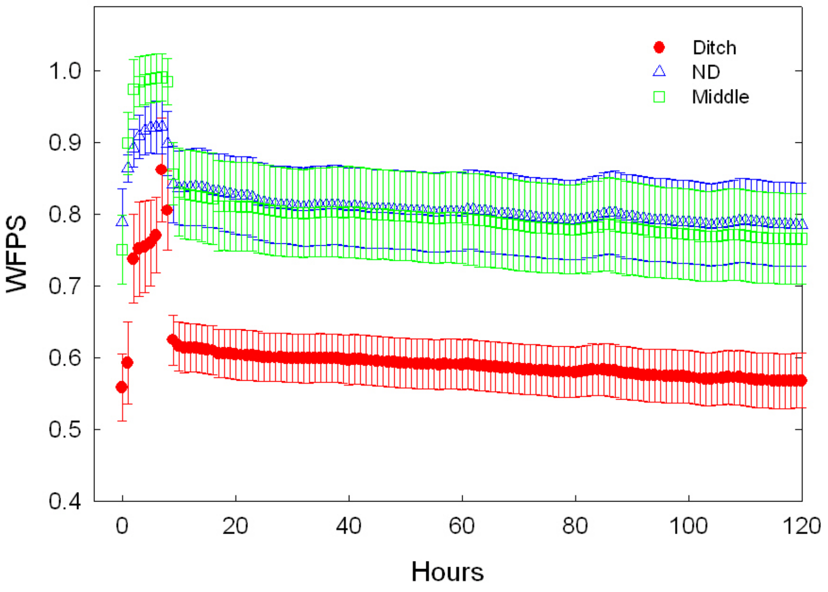


- **Peak N_2O emissions occurred when WFPS was 7-9% above field capacity in both D and ND soils** (see arrows on graphs for peak N_2O emissions and WFPS at field capacity).

- **WFPS at 10 cm is a better predictor of N_2O emissions than WFPS at 20 cm or their mean (see printout).**
- **D soils' relatively low variation in CO_2 or WFPS (see printout) suggests that high variation in D N_2O emissions is due to variability in biologically available N rather than variability in dissolved organic carbon or WFPS.**
- **Our data suggest that management practices promoting D soil water retention above 75% WFPS could increase complete denitrification of nitrate to N_2.**

Acknowledgements

This work was funded by the USDA National Needs Fellowship Program #2005-38420-15774 and the USDA-ARS-PSWMRU, University Park, PA.



- Mean hourly Water Filled Pore Space n = 4 with standard error.
- Note Ditch soils have lowest error/ variance in WFPS.

Gaussian Regression: $y = y_o + ae^{[-0.5((x-x_o)/b)^2]}$

	10 cm WFPS	20 cm WFPS	Mean WFPS
Ditch	***$r^2 = 0.79$; $p < 0.0001$***	***$r^2 = 0.43$; $p = 0.0004$***	**$r^2 = 0.09$; $p = 0.44$**
Near Ditch	***$r^2 = 0.49$; $p < 0.0001$***	**$r^2 = 0.06$; $p = 0.55$**	***$r^2 = 0.44$; $p = 0.003$***
Middle	**$r^2 = 0.15$; $p = 0.18$**	**$r^2 = 0.18$; $p = 0.19$**	**$r^2 = 0.16$; $p = 0.13$**

- Table providing data for WFPS-N_2O regression figure on poster.
- Note 10 cm WFPS is the best predictor of N_2O emissions in both locations that emitted N_2O.
- M soils N_2O emissions did not significantly differ from zero