Nutrient and sediment inputs change soil structure and biogeochemistry in floodplain ecosystems: a cross-study synthesis

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Floodplains are dynamic systems, structured by both channel interactions and internal processes.

How does hydrologic connectivity change floodplain sediment and nutrient fluxes and soils?

How do floodplains typically behave, and how does it change across landscapes?

What are geomorphic-biogeochemical interactions and their consequences?

(Noe 2013 *Treatise of Geomorphology*, modified from NRC 2002 Riparian Areas)
Objectives

Synthesize measurements of inputs and internal cycling of sediment and nutrients made across our multiple studies of floodplains

• Contrast rates among landscape settings and ID watershed controls

• Relate nutrient and sediment inputs to soil characteristics and biogeochemical rates

• Identify typical rates of autochthonous vs. allochthonous C sedimentation rates

→ Insight into consequences of hydrologic connectivity for wetlands
Common measurement techniques across all studies facilitate synthesis

- **Input rates to floodplains**
  - Sediment: accretion, mass accumulation, C, N, P mass accumulation
    → *short-term artificial marker horizons (tile or feldspar)*
  - Dissolved: inorganic N and P
    → *ion-exchange resin bags on soil surface*

- **Sediment and soil characteristics**
  → *short-term artificial marker horizons (tile or feldspar)*
  → *surficial (0-5 cm) cores*

- **Biogeochemical transformation rates**
  - Net N and P mineralization rates
    → *modified resin cores*

*Noe 2011, SSSAJ.*
Floodplain sites

**Sedimentation:**
400 plots
60 river reaches
20 rivers

**Soil N&P mineralization:**
142 plots
29 river reaches
12 rivers

**Landscape settings:**
Nontidal and tidal rivers
## Input rates and sediment characteristics

**Input rates and sediment characteristics**

Average duration = 2.4 yr

**Compared to other studies:**
- Sed fluxes typical
- N conc. and fluxes greater
- C conc. and fluxes greater
- P conc. and fluxes typical

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Mean</th>
<th>Median</th>
<th>Coefficient of variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedimentation (g m$^{-2}$ yr$^{-1}$)</td>
<td>400</td>
<td>4629</td>
<td>1449</td>
<td>377%</td>
</tr>
<tr>
<td>Sediment deposition (cm yr$^{-1}$)</td>
<td>173</td>
<td>0.70</td>
<td>0.52</td>
<td>95%</td>
</tr>
<tr>
<td>Mineral sedimentation (g m$^{-2}$ yr$^{-1}$)</td>
<td>263</td>
<td>5018</td>
<td>1556</td>
<td>406%</td>
</tr>
<tr>
<td>Organic sedimentation (g m$^{-2}$ yr$^{-1}$)</td>
<td>263</td>
<td>553</td>
<td>366</td>
<td>158%</td>
</tr>
<tr>
<td>C sedimentation (g-C m$^{-2}$ yr$^{-1}$)</td>
<td>398</td>
<td>253</td>
<td>168</td>
<td>132%</td>
</tr>
<tr>
<td>N sedimentation (g-N m$^{-2}$ yr$^{-1}$)</td>
<td>398</td>
<td>16.4</td>
<td>10.0</td>
<td>132%</td>
</tr>
<tr>
<td>P sedimentation (g-P m$^{-2}$ yr$^{-1}$)</td>
<td>378</td>
<td>3.41</td>
<td>1.47</td>
<td>193%</td>
</tr>
<tr>
<td>Organic (%)</td>
<td>259</td>
<td>21.0</td>
<td>15.5</td>
<td>72%</td>
</tr>
<tr>
<td>C (%)</td>
<td>389</td>
<td>13.7</td>
<td>9.9</td>
<td>81%</td>
</tr>
<tr>
<td>N (%)</td>
<td>389</td>
<td>0.76</td>
<td>0.60</td>
<td>67%</td>
</tr>
<tr>
<td>P (mg g$^{-1}$)</td>
<td>369</td>
<td>1.10</td>
<td>1.02</td>
<td>51%</td>
</tr>
<tr>
<td>NH$_4^+$ input (g-N m$^{-2}$ yr$^{-1}$)</td>
<td>144</td>
<td>0.99</td>
<td>0.41</td>
<td>257%</td>
</tr>
<tr>
<td>NO$_3^-$ input (g-N m$^{-2}$ yr$^{-1}$)</td>
<td>144</td>
<td>1.73</td>
<td>0.57</td>
<td>216%</td>
</tr>
<tr>
<td>SRP input (g-P m$^{-2}$ yr$^{-1}$)</td>
<td>144</td>
<td>0.54</td>
<td>0.38</td>
<td>114%</td>
</tr>
</tbody>
</table>

