The Impacts of Hydrology and Soil Nitrate Concentrations on Potential Denitrification in Agricultural Ditch Sediments

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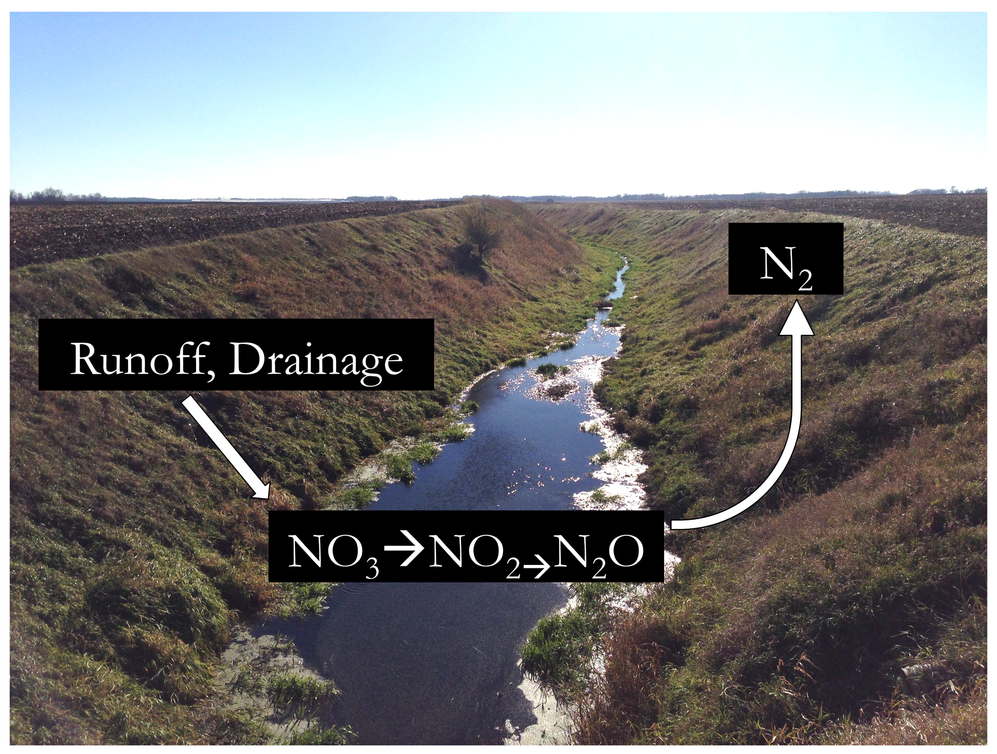
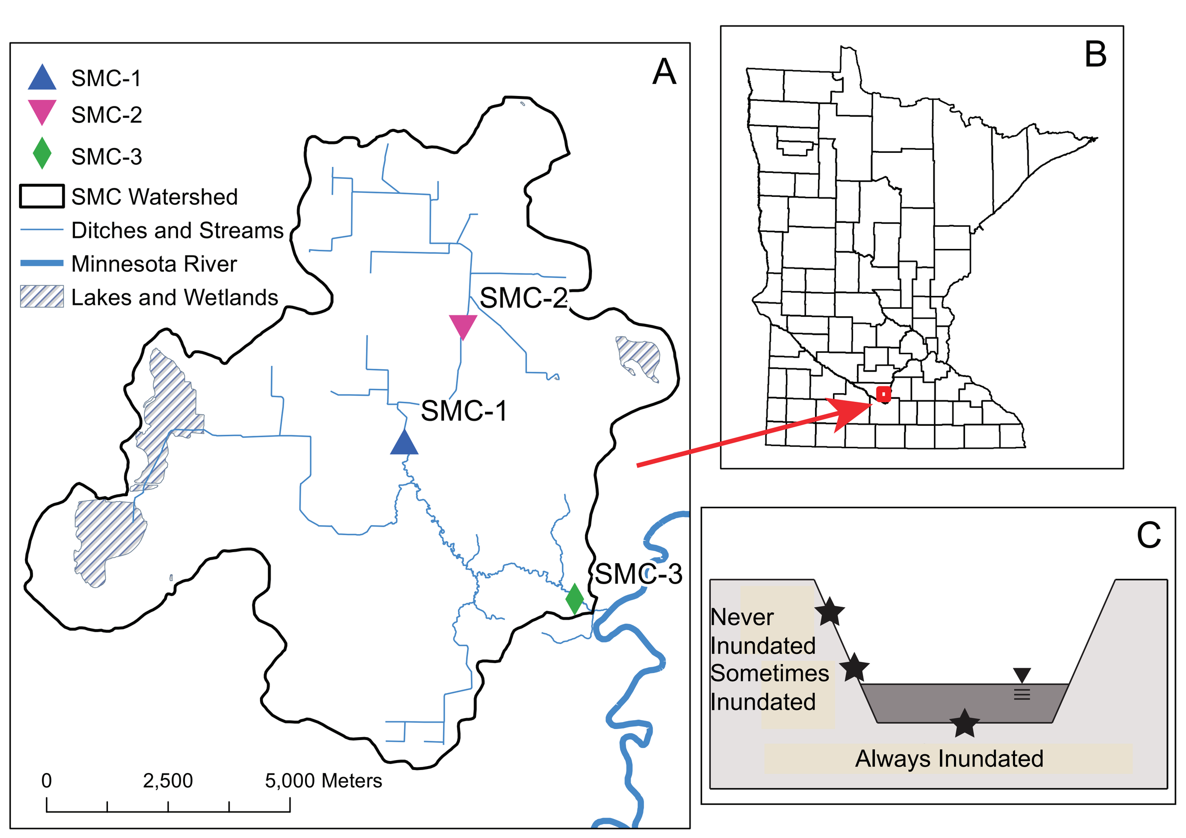
Motivation

