Quantifying the Water Quality Benefits of Urban Tree Canopy

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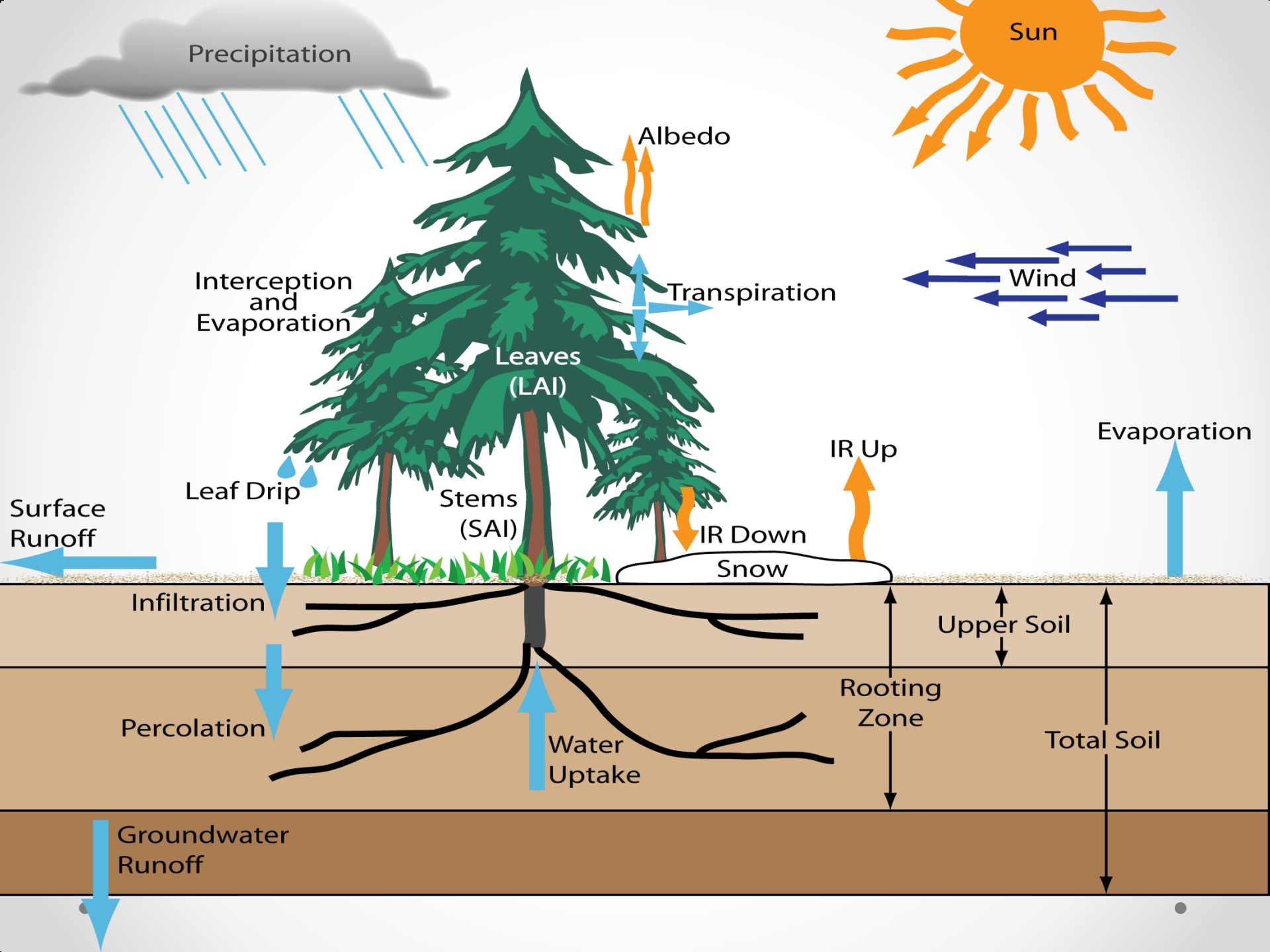
How urban tree canopy impacts nitrogen (TN), phosphorus (TP), and suspended sediment (TSS) in run-off

