Pollution Swapping of N_2O and CH_4 Emissions with Dissolved Nitrogen and Phosphorus Export in Drainage Water Managed Agricultural Fields

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Abstract

Excess nutrient loading to downstream waters has been a persistent environmental concern, especially in agricultural settings. Drainage water management (DWM) is a best management practice intended to reduce nitrogen export from fertilized lands by increasing groundwater levels, slowing the loss of nutrient-rich water and increasing its time in contact with the soil, thus creating greater opportunity for denitrification. This BMP has shown to be effective at reducing dissolved nitrate (TDN) export, but a question remains about potential unintended pollution swapping. The concern is that denitrification could result in nitrous oxide (N2O) emissions and that higher soil moisture could also create suitable conditions for methanogenesis and methane (CH4) emissions. Here we report on two years of monthly static soil gas chamber fluxes and hydrologic nutrient fluxes during a full corn/soybean rotation cycle on the Eastern Shore of Maryland. For N2O, there were significant interactions between season, crop type, and treatment, such as higher fluxes during the fertilization period in the corn year in the DWM treatment, which was consistent with our concern about pollution swapping. However, this brief additional pulse of N2O did not result in a statistically significant increase at an annual scale, nor was there an increase in annual CH4 emissions. At the same time, annual TDN load was significantly lower in the DWM ditches compared to the control. With no significant treatment effect on soil gas fluxes and a significant treatment effect on TDN export, we conclude that pollution swapping of nitrate reduction for greenhouse gases did not occur significantly in this application of DWM to a corn/soybean system. We did, however, find evidence of pollution swapping of phosphorus and nitrogen, as total phosphorus load was higher in the DWM. With more water in the field, the reduced conditions appear to cause a release of soil bound phosphorus. While greenhouse gas production may not be as much of a concern, increased phosphorus export represents a form of pollution swapping that must be accounted for in determining the value of this BMP.

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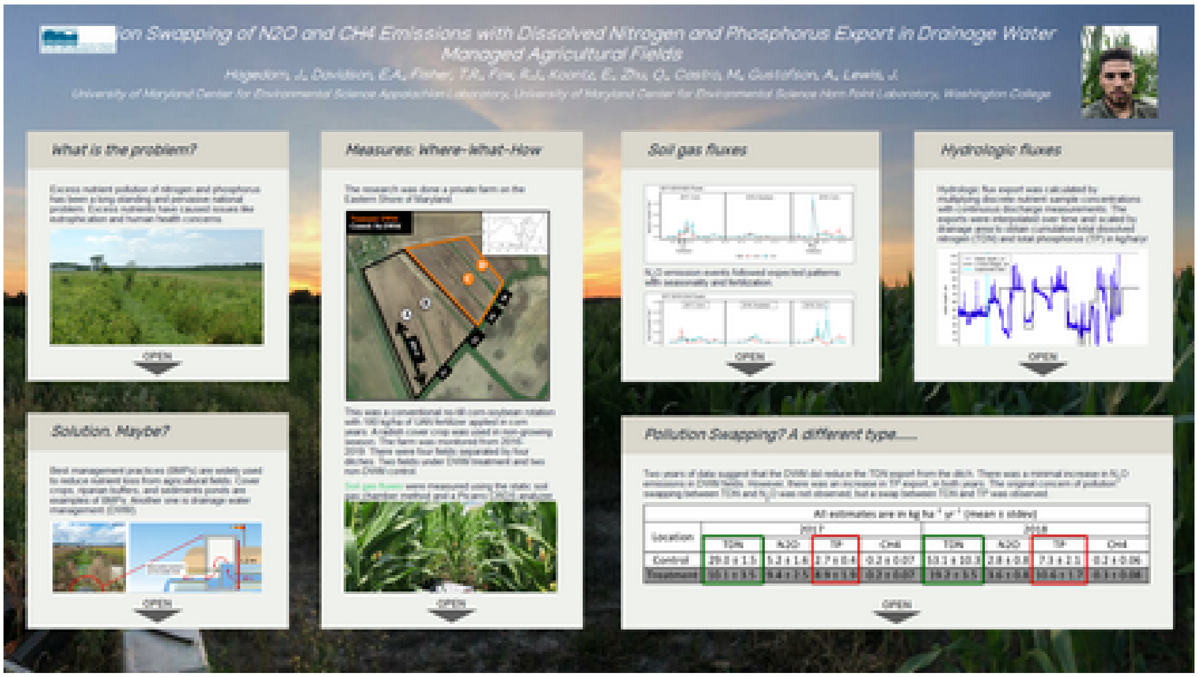

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PRESENTED AT:

WHAT IS THE PROBLEM?

