Tree Canopy Land Use Loading Rates in the Phase 6 Watershed Model

Chesapeake Bay Partnership review of proposed methodology

February 11, 2016

Virginia Tech Invent the Future

Chesapeake Bay Program Science. Restoration. Partnership.

Center for Watershed Protection

Welcome to the Webinar

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Audio/Visual

- Make sure your computer's speakers are ON, and your computer volume is not on mute. If still unable to hear us, we'll provide conference line information in the chat box for you to call in.
- Let us know in the chat box if you're having any technical problems or need audio support

To Ask a Question

- Submit your question in the chat box.
- We will answer as many of your questions as possible during Q&A, following completion of the presentation.
- If we run out of time to respond to all questions, following the webinar, we will post written responses to the questions.

We are Recording this Webinar

- All comments and questions will be recorded and included on the calendar entry along with a link to the recording and related resources.

Today's Agenda

- Tree Canopy Land Uses for Phase 6 Model
  - Rebecca Hanmer, Forestry Workgroup Chair
- Expert Panel review of science/literature
  - Neely Law, Tree Canopy BMP Expert Panel Chair, Center for Watershed Protection
- Methodology - Tree Canopy loading rates
  - Justin Hynicka, Maryland Forest Service
  - Marion Divers, University of Pittsburgh
- Next Steps and Q & A




Why Tree Canopy Land Uses in Phase 6?

- Since 2003, it has been the policy of the Chesapeake Bay Program partners to increase urban tree canopy cover for water quality and other benefits
  - Reaffirmed and strengthened in the 2014 Chesapeake Bay Agreement Tree Canopy Outcome

- Urban tree canopy benefits are not directly accounted for in the CB Model land uses
  - Implication: Retaining tree canopy has no “value” in the TMDL framework, whereas Forest, Open Space, and other preferred land uses do

Key Progress to Date

- Sept. 2015 - Water Quality Goal Implementation Team (WQGIT) provisionally approved Tree Canopy land uses, pending approval of loading rates

- Feb. 2016 – WQGIT approved refined mapping/definition of Tree Canopy land uses, which are now focused only in <u>developed</u> areas located near or over impervious surfaces:
  - Tree Canopy over Turf Grass
  - Tree Canopy over Impervious

- Pollutant loading rates for these two land use classes must be approved by Partnership to include in Phase 6 model

See posted Tree Canopy Land Use Response & Coordination Plan for additional detail

Today and Next Steps

Today:

- Review Tree Canopy science/literature on water quality benefits and proposed methodology for determining loading rates
- Answer questions and receive input before finalizing loading rates

March:

- Present final loading rate recommendations to workgroups and WQGIT

Related Actions in Process

- Incorporating Tree Canopy into urban land use relative loading ratios
  - March 2016 workgroup meetings
- Addressing any remaining modeling or programmatic concerns of jurisdictions
  - March 2016 workgroup meetings
- Urban Tree Canopy BMP Expert Panel Recommendations addressing BMP definition/credit for <u>new tree plantings</u>
  - April 2016 Final Report for partnership review


Urban Tree Canopy Expert Panel

Summary of Literature Synthesis

Neely Law, Urban Tree Canopy BMP Expert Panel Chair,

Center for Watershed Protection

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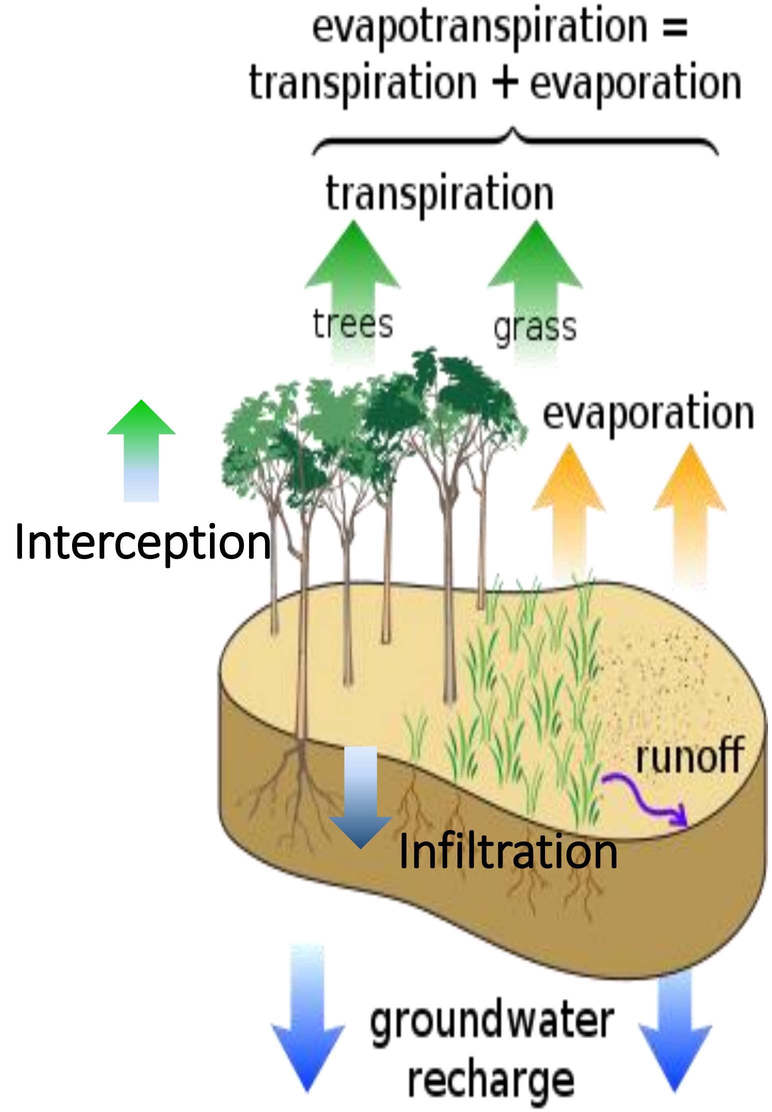
Literature Review and Synthesis

- Support development of a relative land use loading rate and urban tree canopy BMP
- 115 publications reviewed
  - 49 on hydrologic benefits
  - Modeling and measured studies
- Includes non-urban studies and studies from outside the Chesapeake Bay
- Hydrologic and water quality processes well-understood, but direct application of findings limited given variability of data presented