Agricultural nitrogen runoff is a contributing factor to both eutrophication and drinking water contamination in the United States. This study examined relationships between nitrate concentrations and denitrification rates in agricultural ditch sediments. Denitrification is a microbial process that converts nitrate to nitrogen gas, often anaerobically. To protect water resources and engineer systems for maximum nitrogen removal, this work investigated the influence of sediment nitrate concentrations and stream water nitrate concentrations on denitrification rates in a Minnesota watershed.



Simplified nitrogen cycle in agricultural ditch

Site: Seven Mile Creek



Sediment samples were collected monthly from three geographical sites within the heavily agricultural Seven Mile Creek watershed in 2015. Two of the sites, SMC-1 and SMC-2 were located within agricultural ditches. The final site, SMC-3, is a trout stream located in a county park downstream of the agricultural ditches. At each site, samples were taken from the channel (always inundated zone). At the ditch sites, additional samples were taken from a zone which was never inundated by stream water and from a zone which was occasionally inundated by stream water to examine the impact of fluctuating water levels on denitrification processes.

Methodology

Sample Collection

1. Triplicate samples of sediment (top 5 cm) and stream water
2. Samples were homogenized

Soil Nitrate Analysis

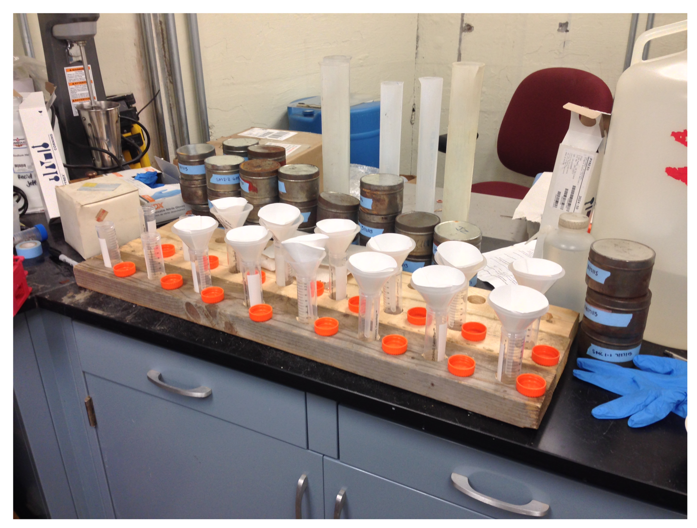
1. Oven dried sediment samples were ground and sieved
2. Sediment and deionized water were mixed and shaken
3. Samples were centrifuged
4. Liquid was filtered though Whatman 2 filter paper and glass fiber filter paper; refrigerated until analysis
5. Samples were analyzed with a QuickChem auto-analyzer using the cadmium reduction method

Stream Water Nitrate Analysis

1. Filtered water samples through glass fiber filter paper
2. Analyzed with QuickChem auto-analyzer cadmium reduction

Denitrification Rates: Denitrifying Enzyme Assay (DEA)

