Living Erosion Pins- Streambank Erosion Rate Assessment Using Exposed Tree Roots

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Why assess streambank erosion?

Traditional assessment methods

What is dendrogeomorphology?

Case studies

Dendrogeomorphology take-aways
WHY ASSESS STREAMBANK EROSION?

- Threat to infrastructure
WHY ASSESS STREAMBANK EROSION?

- Loss of land and channel capacity
WHY ASSESS UPLAND AND STREAMBANK EROSION?

- Excess sedimentation, nutrient loading, and contamination
WHY ASSESS STREAMBANK EROSION?

- Prioritization of restoration projects: “Best Bang for the Buck”
Methods of Quantifying Riverbank Erosion

**Erosion pins**
- Most commonly used method
- Accurate but requires annual monitoring
- Several years of data needed

**Historic aerial photographs**
- Gives long-term erosion rates
- Not as accurate due to scale
- Used for high erosion rates
Methods of Quantifying Riverbank Erosion

**Bank Surveys**
- Toe Pins
- Scan

**Less Common:**
- Photovoltaic
- Lidar

**Analytical Models**
- RUSLE
- USDA Bank Stability Model
Methods of Quantifying Riverbank Erosion

**Empirical Models**

- **BANCS Model:** Uses *erosion rate curves* which relate bank-specific ratings of erodibility to erosion rates.

**Erosion Rate Curve Must Be Developed from Other Method**
Methods of Quantifying Hillslope & Riverbank Erosion

New Method: Dendrogeomorphology

Using tree rings to identify dates of changes in land surfaces

- Root anatomy changes when root is exposed to air/elements
- Now mentioned by Chesapeake Expert Panel
- Dick et al., *River Research and Applications*, 2013
WHAT IS DENDROGEOMORPHOLOGY?

• Dendrogeomorphology - Use of tree growth rings to identify dates of changes in earth surface processes

• Tree rings change in response to environmental factors (e.g. landslide, streambank, and hillslope erosion)
WHAT IS DENDROGEOMORPHOLOGY?

- Used since the 1960s
- Most research done in Europe
- Most research done on conifers
- Initial studies on fluvial erosion in the U.S. in 2008
WHAT IS DENDROGEOMORPHOLOGY?

- Growth anomalies after exposure to atmosphere (erosion):
  - Ring size and eccentricity
  - Change in vessel and fiber size
  - Scarring from debris
WHAT IS DENDROGEOMORPHOLOGY?
WHAT IS DENDROGEOGEOGEOOMORPHOLOGY?

Distance of exposed root from riverbank

ANATOMICAL CHANGE INDICATES YEAR ROOT EXPOSED

Annual Growth ring

Riverbank

Annual Erosion Rate

Inside of root

Outside of root

Inside of root

Outside of root

Years of Exposure
Macroscopic Indicators of Exposure

Cut disk of elm root (*Ulmus rubra*)

Cut disk of hackberry root (*Celtis spp.*)
MICROSCOPIC INDICATORS

• Diffuse-Porous Species
  • decrease in size and increase in number of cells in post-exposure rings
  • division into earlywood and latewood

• Ring-Porous Species
  • change from diffuse-porous cell anatomy to ring-porous anatomy (resembling more the stem).
GROWTH RING ANATOMY

- Root eccentricity
- Growth Ring Thickness
- Often presents much more apparent growth ring boundary
SCARS AND PITH FLECKS

• May or may not be present
• Serve to validate other indicators
• “Multiple lines of evidence approach”

Cut disk of hackberry root (*Celtis spp.*)

Cut disk of elm root (*Ulmus rubra*)
RAY DIRECTION

- Ray bending often occurs in first year of exposure
- And again in re-burial
RING POROUS VS DIFFUSE POROUS

Image credit: https://www.popularwoodworking.com/techniques/understanding-wood-four-structure-types
VESSEL DIAMETER

- Vessels primarily transport water and nutrients
- The “pipes” of the tree tissue
- Roots main function is to transport water
- Stem main function → strength
- Exposure forces root wood development towards strength = STEM-LIKE
- A PRIMARY INDICATOR FOR DIFFUSE POROUS SPECIES
VEESSEL ARRANGEMENT

- Stem-like arrangement of vessels
- Reference material documents stem wood anatomy of most species globally
- **A PRIMARY INDICATOR FOR RING POROUS SPECIES**
VESSEL FREQUENCY AND AREA

- Decrease in vessel frequency is highly apparent in some species.
- Statistical significance in most species with laboratory image analysis.
FIBER/TRACHEID LUMEN DIAMETER AND CELL WALL THICKNESS

