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Invent the Future

# Soil Management for Urban Trees

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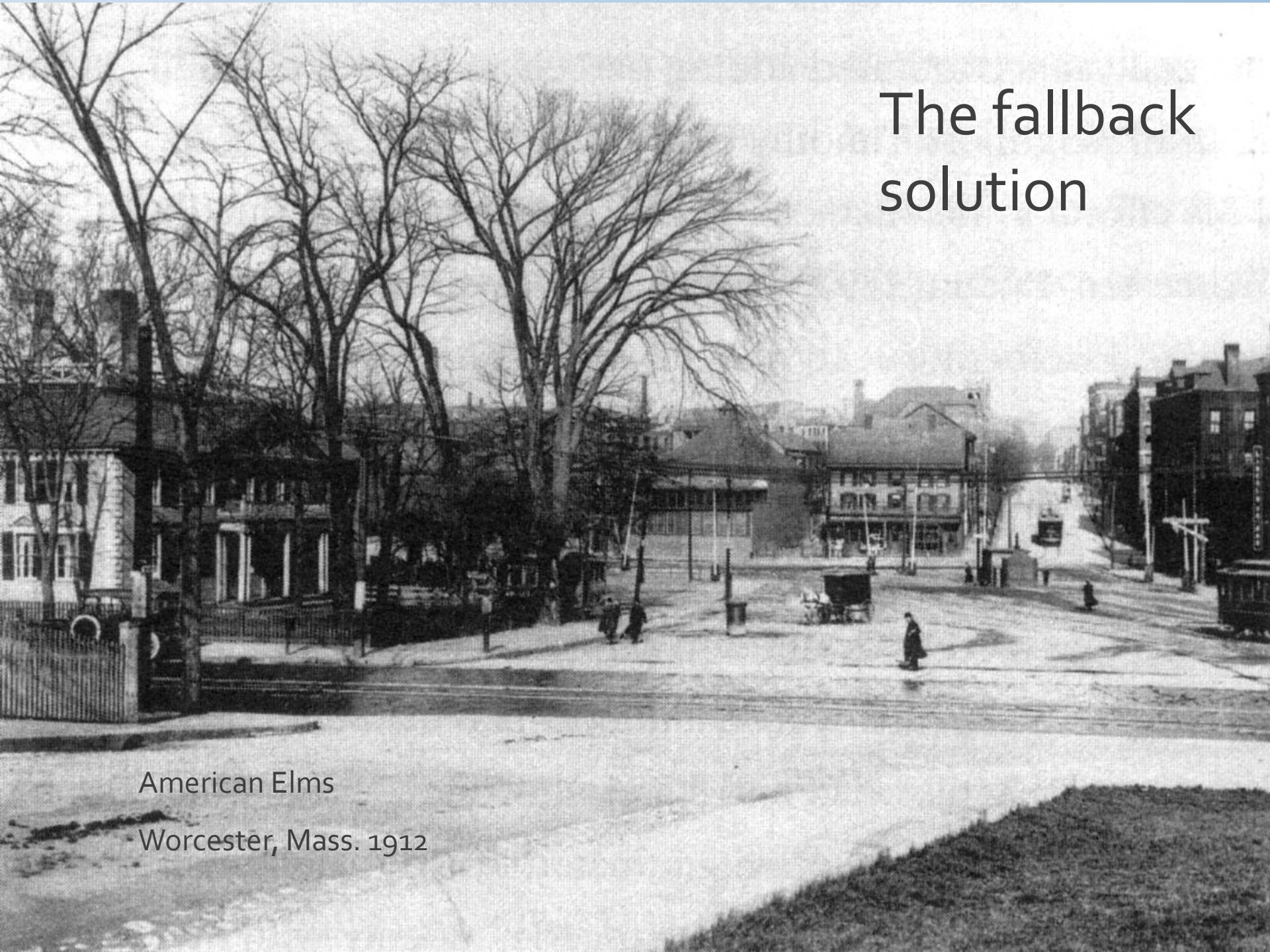
Forest Resources & Environmental Conservation, Virginia Tech

# Brief Agenda

- Soils and Stormwater Management
- How distributed is your stormwater management?
- Soil Surface Treatments and Site Complexity
- Soil Rehab with SPR

# What is good for trees is good for stormwater

# The fallback solution



American Elms

Worcester, Mass. 1912


Tree + ? = stormwater
management?

