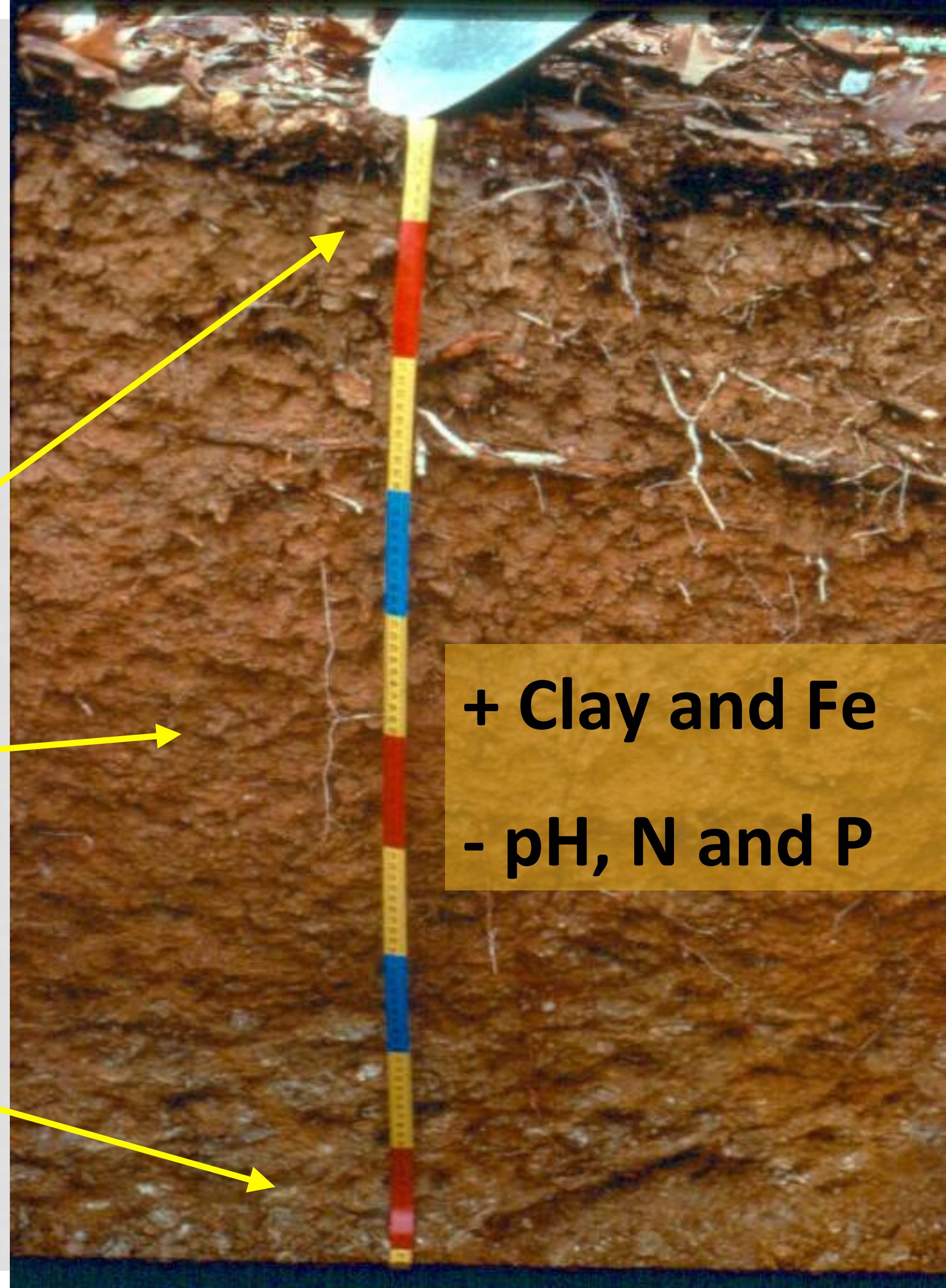
Urban Soils: Assessment and Management

October 31, 2018

Greg Evanylo
Plant and Environmental Sciences
gevanylo@vt.edu

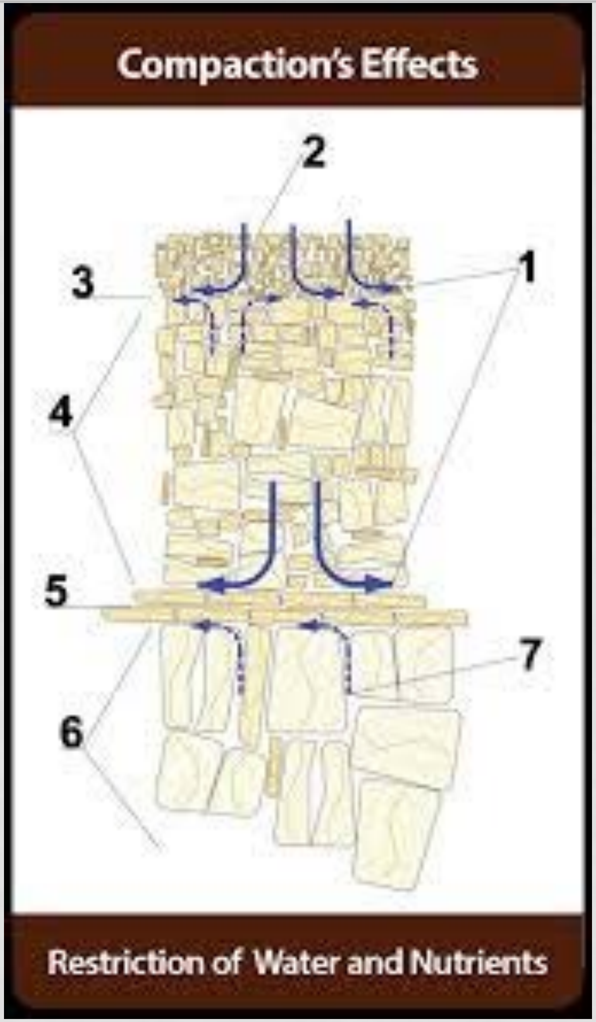
Natural undisturbed forest soil with loamy topsoil A horizon over clayey B horizon over loamy C horizon.