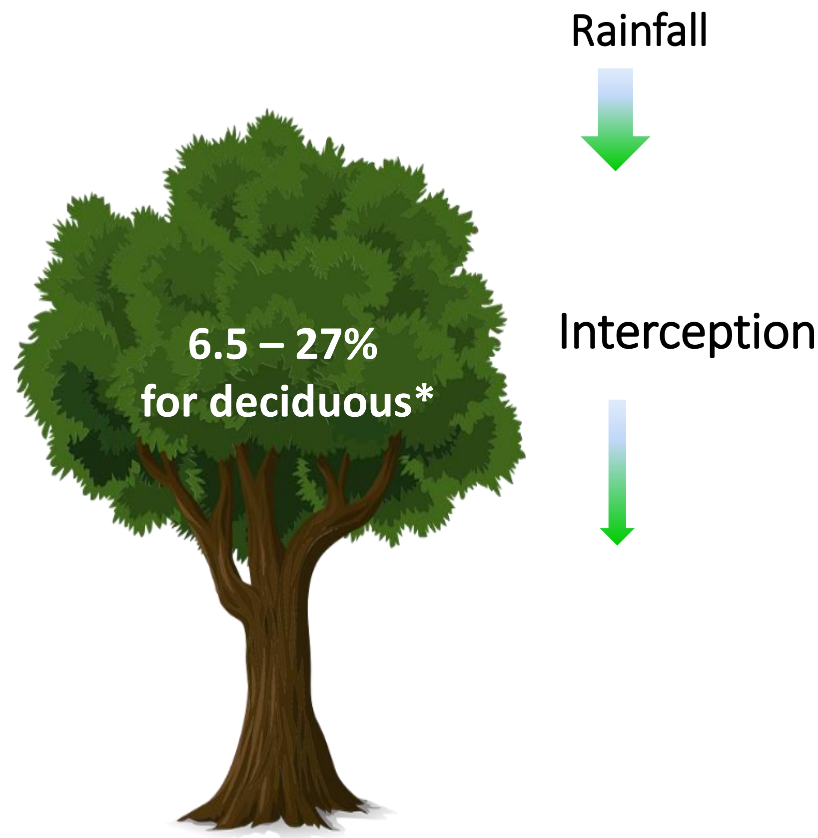
Literature Database and Synthesis

- Studies organized by type of benefit:
  - Hydrologic
    - Interception
    - Evapotranspiration
    - Infiltration
    - Runoff reduction
  - Water quality
    - Pollutant uptake & removal
    - Leaf litter



Key Findings: Interception

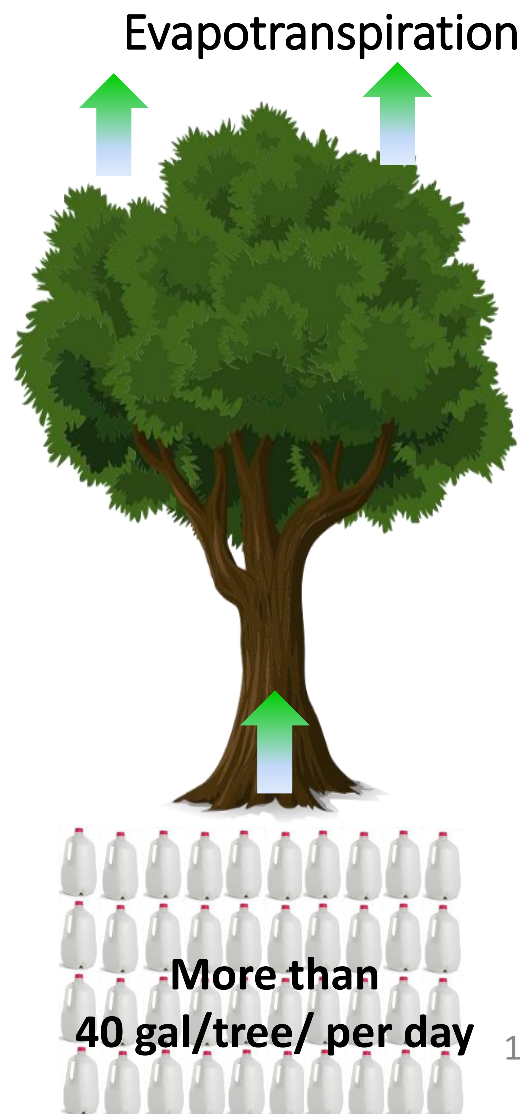
- Annual interception losses account for leaf-on and leaf-off
- Storm events, tree structure, and leaf area index key factors affecting interception losses



* 27 - 66% for evergreen trees

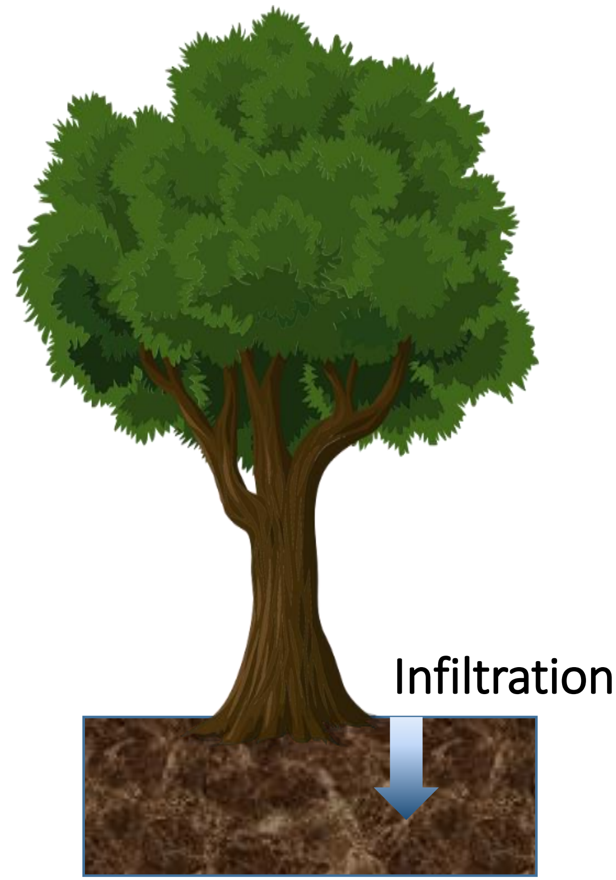
Key Findings: Evapotranspiration (ET)