1. Sediment and site specific water were combined
2. Containers were sealed and flushed with helium gas
3. Acetylene was added to stop denitrification at N_2O
4. Initial N_2O concentration was measured
5. Samples were incubated for 3-4 hours before final N_2O concentration was measured
6. Analyzed N_2O concentrations on a gas chromatograph

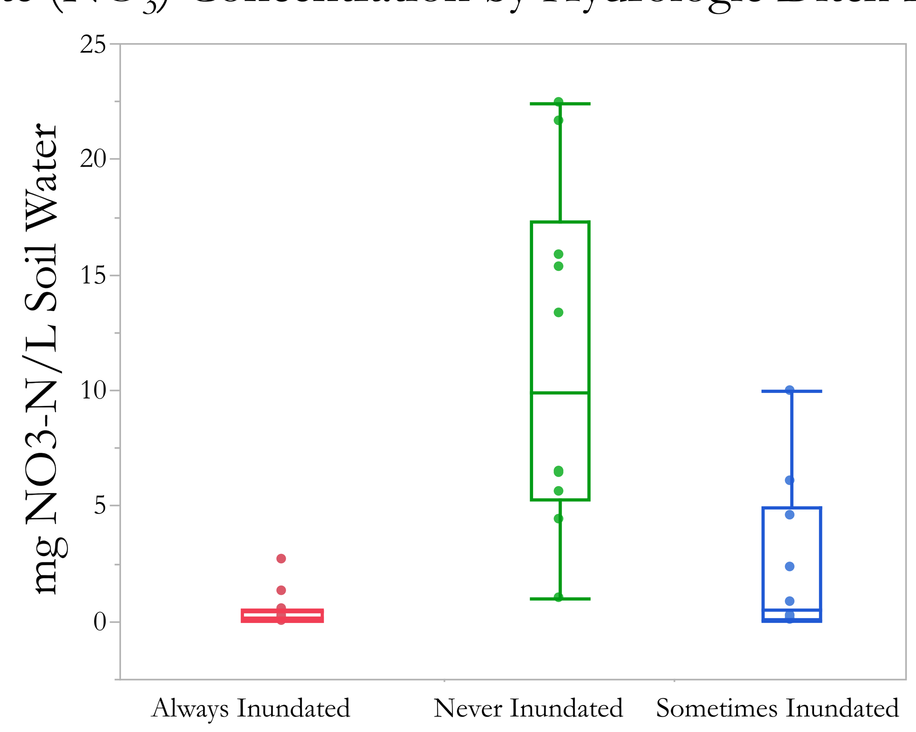


Sediment filtration setup

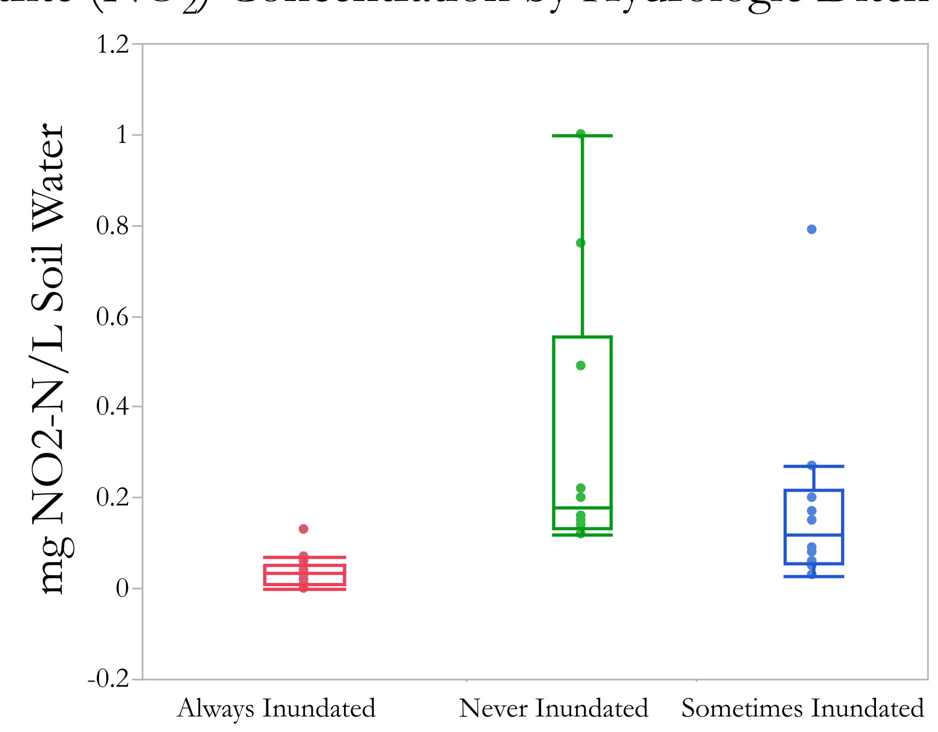
Agricultural ditch in SMC