*Photo: Robert Llewellyn—Magnolia acuminata* (Cucumber Tree)
The Remarkable Trees of Virginia

# How close is your urban forest stormwater system?

17 million people live in the watershed—low-density urbanized land


Six States + the District of Columbia

# Sustainable Land Development?

Prime farmland soil was graded down 3 ft to redirect stormwater to bioinfiltration swale

# At "peak" time of year (May) 3 years later, tree dieback, thin turf, thin canopies, nutrient deficiencies

# Surface Treatments

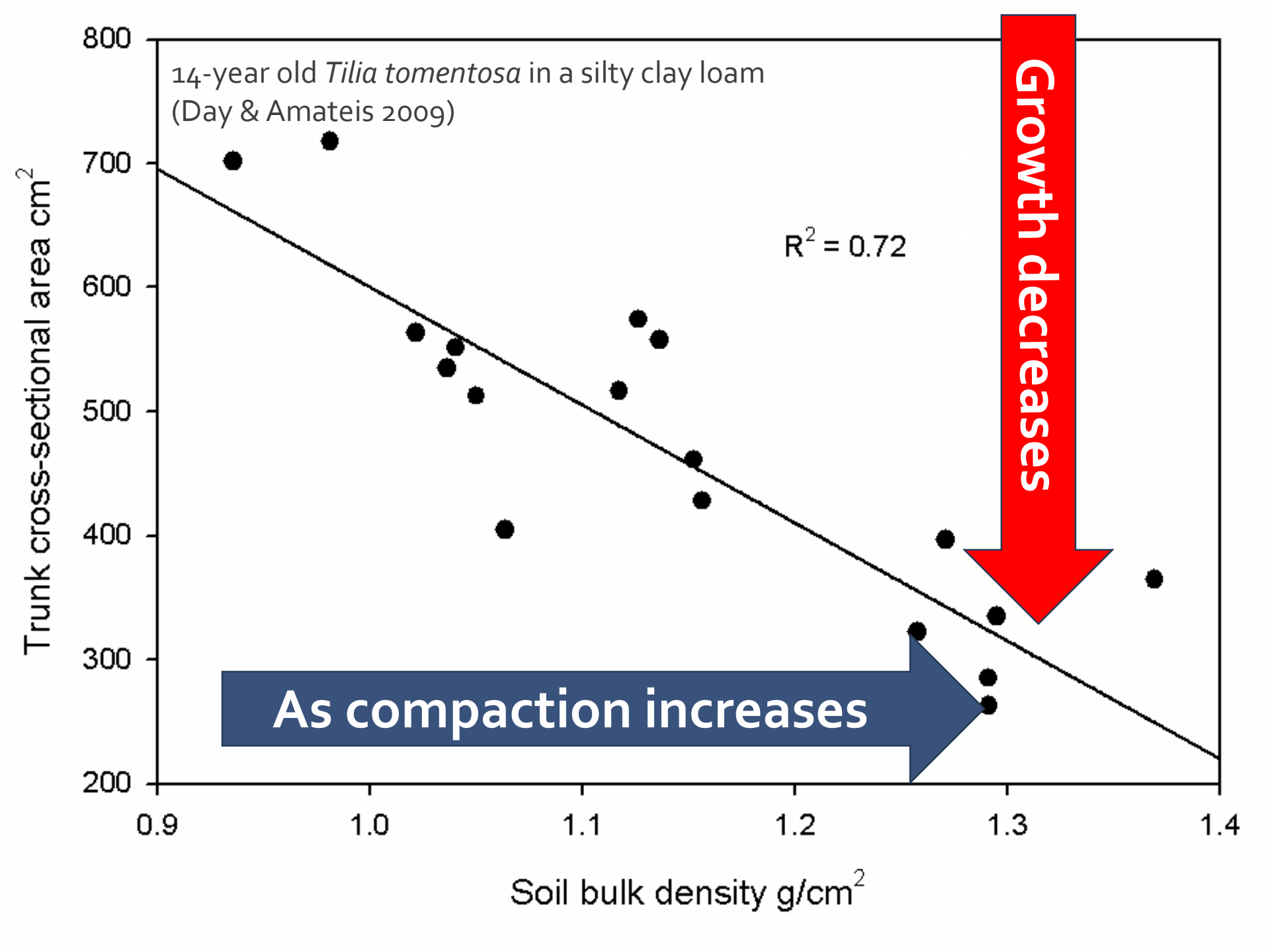
# Surface Treatments have traditionally been thought of in terms of moisture retention and weed suppression

David K. Mitchell et al. 2016 (in preparation)


• At 5-10 cm macroaggregates were reduced by 44%
• Lost 35% of total soil organic carbon (0-10 cm)
• Lost 47% of mineral-bound carbon
• Subsurface drainage reduced from about 3" an hour to less than ½" an hour.
Photo: Rachel M. Layman


Photo: Jeannette E. Spaghetti (CC)


What is my action threshold for addressing compaction?