- Many factors affect ET rates
  - Climate, storm events, tree characteristics
- No studies report ET as % of annual precipitation
- Daily rates of transpiration of urban trees similar to natural forests
  - Urban trees: 0.004 - 0.09 inches/day
  - Natural forests: 0.02 – 0.1 inches/day



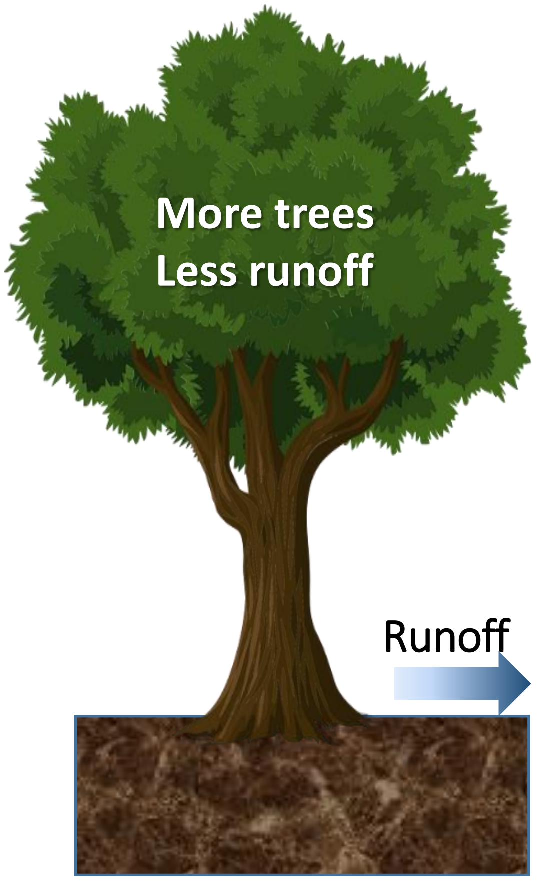
Key Findings: Infiltration

- 6 studies (3 urban areas; 3 non-urban)
- Soil conditions vary considerably, challenge to discern effect of trees Bay-wide
- Trees affect soil infiltration rates, even in highly compacted soils.
- Bartens et al (2008) 63% - 153% increase in soil infiltration rates
- Kays (1980) 35% decrease in suburban forest infiltration rates with removal of the understory and leaf litter
- Mlambo et al (2005) infiltration rates higher under tree canopy (non-urban)



Key Findings: Runoff Reduction

- 7 studies reviewed on runoff reduction due to urban tree canopy
- Studies largely relied upon hydrologic models
- Watershed-scale models show that runoff decreases as canopy in the watershed increases
- Scale matters
    - **Watershed** evaluates % canopy land cover (RR ranges from 5 to 19%)
    - **Site or plot** scale studies includes trees in BMPs observe RR of ~ 60% or greater



Key Findings: Water Quality

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- Primary benefits in total amount of surface runoff reduction and infiltrated runoff (leachate)
- Only one study directly addressed the effect of urban trees on runoff quality (planted and unplanted controls)
  - Denman (2006) evaluated nitrogen in leachate in soil columns
    - With trees: 82% - 95% removal of TN in leachate
    - Unplanted: Maximum 36% removal of leachate

Key Findings: Water Quality

- Pollutants have multiple potential pathways
  - Plant & biological uptake, adsorption, denitrification
- Trees may influence soil moisture and carbon availability to promote denitrification
  - "Redistribution" of below ground water
  - Decomposition of organic matter
- N retention significant but lower in developed watersheds compared to forested (Groffman et al 2009)
  - 95% Forested
  - 77% Agricultural
  - 75% Suburban

Key Findings: Leaf Litter

- Concur with findings from Street Sweeping expert panel report (2016)
    - ".. understanding of the fate, transport and processing of leaf litter in urban watersheds is still emerging, and there were insufficient data to quantify its significance as a nutrient source."
- Leaf litter provides essential resources to support stream ecosystem; methods to quantify its significance on urban nutrient loads limited

- Nutrient loading highly time-dependent
    - Seasonal influence
    - Storm events influence mobility and leachate
    - Decomposition of leaf litter in-situ and movement through the storm drain system.

Summary

- Ability to infer water quality benefits from hydrologic benefits & understanding of processes affecting nutrient removal
- Site specific conditions and tree species contribute to variability and applicability of study findings
- The relationship between runoff reduction and pollutant load reduction is a primary assumption in many watershed models
  - Increased canopy cover in urban watersheds decreases runoff

Tree Canopy, Water Yield, and Nutrient Fluxes from Pervious and Impervious Land Uses

(gettyimages.com)

Justin Hynicka[1] and Marion Divers[2]

1 – Maryland Department of Natural Resources – Forest Service

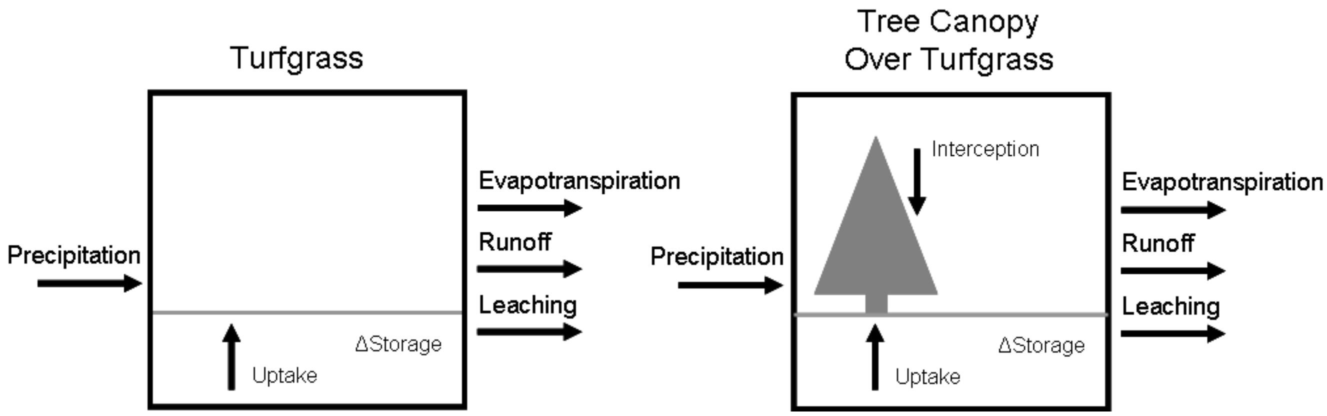
2 – University of Pittsburgh – Department of Geology and Environmental Science