- Decrease in FLD
- Increase in CWT
REACTION WOOD- GELATINOUS FIBERS

- Reaction wood contains gelatinous fibers (g-fibers)
FINDINGS

RING POROUS

40X

RING POROUS

400X
FINDINGS

DIFFUSE POROUS

40X

DIFFUSE POROUS

400X
PUTTING IT TOGETHER
INTRODUCTION TO BANK EROSION HAZARD INDEX (BEHI)
**BEHI EXAMPLES**

Location 997+50 Left Bank

**BANK EROSION HAZARD INDEX (BEHI) 4 RATING EXAMPLE**

<table>
<thead>
<tr>
<th>CHARACTERISTICS OF A BEHI WITH A 2 RATING</th>
<th>SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio of Study Bank Height / Bankfull Height (8.0 ft / 4.0 ft) = 2.0</td>
<td>8.0</td>
</tr>
<tr>
<td>Ratio of Root Depth / Study Bank Height (7.0 ft / 8.0 ft) = 0.875</td>
<td>9.0</td>
</tr>
<tr>
<td>Weighted Root Density = Root Density % X (Ratio of Root Depth / Study Bank Height)</td>
<td>8.0</td>
</tr>
<tr>
<td>30.0 X 0.875 = 26.25</td>
<td></td>
</tr>
<tr>
<td>Bank Angle 70°</td>
<td>8.0</td>
</tr>
<tr>
<td>Surface Protection 5%</td>
<td>9.0</td>
</tr>
<tr>
<td>Bank Material Adjustment (Sand bank adjustment)</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Total Score 47.0
### BEHI EXAMPLES

**Location 975+00 Left Bank**

#### BANK EROSION HAZARD INDEX (BEHI) 4 RATING EXAMPLE

**CHARACTERISTICS OF A BEHI WITH A 2 RATING**

<table>
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<tr>
<th>Characteristic</th>
<th>Score</th>
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<tbody>
<tr>
<td>Ratio of Study Bank Height / Bankfull Height (8.0 ft / 4.0 ft)</td>
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</tr>
<tr>
<td>Ratio of Root Depth / Study Bank Height (8.0 ft / 8.0 ft)</td>
<td>0.0</td>
</tr>
<tr>
<td>Weighted Root Density = Root Density % X (Ratio of Root Depth / Study Bank Height)</td>
<td>7.0</td>
</tr>
<tr>
<td>Weighted Root Density = 20.0 X 1.0 = 20.0</td>
<td></td>
</tr>
<tr>
<td>Bank Angle 15°</td>
<td>1.0</td>
</tr>
<tr>
<td>Surface Protection 10%</td>
<td>9.0</td>
</tr>
<tr>
<td>Bank Material Adjustment (Sand bank adjustment)</td>
<td>5.0</td>
</tr>
</tbody>
</table>

**Total Score** 30.0
EROSION MAPPING
Erosion Rate vs. BEHI Score for Samples on Buffalo Bayou

\[ y = 3 \times 10^{-6}x^{2.9549} \]

\[ R^2 = 0.8729 \]
Case Study: River in Central MI

All samples: Indicates that method can be used to predict erosion rates where no direct erosion rate measurements have been obtained, but BEHI has been measured.

Samples exposed 10 years or less: Indicates older roots may be indicative of different state of erodibility than current bank.
CASE STUDY: BUFFALO BAYOU, HOUSTON TEXAS

- Develop baseline data for future stream stability projects
  “Prioritization of future projects”
• Comparison of erosion rates to BEHI (bank erosion hazard index)
SAMPLE PREPARATION AND ORGANIZATION

• Samples can be analyzed at various levels of magnification
• Lowest level is cut disk with cheap microscope
• Greater magnification and preparation increases certainty for difficult samples
ANALYSIS WITH DIFFERENT MAGNIFICATIONS AND BUDGETS

Portable Microscope, Portable LCD GERI Digital Handheld Microscope 8 LED Photo and Video Capture TV Out
by GERI

$115.00 prime (4 days)
Only 4 left in stock - order soon.

Celestron 44347 TetraView LCD Digital Microscope (Black)
by Celestron

$259.95 prime
More Buying Choices
$259.95 (10 new offers)

VanGuard Brightfield Phase Contrast Clinical Microscope, 1300PHi series, Halogen Illumination
by VanGuard

$1,794.41 - $2,050.00 prime
Some sizes are Prime eligible

More Buying Choices
$500.00 (1 used offer)

https://www.popularwoodworking.com/techniques/understanding-wood-four-structure-types
SAMPLING TIPS

• Measure multiple samples up a riverbank to obtain average erosion
• Collect samples at least 1 meter away from riverbank
Pros/Cons of Dendrogeomorphic Method

**Time Savings Over Other Methods**
- Collection: 20 samples per day;
- Analysis: 20 samples per day (using macroscopic indicators);
- 3-4 samples per day (if using microscopic indicators)

**Potential Disadvantages**
- Longer-exposed samples may not reflect current susceptibility of bank to erosion
- Difficult to obtain samples on banks with worst and least susceptibility to erosion
- Climactic variations can cause difficulty in growth ring observation (mainly in **subtropical** geographies)
DENDROGEOGROMORPHOLOGY TAKE-AWAYS

• Upland or channel erosion assessment is equally possible

• Data where none existed prior to the initiation of concern of a particular study area

• Easy to train staff to implement

• Coarse data can be obtained with hand lens

• Quickly get accurate erosion data on variety of time scales

• Most local tree spp can be used

• Cost effective  -  Long Timeframe of Data – Historical and Predictive
Questions?

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