What’s an Urban Soil?

- Little or no topsoil layer
- Altered/degraded structure
- Compaction!
- Mixed horizons or layered zones
- Inclusion of debris and pollutants

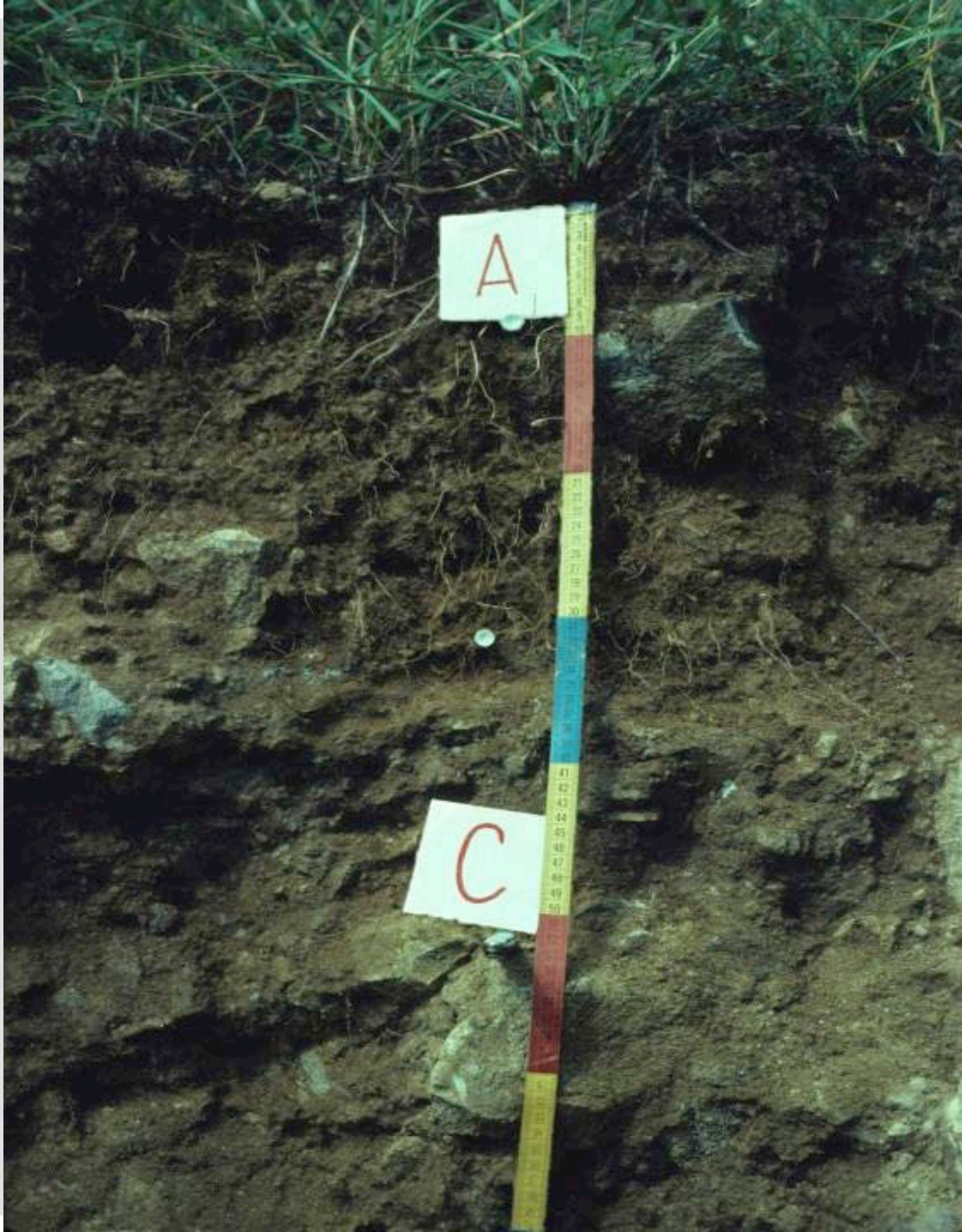
Soil Structure



- Left side freshly tilled
- Large Macro Pores

- Right side tilled
- Then compacted
- Slowed infiltration

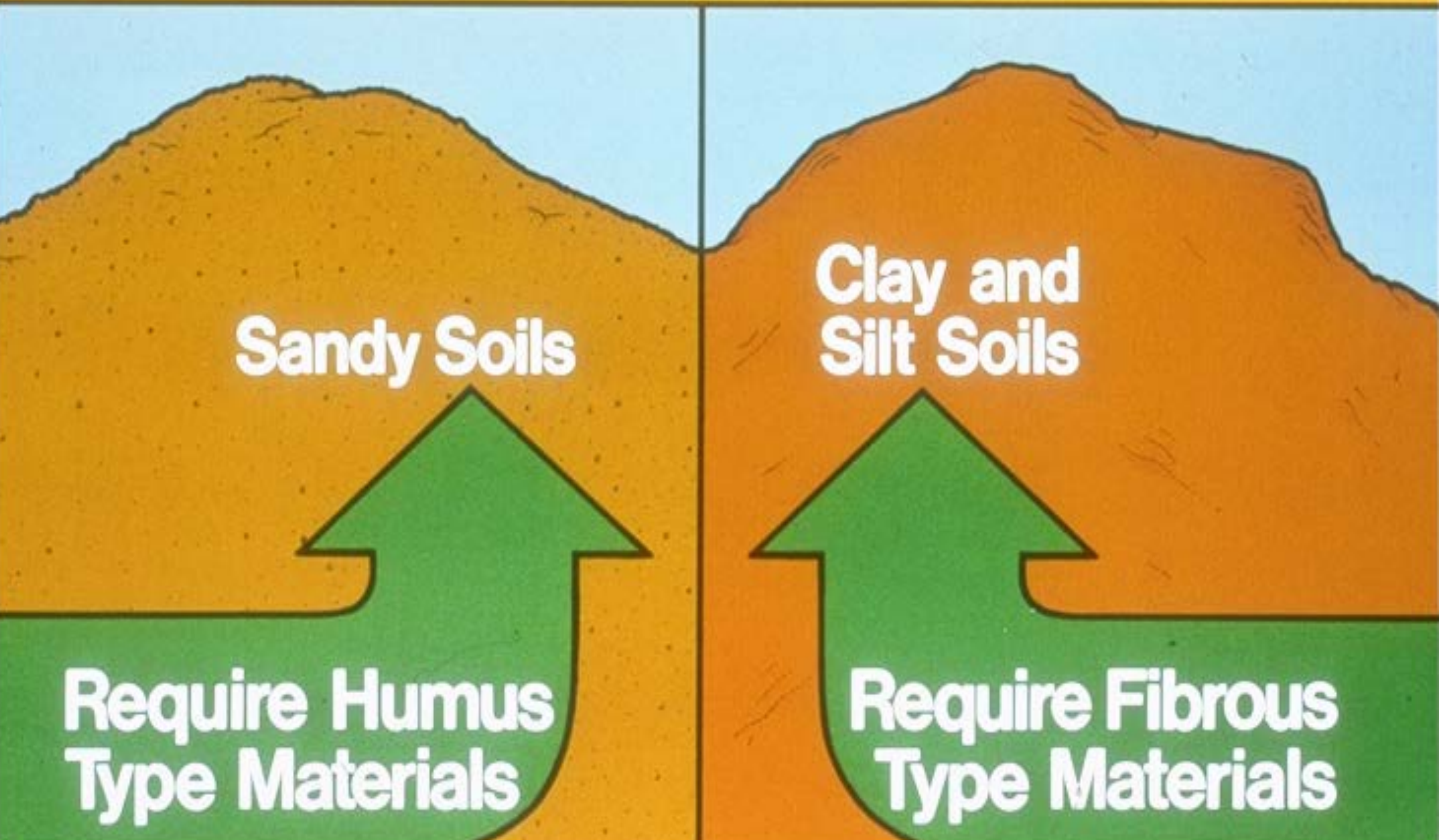
High bulk density ($2.0\ g/cm^3$ BD) traffic pan on a mining site under spoil materials. Roots cannot penetrate or loosen soils that are packed to BD > 1.5 (clay) or 1.9 (sandy) textured soil.



Appropriate “ripper” for these kinds of problems!

At a smaller scale, roto-tiller is the only way to loosen compacted soils in short term (years).