This analysis builds on work by the Tree Canopy EP

- Expands the scope of the previous Tree Canopy Expert Panel Technical Memo beyond canopy interception to include ecosystem level processes
- This analysis draws from an expanded literature review on urban tree planting and canopy (Karen Cappiella, Center for Watershed Protection)
- Combines information from the literature review with other research on plant physiology and watershed processes into a generalizable water balance model
- Describes how changes in water yield due to tree canopy interact with nutrient cycling processes to reduce non-point source pollution

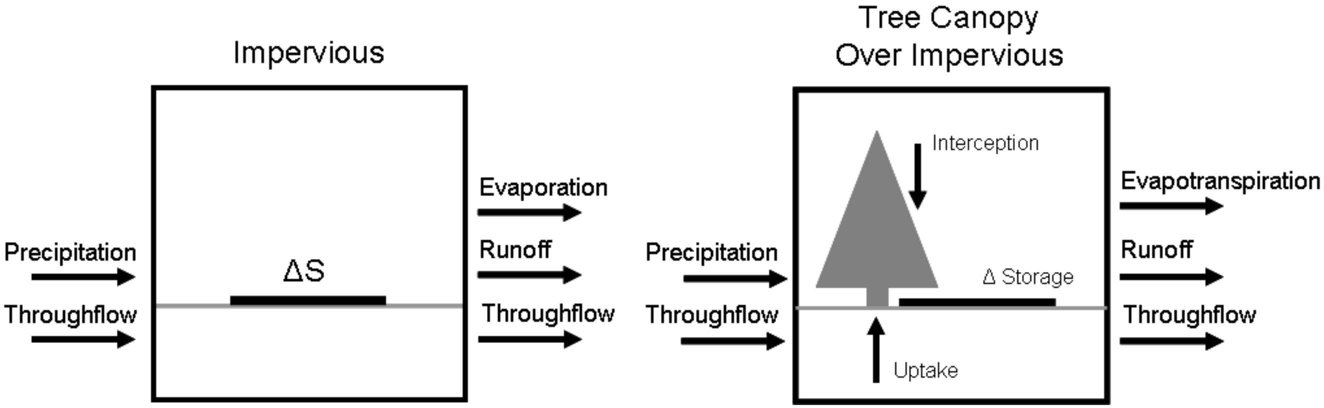
Why water balance, and what does it look like?

- Regardless of the source, nutrients and sediment are transported by water to streams, rivers, estuaries, and beyond.
- For a long-term practice in complex watersheds modeling is the best approach to estimate relative loading rates among land classes



Canopy over impervious surfaces has unique challenges

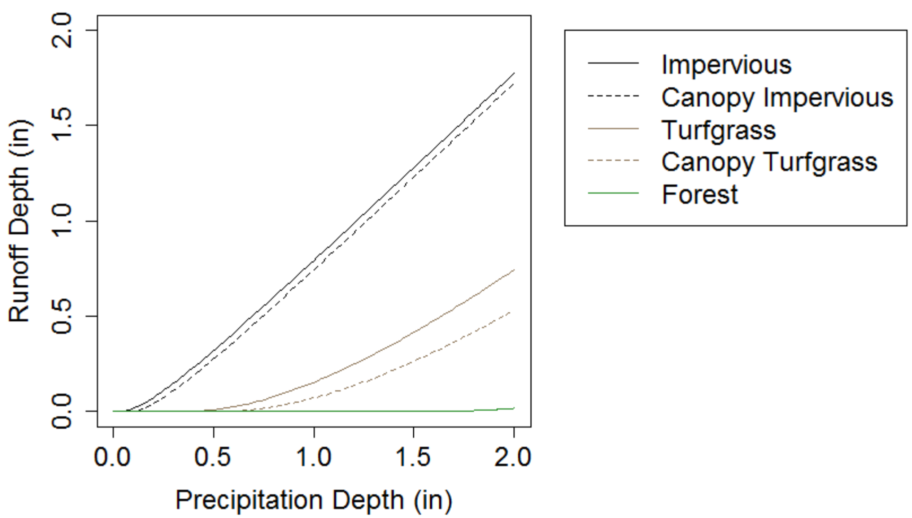
- Requires a source of water and nutrients to build biomass that cannot fully be supplied by atmospheric sources



- Net effect of leaf litter on nutrient loads is ***zero***

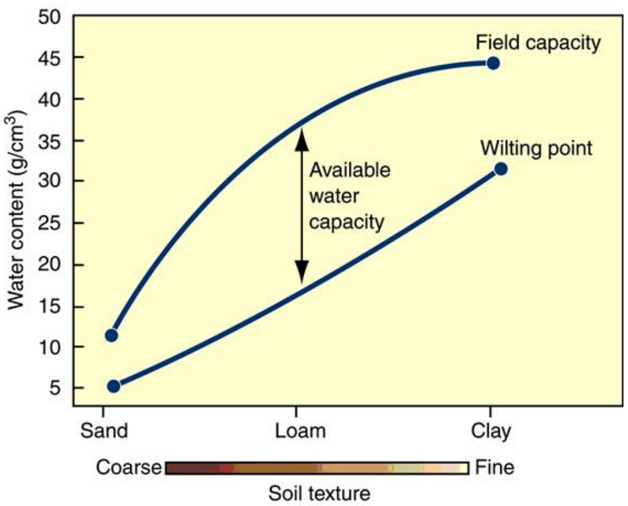
Runoff calculated using the SCS Curve Number Method

- Developed by the USDA Soil Conservation Service (TR-55, 1986)
- The amount of runoff generated varies with the amount of rainfall and the physical attributes of the land surface (*CN*)
- Interception capacity, C_i = 0.05 inches of water per storm
- *CN* = 98, 84, and 80 for impervious, turfgrass, and turfgrass with tree canopy (hydro soil group D)
- This approach is informed by science (EP literature review), scalable, flexible, and robust.



