The Effects of Riparian Ecosystem Processes on Water Quality: Nutrient Mineralization and Budgeting in the Difficult Run Floodplain Study

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Coastal Plain floodplains trap large nutrient loads

1) Measured sedimentation fluxes in plots
2) Scaled to entire CP extent of floodplain
3) Compared to river load

Percent retention for 7 rivers:

<table>
<thead>
<tr>
<th></th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>22%</td>
<td>(5 to 150%)</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>59%</td>
<td>(14 to 587%)</td>
</tr>
<tr>
<td>Sediment</td>
<td>119%</td>
<td>(53 to 690%)</td>
</tr>
</tbody>
</table>

Hydrogeomorphic controls in floodplain ecosystems

Four dimensions of river corridors influence floodplain ecosystem processes through river-floodplain hydrologic connectivity.

This heterogeneity is critical to the prediction and scaling of floodplain effects on water quality.

Difficult Run Floodplain Study
measuring sediment and nutrient retention along lateral and longitudinal floodplain gradients in an urban, Piedmont watershed

lateral gradients

longitudinal gradients

USGS
Historic mill dams and legacy sediment

30% of mainstem length impounded

Dam locations from FCPA

Modeling by Adam Benthem

2.5 m

Plank road
Difficult Run Floodplain Study

measuring sediment and nutrient retention along lateral and longitudinal floodplain gradients in an urban, Piedmont watershed

Goals:

Quantify the sediment and nutrient retention functions of urban, Piedmont floodplains of the Chesapeake Bay

Hypothesis:

Floodplain fluxes increase with distance downstream in the watershed (longitudinal), and at lower elevations within floodplains (lateral), due to greater river-floodplain hydrologic connectivity.
Nutrient cycling in wetlands

Mineralization is a bottleneck biogeochemical process
- long-term retention
- internal cycling
- plant nutrient availability
*in situ* soil net N and P mineralization: modified resin cores

2M KCl: NH$_4^+$, NO$_3^-$, SRP

Upper outer resin bag
Upper middle resin bag
Upper inner resin bag

0-5 cm soil

Lower inner resin bag
Lower middle resin bag
Lower outer resin bag

Hydrogeomorphic and vegetation gradients: PCA

Wetness component (PCA1)

- Soil moisture WFPS
- Soil moisture volume
- Hydroperiod
- Deposition
- Soil moisture grav.
+ Groundwater depth

Soil organic component (PCA2)

+ C:P
+ N:P
+ %C
+ %N
- Bulk density
+ NH$_4^+$
+ C:N

Herbaceous component (PCA3)

+ Herbaceous N flux
+ Herbaceous C flux
+ Herbaceous P flux
+ soil temperature

Soil P / pH component (PCA4)

- pH
+ TP
+ SRP
Mineralization controls

- **Wetness component (PCA1)**
  - N mineralization (mmol m\(^{-2}\) yr\(^{-1}\))
  - Soil organic component (PCA2)
  - Herbaceous component (PCA3)
  - Soil pH
  - P mineralization (µmol m\(^{-2}\) yr\(^{-1}\))
  - P turnover (yr\(^{-1}\))

- **Percent nitrification**

- **Soil organic component (PCA2)**

- **Herbaceous component (PCA3)**

- **Wetness component (PCA1)**

Data points are plotted on graphs showing the relationship between the mineralization controls and the soil pH and PCA components.
Sedimentation stimulates mineralization

Five overbank flood events occurred at the mid-watershed floodplain site during the year of study, for a total of 41.5 hr
Plant uptake vs. mineralization vs. mineralization

Vegetation N uptake

Vegetation P uptake

N mineralization ($\mu$mol-N m$^{-2}$ d$^{-1}$)

P mineralization ($\mu$mol-P m$^{-2}$ d$^{-1}$)

$r = 0.371$
$P = 0.052$

$r = 0.057$
$P = 0.775$
## Turnover of soil N and P pools

<table>
<thead>
<tr>
<th>Rate</th>
<th>Areal mineralization (mmol m(^{-2}) yr(^{-1}))</th>
<th>Turnover rate (mol mol(^{-1}) yr(^{-1}))</th>
<th>Turnover time (yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P mineralization</td>
<td>3.60</td>
<td>0.0026</td>
<td>383</td>
</tr>
<tr>
<td>N mineralization</td>
<td>319</td>
<td>0.044</td>
<td>23</td>
</tr>
</tbody>
</table>

% nitrification | 66%

Noe et al. *in review*
Controls of nutrient mineralization

- Lateral and longitudinal gradients in floodplain hydrology, soil organics, vegetative fluxes, and TP and pH

- Strong lateral gradients of mineralization among floodplain geomorphic zones, but weak longitudinal gradients from headwaters to mouth

- Organic nutrient availability and lability controls N and P mineralization, as well as pH and redox for P

- Wetness and redox determine balance of ammonification and nitrification

- Sedimentation stimulates mineralization
Budgeting: mainstem floodplains

\[
g \text{ m}^{-2} \text{ yr}^{-1} \text{ (average all floodplain plots)}
\]

N net flux = + 11.43
P net flux = + 2.35
Sediment net flux = + 3984

14.09
2.89
5076

7.08
0.65

Headwater basin

Sediment: Mg/yr
All other sites (150 m)

USGS
Nutrient and sediment retention in urban, Piedmont floodplains

- Long turnover of soil N and P, and plant uptake rates ≥ mineralization, indicating tight spiralling of N and P
- The large pool and residence time of floodplain sediment necessitates a geomorphic perspective to understand the fluvial system and identify changes due to BMPs
- Urban Piedmont floodplains can flood and retain N and P and sediment