14-year old *Tilia tomentosa* in a silty clay loam
(Day & Amateis 2009)
$R^2 = 0.72$
Growth decreases
As compaction increases
Trunk cross-sectional area $cm^2$
Soil bulk density $g/cm^2$
800
700
600
500
400
300
200
0.9
1.0
1.1
1.2
1.3
1.4

You can’t interpret soil bulk density without soil texture

Bulk density = 1.4 $g \cdot cm^{-3}$

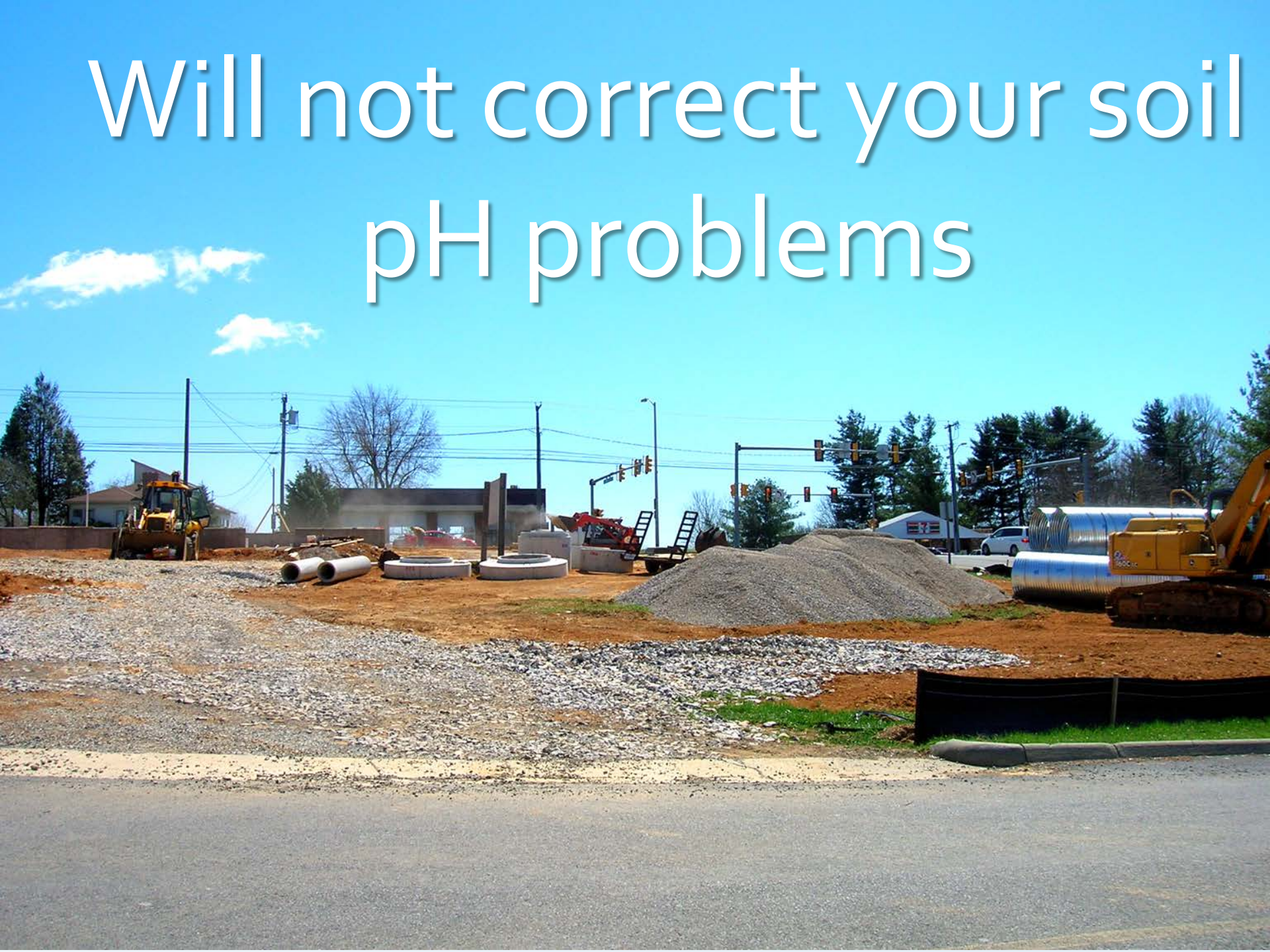
sandy loam—no worries

silty clay loam—watch out

# SOIL PROFILE REBUILDING

- Remediates Soil Compaction
- Sets Soil Formation Processes in Gear
- Increases Ksat, soil C, and tree growth
- Specs are available online
- Peer-reviewed science

# Will not correct your soil pH problems




Not for use around large trees


Will reduce compaction, increase tree growth
improve permeability, increase soil carbon stores
and set long-term soil formation processes on
track