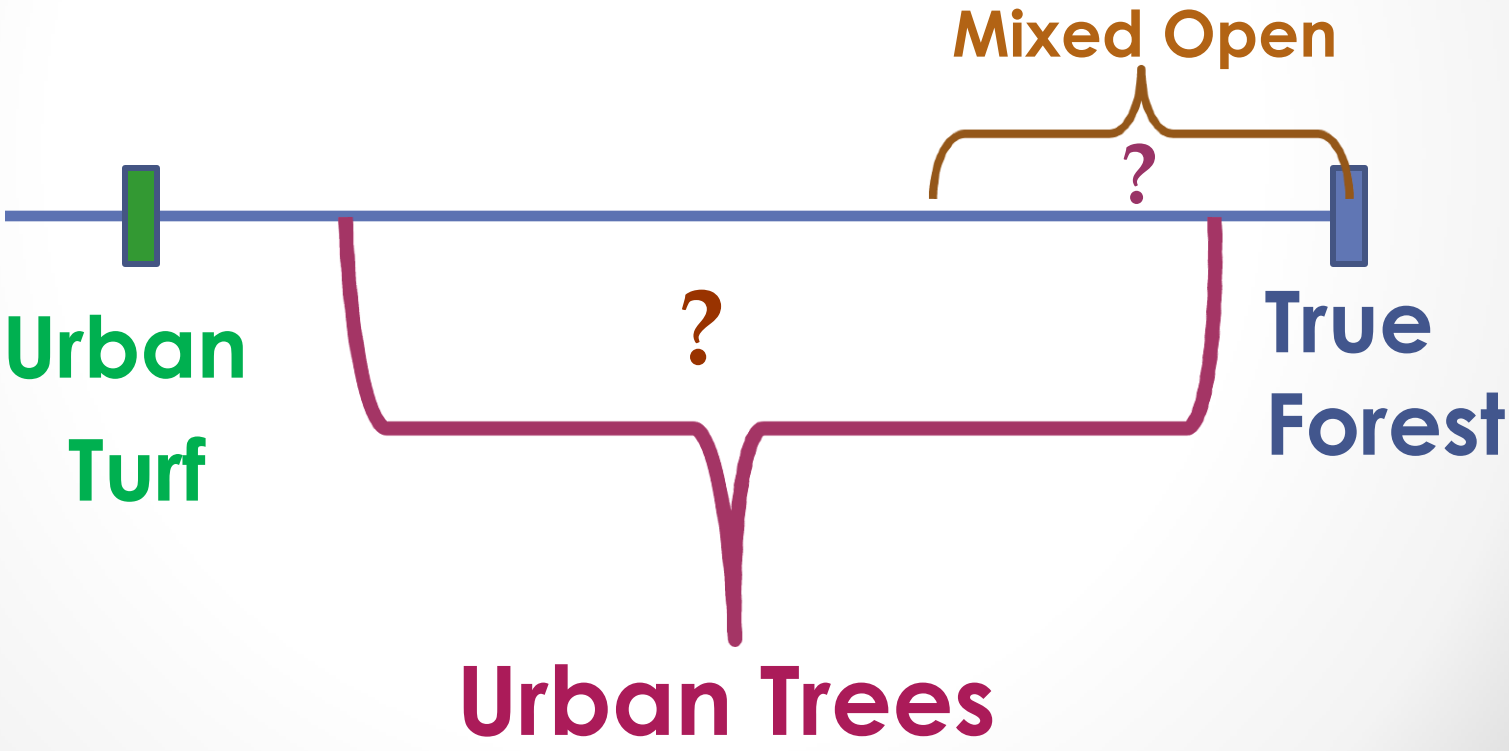
- Currently included as "urban pervious"
- Newly established urban tree canopy gets the pollution reduction credit of a natural forest
- Phase 6.0 proposed changes
- Is it fair to continue to credit new tree canopy and not existing tree canopy?


Precipitation
Sun
Albedo
Interception
and
Evaporation
Transpiration
Wind
Leaves
(LAI)
Leaf Drip
Stems
(SAI)
IR Up
IR Down
Evaporation
Surface
Runoff
Snow
Infiltration
Upper Soil
Rooting
Zone
Percolation
Water
Uptake
Total Soil
Groundwater
Runoff

Current Land Use Loading Values and UTC Expansion BMP Pollution Reduction Efficiency

	TN (lbs/ac/yr)	TP (lbs/ac/yr)	TSS (tons/ac/yr)
Urban Pervious	9.43	0.57	0.07
Forest	3.1	0.13	0.03
Efficiency	66%	77%	57%

Where is UTC along this spectrum?



Benefits of Urban Trees

Interception
Evapotranspiration
Soil storage

} Runoff Reduction

Stormwater treatment { **Soil and root biological processes**

Interception
% of precipitation (12-40%)

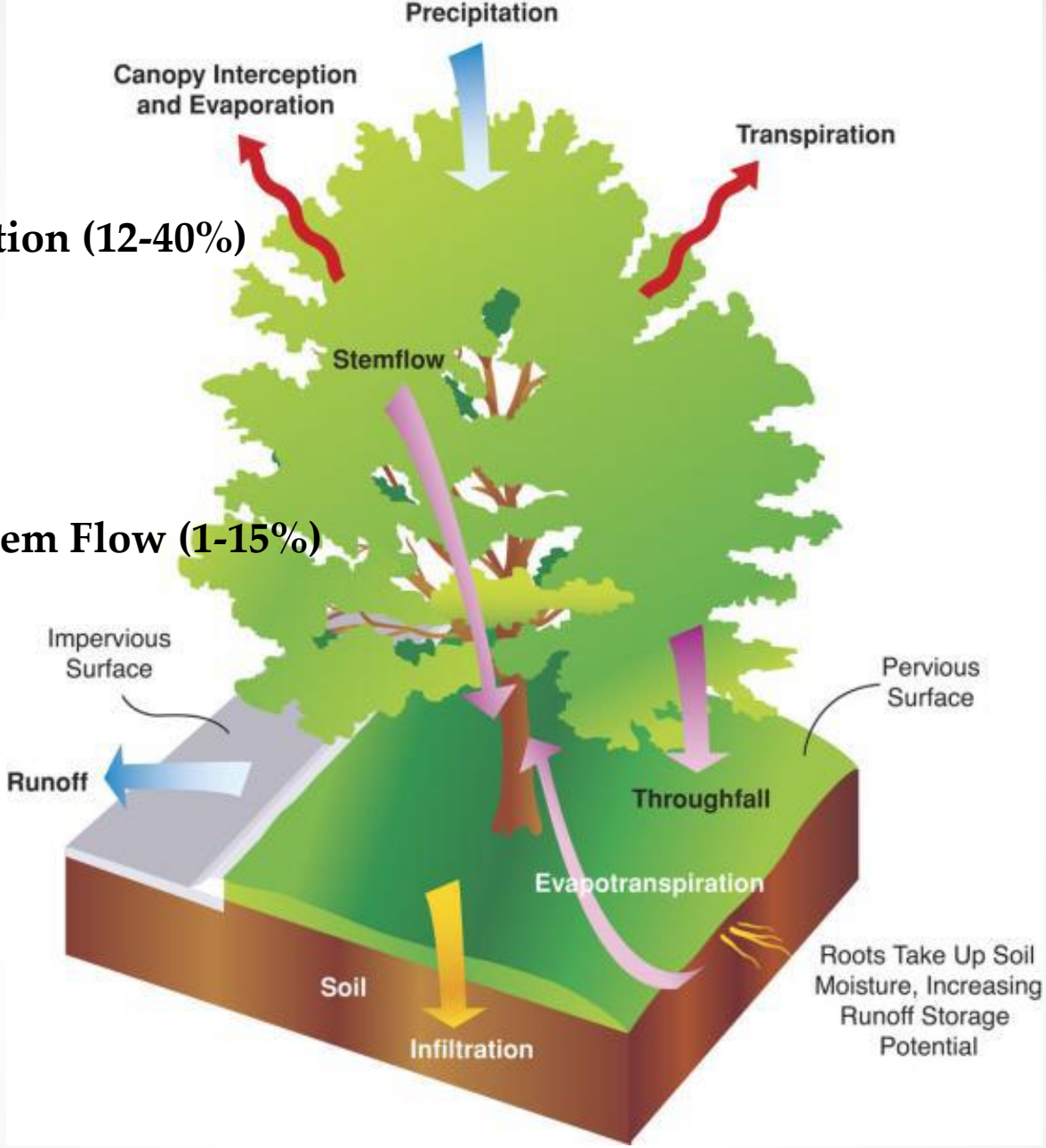
Study	Leaf-On	Leaf-Off
Xiao et al. (Davis, CA)		
Bradford pear		15
Cork oak		27
Xiao et al. (Oakland, CA)		
Lemon	27	40
Sweetgum	27	13
Ginkgo	38	27
Link et al. (Western Cascades)	25	
Pypker et al. (Western Cascades)	21	
Heal et al. (Great Britain)	44	
Zimmerman et al. (Europe)	51	

