Michigan Green Infrastructure Conference

Rebuilding Brown Infrastructure

Understanding Soils, Soil Preparation, and Typical Urban Problems

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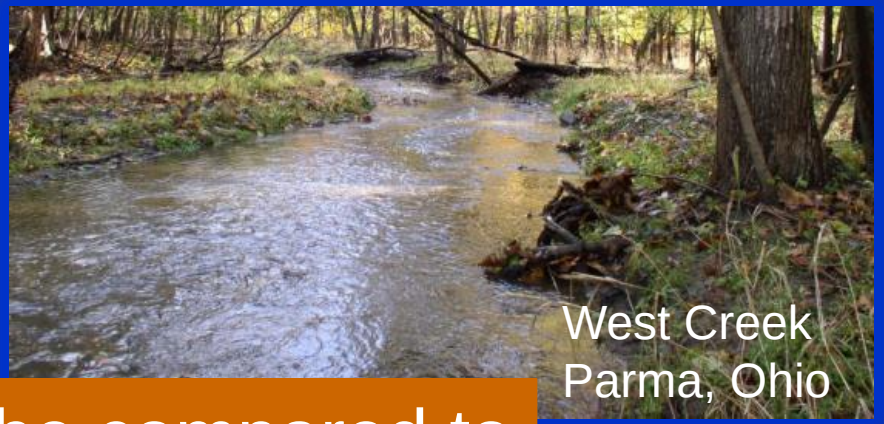
DiGeronimo Aggregates LLC

The Original Lightweight Aggregate

HAYDITE
DiGeronimo Aggregates

Sand filter
Cleveland Airport



West Creek
Parma, Ohio

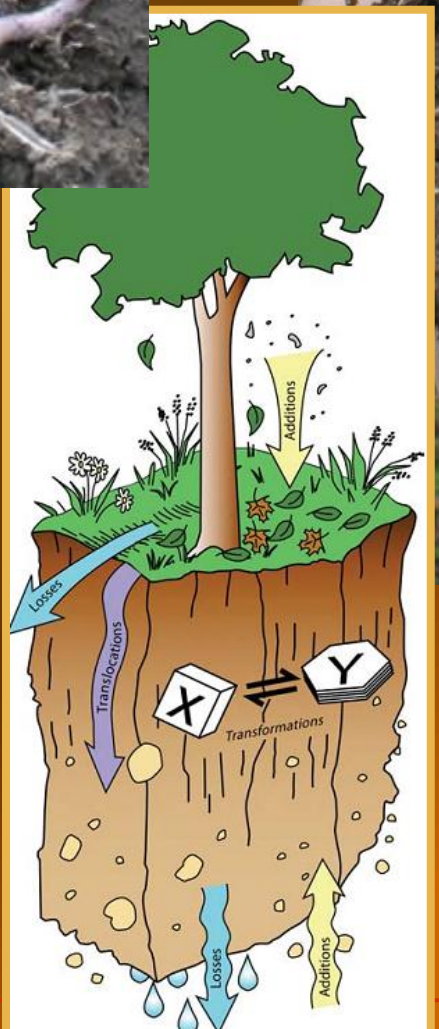
*Brown infrastructure** can be compared to *blue infrastructure*, such as watercourses and wetlands; *green infrastructure*, like trees, shrubs & grass; and *gray infrastructure*, such as sewers & basins.

Pickerel rush

*Pouyat et al., 2010, USFS – Northern Research Station (http://www.nrs.fs.fed.us/pubs/36426)

Brown Infrastructure influences…

- Infiltration
- Air exchange
- Plant available water
- Rooting depth
- Microbial biomass
- Earthworms
- Nutrient recycling, and
- Fate and transport of pollutants, etc.



Urban soils are mostly…

- Compacted
  - Low infiltration
  - Poor air exchange
  - Low plant-available water
  - Low earthworm and microbial activity
- Carbon starved
- Nutrient and pH imbalanced

Depositional crust

Compaction problems

(poor aeration, water regulation, rooting depth, etc.)

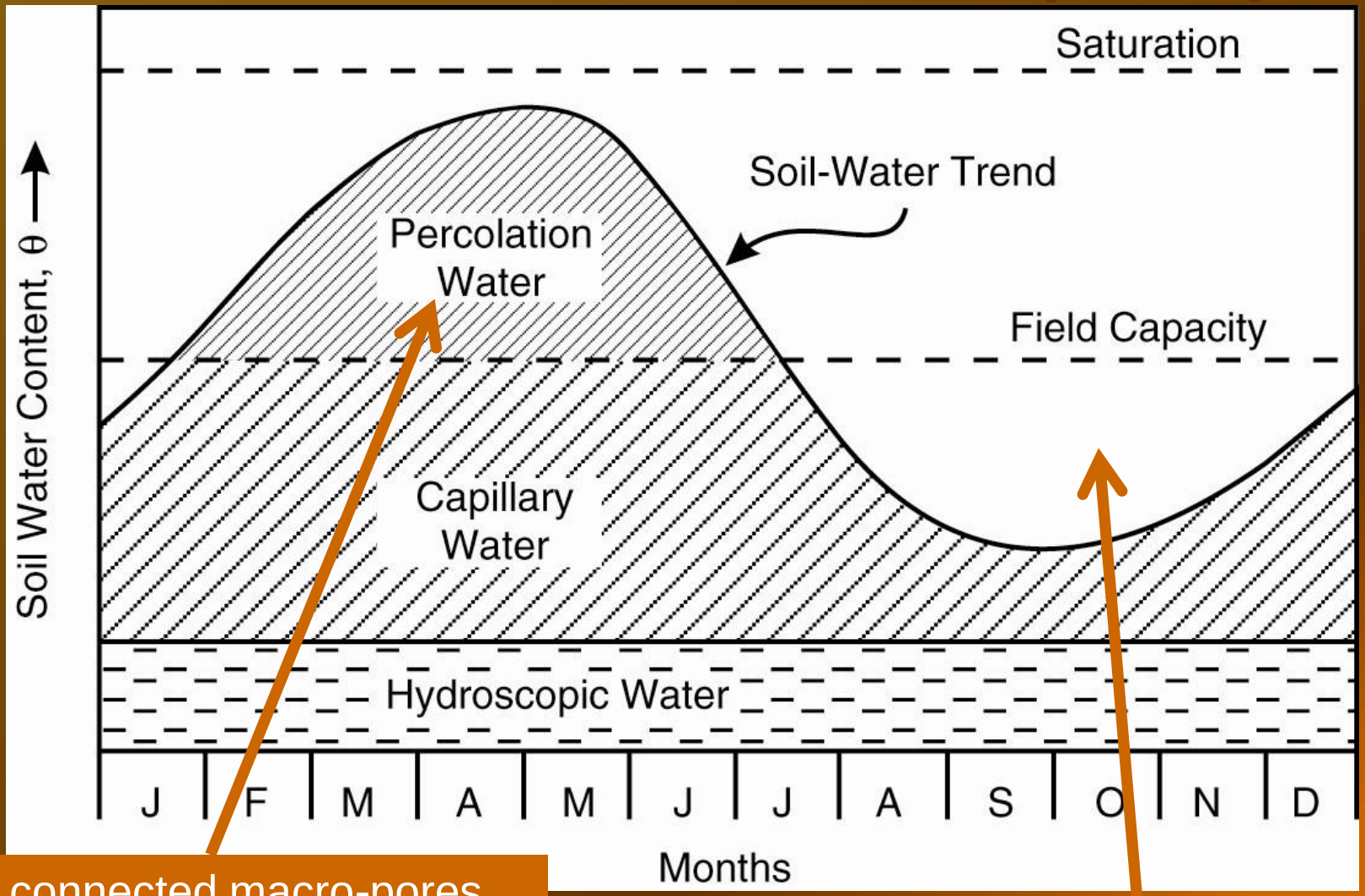
Irrigated lawn

K_{sat}: <0.05 in hr^{-1} (silt loam, ML)
Penetration Resist.: >400 PSI at ~1.5 in.