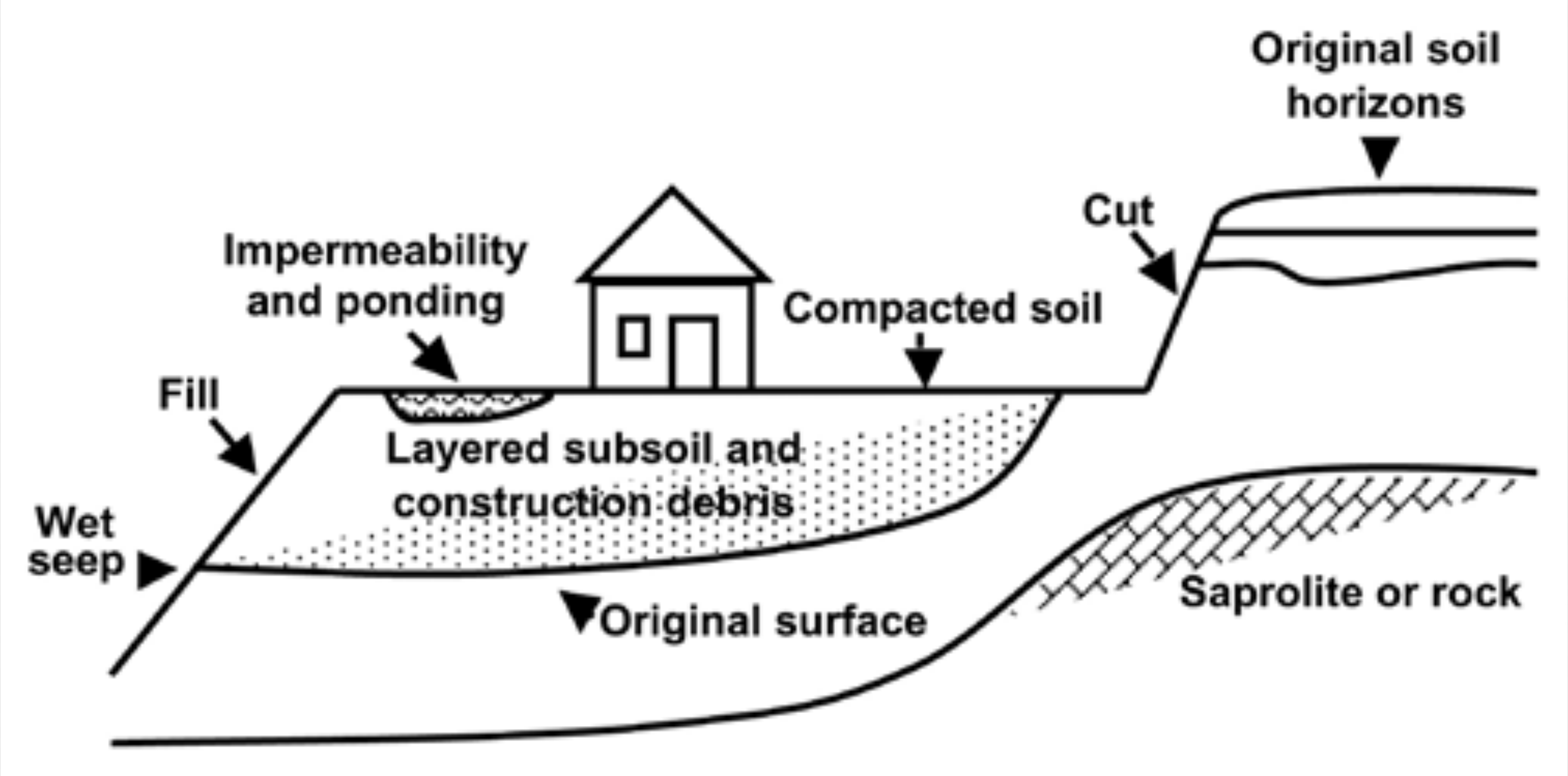
Selecting Physical Soil Amendments for Varying Soil Conditions



Compost improves soil properties (McConnell et al. Biocycle 1993, p 61-63)

Parameter	Rate (T/ Ac)	Effect
Organic matter	18-146	6-163% ↑
Water holding capacity	7-146	5-143% ↑
Bulk density	20-146	4-71% ↓
pH	20-146	0.8-1.4 ↑
Nutrients	18-446	0-500% ↑

Disturbed Soil Layering Due To Cut and Fill



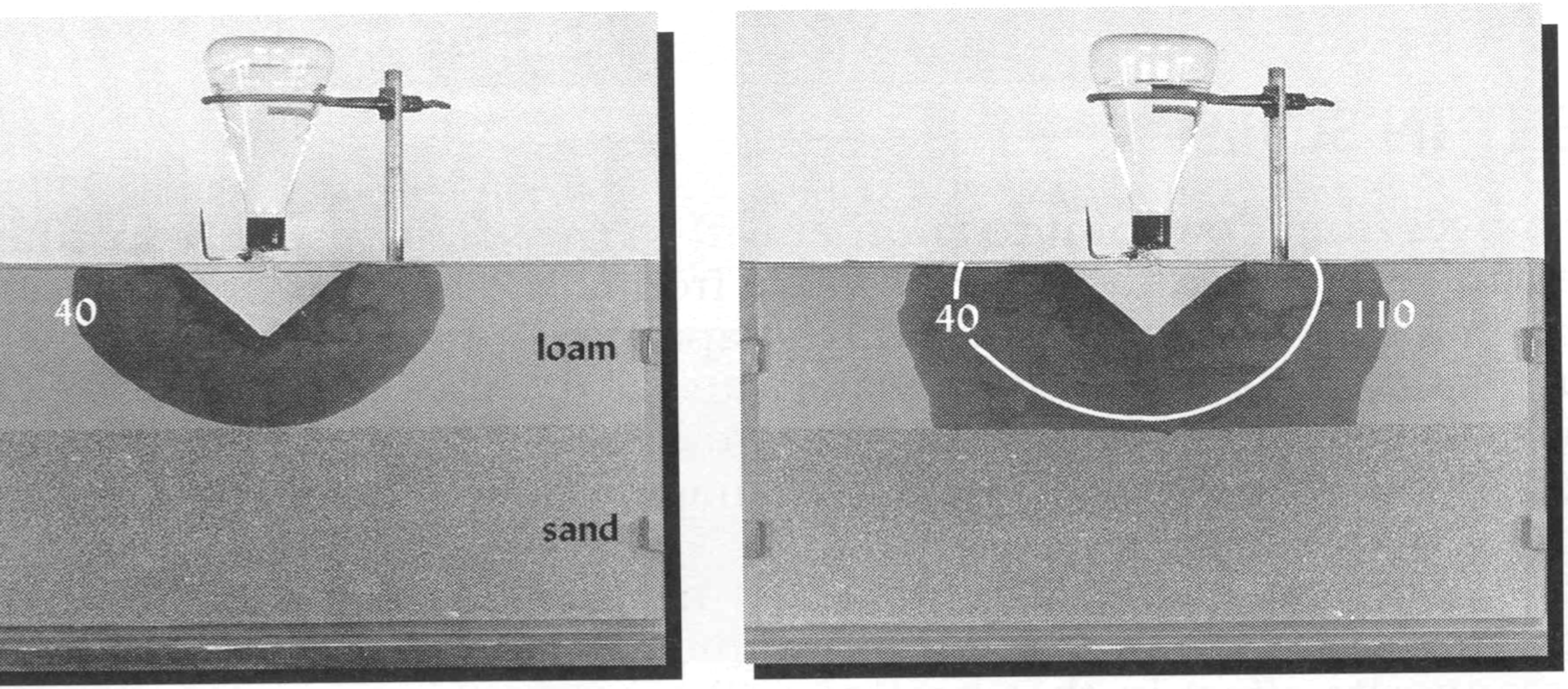
Effects of contrasting zones of texture/bulk density