Leaching is influenced by soil type and evapotransportation

- The water remaining – after interception capacity and runoff – infiltrates into the soil
- The leaching flux depends on the maximum water holding capacity of the soils and the actual volume of soil water
- Model based on silt clay loam soils with a maximum water holding capacity of 2.0 inches per foot of soil

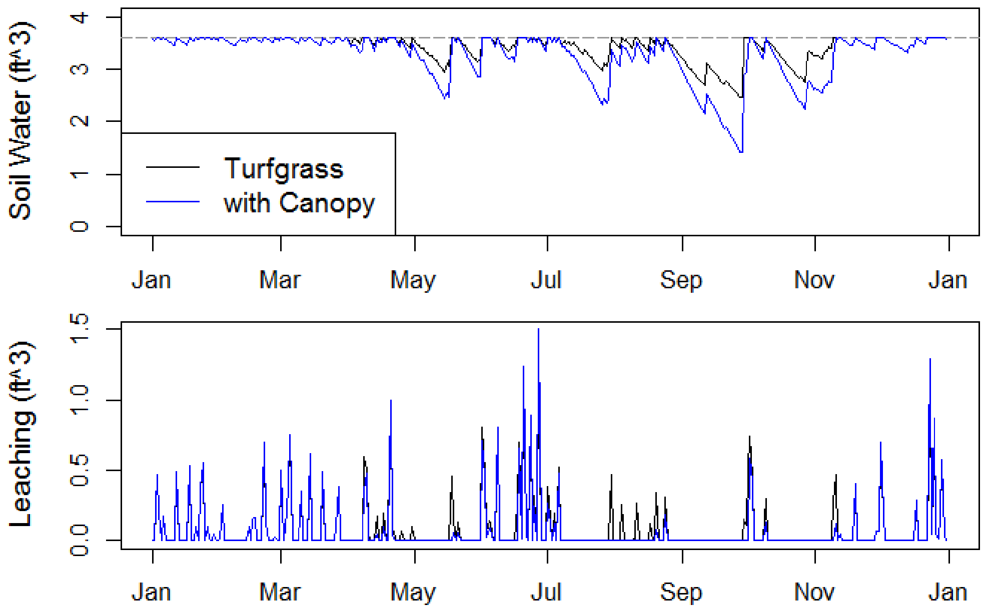


http://www.tankonyvtar.hu/en/tartalom/tamop425/0032_talajtan/ch07s02.html

ET increases water holding capacity between storms

- ET during growing season set to 0.05 and 0.08 inches per day for turfgrass and turfgrass plus trees, respectively
- Tracking changes in soil water also helps to constrain ET

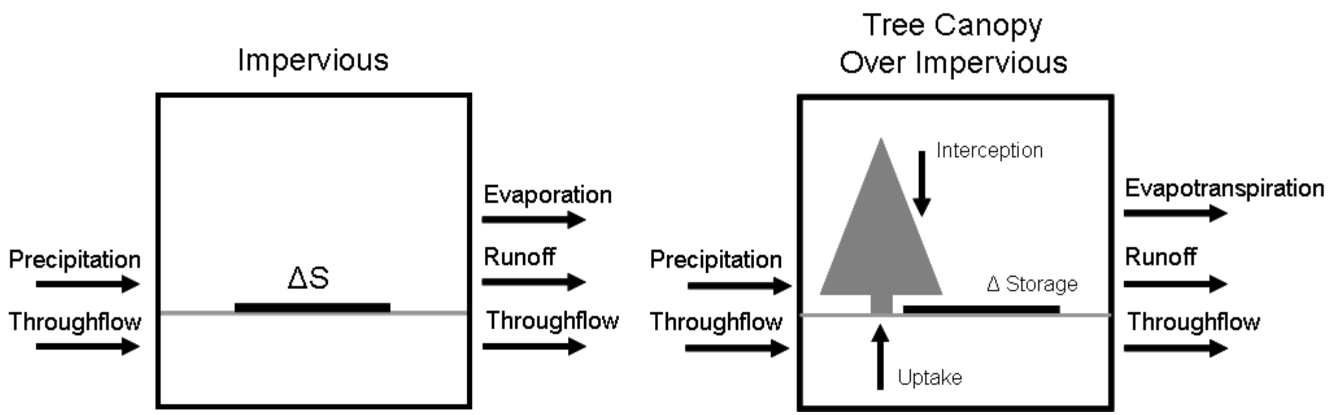
Model output using 2015 daily precipitation data from Baltimore International Airport



Trees capture throughflow beneath impervious surfaces

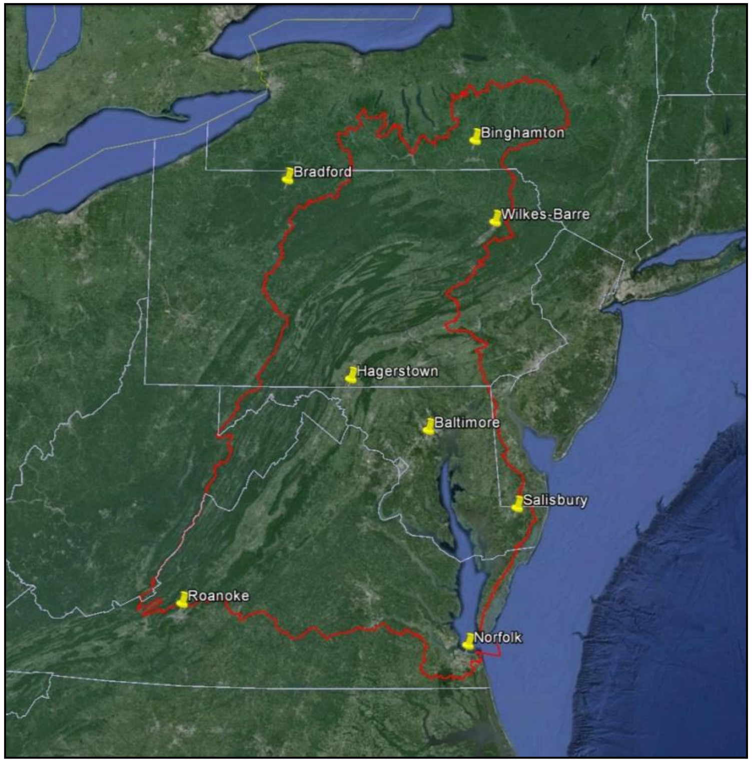
- Average daily throughflow was calculated using the volume of water leached annually from a square meter of turfgrass and redistributing it evenly over the course of a year.