Fine roots at ~3/4 in. depth

Waterlogged soil
(oxidized rhizospheres
7.5YR 5/8 & >20% redox.
depletions 2.5Y 5/1)

Seasonal water balance (Ohio)



Need connected macro-pores (0.08 to >5 mm wide*) to drain excess (percolation) water well

*Brady and Weil, 2002

Need connected meso-pores (0.03 to 0.08 mm wide*) for plant-available water during deficit

Diverse demands are increasing…

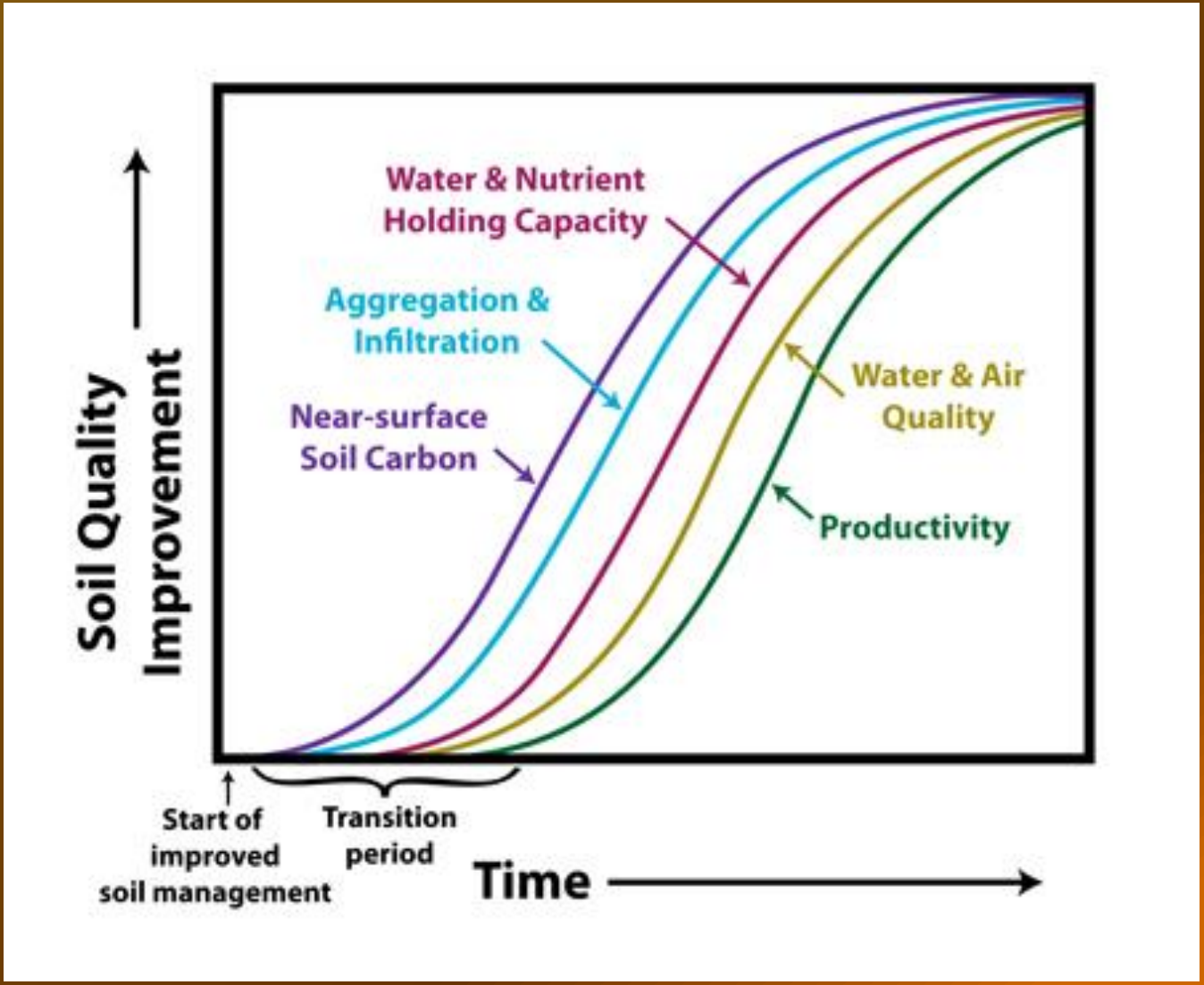
Urban Pasture
Cleveland, Ohio

- Urban agriculture
- High-intensity landscaping
- Urban forests & wildlife habitat
- Soil carbon sequestration
- Storm water quality treatment
- Storm water volume reduction

Sand filter
Cleveland, Ohio

Pocket Park
Cleveland, Ohio

Soil quality emerged from agricultural research



http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/assessment/

…but is applicable to nearly all plant-soil (storm water) systems

Bio-retention (redevelopment)
Cleveland, Ohio

Bio-retention (redevelopment)
Lakewood, Ohio

How do we rebuild *Brown Infrastructure*?

…by rediscovering soil quality indicators

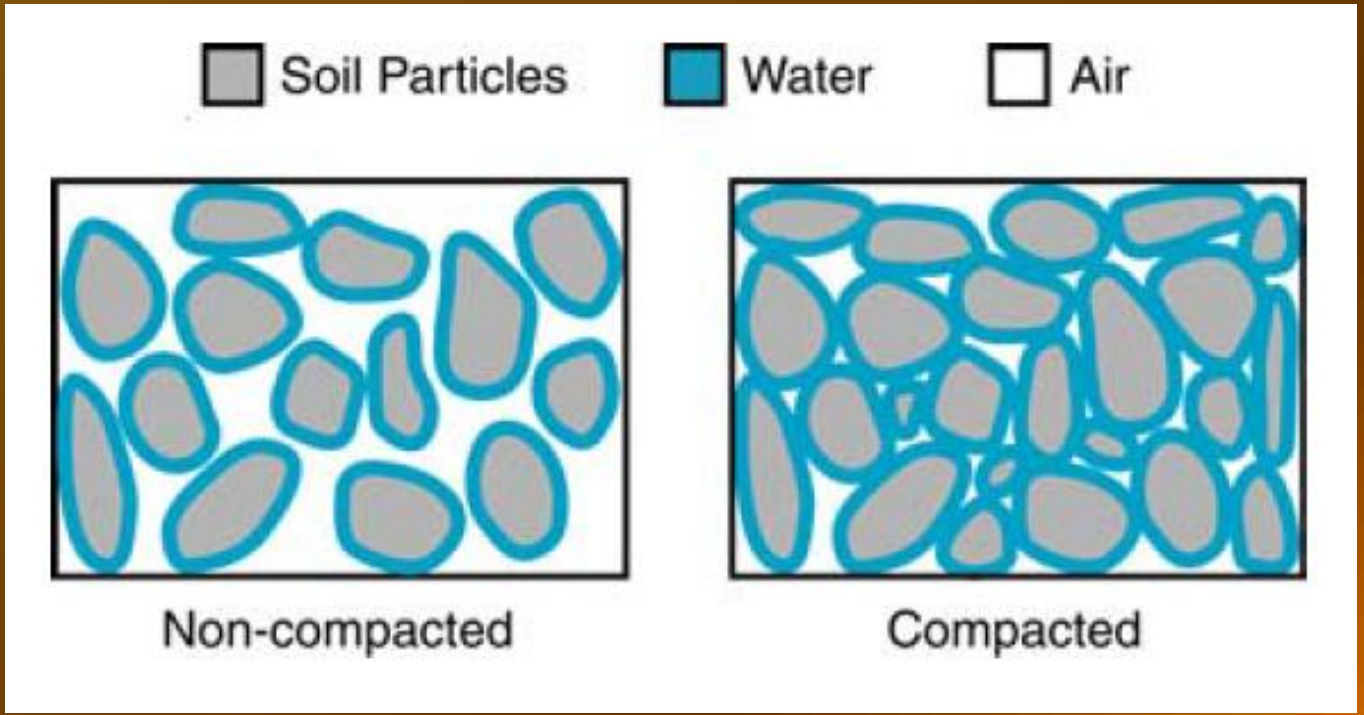
- Infiltration
- Plant-available water
- Density/penetration resistance
- Earthworms
- Microbial respiration
- Total organic carbon
- Electrical conductivity & pH

