Filling a Need: Developing training for stormwater managers about the influence of trees on urban stormwater

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Training is based on:

• Current research review and extrapolation, modeling of KC area watersheds (Trisha Moore’s) presentation.
• Informed by survey results of stormwater managers.
• Meta-analysis of co-benefits database.
• Healthy, growing trees provide the most benefits.
Acknowledge several excellent review reports

• Maximizing Stormwater-Related Benefits at the Tree or Site Scale

• Urban Watershed Forestry Manual (part 1, 2, 3)
Training Products

• Delivered via an archived webinar hosted by the Water Research Foundation. cbarden@ksu.edu.
• Review of refereed research on stormwater impacts of trees.
• Factsheet on predicting urban tree contributions to runoff.
• Factsheet on incorporating forestry into stormwater management.
• Database meta-analysis of co-benefits (Access, Excel) with factsheet and user guide bulletin.
Stormwater manager’s survey

• Online Qualtrics survey conducted May-June 2018
• Promoted via email and newsletter invitation
• 52 respondents from across the US, 16 states
• One third were from 3 states, CA, FL, and TX
Stormwater manager’s survey

• Overall results were positive, but showed room for improvement
• > 60%
  • Consider trees and wooded areas in planning
  • Incorporate trees in engineered stormwater structures
  • Promote trees for their effect on stormwater

• 67% collaborate with city arborist/forester
• Similar survey distributed to Arborists, but only 9 replies
When planning a new stormwater project, do you consider the projected amount of tree canopy in the development watershed?

• 44% yes

• 6 out of the 21 yes respondents provided the method
  • GIS-based canopy coverage data x 2
  • Tree canopy reflected in runoff curve number
  • Measure caliper and canopy of existing trees, unsure if this is used in project modeling
  • NRCS runoff curve number
Modified Simple Method

\[ R_v = (\%N \times R_{vN} + (\%C) \times R_{vC} + (\%I) \times R_{vI}) \]

where: \( R_v \) = weighted site runoff coefficient

\( \%N \) = percent of site in natural cover
\( A_N \) = area of post-development natural cover (ft²)

\( \%C \) = percent of site in compacted cover
\( A_C \) = area of post-development compacted cover (ft²)

\( \%I \) = percent of site in impervious cover
\( A_I \) = area of post-development impervious cover (ft²)

\( S_A \) = total site area (ft²)

\( R_{vN} \) = runoff coefficient for natural cover (0.00)
\( R_{vC} \) = runoff coefficient for compacted cover (0.25)
\( R_{vI} \) = runoff coefficient for impervious cover (0.95)
What tree locations do you consider when assessing stormwater effects?

- Street Trees
- Trees on private property
- Park trees with turf
- Riparian trees
- Natural wooded areas
- Trees in floodplains
What values and benefits do you attribute to the location of trees?

- Street trees
- Trees on private property
- Park trees with mowed grass groundcover
- Trees in riparian (streamside areas)
- Natural wooded areas with understory plants and a ground cover
- Trees in floodplains

### Reduce stormwater runoff quantity
- 15%

### Shading and summer temperature reduction of streams
- 15%
Incorporating Forestry Factsheet

• Basic Hydrology
• Streamflow components
• Goal of green infrastructure
• Development effects on the hydrograph
Incorporating Forestry Factsheet

- Basic Hydrology
- Streamflow components
- Goal of green infrastructure
- Development effects on the hydrograph

[Diagram showing hydrologic cycle with labels for different components such as precipitation, evapotranspiration, infiltration, recharge, and discharge to streams.]
Anatomy of a hydrograph: pre- to post-development
Chester Creek Example

Impervious area increases by 5% for every 1 person per hectare of added population

Annual Stream Flow (inches)

40% of Precipitation

70% of Precipitation

Stream Flow

Urban Land Use

Percent Urban Land Use

How do trees reduce stormwater volumes?

- High evapotranspiration Et rates
- Interception (17%-31%)
- Reduced energy and volume of throughfall
- Stemflow with infiltration at base of tree
Tree characteristics that maximize stormwater benefits

• Larger trees greatly increase stormwater control and other co-benefits, based on area of the crown or trunk cross section.
• A 6” diameter tree will have >3 times the impact of a 3” tree.
• Area of a circle $3.14 \times \text{radius}^2$

3” 7.1 in$^2$ vs 28.3 in$^2$

6” 21.3 in$^2$ vs 28.3 in$^2$
How to grow larger trees?

• Select species that are well adapted to the site conditions.

