Using Riparian Buffer Strips to Manage Denitrification

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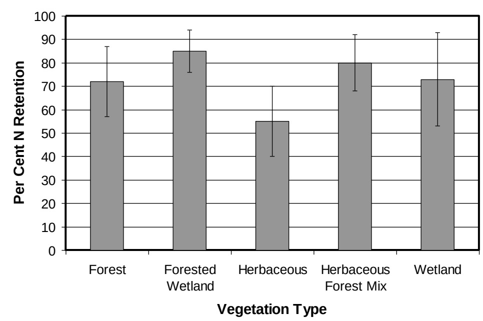
Riparian buffers and wetlands

Outline

- N retention and denitrification in riparian buffers
- Factors affecting denitrification and N retention
- Modeling of denitrification using the Riparian Ecosystem Management Model
  - Effects of loading on modeled $N2/N_2O$ ratios
  - Effects of management in a re-saturated buffer



From Paul Mayer et al, 2007, J. Environ.Qual. Nitrogen removal effectiveness in riparian buffers by vegetation type. Bars represent per cent removal plus or minus standard error. Mean ranks of vegetation types do not differ based on Kruskal-Wallis test, p=0.14.

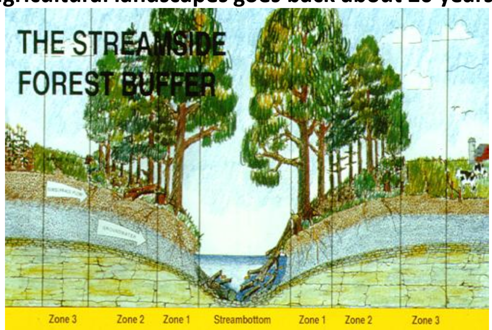
Denitrification in riparian systems

Loc	Site Type	Soil Drainage	Rate	Reference
CT, USA	Riparian	PD	5	Clausen et al, 2000*
GA, USA	Riparian	PD	32	Henrickson, 1982 Lowrance et al., 1984
GA, USA	Riparian	PD	68	Lowrance et al., 1995
MI, USA	Forested	PD	40	Groffman & Tiedje, 1989
PA, USA	Floodplain	WD/PD	<2/110	Schnabel & Stout, 1994
RI, USA	Riparian	WD/PD	<1/5	Groffman et al., 1991
RI, USA	Riparian	MWD/PD	<5/40	Hanson et al., 1991
RI, USA	Riparian	VPD	2-135	Groffman & Hanson, 1997
NY, USA	Riparian	PD	10	Ashby et al., 1998

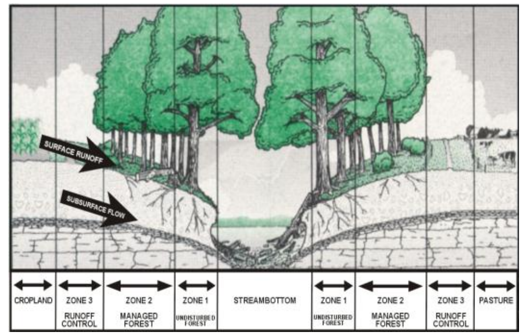
Denitrification in riparian systems

Loc	Site Type	Soil Drainage	Rate	Reference
France	Riparian	PD	104	Pinay et al., 1993
NZ	Riparian	PD	105**	Cooper, 1990
NZ	Rip./Seep	PD	4088**	Schipper et al, 1993
Denmark	Riparian Fen	PD/VPD	6-80	Ambus & Christensen
Nether.	Riparian Forest/Grass	PD	116/13	Hefting & de Klein, 1998
PA, USA	Riparian	PD	43-160	Watts & Seitzinger, 2000
NJ, USA	Sw. Forest	VPD	12-301	Same, N2 flux
LA, US	Sw. Forest	PD	292-839	Delaune et al., 1998 N-15 gas flux

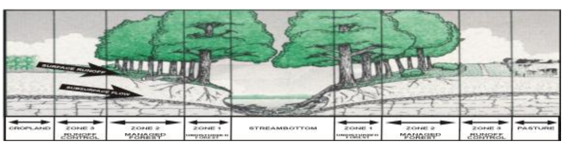
Original idea for a multiple zone buffer based on early studies (30 yrs) of riparian zones in agricultural landscapes goes back about 20 years



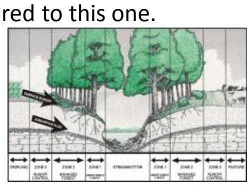
Much Denitrification?