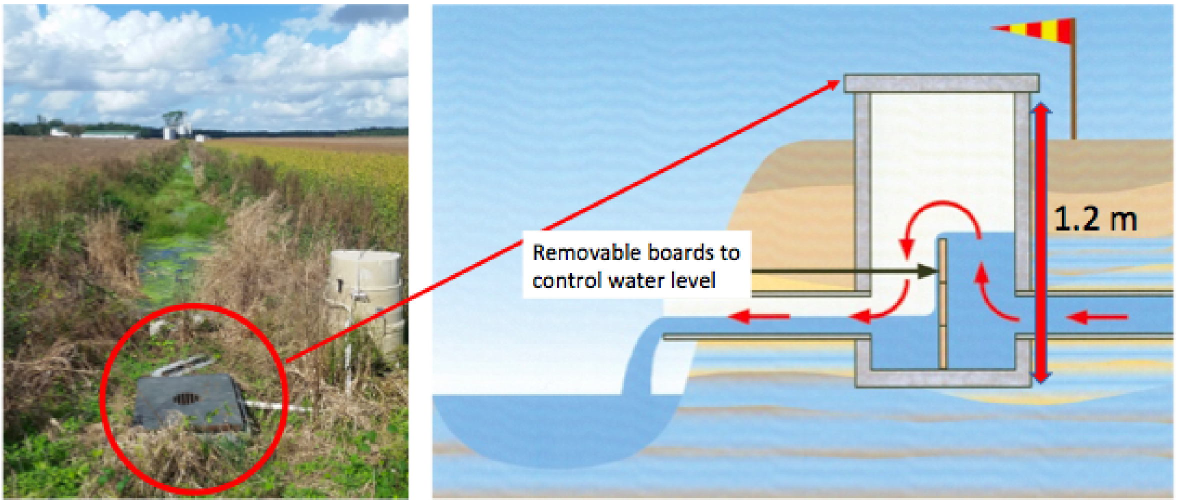
Excess nutrient pollution of nitrogen and phosphorus has been a long-standing and pervasive national problem. Excess nutrients have caused issues like eutrophication and human health concerns.

Agricultural activities comprise a large proportion of these excess nutrients through fertilizer input into waterways.


HAGIE

SOLUTION. MAYBE?

Best management practices (BMPs) are widely used to reduce nutrient loss from agricultural fields. Cover crops, riparian buffers, and sediments ponds are examples of BMPs. Another one is drainage water management (DWM).

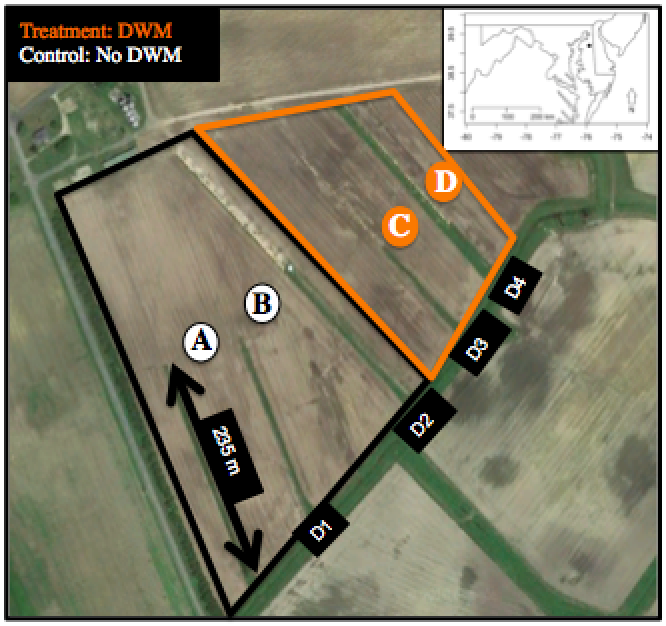


Drainage water management uses engineered boards to slow drainage from surface ditches. This creates more anaerobic denitrifying conditions in the fields that can reduce total dissolved nitrogen (TDN) concentrations.