• Increase available rooting volume
  • One large planter (96 ft$^3$) will grow two trees larger, than two small planters each 48 ft$^3$
  • Use structural soil or suspended pavement to allow root growth
Use evergreen trees wherever feasible

- Evergreens have higher annual interception rates and much higher winter Et.
- Produce lower volumes of litter annually, with much lower nutrient concentrations than deciduous species.
Scaling up benefits

• More and larger trees
• Retention or planting of riparian buffers
• Allow a forest floor of leaves and twigs to develop under extensive plantings

2006

2014
Flood reduction

• Green infrastructure will **not** prevent flooding

• Primary benefit is to reduce stormflow peaks and volumes from routine, frequent precipitation events
Cost-benefit database tool

Objectives:

1. Provide a *comprehensive compilation* of datasets in which costs and/or benefits of urban trees have been economically valued

2. **Produce a searchable tool** with which stormwater managers or others interested in assessing costs, benefits, and/or return on investment (ROI) associated with urban tree systems can obtain this information
Database at a glance

- 38 unique studies
- 25 Cost data points
  - Based on reported cost data
- 182 Co-benefit value data points
  - 59% used i-Tree software

Tree/forest systems included:
- General (107)
- Parks (8)
- Residential (3)
- Street trees (63)

Co-benefit categories:
- Environmental: 116
- Economic: 65

- Air quality (42)
- C Sequestration (43)
- Runoff volume (29)
- Water quality (1)
- Energy savings (44)
- Real estate value (18)
Database at a glance

- 38 unique studies
- 25 Cost data points
  - Based on reported cost data

Cost (\$, 2017 dollars) per tree per year

- Planting
- Establishment
- Pruning
- Litter Management
- Infrastructure repair
- Disease control
- Liabilities
- Admin
- Removal

+1 st. dev
75th percentile
*median
25th percentile
- 1 st. dev.
Database at a glance

- **38 unique studies**
- **182 Co-benefit value data points**
  - 59% used i-Tree software

### Value ($, 2017 dollars) per tree per year

- **Real estate value**
- **Energy savings**
- **Air quality control**
- **Stormwater control**
- **C Sequestration**
- **Water Quality**

- **25th percentile**
- **75th percentile**
- **+1 st. dev**
- **-1 st. dev**
- **Median**

- **Real estate value:**
  - 25th percentile: $20
  - 75th percentile: $80
  - +1 st. dev: $140
  - -1 st. dev: $0

- **Energy savings:**
  - 25th percentile: $20
  - 75th percentile: $80
  - +1 st. dev: $140
  - -1 st. dev: $0

- **Air quality control:**
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Database structure

Microsoft Access version

Microsoft Excel version (database light)
Application: example framing questions

1. What is the average value of stormwater (or other co-benefit) reported for street trees?
2. What is the average value of a co-benefit “bundle” provided by urban trees?
3. What is the Return on Investment (ROI) over the life cycle of an urban tree?
4. What is the life cycle cost per cubic meter of runoff reduction by an urban tree?
What is the value of stormwater reduction benefits reported for street trees?
What is the **Return on Investment (ROI)** over the life cycle of an urban tree?

<table>
<thead>
<tr>
<th>Co-benefit categories</th>
<th>Median value, 2017 $ per year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Environmental Co-benefits</strong></td>
<td></td>
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<tr>
<td>Air quality control</td>
<td>Not included</td>
</tr>
<tr>
<td>C Sequestration</td>
<td>Not included</td>
</tr>
<tr>
<td>Stormwater control</td>
<td>Yes</td>
</tr>
<tr>
<td>Water quality</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Economic benefits</strong></td>
<td></td>
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<tr>
<td>Energy Savings</td>
<td>Yes</td>
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<tr>
<td>Increase real estate value</td>
<td>Yes</td>
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<tr>
<td><strong>Total annual co-benefit value</strong></td>
<td>$74.79</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost Categories</th>
<th>Include?</th>
<th>Mean value, 2017 $ per year</th>
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</thead>
<tbody>
<tr>
<td>Planting</td>
<td>Yes</td>
<td>$2.05</td>
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<tr>
<td>Establishment</td>
<td>Yes</td>
<td>$4.36</td>
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<td>Pruning</td>
<td>Yes</td>
<td>$25.21</td>
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<td>Litter Management</td>
<td>No</td>
<td>Not included</td>
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<tr>
<td>Infrastructure repair</td>
<td>No</td>
<td>Not included</td>
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<td>Disease control</td>
<td>Yes</td>
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<td>Liabilities</td>
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<td>Administration</td>
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<td>Removal</td>
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<tr>
<td><strong>Total annual life cycle cost</strong></td>
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<td>$46.47</td>
</tr>
</tbody>
</table>

**Return on Investment (ROI)**: 0.61

*Note: A ROI greater than 0 indicates the benefits provided by trees outweigh the economic expenses invested in tree planting, maintenance and other life cycle costs. A negative ROI indicates life cycle costs exceed benefits.*
Database limitations

• Representative of available (peer-reviewed) published data and valuation methods
• Only includes co-benefits that have been economically valued. Thus, does not capture broader, non-monetary values
• Geographically limited
• Most representative of city-scale assessments
• Does not reflect forest structure (e.g., age, size, species, etc.)
Acknowledgments

- Funding and support originally from the Water Environment & Reuse Foundation (WERF)

- Merged with Water Research Foundation, Katie Henderson- project manager

- Additional project advisors- Tom Jacobs with Mid America Resource Council (MARC), and Lisa Treese with Kansas City Water Services
Questions?

21.3 in² vs 28.3 in²