Mapping the capacity of watersheds to regulate floods

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What do we mean by capacity?
Why do we care about regulating inland floods?
Landscapes can regulate floods < 10-year flood
Biophysical features that regulate floods

The transition between the previous slide and this one seemed very rough.
Technological features that regulate floods, and water
What landscape processes regulate floods?

The transition between the previous slide and this one seemed very rough.
12+ papers on mapping flood regulation as an ES

- Technological features not included
- Role of landscape features not assessed with long-term hydrologic records
Study objectives

1) Identify landscape indicators that regulate floods

2) Assess the relative importance of each indicator in explaining flood metrics

3) Map technological and biophysical flood regulation capacities based on indicator-importance

4) Assess how observed flooding respond to biophysical and technological regulation capacity
8 watersheds

Piedmont of North Carolina

Drainage area ≤ 80 km²

Urban (60-100%)

Forest (0-34%)

Mean Rainfall 1060 mm yr⁻¹

Sandy/Loamy soils 12-77%
Hydrologic records
1991 – 2013 (23 years)

Magnitude

Duration per event

Discharge

Time

< 10-year flood

≥ 80% of a 1-year flood

$\text{Magnitude}$

$\text{Duration per event}$

$t_1$

$t_2$
Spatially explicit landscape indicators that regulate floods

- Evapotranspiration Rate (mm yr\(^{-1}\))
- Saturated Hydraulic Conductivity (um s\(^{-1}\))
- Streams (m\(^2\))
- BMPs and AWBs (m\(^2\))


Compiled database; verified, digitized, dated

Johnson and Fecko (2008) equation: from DA to width

Streams (m\(^2\))

SSURGO 10m Database

Need to make clearer what I will define as biophysical and technological

*ET, BMP, AWB change through time
2a Derive indicator importance factors based on flood metrics

Generalized Linear Mixed Model (GLMM) set up:

<table>
<thead>
<tr>
<th>RESPONSE</th>
<th>EXPLANATORY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnitude</td>
<td>Biophysical Indicators</td>
</tr>
<tr>
<td></td>
<td>Evapotranspiration Rate (ET), Saturated Hydraulic Conductivity (Ksat), Available Water Storage (AWS), Slope, % Streams</td>
</tr>
<tr>
<td>Magnitude</td>
<td>Technological Indicators</td>
</tr>
<tr>
<td></td>
<td>Best Management Practices (% BMPs) and Artificial Waterbodies (% AWBs)</td>
</tr>
<tr>
<td>Duration</td>
<td>Biophysical Indicators</td>
</tr>
<tr>
<td></td>
<td>Evapotranspiration Rate (ET), Saturated Hydraulic Conductivity (Ksat), Available Water Storage (AWS), Slope, % Streams</td>
</tr>
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<td>Duration</td>
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</tr>
<tr>
<td></td>
<td>Best Management Practices (% BMPs) and Artificial Waterbodies (% AWBs)</td>
</tr>
</tbody>
</table>
Derive indicator importance factors based on flood metrics

GLMM example -
Response Variable: Magnitude
Random Effect: Station ID
Fixed Effects:
  Mean annual precipitation
  Technological indicators (2)

- Derive AIC
- Calculate AIC weight
- Sum weight for each indicator

```
<table>
<thead>
<tr>
<th>Model</th>
<th>Variables</th>
<th># parameters</th>
<th>AICc</th>
<th>AICc weight</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Intercept only</td>
<td>1</td>
<td>381.16</td>
<td>0.02</td>
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<tr>
<td>2</td>
<td>Int, AWB</td>
<td>2</td>
<td>375.17</td>
<td>0.42</td>
</tr>
<tr>
<td>3</td>
<td>Int, BMP</td>
<td>2</td>
<td>375.19</td>
<td>0.41</td>
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<tr>
<td>4</td>
<td>Int, AWB, BMP</td>
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<td>377.25</td>
<td>0.15</td>
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</tbody>
</table>
```

Sum BMP weight is 0.56

Conducted this process for B indicators and magnitude, and duration – B and T
<table>
<thead>
<tr>
<th>Components</th>
<th>Indicators</th>
<th>Magnitude</th>
<th></th>
<th>Duration</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Unscaled</td>
<td>Scaled</td>
<td>Unscaled</td>
<td>Scaled</td>
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<tr>
<td>Biophysical</td>
<td>ET</td>
<td>0.37</td>
<td>0.62</td>
<td>0.95</td>
<td>1.00</td>
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<tr>
<td></td>
<td>Ksat</td>
<td>0.32</td>
<td>0.54</td>
<td>0.36</td>
<td>0.38</td>
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<tr>
<td></td>
<td>AWS</td>
<td>0.30</td>
<td>0.50</td>
<td>0.51</td>
<td>0.54</td>
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<td>Slope</td>
<td>0.42</td>
<td>0.70</td>
<td>0.31</td>
<td>0.33</td>
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<tr>
<td></td>
<td>% Stream</td>
<td>0.59</td>
<td>1.00</td>
<td>0.57</td>
<td>0.60</td>
</tr>
<tr>
<td>Technological</td>
<td>% BMP</td>
<td>0.56</td>
<td>0.99</td>
<td>0.49</td>
<td>0.76</td>
</tr>
<tr>
<td></td>
<td>% AWB</td>
<td>0.57</td>
<td>1.00</td>
<td>0.64</td>
<td>1.00</td>
</tr>
</tbody>
</table>

**Derive indicator importance factors based on flood metrics**
3a

Map Flood Regulation Capacities

Standardize indicators in GIS from 0 to 1

\[
\frac{(X - X_{\text{min}})}{(X_{\text{max}} - X_{\text{min}})}
\]

Example: Evapotranspiration Rate

Mapped 2011-2013
Map Flood Regulation Capacities

Magnitude

Biophysical Capacity = 1.0(Streams) + 0.7(Slope) + 0.62(ET) + 0.54(Ksat) + 0.5(AWS)

Indicator importance factors

Stream
Slope
ET
Ksat
AWS

Re-standardized from 0 to 1
Magnitude-derived capacity

Biophysical Capacity
High : 1
Low : 0

Technological Capacity
1
0.99
0

Duration-derived capacity

Biophysical Capacity
High : 1
Low : 0

Technological Capacity
1
0.76
0
Assess how capacities respond to flood metrics
Floods are responding as expected based on what we know about the landscape.
In this study, we

Included technological features

Derived indicator-importance factors based on flood metrics

Mapped technological and biophysical flood regulation capacity

Transferability and limitations

- Importance-values are location-specific
- Long-term hydrologic records
- Publicly available databases
Thank you

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