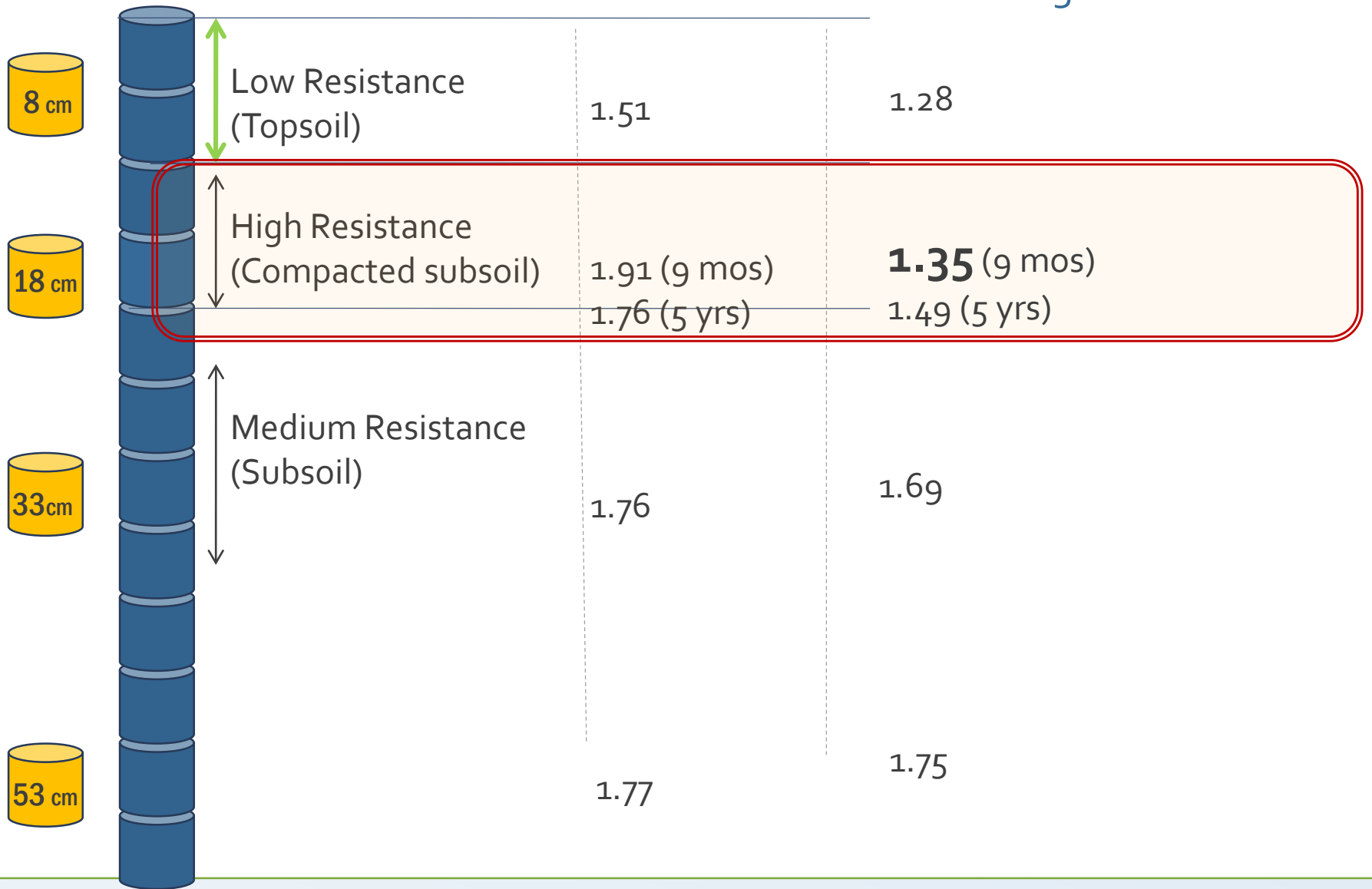

Photo: Jeannette E. Spaghetti (CC)