Interception is important because…

- Captures, slows rainfall before it hits the ground
- Canopy takes the first ~1/2" of rain
- Reduces runoff, soil erosion and P loss

Interception (12-40%)

Stem Flow (1-15%)



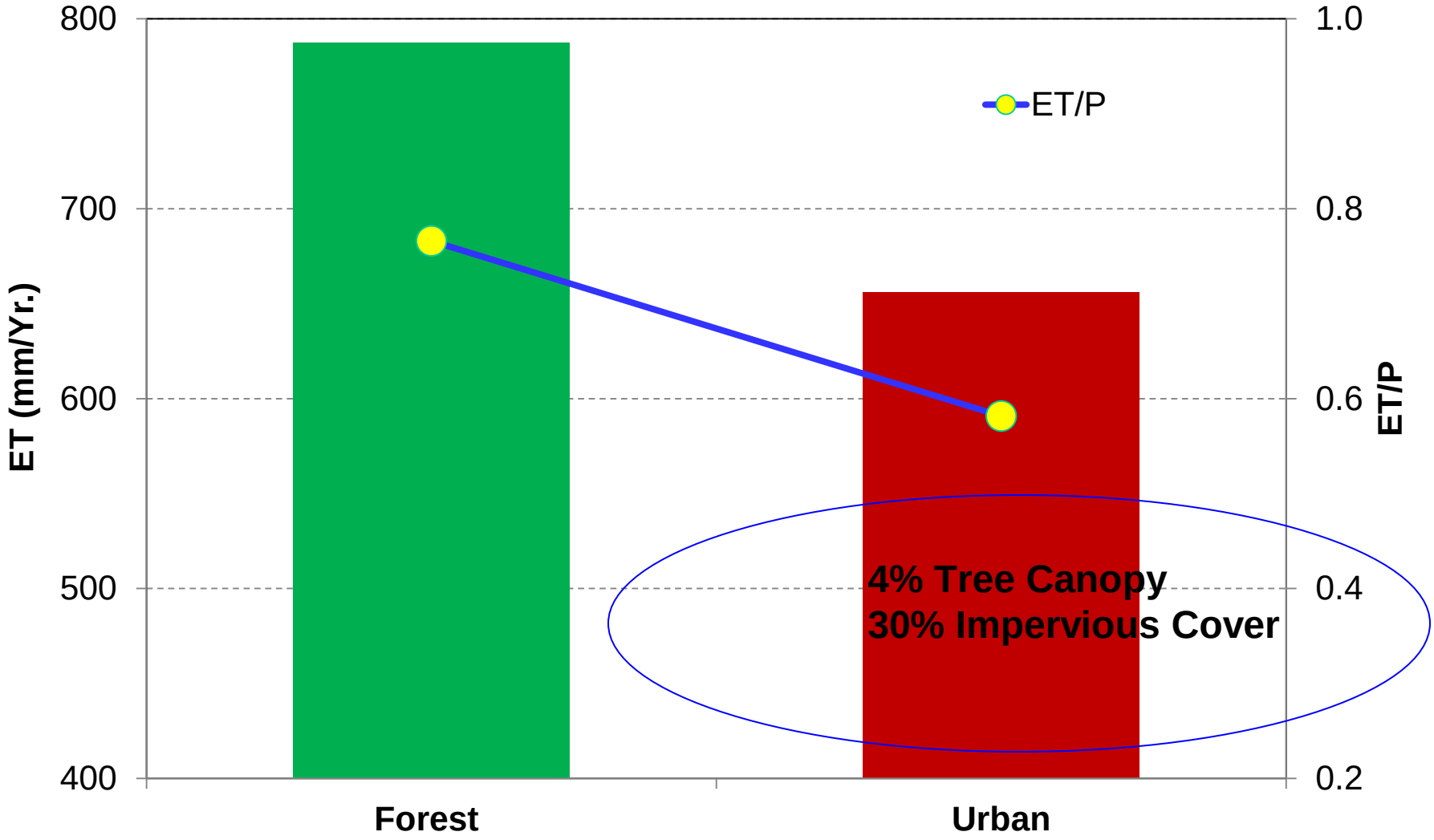
Xiao, Q.; McPherson, E.G.; Ustin, S.L.; Grismer, M.E. 2000. A new approach to modeling tree rainfall interception. Journal of Geographical Research Atmospheres 105: 29173