Sediment Nitrogen and Hydrologic Location

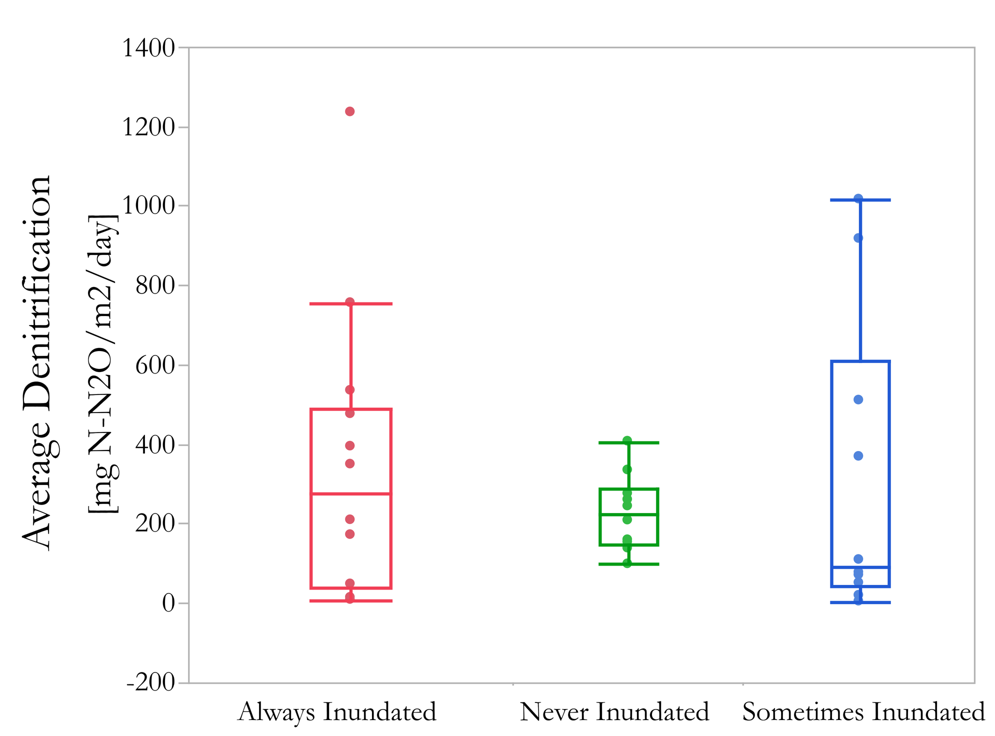
Nitrate (NO_3) Concentration by Hydrologic Ditch Zone



Nitrite (NO_2) Concentration by Hydrologic Ditch Zone



Denitrification Rates by Hydrologic Ditch Zone



All statistical tests were performed at alpha=0.05.

Sediment Nitrate Concentrations: Sediment samples from Always Inundated and Never Inundated, as well as Sometimes Inundated and Never Inundated show significant differences in nitrate concentrations