- ET of trees during growing season set to 0.05 inches per day



Model results

- Percent reductions in water yield by trees relative to the underlying land use without trees
- Averages based on 2015 rainfall data from eight regional locations



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Land Use	Precip. (in)	Runoff Red. (%)	Leaching Red. (%)	Throughflow Red. (%)	Total (%)
Canopy over Turfgrass	43.6	39.1	23.3	NA	26.0
Canopy over Impervious					

$$Total = \left(1 - \frac{\sum R_C + \sum L_C}{\sum R + \sum L}\right) \times 100$$

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Model results

- These results should be considered a starting point for characterizing pollution transport.

- How do changes in water yield by trees interact with nutrient cycles to enhance pollution removal processes?

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1. Water vapor is returned to the atmosphere through **evapotranspiration**

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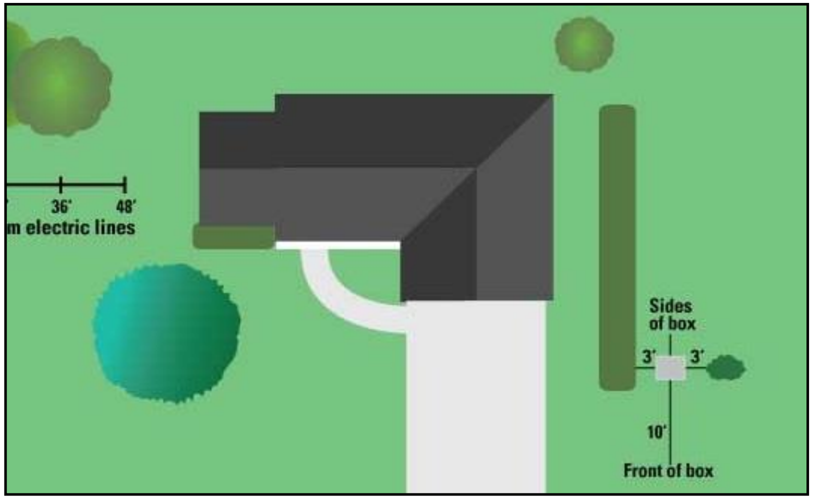
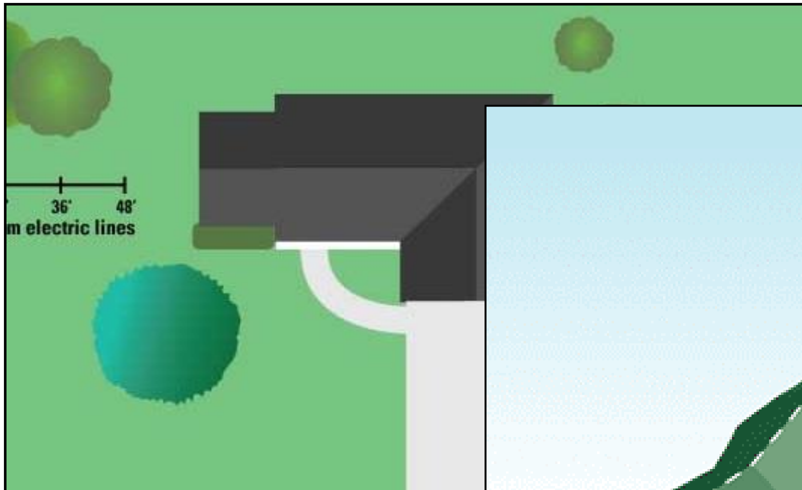
4. Sediment from the atmosphere is **incorporated** into the soil
5. **Erosion is minimized**

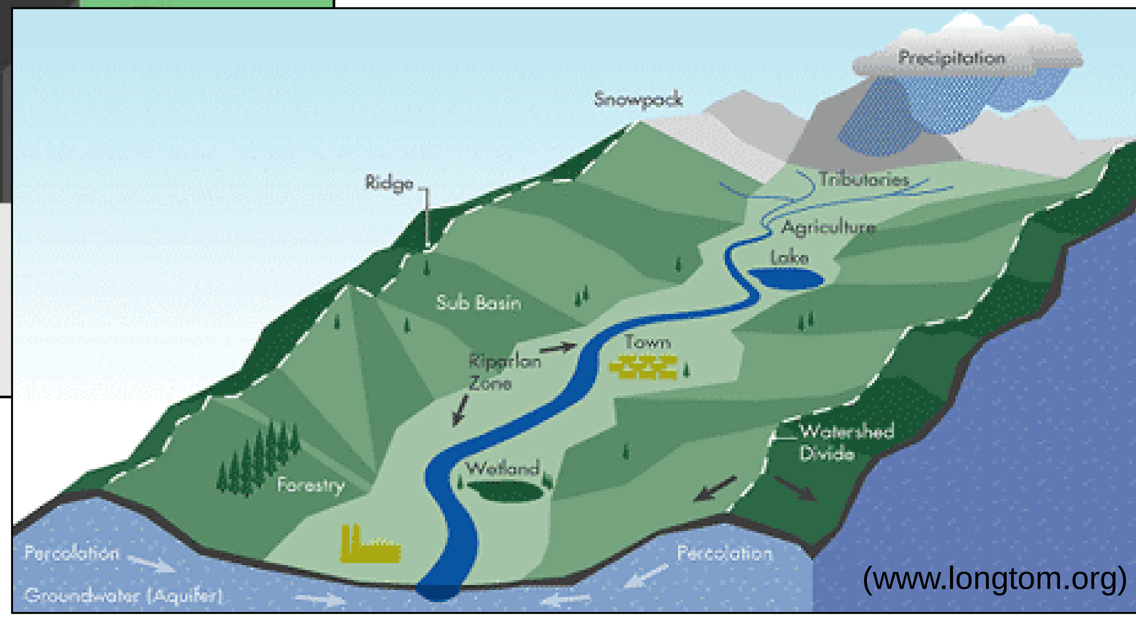
Direct versus indirect benefits of reduced water yield



- Direct benefits occur at the **parcel scale**.
- Result from less N, P, and sediment transport from the land surface in runoff and soil leachates.