EvapoTranspiration

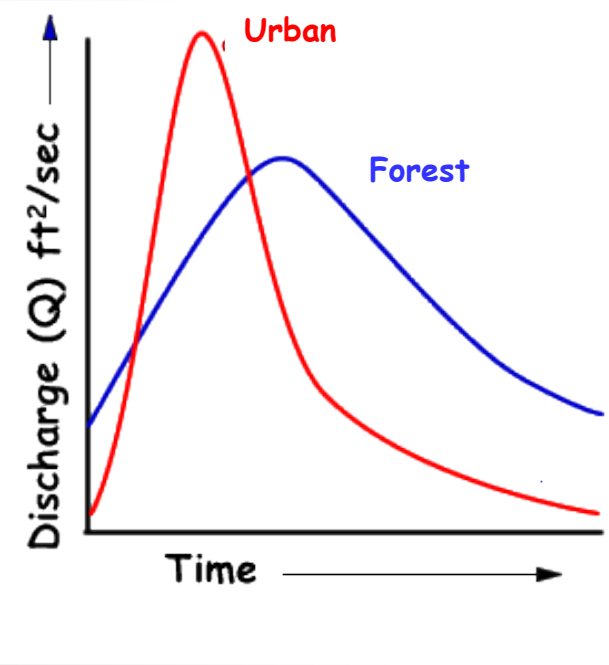
Is ET the Answer?

- ET is key to controlling urban storm flow
- Various bodies of work comparing streamflow to ET
- The more biomass/Leaf Area Index (LAI), the higher ET
- ET also varies with
  - tree shape, species
  - Climate, season
  - Storm intensity, frequency, duration
  - Proximity to impervious surface

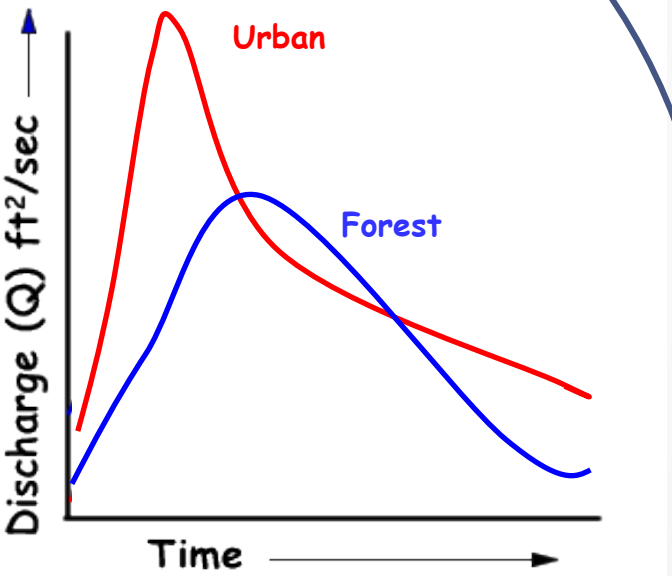
20% Higher ET in Forested v. Urban Watersheds in Piedmont NC (from Sun)



Forested watersheds have lower baseflow, more ET (77%) than commonly depicted; Urban watersheds have lower ET (58%)