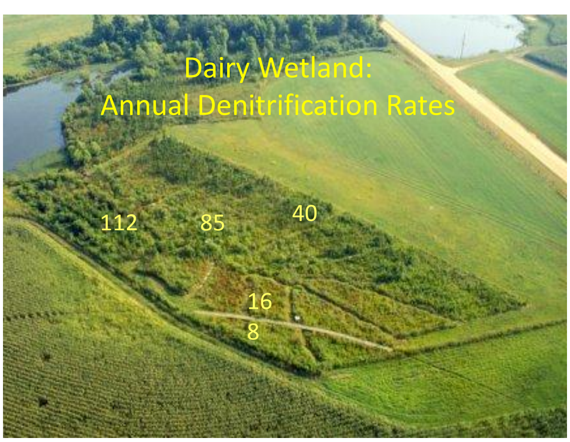


We would probably expect more denitrification from this buffer…



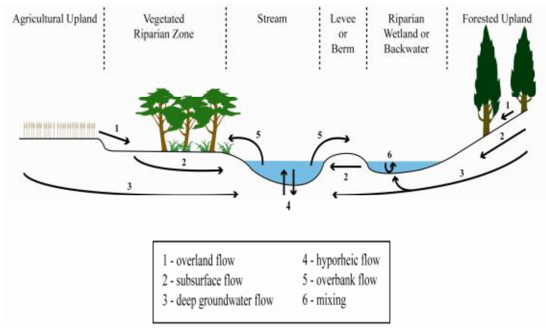
compared to this one.





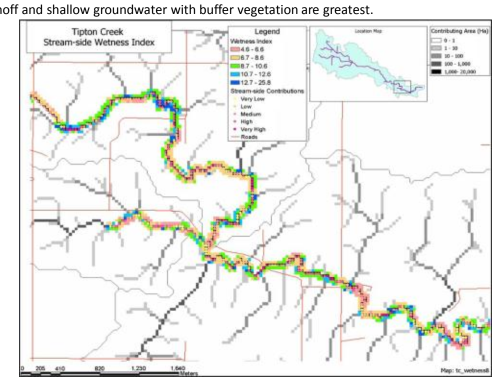
Factors Affecting Denitrification

- Nitrate loading
- Travel time for nitrate laden water
- Soil Carbon
- Soil Nitrogen
- Denitrifier enzyme assay (denitrification potential)
- Vegetation



From Philippe Vidon et al., 2010

Map of riparian-cell wetness index values for a part of Tipton Creek (Mark Tomer et al. 2005). Riparian areas with green and blue shading indicate where opportunities to intercept surface runoff and shallow groundwater with buffer vegetation are greatest.



Riparian Ecosystem Management Model (REMM)

- Developed as a design tool for multiple zone buffers so that variable buffer properties and variable upland loadings could be examined
- Simulates processing of N, C, P, sediment, and pesticides by multiple zone riparian buffers or open water wetlands
- Simplified approach to distinguish nitrous oxide from di-nitrogen in denitrification

Denitrification

Calculated as product of:

- Denitrification rate constant (denitrification potential *aka* denitrification enzyme assay- DEA - field measureable)
- Anaerobic Factor
- Temperature – Based on Q-10
- Carbon – Mineralizeable (Active Soil C pool)
- Nitrate – Zero order above Critical Nitrate Level (CNL)
- Limited by nitrate in the soil or litter layer

Validation - Comparison to Measured Rates

(kg N $ha^{-1}yr^{-1}$)

Soil	Loading	Field Estimate	Model Estimate
Alapaha	139	68*	63
Alapaha	30	39**	24

*Acetylene inhibition, intact cores – Vellidis et al., 2003
** Acetylene inhibition, intact cores – Inamdar et al, 1999a

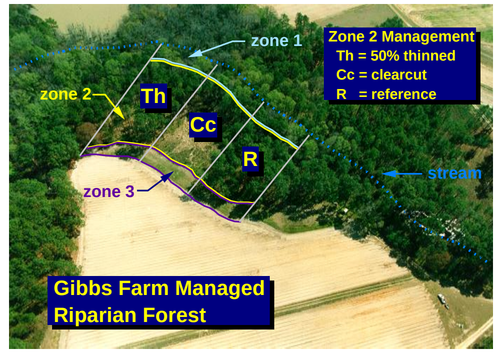
Nitrous Oxide Production in Denitrification

- Nitrous Oxide production is Zero below a Minimum Nitrate Level (MNL). May be set the same as the CNL for denitrification (nitrate limiting denitrification) or other value
- Buffers receiving low N loadings will generally have low levels of nitrous oxide production in denitrification