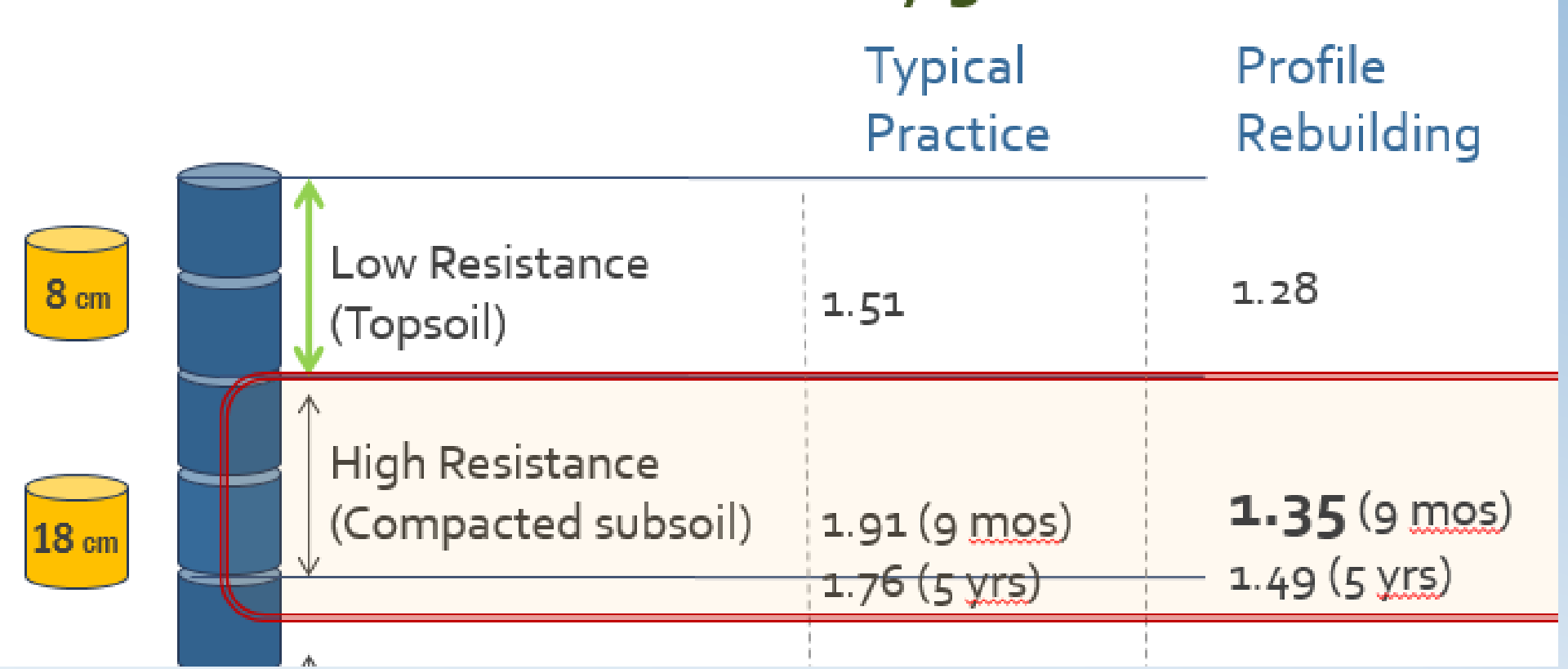
# Soil Profile Rebuilding—A rehabilitation technique


Backhoe to 2 ft, scoop up and drop to create compost veins to 2 ft.

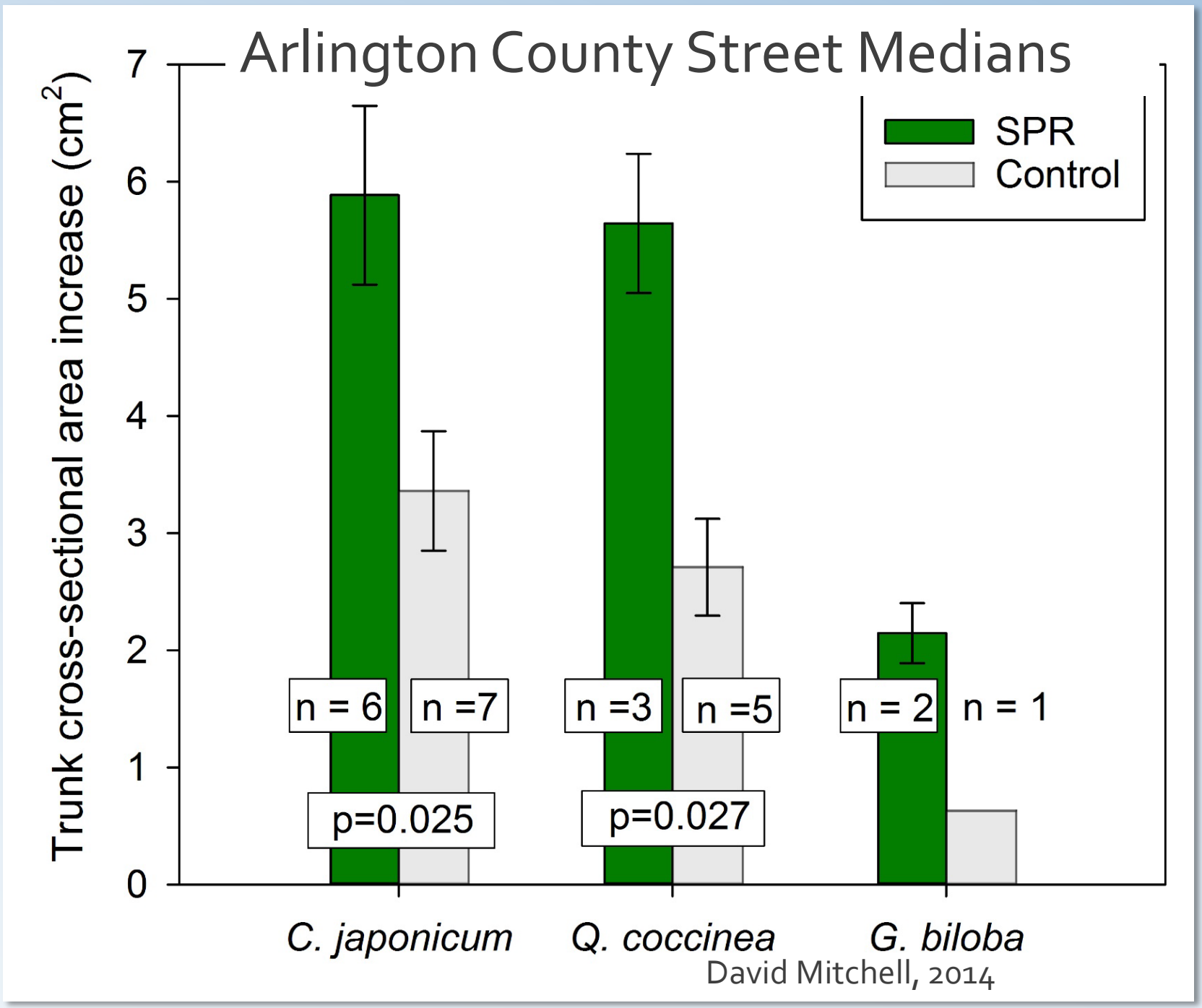
- Return topsoil as usual (4” min.) and till 8”
- Plant trees or other woody veg
- Treat surface to reduce erosion and maintain infiltration