Textbook view



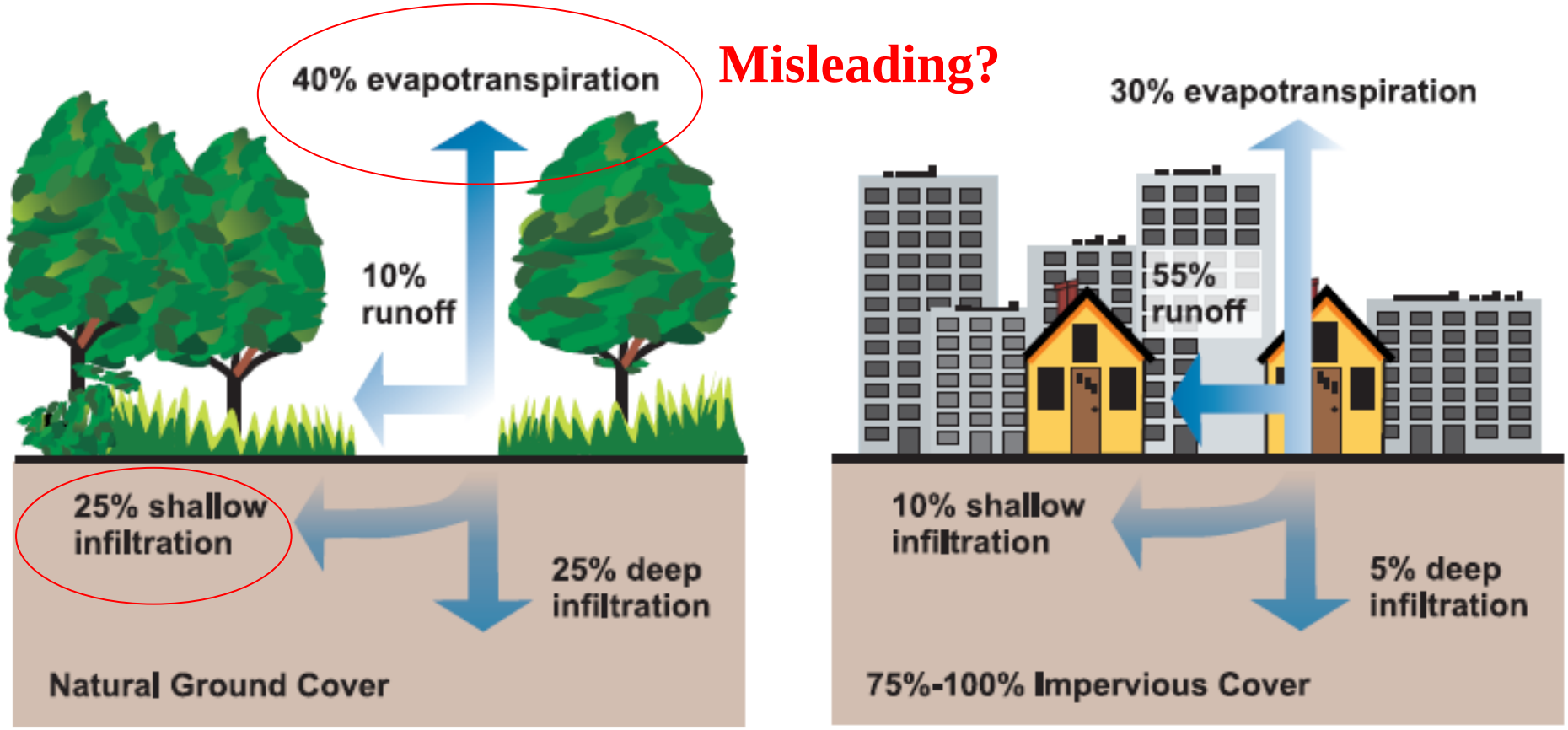
More likely reality

EPA
United States
Environmental Protection
Agency

EPA 841-F-03-003

Protecting Water Quality *from* URBAN RUNOFF

Misleading?



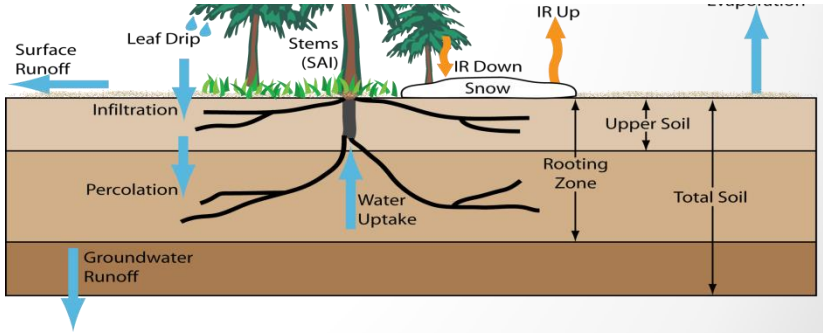
Relationship between impervious cover and surface runoff. Impervious cover in a watershed results in increased surface runoff. As little as 10 percent impervious cover in a watershed can result in stream degradation.

MN Example

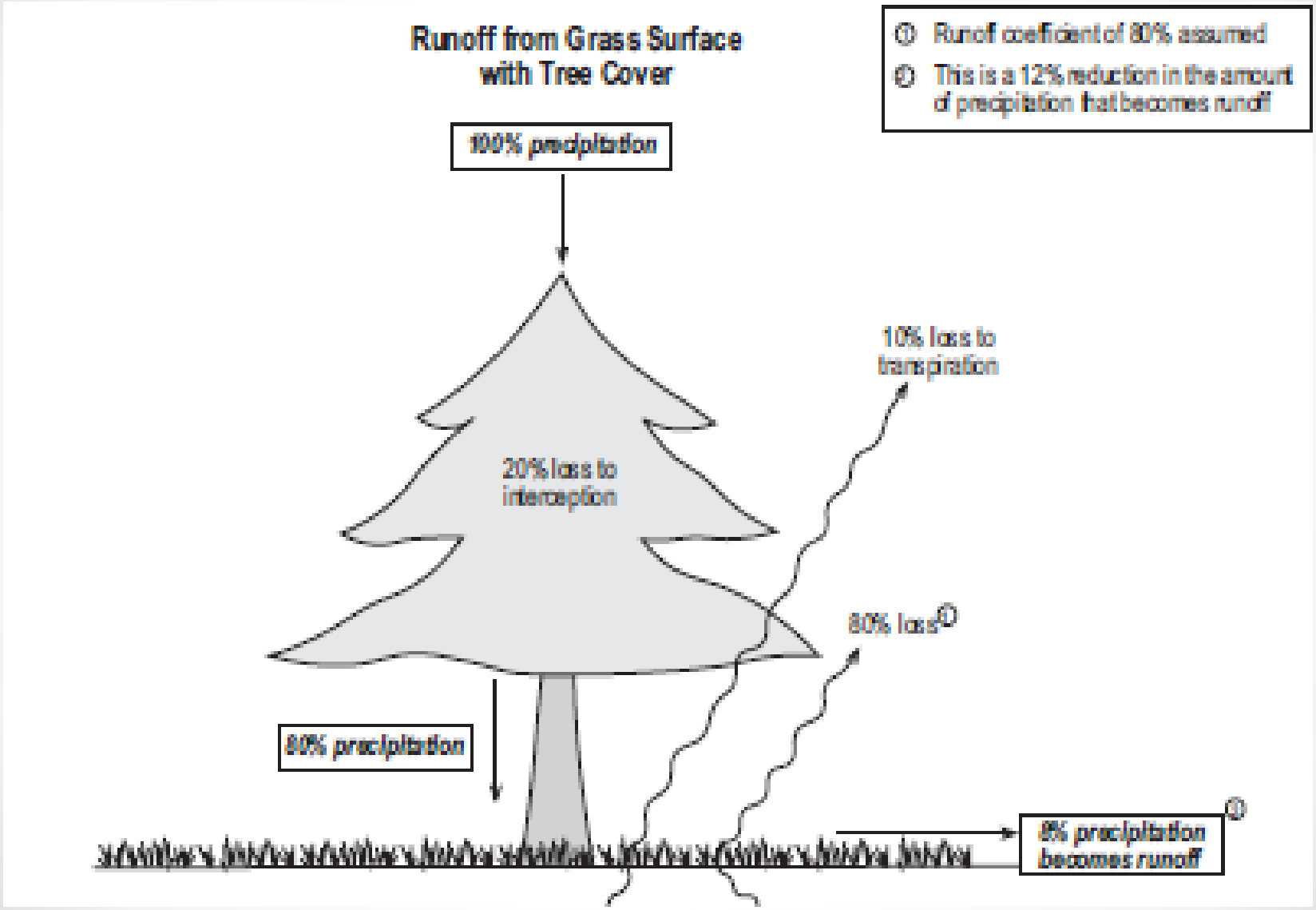
- Developed a formula to credit ET (trees) in stormwater mgt
- Water taken up by plants & soil
- Tied to canopy size
- Based on mature size if planted correctly
- 2 ft^3 soil per 1 ft^2 canopy