Anaerobiosis Control of Nitrous Oxide Production

- Anaerobic Factor Controls di-Nitrogen Production above Minimum Nitrate Level
- Nitrous Oxide determined by difference
- Similar to approaches used in DayCent model by Del Grosso et al. (2000)

Effect of Loading in a Calibrated Coastal Plain Buffer



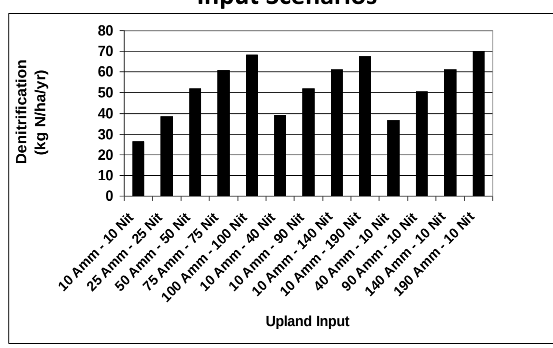
Loading scenarios simulated

Nitrate in subsurface flow, Ammonium in surface runoff

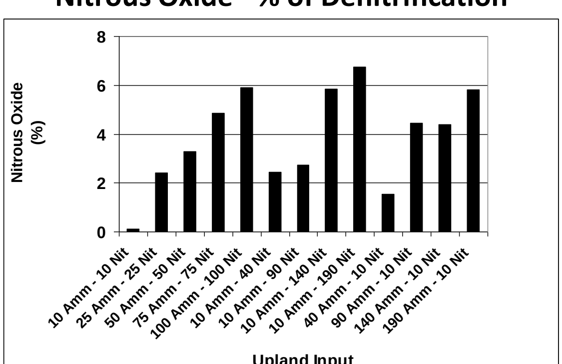
kg N $ha^{-1}yr^{-1}$

Total Inorganic Load	Equal (NH_4:NO_3)	High Nitrate (NH_4:NO_3)	High Ammonium (NH_4:NO_3)
20	10:10	NA	NA
50	25:25	10:40	40:10
100	50:50	10:90	90:10
150	75:75	10:140	140:10
200	100:100	10:190	190:10

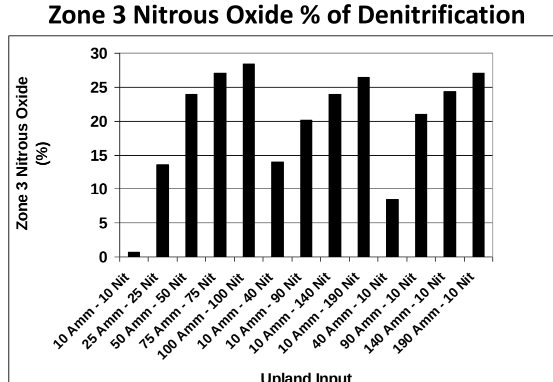
Entire Buffer Denitrification – Multiple Input Scenarios



Nitrous Oxide - % of Denitrification



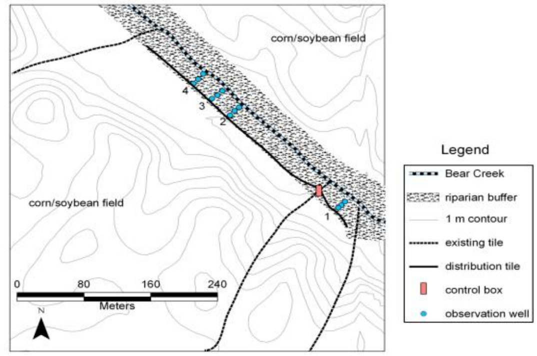
Zone 3 Nitrous Oxide % of Denitrification



Bear Creek National Buffer Demonstration Site

Saturated Buffer (D. Jaynes, T. Isenhart et al.)

Bear Creek Saturated Buffer




2009 during installation


2011 spring after installation


2012 spring


Bear Creek looking upstream

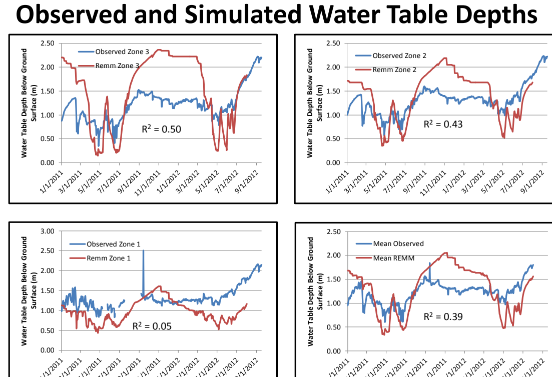
Use REMM to Understand Management Effects on Denitrification in Saturated Buffer