Penetrometer


Platy structure


Earthworm macro-pores
(5 to 8 mm wide)

…and reconnecting soil macro (and meso) porosity.



http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_052835.pdf

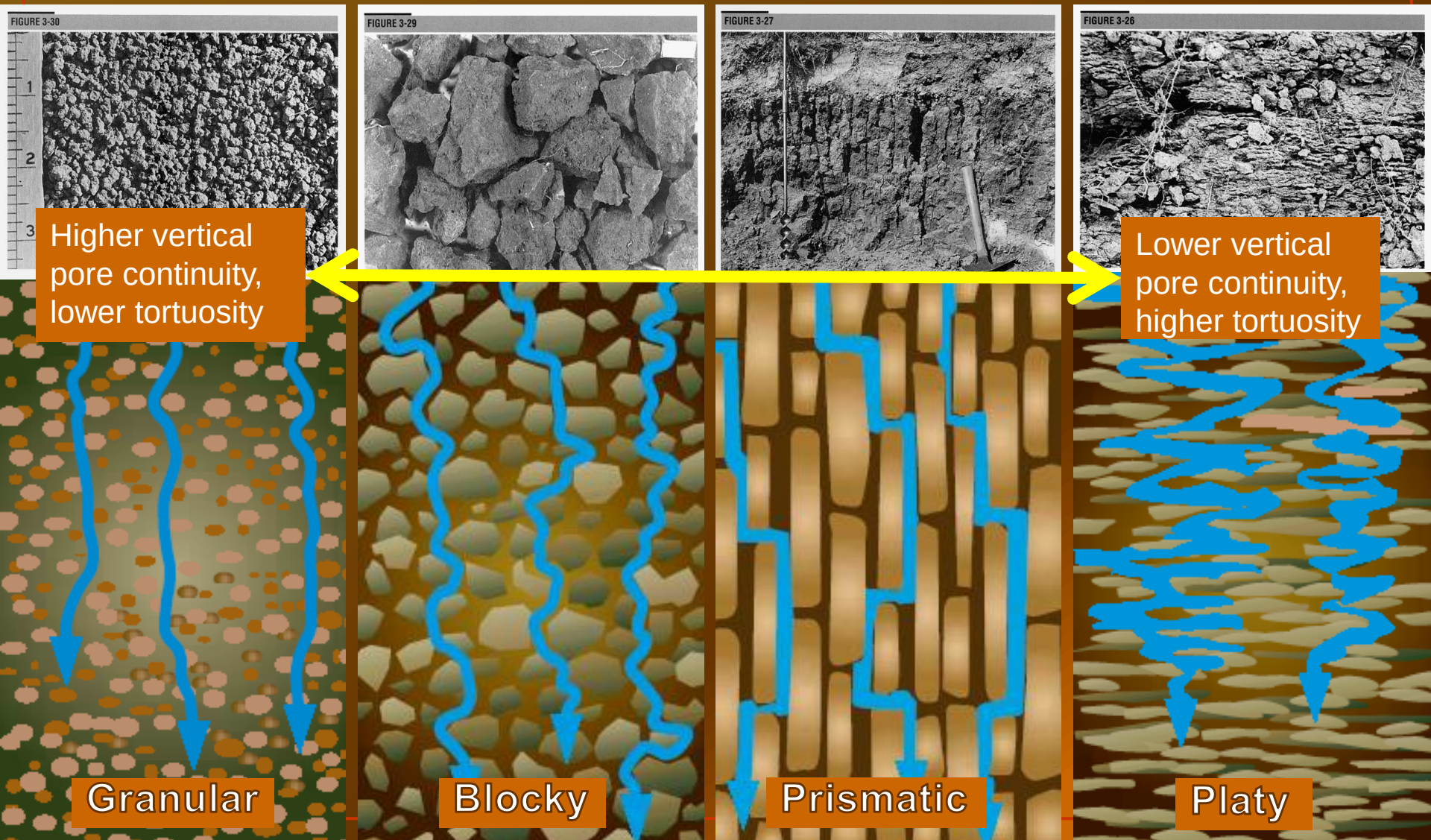
Vacant land
Garfield Heights, Ohio

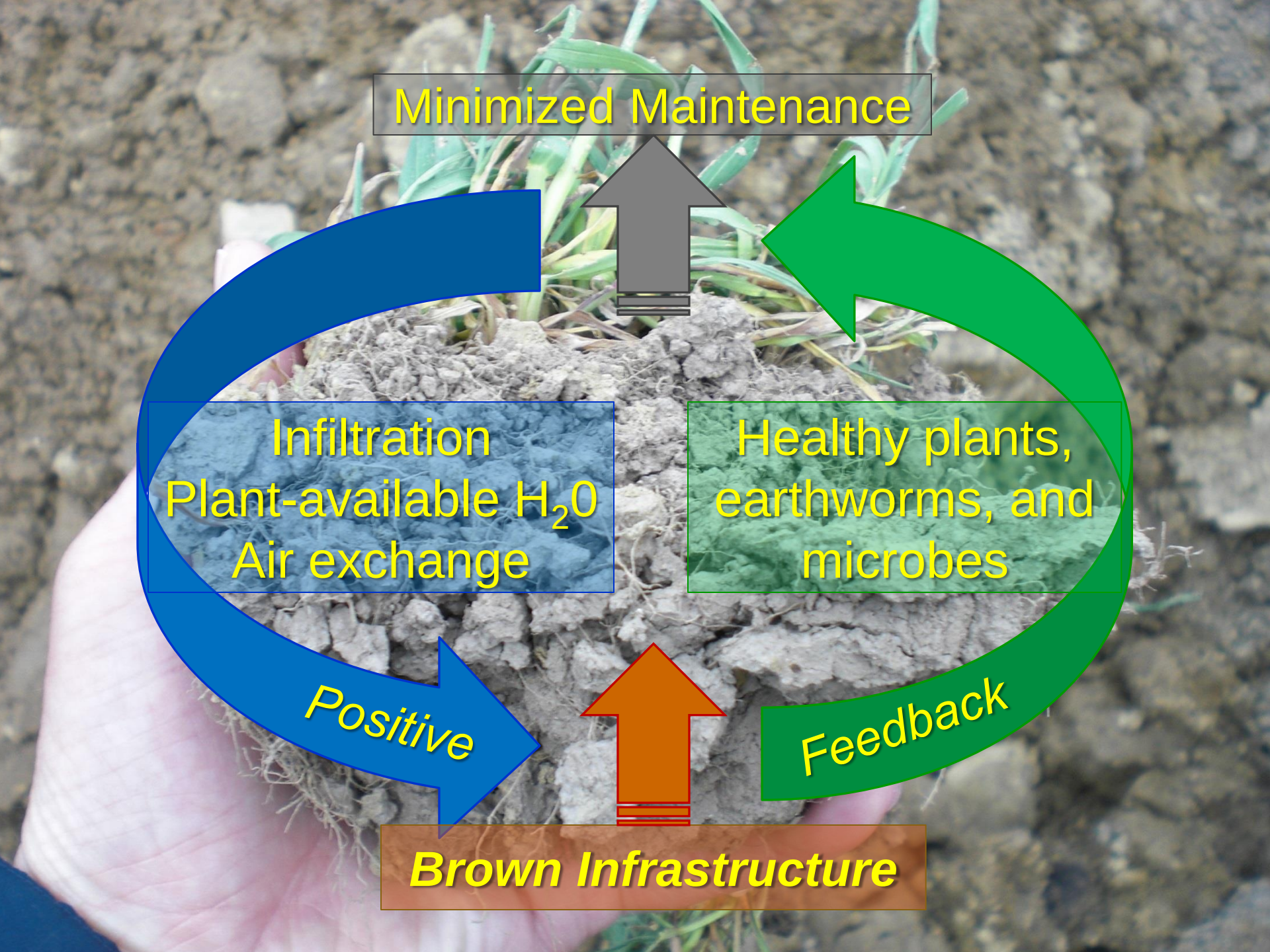
Platy soil structure
(failed bio-retention)