Soil and Roots

- undisturbed
- rich OM
- loose, oxygenated
- microbes and fungi
- high fungi:bateria ratio
- roots create macropores
- big reservoir



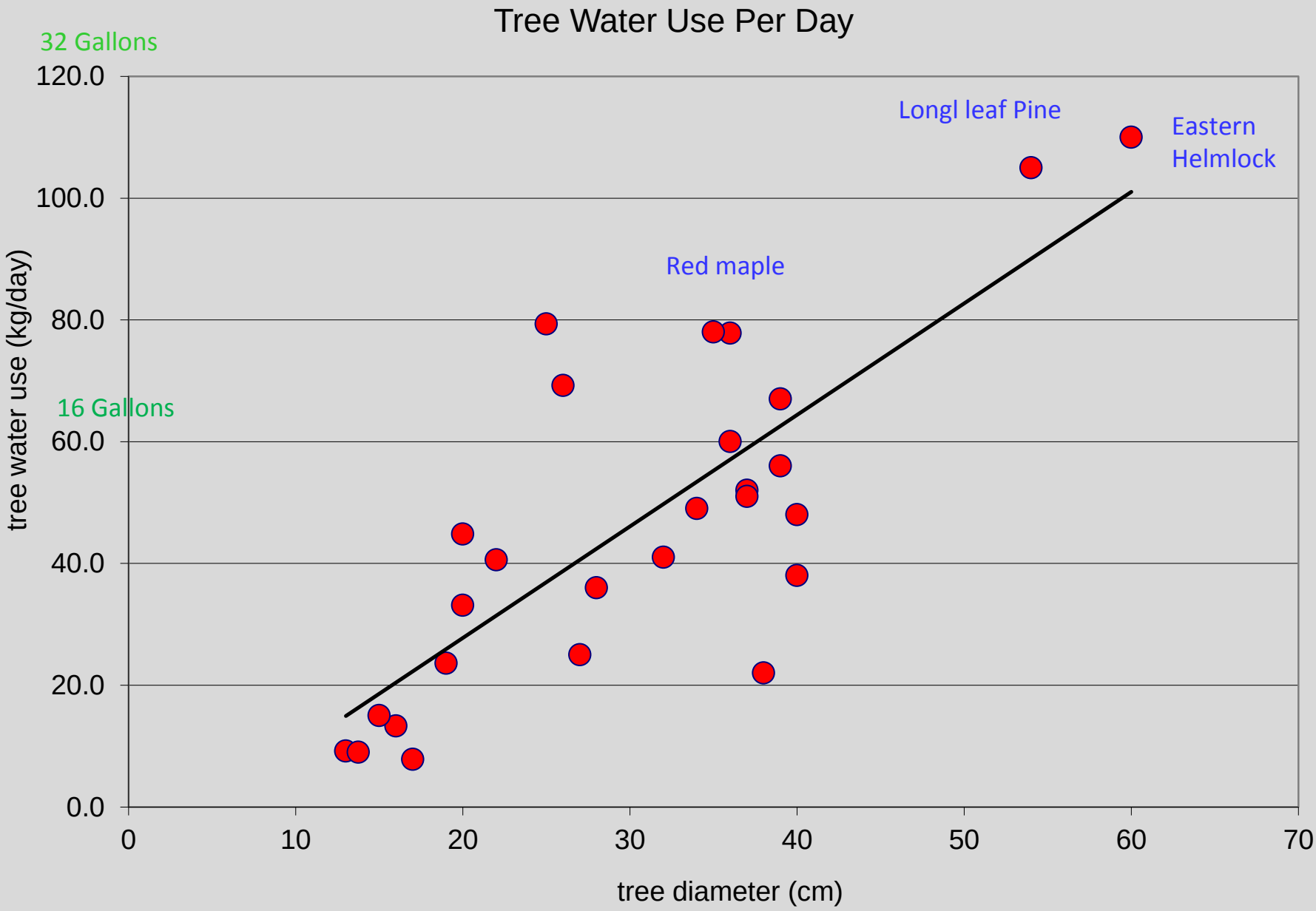
Mass Balance Approach

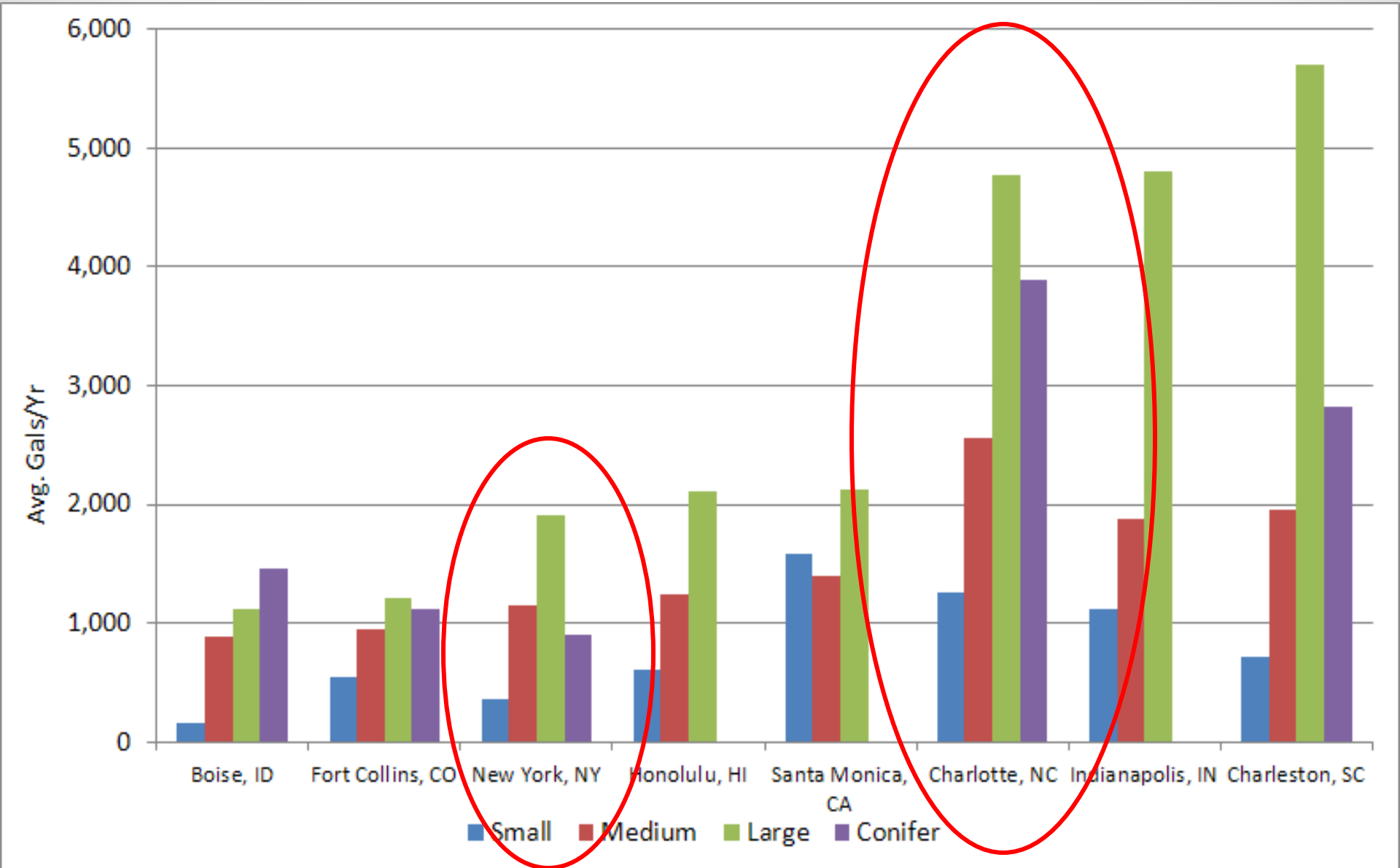


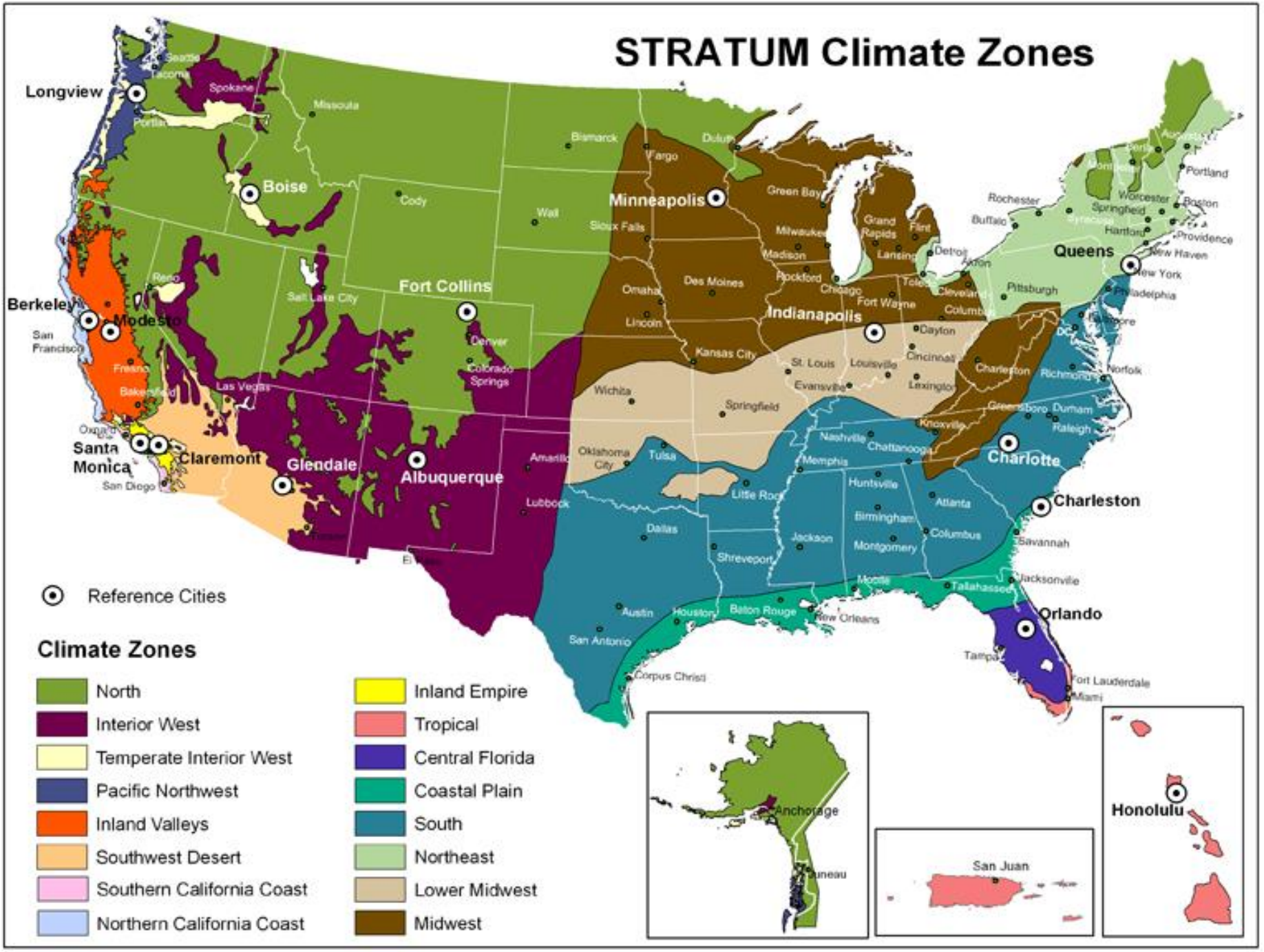
From Herrera 1996

Runoff Reduction values

Baldwin 1938	60%	Old growth
Xiao and McPherson 2002	15-27%	Urban, California
Herrera 1998	30-40%	Washington state
Zinke 1967	15-40%	urban coniferous stands
Zinke 1967	10-20%	urban hardwood stands
iTree	51-61%	
Elmendorf pub	~75%	engineered tree bioswale in MA

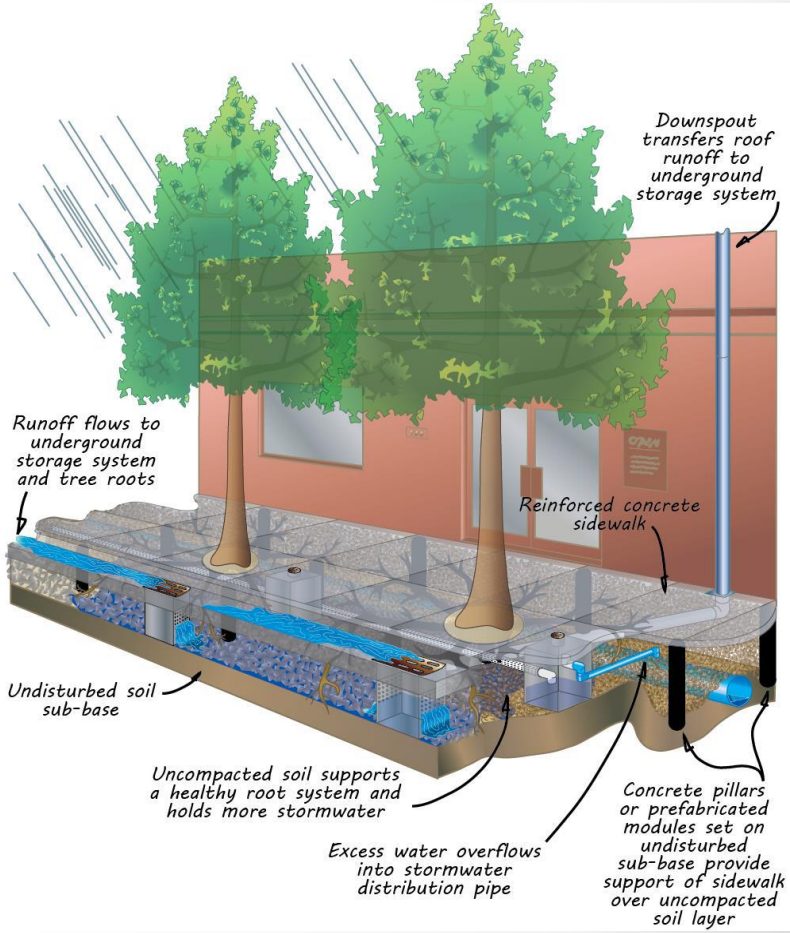

Tree Water Use Per Day
32 Gallons
16 Gallons
120.0
100.0
80.0
60.0
40.0
20.0
0.0
tree water use (kg/day)
0
10
20
30
40
50
60
70
tree diameter (cm)
Longl leaf Pine
Eastern Helmlock
Red maple


6,000
5,000
4,000
3,000
2,000
1,000
0
Avg. Gals/Yr
Boise, ID
Fort Collins, CO