Mitsch et al. 2005:
- median NO$_3^-$ N removal = 29 g-N m$^{-2}$ yr$^{-1}$

Noe et al., manuscript in prep.
Sedimentation rates

High:
Valley + Ridge
Coastal Plain
Oligohaline

Low:
Piedmont
TFFW

Restored/created similar to natural in same province

Noe et al. in prep.
Sedimentation controls (nontidal floodplains only)

Boosted Regression Trees:
[25 watershed attributes considered]
Explained deviance = 49%
CV correlation = 0.64

Evapotranspiration (24%)
Infiltration-excess overland flow % (23%)
Natural soil P (13%)
Geologic SiO₂ (12%)

Impervious % (11%)
Pasture % (9%)
Log Basin area (9%)

N and P sedimentation:
Pasture, Developed land use also important
Organic sedimentation

\[ y\text{-intercept} = 212 \text{ g-OM m}^{-2} \text{ yr}^{-1} \ (95\% \ CI: 171 \text{ to } 253) \]

NAPP – decomposition = 133-200 g-OM m\(^{-2}\) yr\(^{-1}\)
(Conner and Cherry 2013), (Lockaby and Walbridge 1998)

Disconnected floodplain deposition = 165 g-OM m\(^{-2}\) yr\(^{-1}\)
(Noe and Hupp 2005)

autochthonous \sim 180 \text{ g-OM m}^{-2} \text{ yr}^{-1}, \ 70 \text{ g-C m}^{-2} \text{ yr}^{-1}
allochthonous \sim 370 \text{ g-OM m}^{-2} \text{ yr}^{-1}, \ 150 \text{ g-C m}^{-2} \text{ yr}^{-1}
P mineralization controls

**Boosted Regression Trees:**
Deviance explained = 93% P min., 89% P turnover
CV correlation = 0.81 P min., 0.80 P turnover

P min.: 60% control by material inputs, 40% by soil character.
P turn.: 26% … , 74% …

PO$_4$ inputs, WFPS, and pH most important
N mineralization controls

Boosted Regression Trees:
Deviance explained = 49% P min., 63% P turnover
CV correlation = 0.30 N min., 0.50 N turnover

N min.: 65% control by material inputs, 35% by soil character.
N turn.: 62% … , 38% …

Sedimentation, NH$_4$ inputs, and pH most important
Sediment inputs stimulate denitrification

Individual studies...

Chesapeake floodplains

<table>
<thead>
<tr>
<th>Soil pH</th>
<th>Soil OM</th>
<th>Soil N</th>
<th>Soil P</th>
<th>Soil NO₃</th>
</tr>
</thead>
</table>

Korol et al. in review

Urban restored streams, Charlotte NC

![Graph showing the relationship between log sedimentation rate and root DEA (mg m⁻² h⁻¹).](Image)
Conclusions

This multi-study synthesis, comparing common measurements across a wide range of floodplains, provides comprehensive flux #’s and highlights the importance of ecogeomorphology:

- Landscape/watershed (and reach geomorphology) controls on variation in sedimentation and N and P input fluxes can provide predictability.
- Hydrologic connectivity → C, N and P inputs → mineralization and denitrification.
Dissolved inorganic nutrient inputs

Increase with watershed agriculture and development

Greater than atmospheric deposition to most wetlands

Particulate NP >> Dissolved NP inputs
3.6 g-P m$^{-2}$ yr$^{-1}$ 0.6 g-P m$^{-2}$ yr$^{-1}$
13.6 g-N m$^{-2}$ yr$^{-1}$ 2.1 g-N m$^{-2}$ yr$^{-1}$

(Johnston 1991)
Soil N and P mineralization

P min. more variable than N min.

N turnover more variable than N min.
P turnover = P min.

Created = or > Natural