“We don’t have runoff problems…
we have an infiltration problem.”
(Ray Archuleta, NRCS – National Soil Health and Sustainability Team)

Vacant land
Detroit, Michigan

Influence of connected soil porosity on (vertical) air & water movement




Minimized Maintenance
Infiltration
Plant-available H_20
Air exchange
Healthy plants, earthworms, and microbes
Positive
Feedback
Brown Infrastructure

Tools for reconnecting soil porosity

- Manufactured soils and coarse fragments (e.g. expanded shale, clay and slate)
- Organic amendments (e.g. yard waste compost)
- Gypsum (temporary, often less than months*)
- Tough plants

*Washington State Univ. Ext.

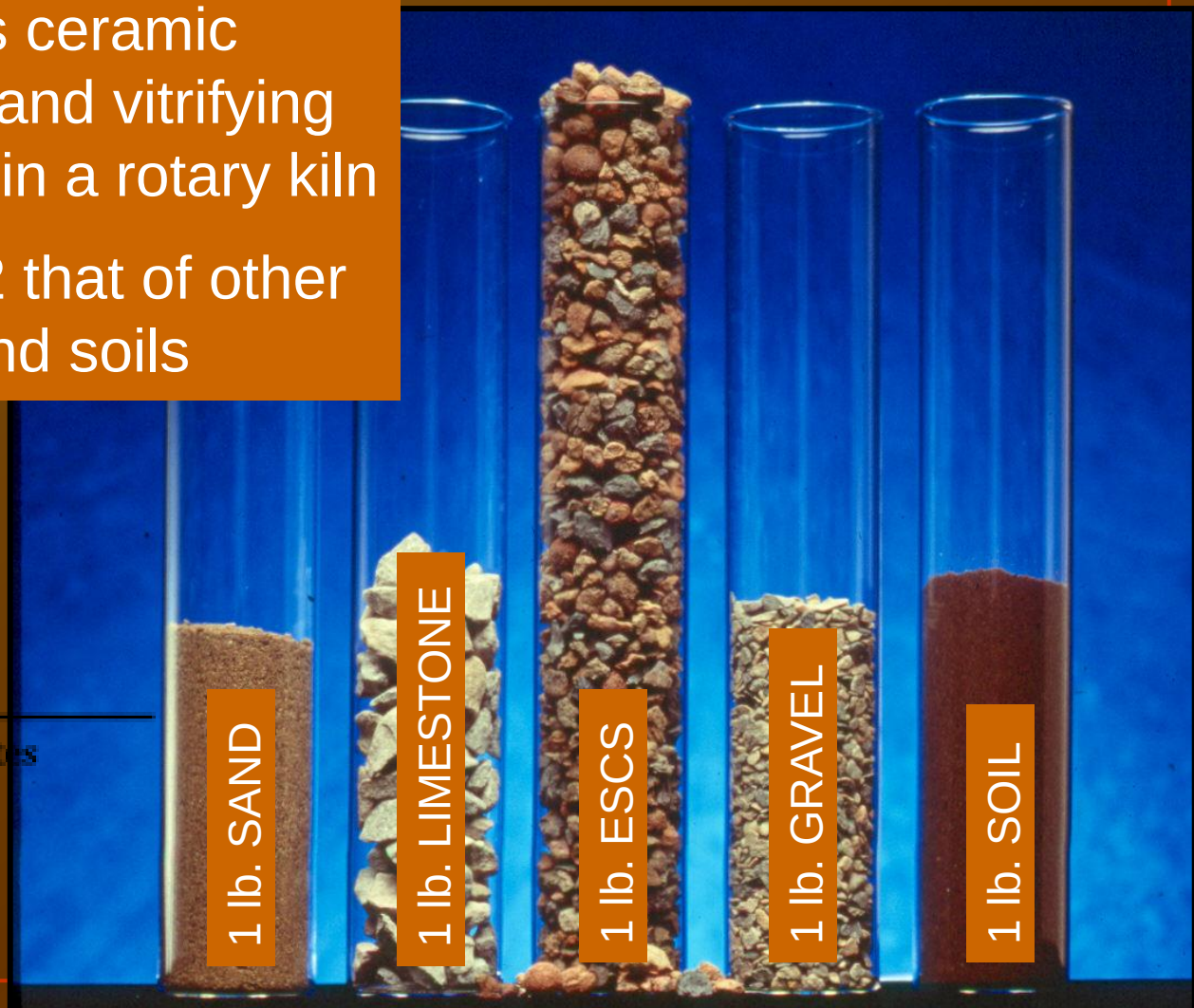
What is Expanded Shale, Clay & Slate (ESCS)?

- Lightweight, porous ceramic made by expanding and vitrifying select raw materials in a rotary kiln
- Bulk density is ~1/2 that of other granular materials and soils

The Original Lightweight Aggregate

HAYDITE

DiGeronimo Aggregates



Haydite expanded shale physical properties

- Soil (size A*) texture: gravelly (22-26%) sand (SP)
- Dry (size A) density: 0.86 g cm^{-3} (54 lb. ft^{-3})
  - Ideal density: <1.6 g cm^{-3} for sands**
  - Root growth restriction: >1.8 g cm^{-3} for sands**
- Particle density (size A): 1.67 g cm^{-3}
  - Most soil minerals 2.6-2.75 g cm^{-3}***
- H_2O Absorption Capacity (by weight): ~20%
- Specific surface area (BET): 1.3-1.5 m^2 g^{-1} †
  - Montmorillonite 80-150 m^2 g^{-1}***
  - Coarse sand: 0.0011-0.0023 m^2 g^{-1} ††
- Raw material: Ohio Shale (high montmorillonite)

*size A: #4 x 0
** NRCS-Soil Quality Instit
*** Brady and Weil, 2002
† E.S. Filter Testing, 2007
†† Univ. of Arizona Ext.