Direct versus indirect benefits of reduced water yield





(www.longtom.org)

- Indirect benefits occur at the **watershed scale**
- Result when stream bank erosion is minimized

Direct versus indirect benefits of reduced water yield

- Both direct and indirect benefits help to explain nutrient and sediment loads observed at monitoring stations

American elm was one of the most abundant tree species

Catastrophic loss of elm between 1980 to 1990

- Chart and map from a presentation by Peter Macdonagh, Kestrel Design Group (2015)

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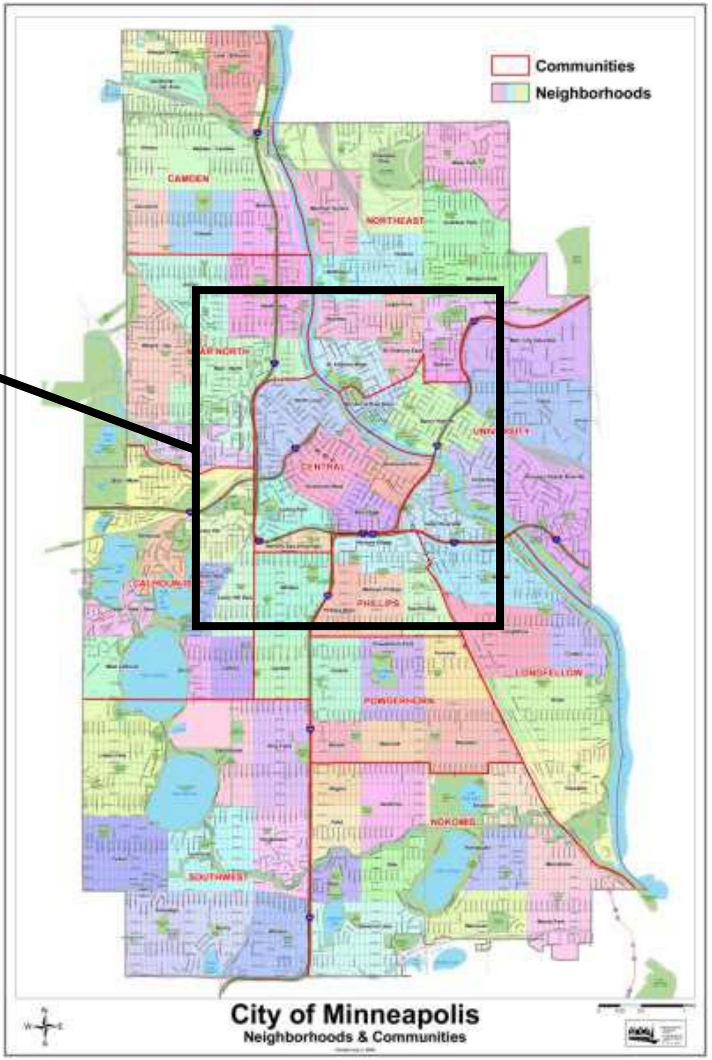
~10 % loss of total street trees



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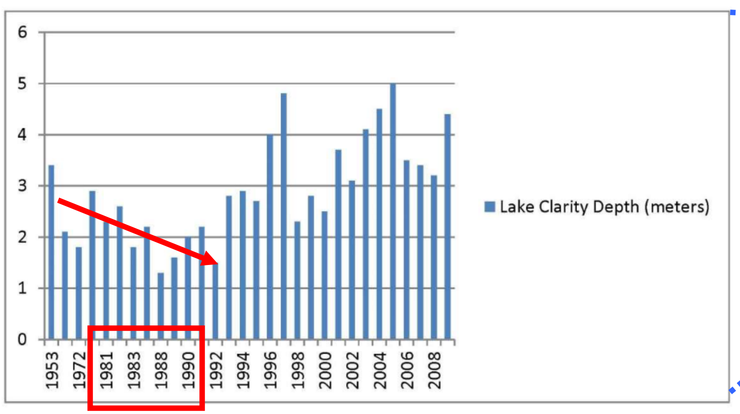
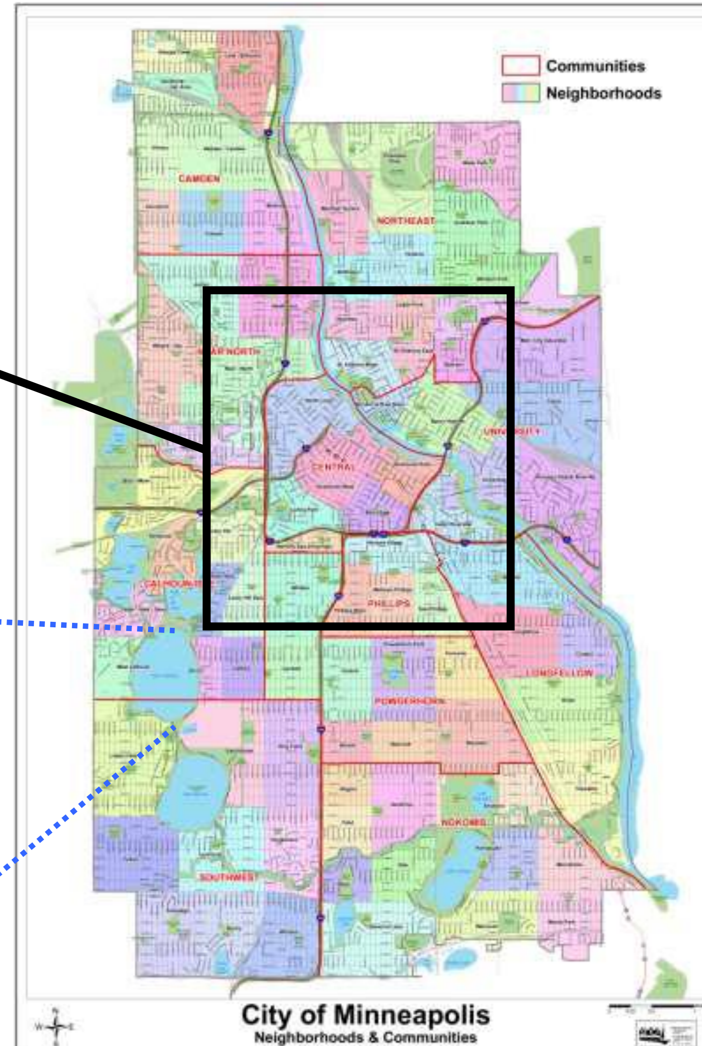
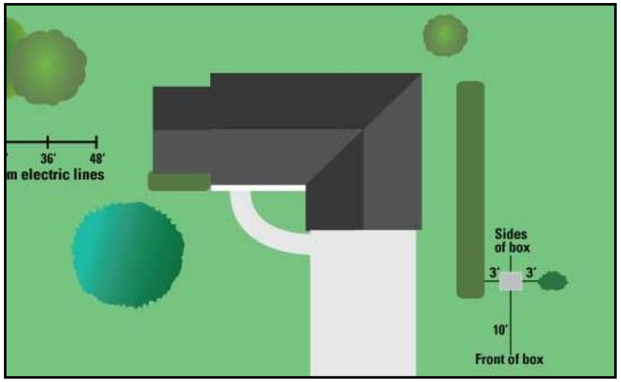
Water clarity declines with tree mortality





