Site Factors Affecting Riparian Groundwater Nitrate Removal

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ABSTRACT

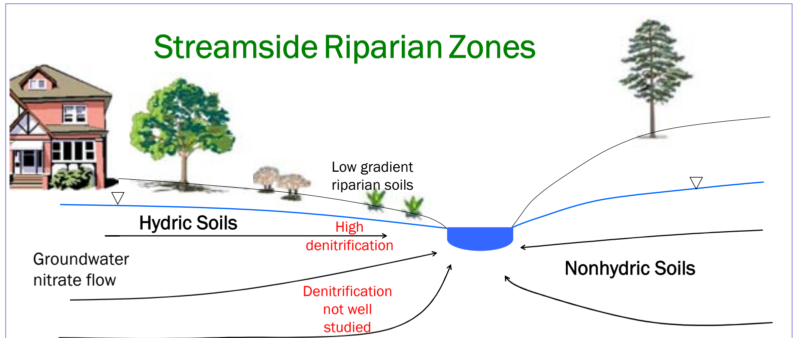
Riparian zones can play an important role in regulating the export of watershed nitrate, but variation between sites hinders the modeling and management of watershed nitrate. Previous research has found that hydric soils promote groundwater denitrification in the shallow groundwater (< 1 m) of riparian zones. However, in many riparian settings, substantial nitrate flux occurs through deeper portions of the riparian aquifer. We hypothesized that groundwater denitrification in hydric soils of riparian areas would vary with geomorphic setting (glacial outwash and alluvial) in the glaciated northeast. We suspected that riparian zones in glacial outwash would have limited potential for groundwater nitrate removal due to an abrupt decline of C with depth. In contrast, we assumed that buried carbon rich layers in alluvial settings would induce nitrate removal throughout the riparian aquifer.

We studied groundwater denitrification and flow paths to a depth of 3 meters in hydric soils at both glacial outwash and alluvial settings. We quantified denitrification by introducing ^{15}N enriched nitrate into the groundwater and tracking the evolution of ^{15}N enriched denitrification gases. We rejected our hypothesis, finding no significant differences when sites were grouped by geomorphic setting. Substantial denitrification rates were observed throughout the riparian aquifers at all depths. We found buried C deposits in the subsurface groundwater environment of all riparian zones, suggesting that both recent and historic fluvial processes can contribute to riparian ecosystem function. Future efforts will focus on scaling up our results from the site scale to the catchment scale to target prime riparian locations for protection and restoration.

HYPOTHESIS

The vertical pattern and extent of groundwater denitrification in hydric riparian soils in stratified deposits will vary with geomorphic setting (glacial outwash and alluvial), following the expected pattern of carbon distribution in the subsurface.

Streamside Riparian Zones



Groundwater denitrification potential is known to be HIGH in shallow portions of hydric soils.
- Water table approaches surface; groundwater flows through organically-enriched material and roots
- Anaerobic conditions develop
- Organic matter accumulates
- Groundwater NO_3^--N removal often observed

Groundwater denitrification potential is LOW in nonhydric soils.
- Water table below surface soils
- Aerobic conditions persist
- Low levels of organic matter
- Groundwater NO_3^--N removal **not** often observed

METHODS

Does geomorphology affect the depth of denitrification in hydric riparian zones?

Sites: 2 mapped outwash
2 mapped alluvial

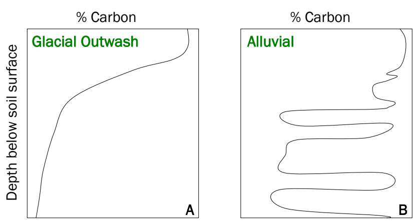
- In situ "push-pull" incubations
  - Spring and Fall
  - 3 depths (3 reps per depth)
- Pits dug below water table and analyzed for distribution, genesis and lability of organic deposits
- Additional field surveys of buried organic deposits at 25 hydric riparian sites
- Piezometer network for flow path analysis

Installation of mini-piezometers connected to gas-impermeable teflon tubing.

Geomorphic Setting and Carbon Distribution

Glacial Outwash: Stratified sands, high permeability

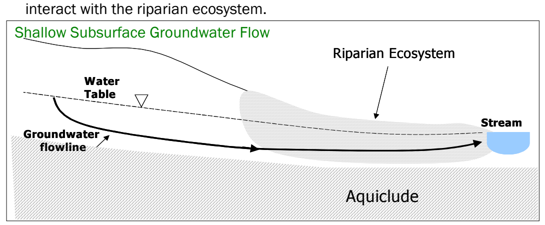
Alluvial: created by riverine actions

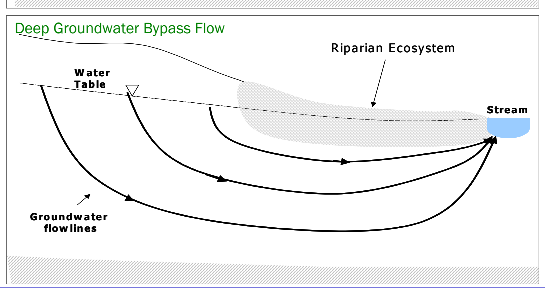


The expected carbon distribution with depth below the soil surface in (A) glacial outwash and (B) alluvial geomorphic settings. Labile carbon is often essential for the microbial process of denitrification. Following the expected carbon distribution within each setting, we expected a dramatic decline in denitrification with depth in outwash settings versus a relatively constant level of denitrification in subsoils of alluvial settings.