But, denitrification can also produce a greenhouse gas, nitrous oxide (N_2O). With the potential of reducing nitrogen export from fields but also increasing greenhouse gas emissions, could this BMP trade one form of pollution for another? Also, do higher moisture conditions increase methane (CH_4) emissions?

MEASURES: WHERE-WHAT-HOW

The research was done a private farm on the Eastern Shore of Maryland.



This was a conventional no-till corn-soybean rotation with 180 kg/ha of UAN fertilizer applied in corn years. A radish cover crop was used in non-growing season. The farm was monitored from 2016-2019. There were four fields separated by four ditches. Two fields under DWM treatment and two non-DWM control.

Soil gas fluxes were measured using the static soil gas chamber method and a Picarro CRDS analyzer.

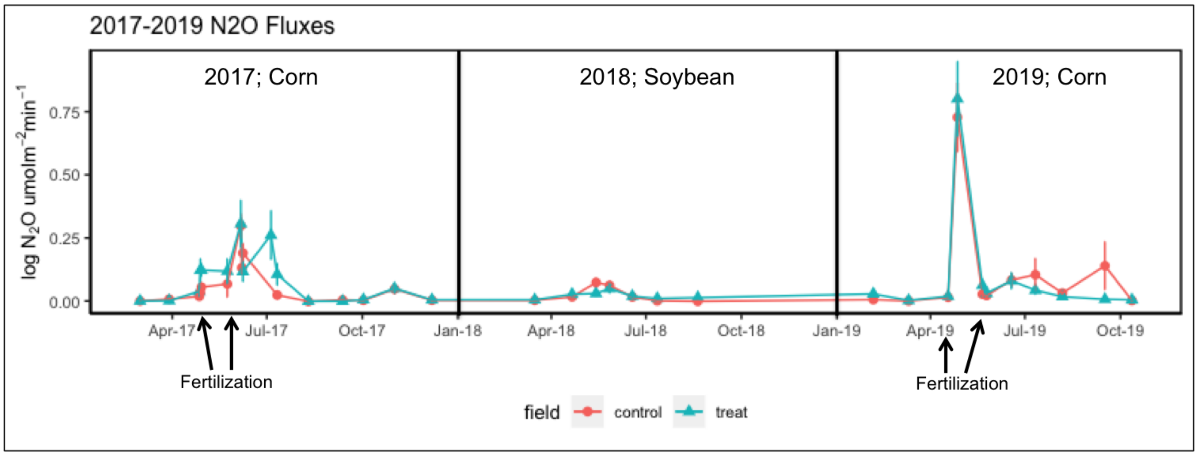
Soil temperature, nitrate content, and moisture were measured at each chamber location. There were 8 chamber locations per field, placed equidistant perpendicular to the drainage ditch. The chambers were measured 1-2 times per month, focusing around farm management events.

Hydrologic fluxes were measured using a v-notch weir placed in the drainage control structures at the end of each drainage ditch.