- Parameterize and test REMM for the Bear Creek Saturated Buffer, Iowa
- Testing will eventually include calibration, validation, and sensitivity analysis
- Use REMM to look at how the Bear Creek Buffer could be managed to enhance denitrification
- Nitrate inputs are from the measured subsurface flow being put into the buffer from the distribution line

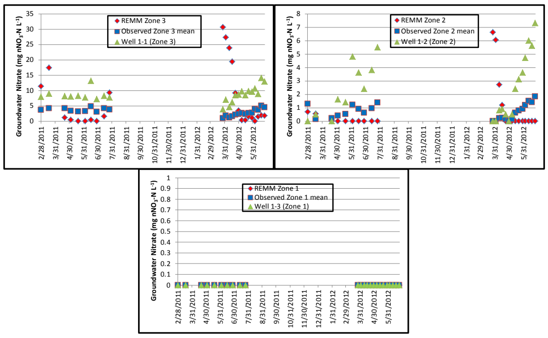
Parameterizing and *Testing* REMM for the Bear Creek Saturated Buffer

- Field Data from Jaynes et al.
- Soil data from Jaynes et al., and USDA-NRCS for Coland soil series
- Estimates of organic matter pools based on field data and Century model
- Estimates of DEA from Nelson et al., unpublished abstract
- (low = 1500 ng N_20 g soil^{-1} day^{-1}, high = 12,000 ng g^{-1} day^{-1}).
- *Compare groundwater table depths*
- *Compare groundwater nitrate concentrations*

Observed and Simulated Water Table Depths



Observed and Simulated Groundwater Nitrate

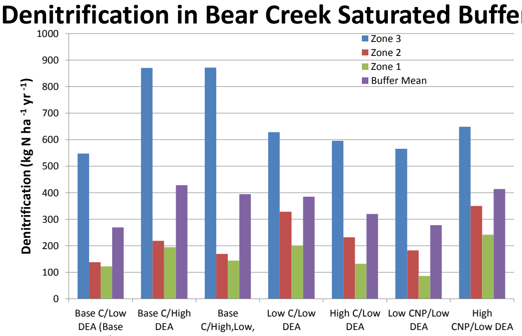


Denitrification Management for the Bear Creek Saturated Buffer

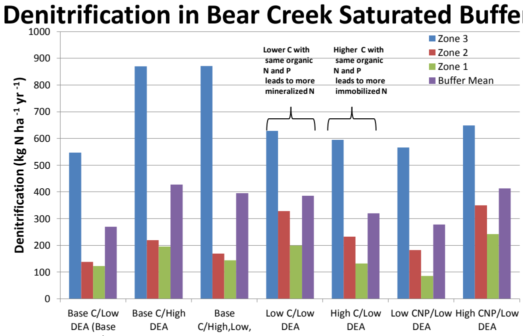
Simulate effects on denitrification of:

- Increase DEA (low and high reported values for the buffer)
- Increase soil carbon pools alone (+/- 50%)
- Increase soil carbon, organic N and P pools (+/- 50%)
- Increase subsurface flow (+100%)
- Increase nitrate load (+100%)
- Increase subsurface flow and nitrate load (+100% for both)

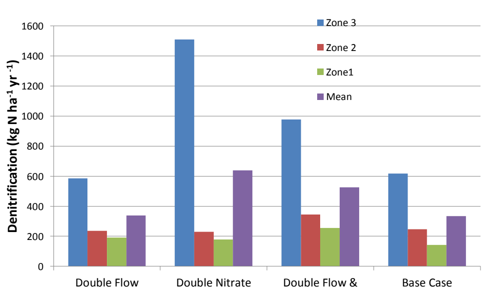
Effects of DEA, Soil Carbon, and Nutrients on Denitrification in Bear Creek Saturated Buffer



Effects of DEA, Soil Carbon, and Nutrients on Denitrification in Bear Creek Saturated Buffer



Effects of Increased Flow, Nitrate, or Flow +Nitrate on Denitrification



Conclusion

- Denitrification management in riparian buffers is a very complex subject.

Conclusions

- Denitrification management in riparian buffers is a very complex subject – so actually more questions??
- Build organic carbon in soil but don't necessarily want to enhance high C/N ratio material
- Slow down water - this means when possible both slow down at the outlet and enhance infiltration – unfortunately these are usually in conflict
- What do we do to build denitrification potential?