Detrimental Layering Properties

- **Water, roots, and air will not penetrate strongly contrasting zones of texture and density.**
- **Any linear boundary with a texture difference >2 texture classes (e.g., loamy sand over clay loam) or bulk density difference > 0.33 g/cm^3 is subject to this problem.**

Contrasting textural layers affect water movement

"P*erching*"



(*a*) (*b*)

Urban Soil Chemical Problems

- pH
  - Natural range: 4.0-8.0
  - Ideal: 5.8-6.8
  - Low: < 5.5
  - High: >7.5
- Low nutrient content (esp., N & P)
- Pollutants


Tavistock Farms, Leesburg: Fill area comprised of Triassic shrink-swell clays amended with CaO for "stability."
Developer's plan: Use upper 18 inches plus soil excavated for footers for turf, hardwood trees, and shrubs.
2 9 2004

Soil pH: 6.9 to > 9.5, where CaO is unreacted.

Challenge: Calculate S rate to lower pH and processing to reduce cemented soil size to hold plant-available water.

What Are Acid Sulfate Soils?

Soils formed from the weathering of sulfide-bearing parent materials (iron pyrite), resulting in low pH.

$$FeS_2 + 15/4O_2 + 7/2H_2O \rightarrow 2H_2SO_4 + Fe(OH)_3$$

Typical young acid-sulfate soil profile

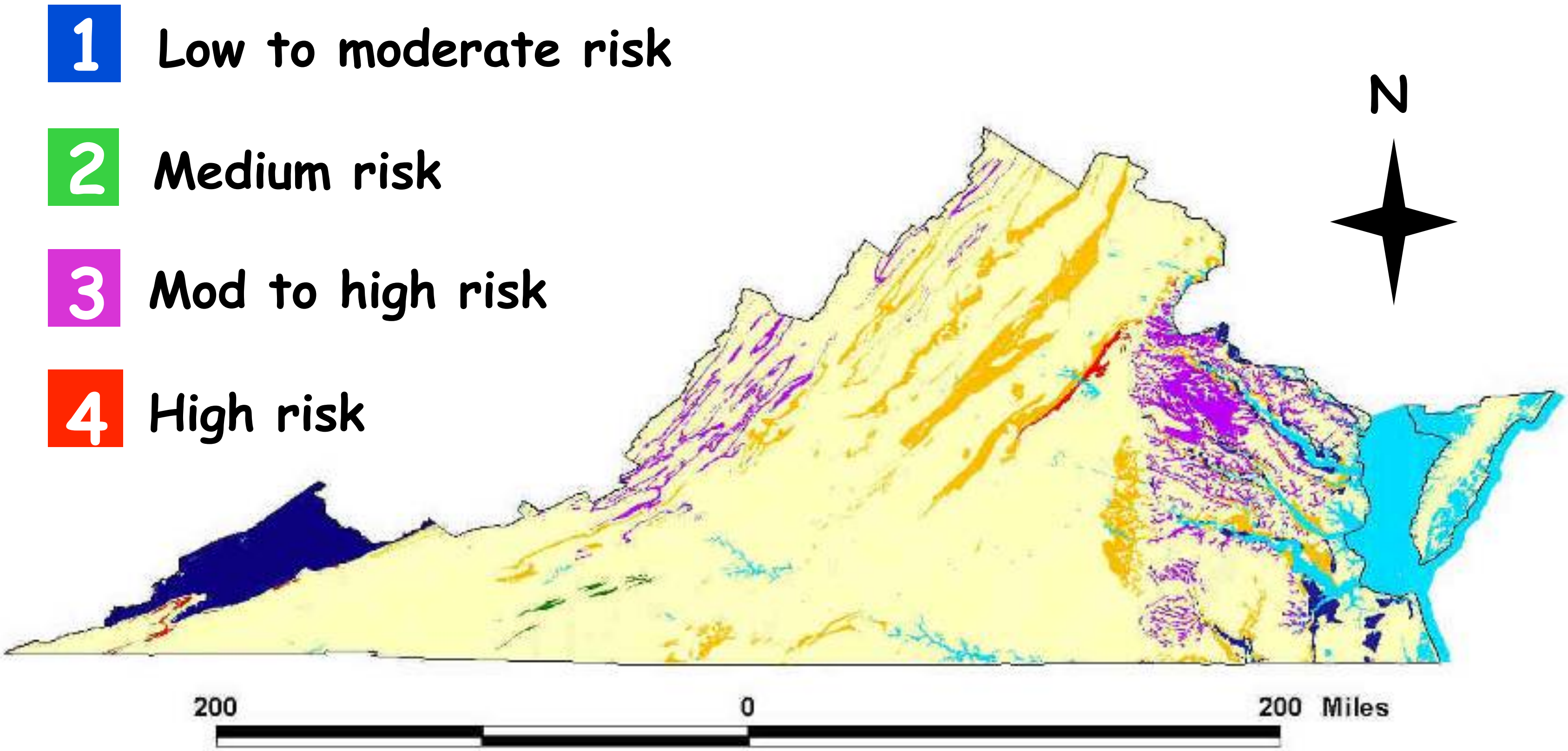
Overlying oxidized material is typically a light yellowish brown with pH ~ 3.