Haydite expanded shale chemical properties

- pH: 6.7 (Fines, size A*)
- CEC: 2.75 $cmol_c\ kg^{-1}$**
  - Most sands ~0 $cmol_c\ kg^{-1}$
  - Mollisol (grassland soil): 24 $cmol_c\ kg^{-1}$***
    (pH 7, 20% montmorillonite, 4% OM)
- Al_20_3: 18%
- Fe_20_3: 6%
- K_20: 4%
- MgO: 1.7%
- CaO: 0.9%

*size A: #4 x 0

**Sloan et al., 2011

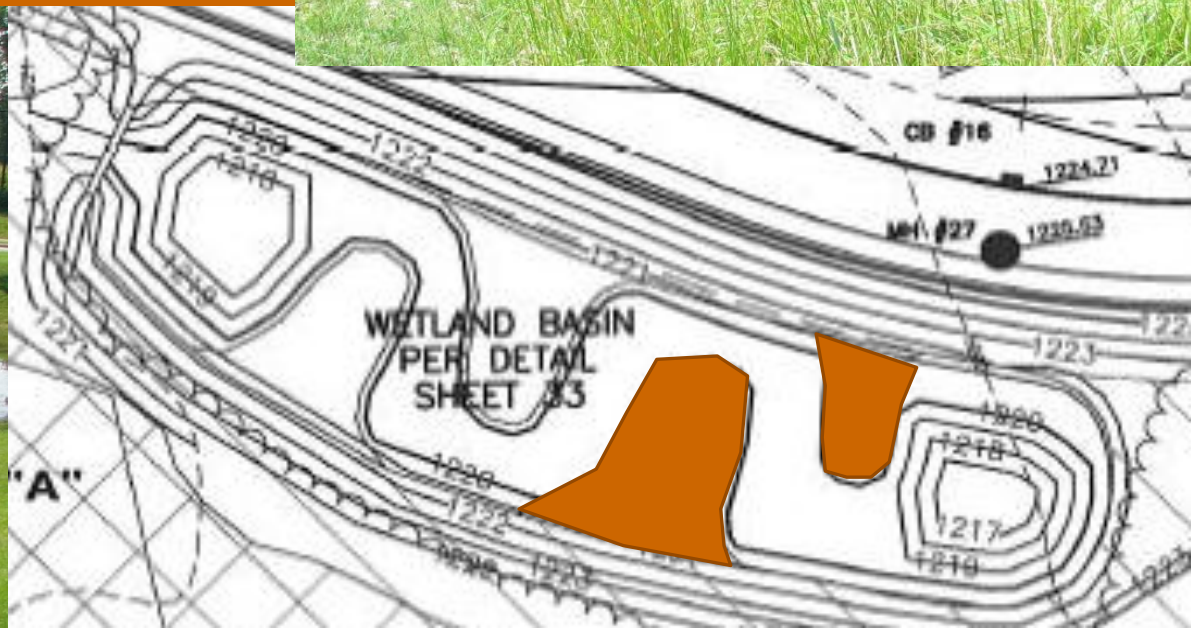
***Brady and Weil, 2002

Plant-soil (storm water) system uses

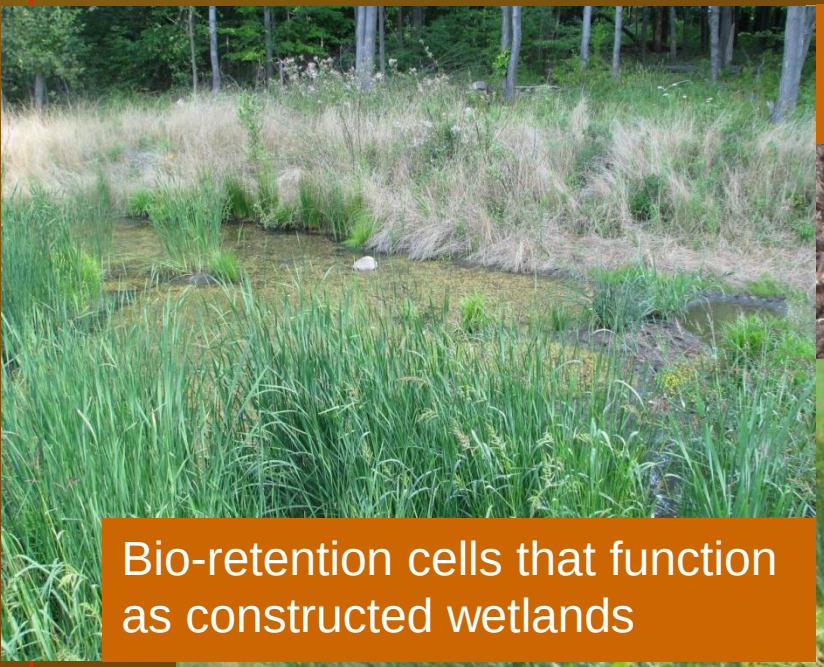
- Bio-retention planting soil & gravel media
- Subsurface gravel wetlands
- Wet extended basin/ constructed wetland features
- Tree box filter medium
- Soil amendment (clayey materials)
- Green roofs

Subsurface gravel/ constructed wetland features (planting medium)

Higher surface area of ESCS provides “habitat” for microbes that degrade pollutants flowing through the medium.