New York, NY
Honolulu, HI
Santa Monica, CA
Charlotte, NC
Indianapolis, IN
Charleston, SC
Small
Medium
Large
Conifer


STRATUM Climate Zones
Longview
Boise
Minneapolis
Fort Collins
Berkeley
Modesto
Santa Monica
Claremont
Glendale
Albuquerque
Indianapolis
Queens
Charlotte
Charleston
Orlando
Reference Cities
Climate Zones
North
Interior West
Temperate Interior West
Pacific Northwest
Inland Valleys
Southwest Desert
Southern California Coast
Northern California Coast
Inland Empire
Tropical
Central Florida
Coastal Plain
South
Northeast
Lower Midwest
Midwest
Anchorage
San Juan
Honolulu

Engineered Plantings (tree pit and/or soil amendments)

- Very effective portion of overall canopy
- Small percentage of current plantings
- Could be different BMP (e.g., bioswale)



Reinvisioning Cities

June 2008 – 0.5 years after planting

Case Study: Olympic Village Vancouver, Canada

Deep Design: Structural Cells, Infiltration, and Water Storage

Average DBH increase in 4 years: 3.5”

July 2012 – 4.5 years after planting

Panel of UTC Experts: Big Picture Topics

- Tree Patches v Individual open-grown trees
- Runoff reduction attributable to urban trees
- Amount of Imperviousness area v. Tree Canopy (iTree Hydro discussion)
- Engineered Plantings (tree pit size, soil amendments)

Other Topics Discussed by Expert Panel

- More credit for large canopy trees?
- Add lag time until fully-performing?
- Is understory managed/fertilized?
- Beneficial response of soil due to tree planting
- Technical issues: verification, tracking, maintenance, replanting, etc.

Urban Forest

- Less disturbed soil
- Deep roots (3-20')
- More groundwater storage
- High biomass/ET- 70%
- ET "Plus" biological drainage
- Stream baseflow lower

Where to focus?

- Interception
- Evapotranspiration
- Soil storage
- Soil and root biological processes
- Other…