Underlying reduced material is typically drab blue or gray, with pH > 5.5.

Assessment and Remediation

- ~1.2% pyritic S in soil
- Recommended:
  - 25–30 tons $CaCO_3$/ac
  - 300 lbs P/ac
  - compost, if possible
- Cost ~ $7000

Vrginia Sulfide Hazard Map



http://www.landrehab.org

Urban Soil Contaminant Assessment

Can soil be used for gardening?

What level of contamination is acceptable?

- Do not assume that soil is uniform.
- Sample various locations and test individually.

Common Sources of Urban Contamination (USEPA)

Source	Prior site uses	Contaminants
Paint (<1978)	Homes	Pb
Burning	Residential refuse	Polycyclic aromatic hydrocarbons (PAHs), dioxins
High traffic areas	Adjacent to roadways	Pb, Zn, PAHs
Petroleum	Storage tanks	PAHs, benzene, toluene
Pesticides	Orchards	Pb, As, Hg, chlorinated pesticides
Commercial/industrial site use		PAHs, Pb, As, Zn, solvents
Dry cleaners		Tetrachloroethene (TCE)

Phase I Environmental Site Assessment (ASTM E1527-05)

- Historical Use
  - Interview neighbors, city officials, property owners
  - Acquire aerial photographs or maps
  - Gather information from local conservation district offices (e.g., soil surveys), city halls (e.g., permits), county offices (e.g., tax records), libraries, and historical societies and preservation offices (e.g., photos, hand-drawn site maps)
  - Evaluations of public land ownership records and environmental databases

Phase II Environmental Site Assessment (ASTM E1903)

- Field assessment – guided by site history
  - Document existing utilities (e.g., Miss Utility)
  - Assess topographic, hydrologic, and biological conditions
    - Slope, concentrated flow or erosion, drainge patterns, impervious area, depressions, wetlands
  - Soil evaluation
    - Soil type; particle size analysis/texture
    - Compaction – visual, field measurements, lab analysis
    - Presence of demolition debris
    - Soil sampling and analysis

Laboratories for Agronomic and Environmental Soil Testing

Laboratories	Agron	Environ
Virginia Tech Soil Testing Lab, Blacksburg: https://www.soiltest.vt.edu/	XX	
A&L Eastern Labs/Waypoint, Richmond: http://www.al-labs-eastern.com/	XX	X
Agricultural Analytical Services Lab, Penn State: http://agsci.psu.edu/aasl/soil-testing	XX	X
University of Delaware Soil Testing Program: http://extension.udel.edu/dstp/	XX	X
Air, Water and Soil Laboratories, Inc., Richmond: http://www.awslabs.com/index.html		XX
Environmental Systems Services, Ltd., Culpeper: http://www.ess-services.com/		XX

Assessing and Remediating Urban Soil Pollutants

- **USEPA established Soil Screening Levels (SSLs) to identify sites that can be considered low risk for health and pollution impacts.**
- **SSLs were designed for brownfield cleanup not for soil contaminant levels for food production.**
- **No consensus on urban soil agriculture testing protocols, and few municipalities have been engaged in soil testing.**

Residential SSLs for Selected Contaminants

Metals	Conc. (ppm)	Non-metals	Conc. (ppm)
As	0.68	Dieldrin	0.034
Cd	71	Dioxin, mixed	0.0001
Cr^{6+}	0.30	PCBs	0.2-35
Cu	3,100	Benzo[a]pyrene	0.016
Pb	400	Dicamba	1900
Hg (me)	7.8	TCE	0.91
Zn	23,000	Chlopyrifos	63