Bio-retention needs connected macro-porosity for drainage



Bio-retention cells that function as constructed wetlands

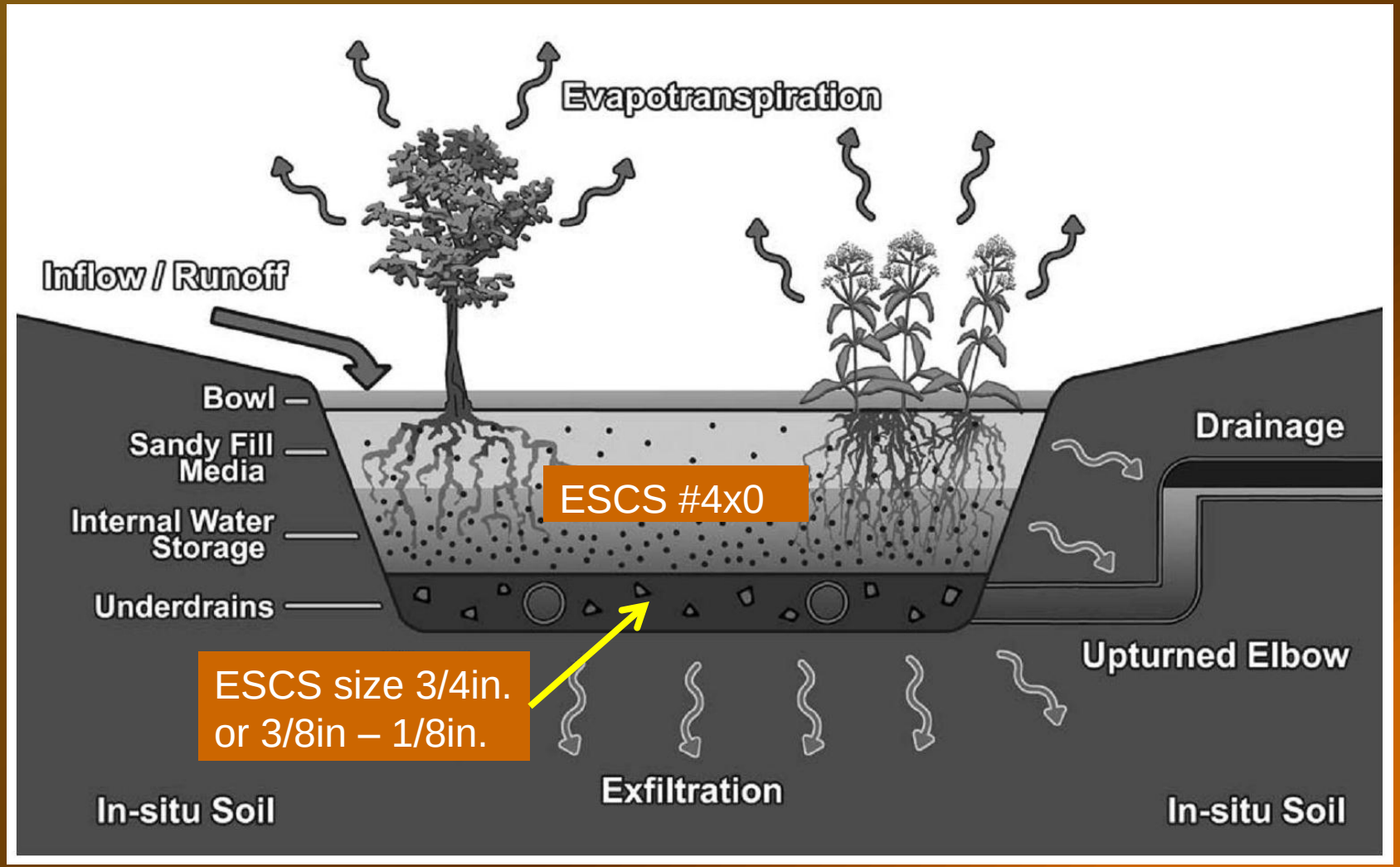
K_{sat}: <0.05 in hr^{-1} (sandy loam, SM)
Penetration Resist.: >400 PSI at ~3 in.

Bio-retention needs connected meso-porosity for plants

Plantings struggling after ~1 year (July)

Frequent irrigation during warmer months

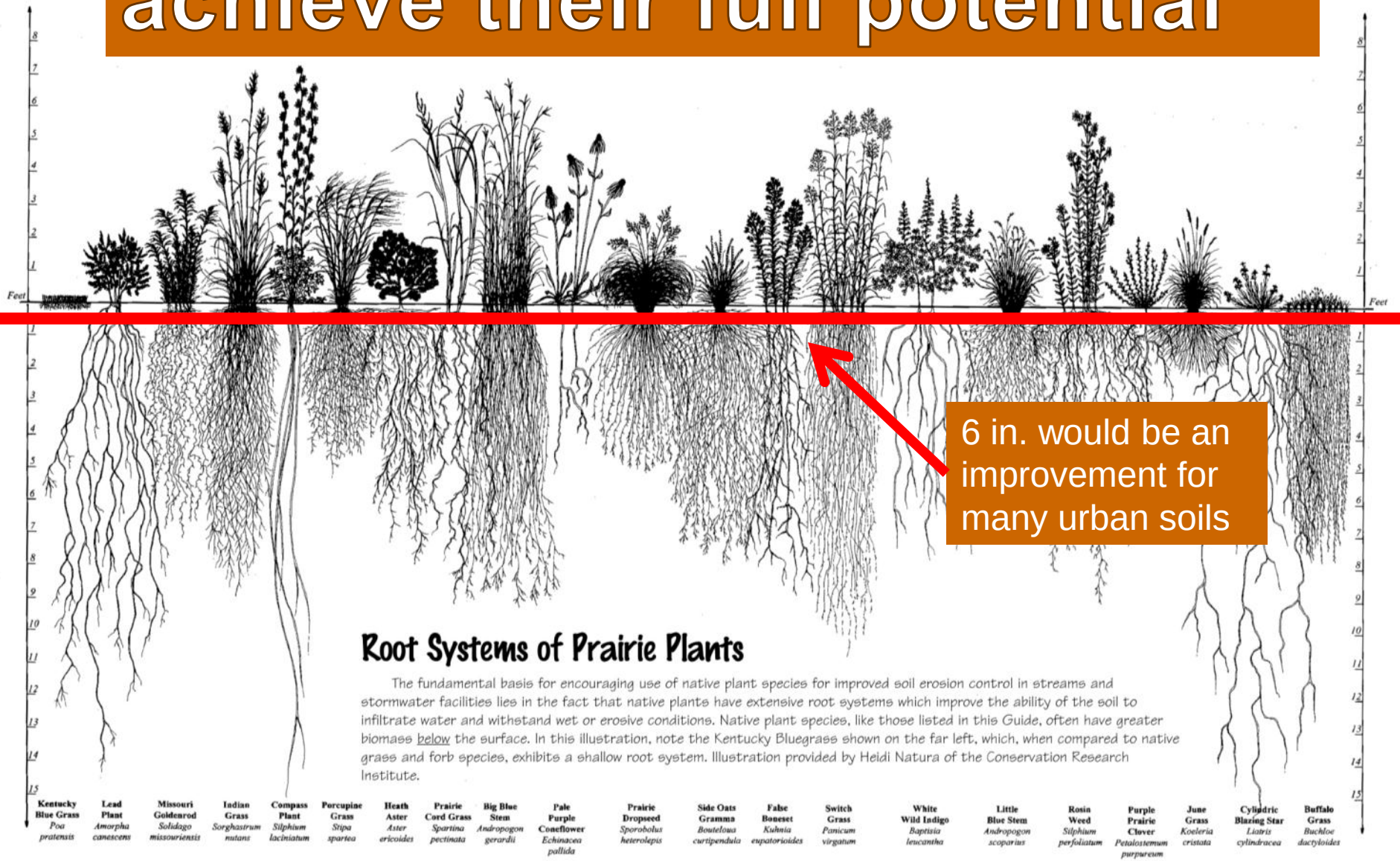
Bio-retention with internal water storage (improved denitrification)