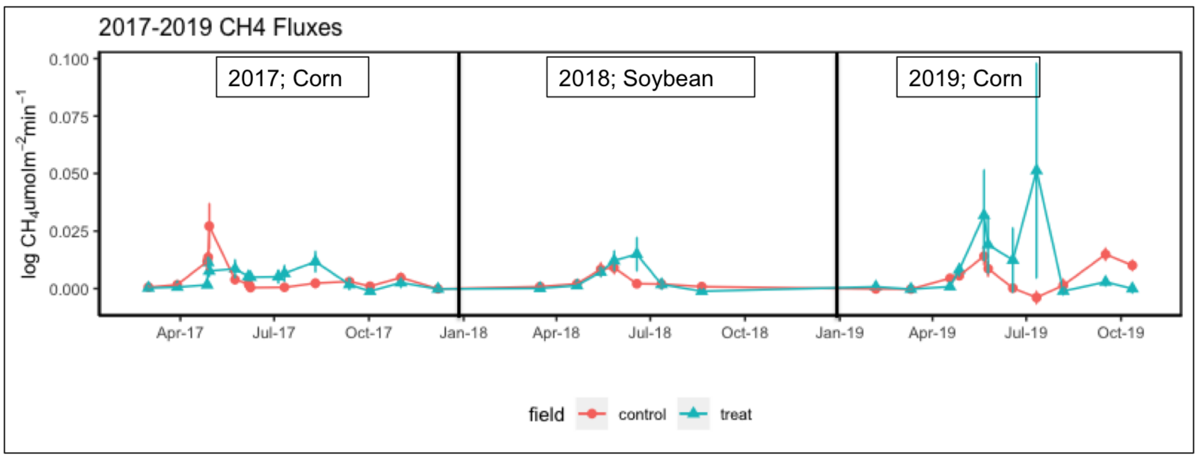
Continuous waterlevel was measured and baseflow water samples were collected once a month. Storm water samples were collected via ISCO sampler 4-5 times per year.

Water samples were analyzed for total dissolved nitrogen (TDN), total phosphorus (TP), and nitrate.

SOIL GAS FLUXES



N_2O emission events followed expected patterns with seasonality and fertilization.



CH_4 emission events were small and variable with some spikes in 2019.

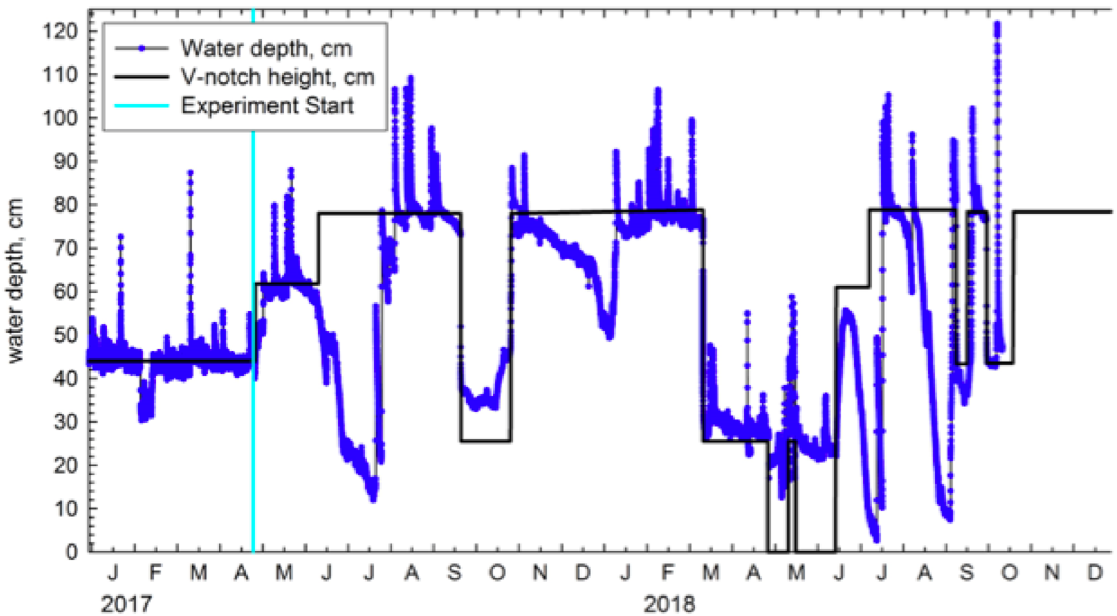
A multi-level model with a likelihood ratio test indicated that there was a treatment effect during the 2017 corn post-fertilization period but not cumulatively. CH_4 emissions showed treatment differences in two years in the summer period but no cumulative treatment difference.