Potential Environmental Problems from Highly Metal Contaminated Garden Soils

- Excessive Pb absorption by children
  - Hand-to-mouth transfer of house dust increases ingestion
  - Most important for gardens: Keep soil out of homes
- Phytotoxicity from Zn (possibly, Cu, Ni)
  - Only with Zn-sensitive vegetable crops
  - Very low soil pH (<<5.5), unwise for gardening
- Excessive Cd in crops
  - Highly contaminated soils
  - Low soil pH
  - High Cd/Zn ratio allow food-chain transfer

Crops Differ in Pb Accumulation in Edible Plant Tissue

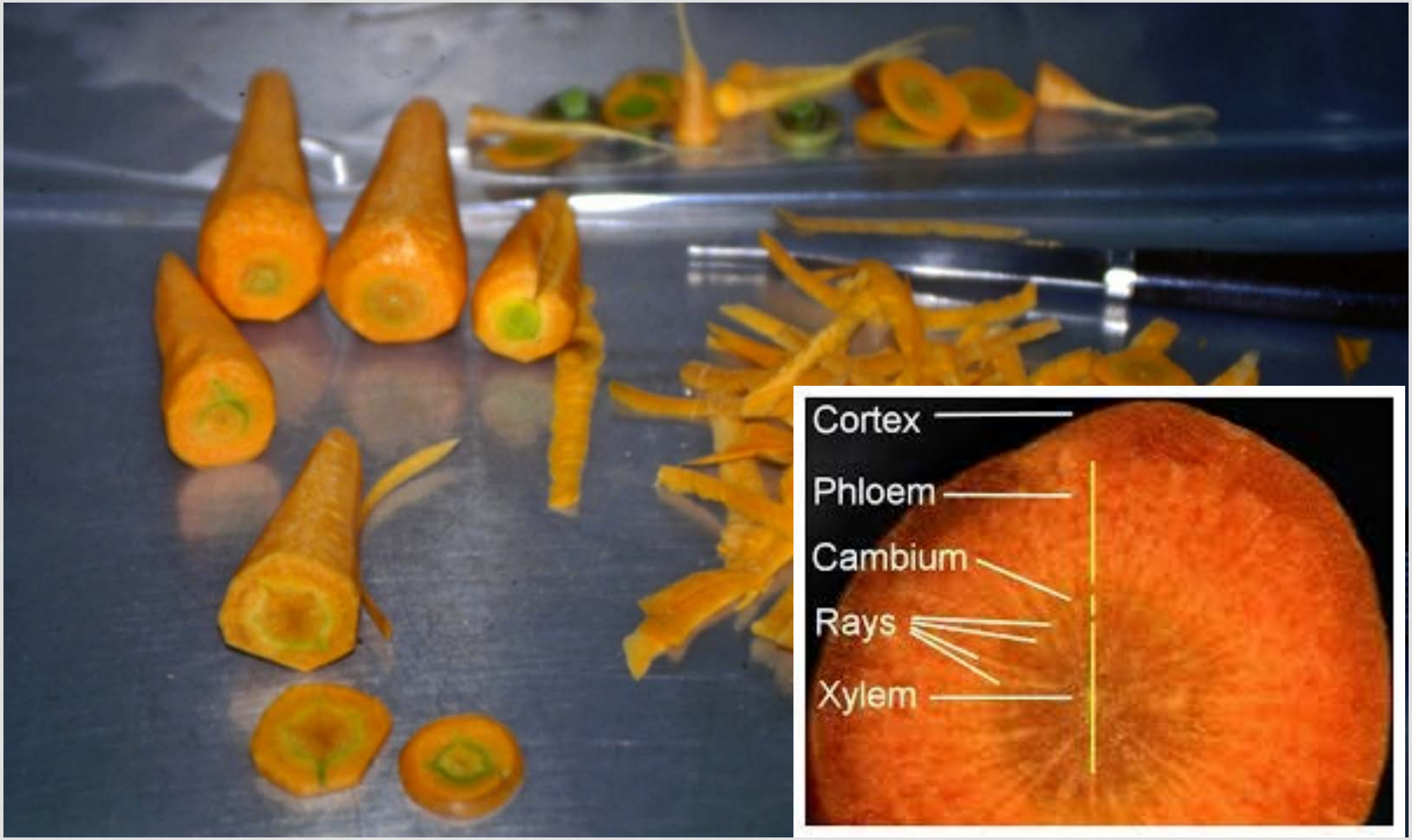
- Low growing leafy vegetables accumulate Pb via uptake from soil and from soil splash onto leaves.
  - Lettuce, spinach, chard, herbs
- Root vegetables can accumulate Pb within their xylem.
  - Carrot, beet, turnip, radish
- Tubers are phloem fed and very low in Pb.
  - Potato
- Fruit and Seed crops are very low in Pb even when grown in high Pb soils.

Pb Concentration in Soil and Carrots (Codling et al., 2014)

Soil series*	Soil Pb	Peeled root	Peel
	------------------- ppm Pb -------------------		
Christiana	20	0.21d	0.15d
Bagstown	676	2.79c	0.75c
Hudson	435	3.53b	0.97bc
Spike	350	2.67c	1.05b
Cashmont	961	7.30a	1.56a

* Christiana = control soil (MD); Bagstown (MD), Hudson (NY), Spike (MI), and Cashmont (WA) are old orchard soils.