http://www.bae.ncsu.edu/stormwater/PublicationFiles/ConstructionLID.2009.pdf

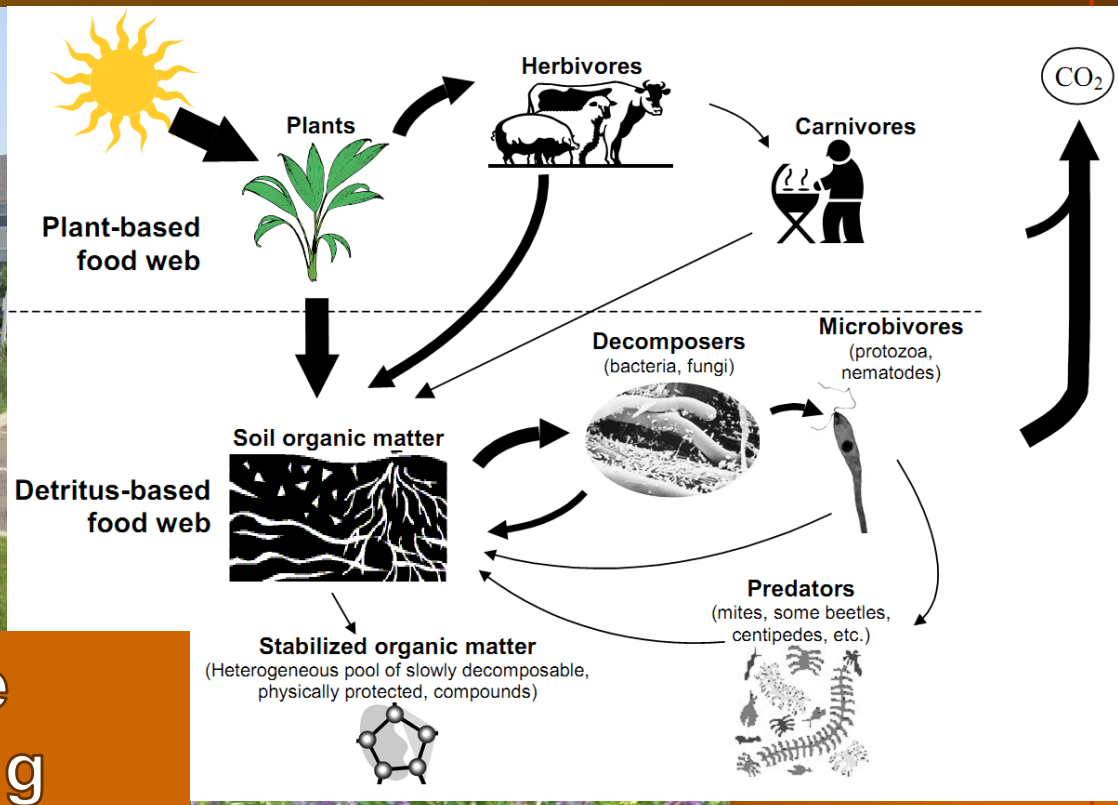
Additional benefits of reconnecting soil porosity

Deeper rooting plants can achieve their full potential



Herbaceous plants are an efficient mechanism for soil carbon sequestration

(ex. Mollisols aka grassland/prairie soils)



Even when grasses are harvested the remaining root and crown tissues comprise as much as 84% of the total plant biomass

(A.B. Frank et al., 2004. Biomass and carbon partitioning in switchgrass. Crop Sci. 44:1391-1396)

Every 1% increase in SOM results in as much as 25,000 gal. of plant-available water per acre

(http://www.nrcs.usda.gov/ Internet/FSE_MEDIA /stelprdb1186185.jpg)

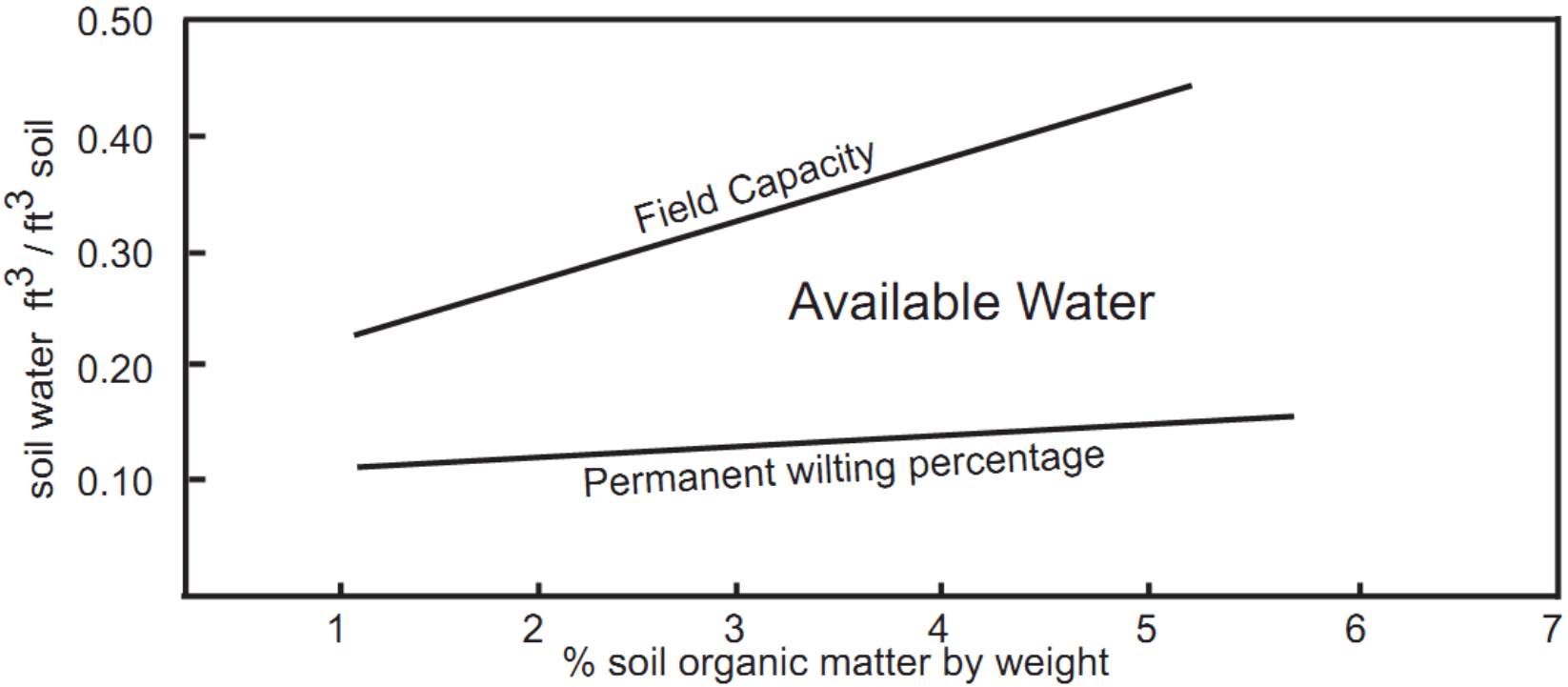
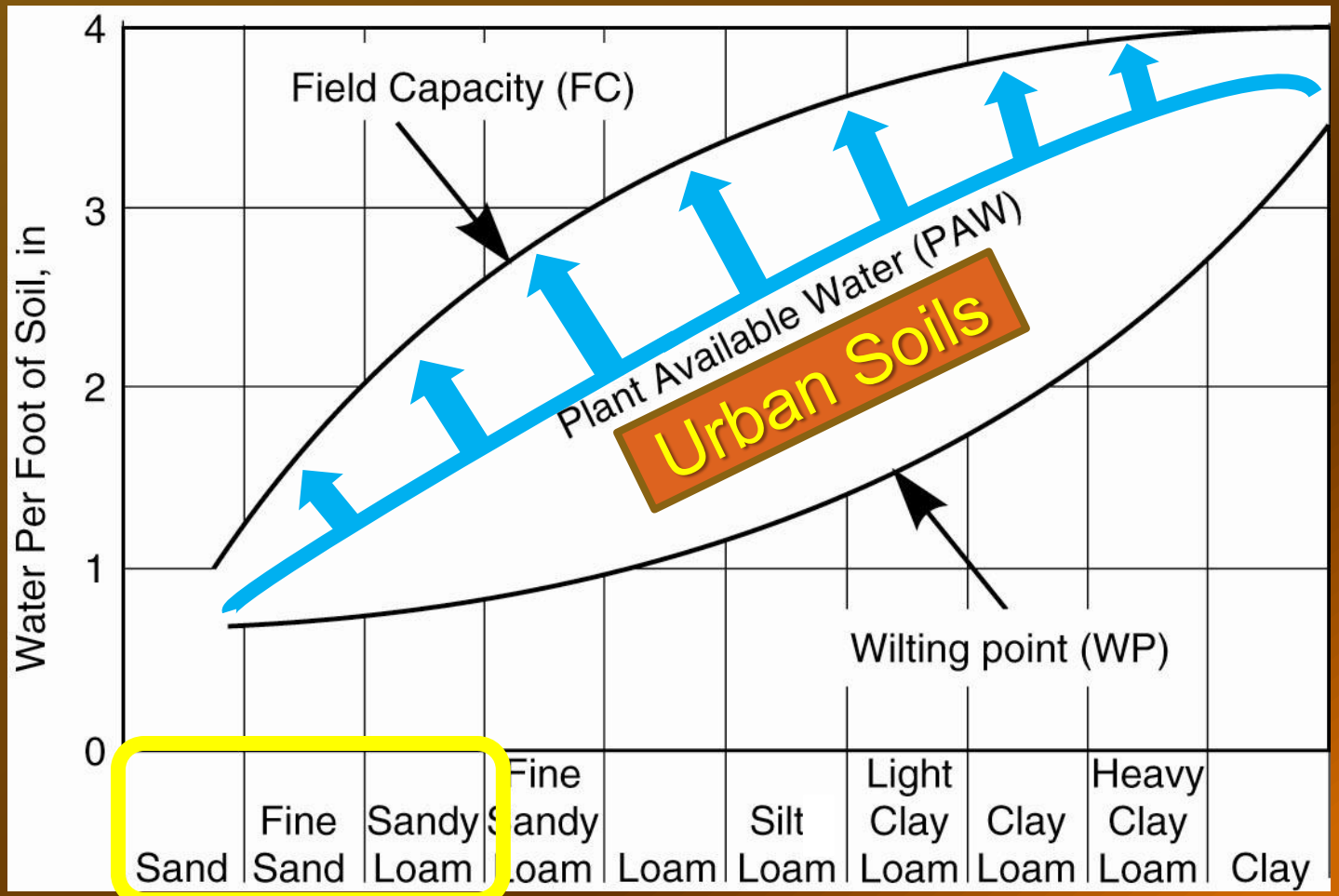