Variable or Interaction	CH4	N2O
Treatment	NS	NS
Period	***	***
Year	NS	*
Treat x Year	NS	NS
Treat x Period	***	NS
Treat x Period x Year	***	***
NS= not significant , *(p<0.05), **(p<0.01), ***(p<0.001)		

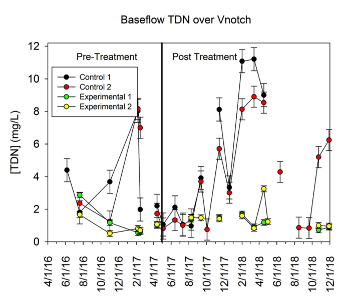
Based on these data, gas fluxes were interpolated across time and space to produce annual estimates in units of N_2O-N kg/ha/yr.

HYDROLOGIC FLUXES

Hydrologic flux export was calculated by multiplying discrete nutrient sample concentrations with continuous discharge measurements. The exports were interpolated over time and scaled by drainage area to obtain cumulative total dissolved nitrogen (TDN) and total phosphorus (TP) in kg/ha/yr



Water depth/Discharge (L/yr) X Concentration (mg/L)



POLLUTION SWAPPING? A DIFFERENT TYPE......

Two years of data suggest that the DWM did reduce the TDN export from the ditch. There was a minimal increase in N_2O emissions in DWM fields. However, there was an increase in TP export, in both years. The original concern of pollution swapping between TDN and N_2O was not observed, but a swap between TDN and TP was observed.

All estimates are in kg ha^{-1} yr^{-1} (mean ± stdev)								
Location	2017				2018			
	TDN	N2O	TP	CH4	TDN	N2O	TP	CH4
Control	29.0 ± 1.5	5.2 ± 1.6	2.7 ± 0.4	0.2 ± 0.07	53.1 ± 10.3	2.8 ± 0.8	7.3 ± 2.1	0.2 ± 0.06
Treatment	10.1 ± 3.5	9.4 ± 2.5	8.9 ± 1.9	0.2 ± 0.07	19.2 ± 3.5	3.6 ± 0.8	10.6 ± 1.7	0.3 ± 0.08

Green = decrease in nutrient, Red= increase in nutrient

This finding seems reasonable because in a phosphorus fertilzed soil reducing conditions could free bound ferric phosphate into ferrous iron and soluble phosphate, increasing TP export. Future work should include simultaneaously implementing a phosphorus reducing BMP like slag boxes or aragnoite bags along with drainage water managment.

Go see a talk about continuous tower flux data collected from this site!

Poster #2471: A comparison between the tower-based gradient method and the automated chamber method for measuring N2O fluxes from an agricultural field. Qiurui Zhu. Thurs morning.

Acknowledgments: USDA-NIFA, Maryland Sea Grant, UMCES, Picarro

ABSTRACT

Excess nutrient loading to downstream waters has been a persistent environmental concern, especially in agricultural settings. Drainage water management (DWM) is a best management practice intended to reduce nitrogen export from fertilized lands by increasing groundwater levels, slowing the loss of nutrient-rich water and increasing its time in contact with the soil, thus creating greater opportunity for denitrification. This BMP has shown to be effective at reducing dissolved nitrate (TDN) export, but a question remains about potential unintended pollution swapping. The concern is that denitrification could result in nitrous oxide (N2O) emissions and that higher soil moisture could also create suitable conditions for methanogenesis and methane (CH4) emissions. Here we report on two years of monthly static soil gas chamber fluxes and hydrologic nutrient fluxes during a full corn/soybean rotation cycle on the Eastern Shore of Maryland. For N2O, there were significant interactions between season, crop type, and treatment, such as higher fluxes during the fertilization period in the corn year in the DWM treatment, which was consistent with our concern about pollution swapping. However, this brief additional pulse of N2O did not result in a statistically significant increase at an annual scale, nor was there an increase in annual CH4 emissions. At the same time, annual TDN load was significantly lower in the DWM ditches compared to the control. With no significant treatment effect on soil gas fluxes and a significant treatment effect on TDN export, we conclude that pollution swapping of nitrate reduction for greenhouse gases did not occur significantly in this application of DWM to a corn/soybean system. We did, however, find evidence of pollution swapping of phosphorus and nitrogen, as total phosphorus load was higher in the DWM. With more water in the field, the reduced conditions appear to cause a release of soil bound phosphorus. While greenhouse gas production may not be as much of a concern, increased phosphorus export represents a form of pollution swapping that must be accounted for in determining the value of this BMP.