# Loam Soil—Soil Bulk Density g/cm³

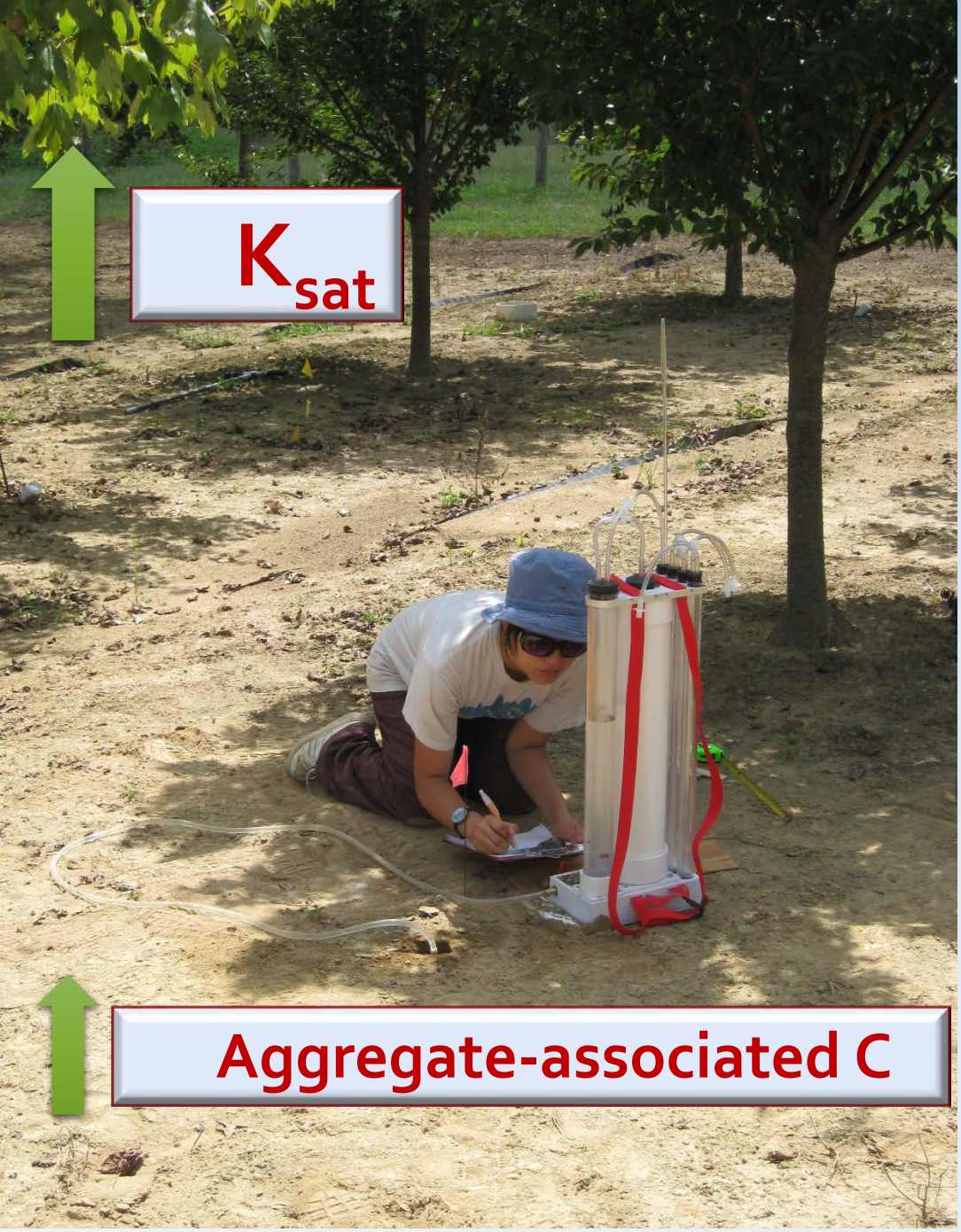


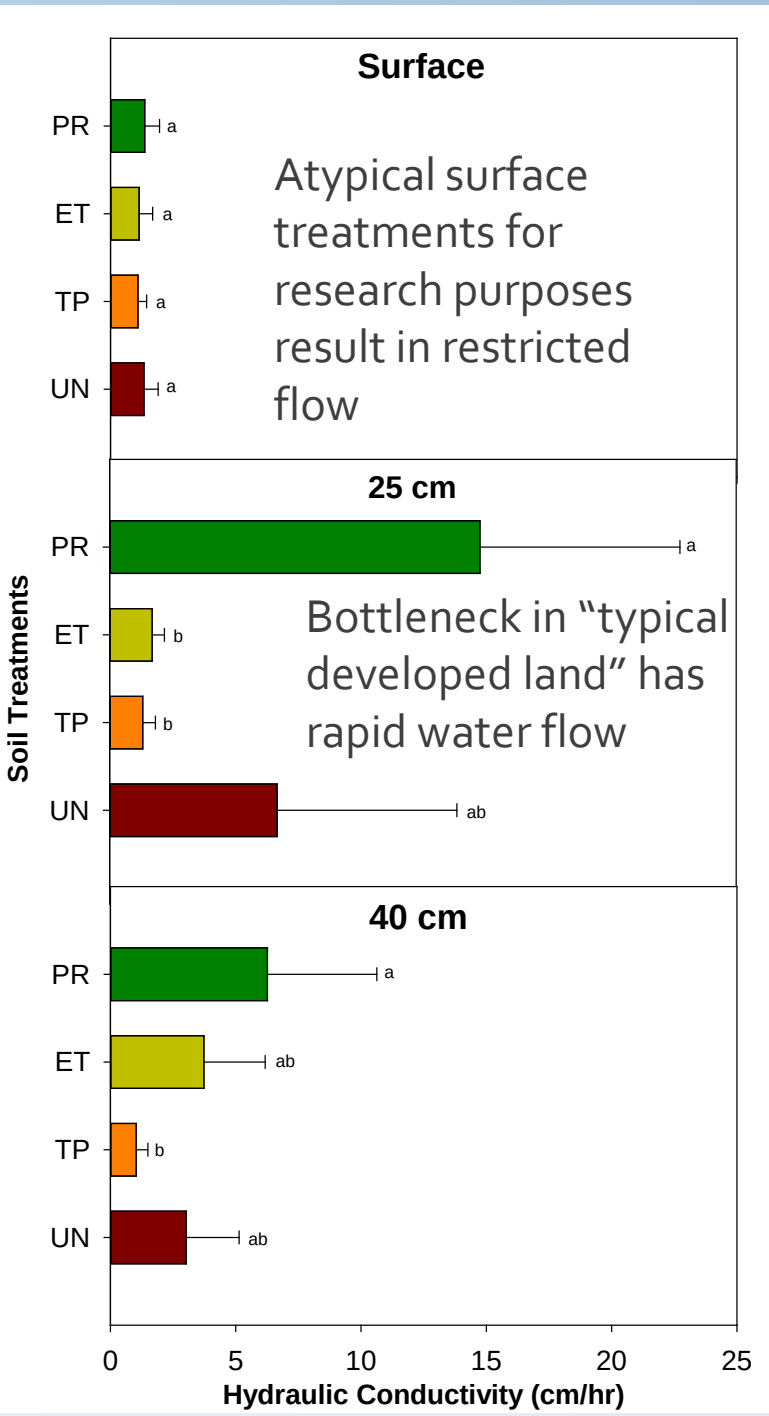

Typical Practice
Profile Rebuilding
8 cm
18 cm
Low Resistance (Topsoil)
High Resistance (Compacted subsoil)
1.51
1.91 (9 mos)
1.76 (5 yrs)
1.28
1.35 (9 mos)
1.49 (5 yrs)