Figure 2. Effect of increasing organic matter on available water capacity of silt loam soils. Adapted from Hudson, SWCS, 1994.

Reconnecting soil porosity increases plant-available water for all urban soils



Most manufactured mediums for plant-soil (storm water) systems.

Cal. Stat Univ. – Sacramento et al. 2005 Comparative (storm water) testing

- Sand
  - Fine (0.45-0.55 mm)
  - Coarse (0.8-1.2mm)
  - Concrete (ASTM C-33)
  - Limestone #4 (~ASTM C-33)
- Activated Alumina and Aluminum Oxide
- Zeolite
- Expanded shale
- Wollastonite

Turbidity

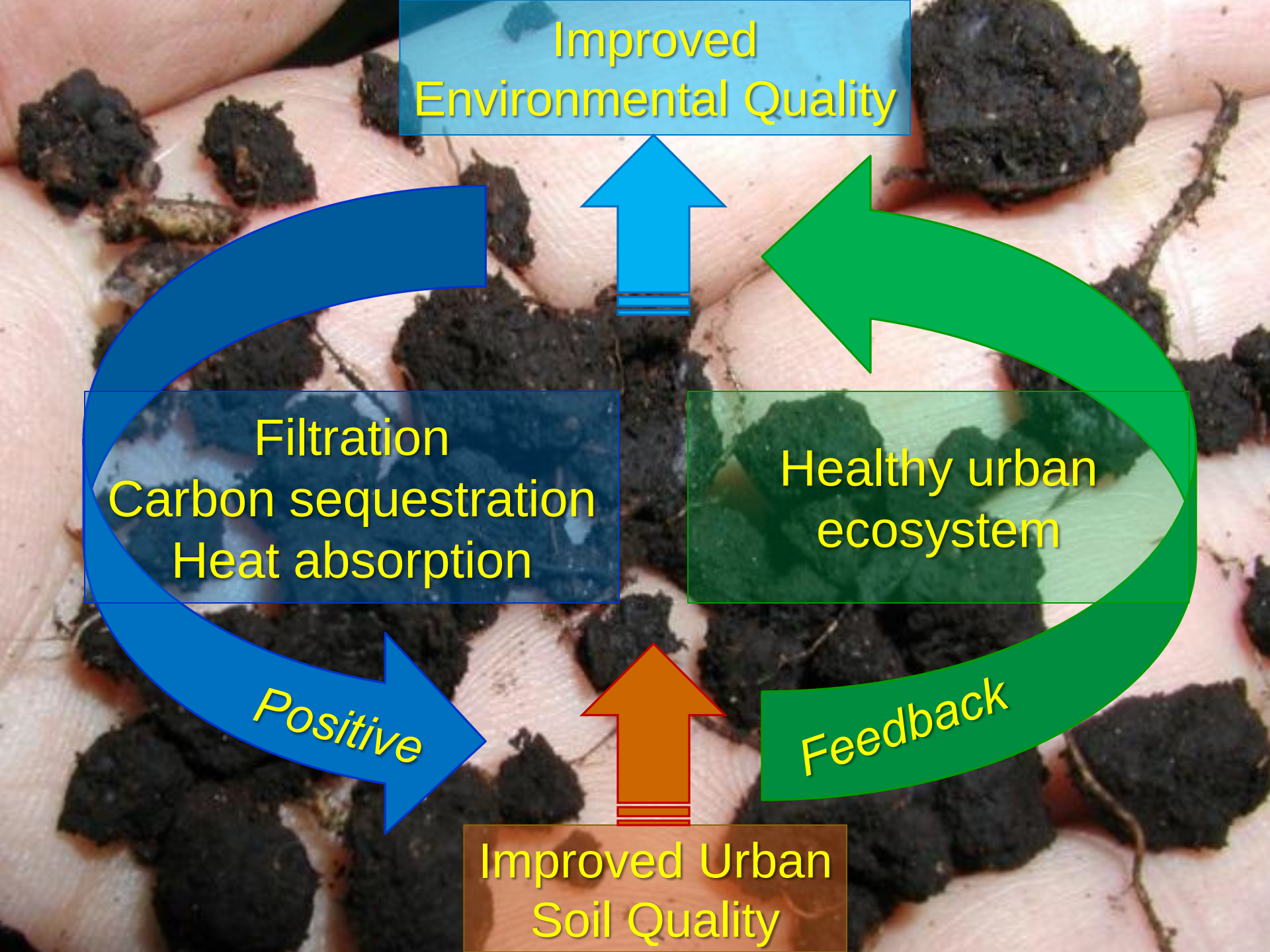
- “Expanded shale and activated alumina media were more effective than sand and were the only media that consistently met or nearly met the 20 NTU regulatory limit, even without chemical addition.”

(http://www.owp.csus.edu/research/papers/papers/PP063.pdf)

Total Phosphorus

- “The key observations to be made here are that the [expanded] shale and activated alumina filters…consistently met or nearly met the 0.1-mg/L regulatory limit for total phosphorus. Sand filters (without chemical addition) did not come close to meeting the total phosphorus limit…”

(http://www.owp.csus.edu/research/papers/papers/PP063.pdf)


Improved
Environmental Quality
Filtration
Carbon sequestration
Heat absorption
Healthy urban
ecosystem
Positive
Feedback
Improved Urban
Soil Quality

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