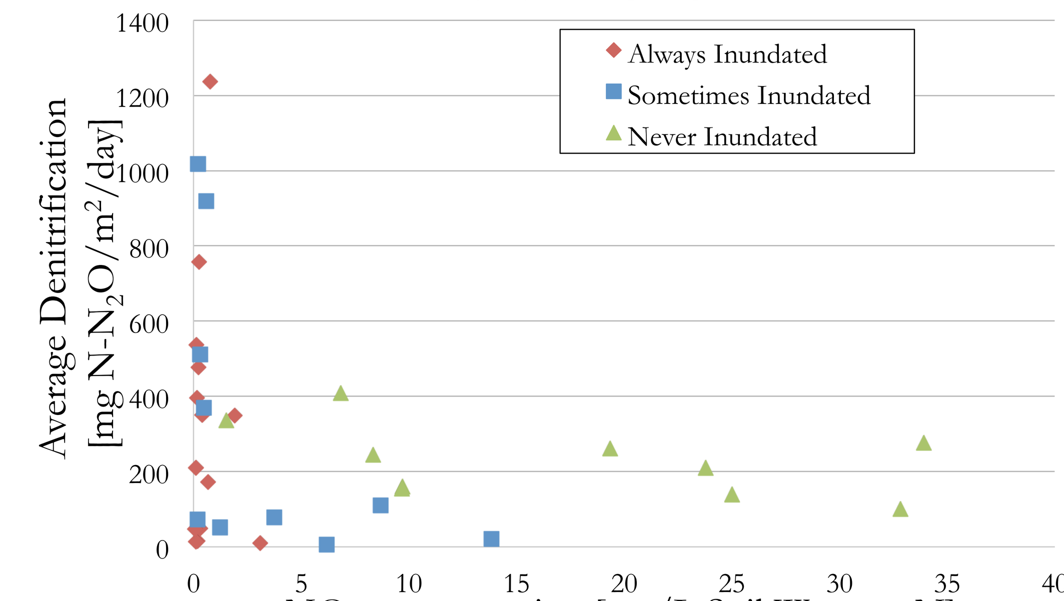
Sediment Nitrite Concentrations: Sediment Samples from Always Inundated and Never Inundated, as well as Always Inundated and Sometimes Inundated show significant differences in nitrite concentrations

Denitrification Rates: No significant differences in denitrification rates were present when hydrologic ditch zones were considered

Denitrification Rate Trends

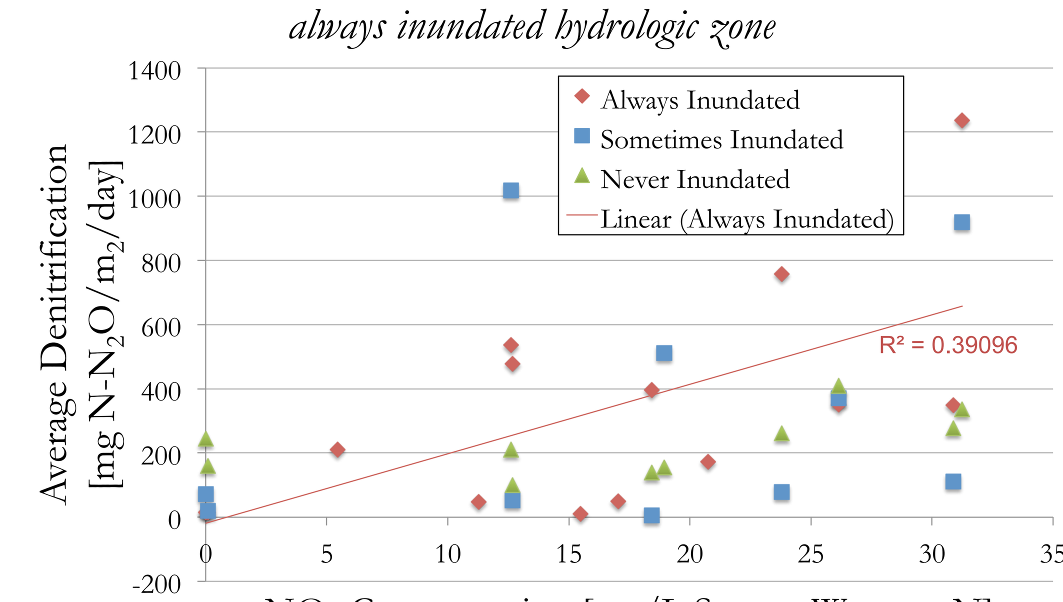
Denitrification Rate versus Nitrate Concentration in Soil Water

No significant correlation between soil water nitrate and denitrification rates in any hydrologic zone



Denitrification Rate versus Nitrate Concentration in Stream

Significant correlation between nitrate concentration and denitrification rates in always inundated hydrologic zone



Conclusion

Soil nitrate does not appear to be the primary variable that drives potential denitrification rates in agricultural ditch environments. The following observations were made:

- Sediment nitrate and nitrite concentrations varied by hydrologic ditch zone
- Due to high variability, denitrification rates did not vary significantly by hydrologic ditch zone
- No statistical correlation found between sediment nitrate concentrations and potential denitrification rates
- Statistical correlation present between stream water nitrate concentrations and potential denitrification rates in the always inundated zone

Further investigations will examine how additional environmental parameters (organic matter, moisture content, soil bulk density, and microbial community) impact denitrification rates

Acknowledgements

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