Canopy Area approximately doubled compared to controls after 7 years in designed experiments




David Mitchell, 2014


$K_{sat}$
Aggregate-associated C


Surface
PR
ET
TP
UN
a
a
a
a
Atypical surface treatments for research purposes result in restricted flow
25 cm
PR
ET
TP
UN
a
b
b
ab
Bottleneck in "typical developed land" has rapid water flow
40 cm
PR
ET
TP
UN
a
ab
b
ab
Soil Treatments
0
5
10
15
20
25
Hydraulic Conductivity (cm/hr)

# Site-level Effects Subsurface Permeability 10-40 cm (Ksat)

Agricultural Soil—4 to 5 cm/hr
Compare to HSG B

**Urban land development**

Simple grading, urban land development—1 to 2 cm/hr
Compare to HSG C or D

**Soil Management**

Rehabilitated soil—10 to 11 cm/hr
Compare to HSG A or B

Chen et al. *Science of the Total Environment* 2014.

# Journal Articles for SPR

Chen, Y., Day, S. D., Shrestha, R. K., Strahm, B. D., Wiseman, P. E., 2014. Influence of urban land development and soil rehabilitation on soil–atmosphere greenhouse gas fluxes. *Geoderma* 226, 348-353.

Chen, Y., Day, S. D., Wick, A. F., McGuire, K. J., 2014. Influence of urban land development and subsequent soil rehabilitation on soil aggregates, carbon, and hydraulic conductivity. *Science of the Total Environment.* 494–495, 329-336.

Chen, Y., Day, S. D., Wick, A. F., Strahm, B. D., Wiseman, P. E., Daniels, W. L., 2013. Changes in soil carbon pools and microbial biomass from urban land development and subsequent post-development soil rehabilitation. *Soil Biology and Biochemistry* 66, 38-44.

Layman, R.M., Day. S.D., Mitchell, D.K., Chen, Y., Harris, J.R., Daniels, W.L. 2015. Below ground matters: Urban soil rehabilitation increases tree canopy and speeds establishment. Under review at *Urban Forestry & Urban Greening*

**urbanforestry.frec.vt.edu**

# Soil Profile Rebuilding: An Alternative to Soil Replacement

by Susan Downing Day, Associate Professor, Depts. of Forest Resources & Environmental Conservation and Horticulture, Virginia Tech

Urban foresters know poor soils can lead to an endless cycle of dieback and tree replacement. Even if trees do establish, growth can be underwhelming and tree health disappointing. Increasingly, project managers have been turning to soil replacement, where existing soils are excavated and removed and replaced with "recycled" or blended soils. These soils present their own challenges, however. For example, many imported blends rely on high sand contents to improve drainage, resulting in low water-holding capacity and drought stress for unirrigated plantings. Resulting sharp transitions in soil texture introduce the possibility of creating a "bath tub" effect in situations where it is impossible to replace all the soil and new soils are confined to the immediate vicinity of individual trees.

There is an alternative to soil replacement that is especially appropriate where there are extended open soil (unpaved) areas such as in street medians--soil rehabilitation. Soil rehabilitation can help restore important ecosystem functions such as stormwater transmission and vegetation support to existing native soils.

In soil management, urban foresters and designers need confidence that they will get the results they desire and that soil improvements will persist for the long term. Researchers at Virginia Tech developed specifications for **Soil Profile Rebuilding (SPR)**, a soil rehabilitation technique, and have been evaluating performance for nearly a decade. This process can improve tree establishment,

### The Theory behind SPR

SPR works by creating veins of compost deep in the soil profile that hold soil channels open for root penetration. The introduction of organic matter coupled with root activity can create conditions that will lead to formation of soil aggregates over time—leading to long-term soil quality enhancement.

This site is a good candidate for SPR because soil is compacted and has an impermeable layer that can likely be broken up by the backhoe subsoiling process. Note limestone gravel mixed in soil indicates pH will be high, which will not be altered by the rehabilitation process. Surface gravel should be removed if possible and underground infrastructure clearly marked. Photo by Susan D. Day



# Want more info?

- Recent Article
  *City Trees* (Sept/Oct)
- Download Specifications
  **urbanforestry.frec.vt.edu/SRES**
- Details under production

# Thank you

Collaborators: J. R. Harris, Joseph Dove, Qingfu Xiao, E.G. McPherson, N. Bassuk, Brian Strahm, Abbey Wick, W. Lee Daniels, P. Eric Wiseman, Kevin McGuire, Tess (Wynn) Thompson, and Vincent Verweij

Graduate Students: Rachel Layman, Yujuan Chen, Julia Bartens, and David Mitchell

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Soil Profile Rebuilding Specifications available at urbanforestry.frec.vt.edu/SRES

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