Tree canopy over turfgrass directly reduce pollution loads by promoting the natural retention processes

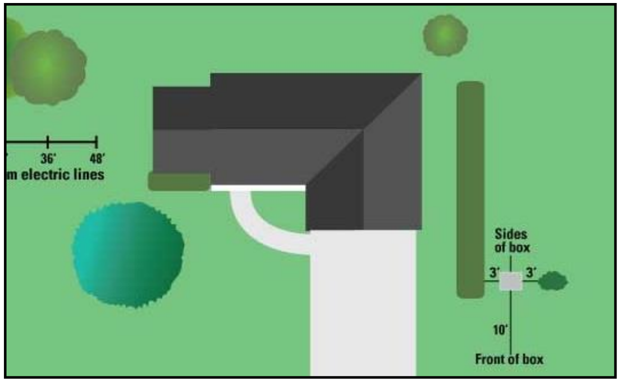
Underlying Land Use	Direct Benefits	Indirect Benefits
Turfgrass	High	
Impervious		



- Increased infiltration with trees in turfgrass leads to greater filtration/capture of nutrients and sediments
- Increased soil moisture and soil organic matter from trees enhances the conditions required for denitrification
- Diffusion of N and P from tree leaves into throughflow is small relative to other inputs
- **Result: reduction of nutrient loads from trees over turfgrass are likely *directly proportional* to reductions in water yield**

Tree canopy over impervious surfaces provides a low level of direct benefits for pollution reduction

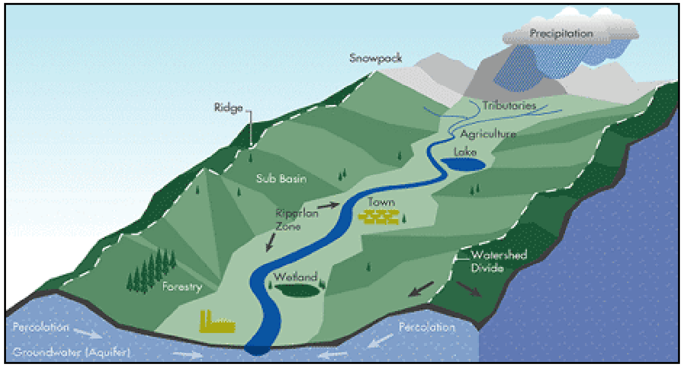
Underlying Land Use	Direct Benefits	Indirect Benefits
Turfgrass		
Impervious	Low	



- Tree soil pits surrounded by impervious surfaces likely not sized to capture water and allow filtration of sediments and nutrients
- Trees over impervious surfaces provide little opportunity for long-term nutrient storage (except in wood) or volatile losses
- **Result: nutrient loads from this land use are NOT directly proportional to water yield**

Tree canopy over turfgrass has low to moderate benefits on indirect pollution reduction

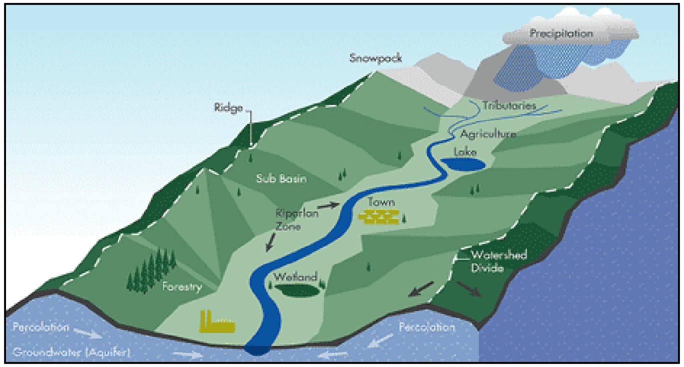
Underlying Land Use	Direct Benefits	Indirect Benefits
Turfgrass		Low to Moderate
Impervious		



- Turfgrass is relatively efficient at limiting runoff, which makes the interception benefits of trees most important in extreme storm events
- Opportunities to further reduce downstream sediments, nutrients, and erosion, beyond reductions already attributed to increased infiltration in this landuse, are limited because of low runoff
- **Result: Trees over turfgrass have only *low to moderate INDIRECT* benefits**

Tree canopy over impervious surface can have a HIGH indirect effect on pollution reduction

Underlying Land Use	Direct Benefits	Indirect Benefits
Turfgrass		
Impervious		High



- Trees intercept precipitation on leaves and branches
- Trees reduce rainfall intensity, volume, and velocity, by increasing the surface roughness of the impervious landscape
- **Result: Trees over impervious surfaces have *high INDIRECT* benefits as downstream loads of sediment and nutrients are mitigated.**

Summary and Conclusions

Underlying Land Use	Direct Benefits	Indirect Benefits
Turfgrass	High	Low to Moderate
Impervious	Low	High

Summary and Conclusions

Underlying Land Use	Direct Benefits	Indirect Benefits
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- Pollution loads from trees over turfgrass are ***directly proportional*** to reductions in water yield

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- In contrast, pollution loads from trees over impervious surfaces are ***not directly proportional*** to reductions in water yield

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Land Use	Pollution Reduction (%)
Canopy over Turfgrass	26.0
Canopy over Impervious	7.1

Timeline and Next Steps

- **February 11** – Today's webinar
- **February 22** – Deadline for feedback on loading rates and methods
  - Submit input to Julie Mawhorter (CB Tree Canopy Coordinator), jmawhorter@fs.fed.us
- Brief workgroups and seek their approval where needed
  - **March 2**: Forestry Workgroup
  - **March 2**: Land Use Workgroup
  - **March 3**: Watershed Technical Workgroup
  - **March TBD**: Modeling Workgroup
  - **March 14**: Water Quality Goal Implementation Team
  - **March 15**: Urban Stormwater Workgroup

Land Use	Pollution Reduction (%)
Canopy over Turfgrass	26.0
Canopy over Impervious	7.1

After the webinar, you can send written questions and comments to jmawhorter@fs.fed.us by Feb. 22