Groundwater Flowpaths

- Important component of the overall groundwater denitrification potential in any wetland riparian area.
- Shallow aquifers underlain by an aquiclude force groundwater flow through the carbon-rich surface soils, the so-called biologically active zone.
- Deep aquifers may allow groundwater to flow below the biologically active zone, thus decreasing the potential for nitrate-enriched groundwater to interact with the riparian ecosystem.



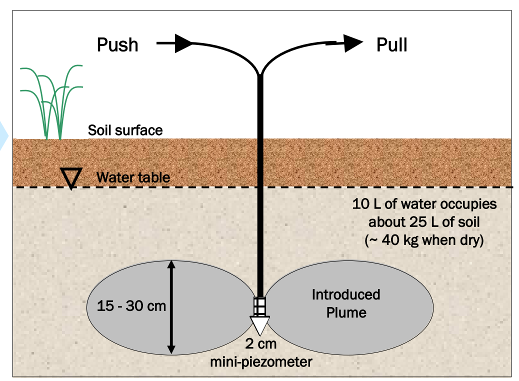


Push-Pull Method

(Addy et al., 2002)

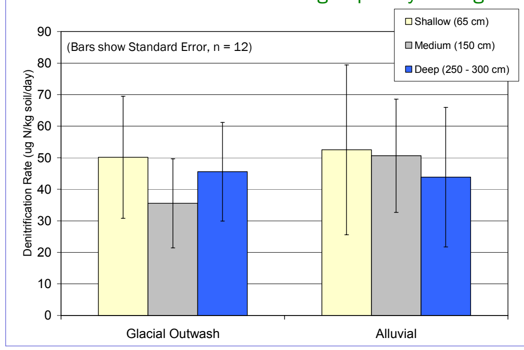
1. Pump groundwater
2. Amend with $^{15}NO_3^-$ and Br^-
3. Lower DO to ambient levels with gaseous SF_6
4. Push (inject) into well
5. Incubate
6. Pull (pump) from well
7. Analyze samples for $^{15}N_2$ and $^{15}N_2O$, the products of microbial denitrification

A stainless steel sampling port connected to a peristaltic pump enables the collection of groundwater samples in a syringe without contamination from the atmosphere.

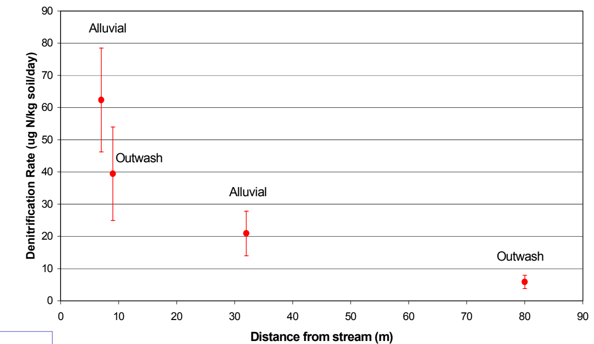


RESULTS

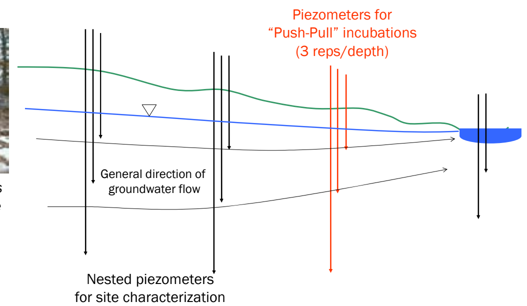
We rejected our hypothesis, finding no significant differences when sites were grouped by setting.



However, we did find significant correlation between groundwater denitrification rates and distance from the stream.



Site Sampling Design: Cross-Section of Riparian Zone



Deposits of carbon below the water table can be derived from:

- Roots
- Buried surface organic matter from flooding events
- Buried relic stream channels

A companion study found that 16 out of 18 riparian sites mapped as "outwash" had buried carbon-rich layers to a depth of 1 meter within 10 meters of the stream suggesting that episodic fluvial events altered the near stream subsurface environment.

SUMMARY

- Landscape attributes hold promise for evaluating the riparian nitrate sink at landscape or watershed scales
- Further work is needed to quantify riparian nitrate transformations at the watershed scale

CHALLENGE

How to extend from the site to the watershed scale?

Approach: Relate nitrate removal capacity to "mappable" site features
- Hydric status
- Geomorphic setting
- Stream morphology (Rosgen classification)

REFERENCES

Addy, K., D.Q. Kellogg, A.J. Gold, P.M. Groffman, G. Ferendo, and C. Sawyer. 2002. In situ push-pull method to determine ground water denitrification in riparian zones. J. Environ. Qual. 31:1017-1024.

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