Carrot processing of xylem and phloem



Concentration of Pb in lettuce grown in amended urban garden soil (Sterrett et al., 1994); MCL = 5-6 ppm (WHO)

Treatment	Soil Pb concentration, ppm			
	12	413	1334	5210
	Lettuce Pb, ppm			
Control	2.8a	15.7a	17.7a	37.8ab
NPK	2.0a	3.8b	8.4a	26.6bc
NPK + CaCO3	1.8a	9.3ab	6.0a	43.7a
NPK + P	2.9a	4.4b	10.5a	17.2c
NPK = 5% compost*	2.2a	2.4b	6.5a	16.1c
NPK + 10% compost*	2.6a	2.8b	5.3a	19.7c
*Composted biosolids rich in P and Fe oxides				

Soil Pb Summary

- Urban soils may be high in Pb.
- Soil ingestion is the major risk pathway.
- Plant uptake is limited, but soil splash can contaminate leaves.
- Bioavailability in ingested soil or crops << 100%.
- Ingestion with food reduces bioavailability.
- Treatment of soils with phosphates or composts can reduce bioavailability.
- Crops vary greatly in accumulation in edible parts.
- Inexpensive soil test available to assess risk. Can follow up with bioaccessibility test, if needed.

Common Sense Gardening in Metal-enriched Soil

- Identify previous land use and contamination sources before choosing location of garden.
- Analyze garden soils for Pb, As, Cd, Zn and pH, and site garden where metals are low, e.g. 3 ft from side of house.
- If bare soil total Pb > 400 ppm (or estimated from M3 test), seek analysis of bioaccessible Pb; limit exposure of children.
- Omit leafy or root vegetables

  where Pb >1000 ppm,

  or grow in clean soil raised beds

Philadelphia Food Policy Advisory Council Proposed Soil Safety And Urban Gardening Guidelines

Concern	Definition	Next step
Low	Garden site has always been residential, parkland, child care center, school	Action 1
Medium	Garden site is/has been remediated industrial land; a risk managed park, orchard, commercial land use (not gas station, dry cleaner, printing and auto body shop); or is located within a former landfill or 30 m from a former rail line or major road.	Test soil; Action 2
High	Garden site is/has been industrial land, gas station, dry cleaner, printing shop, auto body shop, rail line or rail yard; or reveals indications of dumping or burning, smells, or staining in the soil.	Action 3

Recommended Actions To Reduce Gardeners' Exposure To Soil Contaminants

Action	Recommended action
1	Use good gardening practices: • Wash hands • Wash produce
2	Use good gardening practices AND: • Reduce contaminant concentration by amending soil • Cover bare soil with vegetation or mulch • Peel root vegetables before eating • Avoid produce that accumulates contaminants
3	Use good gardening practices AND: • Cover bare soil with vegetation or mulch • Build raised bed gardens • Add clean soil and organic matter annually

Summary

- Urban soils often have physical, chemical and biological limitations to plant growth.
- Urban soils will be non-uniform and extensive sampling may be necessary.
- Remediation practices can include:
  - Physical manipulation
  - Application of acid- or alkaline-forming materials
  - Amending with organic by-products

References

- Craul, P. 1994. Urban soils: An overview and their future. In *The Landscape Below Ground: Proceedings of an International Workshop on Tree Root Development in Urban Soils*, Sep. 30–Oct. 1, 1993, pp. 115–125. Eds. G.W. Watson and D. Neely. International Society of Arboriculture.
- USDA-NRCS. Urban agriculture. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/landuse/urbanagriculture/
- USEPA. 2011. Evaluation of urban soils: Suitability for green infrastructure or urban agriculture. EPA Publ. No. 905R1103. http://nacto.org/docs/usdg/evaluation_of_urban_soils_epa.pdf

soils.org


Soil Science Society of America
SEARCH
LOG IN
Soils Sustain Life
Discover Soils
Science Policy
Publications
Membership
Certifications
Meetings
Education
Newsroom
Careers
> DISCOVER SOILS
> FOR TEACHERS
> FOR STUDENTS
> FOR MEMBERS
> FOR MEDIA
Click to enter 2018 Photo Contest! (2017 3rd Place: Vivian Wauters)
SCIENCE NEWS
Corn with straw mulch builds yield, soil carbon | More
Root exudates affect soil stability, water repellency | More
Faba fix for corn's nitrogen need | More
Dry the weeds, keep the crops | More
DL DIGITAL LIBRARY
Soils Across Latitudes
JAN. 6-9, 2019 | SAN DIEGO, CA
SSSA NEWS
Apply: $5,000 New Zealand Soil Science Travel Award | More
Announcing: 2018 SSSA Election Results | More
VZJ Special Section: The Root Zone (Open Access) | More
Register, Reserve Hotel: Sustainable Agronomy Conference | More
SOILS MATTER
What is a "green roof" and are they helpful to the environment?
Green roofs are vegetated rooftops, and they are gaining popularity in the United States. They are designed...
Why do forest soils need to be managed?
Forest soils are an important natural resource in the United States. Almost one-third of U.S. soil is...
EXPLORE SSSA
Membership Benefits
Join Today
Renew Today