IPM Benefits of Healthy Soils:
Soil Science and Maintenance Practices for Sustainable Landscapes

Healthy Soils parts 1+2 - short for WSU ReCert class 12-4-2019.pptx, and City of Seattle IPM Seminar 9-30-2019

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With slides from
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Urban Tree + Soils

Based on Healthy Soils Part 1 and Healthy Soils Part 2 by James Urban and David McDonald from ASLA conference Phoenix 9/6/2012, and Soil Improvement for Stormwater, Erosion, & Landscape Success by David McDonald for WSU Low Impact Development. Updated 2/27/2019

www.SoilsforSalmon.org
www.BuildingSoil.org
Natural soils vs. Disturbed urban soils

- Uniform across site
- Natural horizons
- Adequate OM, nutrients, structure for native plants

- Vary across site
- Topsoil layer removed
- Compaction, low OM
- Subsoil (or worse) fill layers
- Debris, toxins?
Soil Goals and Requirements

Tree Issues
- Expected canopy size
- Tree growth
- Tree stability

Use Issues
- Use intensity
- Irrigation or rain harvesting?
- Storm water?
- Lawn?
- Maintenance?
- Food?

Soil Issues
- Soil drainage
- Space for roots and trunk flare
- Sufficient soil volume
- Imported soil sources
- Existing soil conditions
- Grading
Physical properties of soil

- Texture: sand / silt / clay
- Structure: Clumps / clods / peds
- Density: weight / volume pore space
- Soil Biology: Organic matter / Carbon
- Nutrients: N, P, K, +
- pH: Acidity

Air and water movement / Soil Profile
Sub-Soils in the Puget Sound Basin: Leftovers from glaciers & volcanoes

**glacial till**: unsorted, unstratified mixtures of clay, silt, sand, gravel, and boulders; deposited under ice, or in moraines

**hardpan**: till compacted under glacier

**outwash soils**: layers sorted by particle size by water - sand / gravel / rocks

**lake/marine bed soils**: clay or silt that settled out in lakes & estuaries

**volcanic ash**: light, fertile, holds moisture - mostly blown east of Cascades

**mudflows**: mixed size, compact - like till

Learn about Puget Sound soils at: www.puyallup.wsu.edu/soilmgmt/Soils.html
Soil Texture (= particle size)
Ribbon+feel test:
Moisten soil, roll between hands, then squeeze out with thumb:

- Sand: no ribbon, grainy
- Sandy loam: ½ inch ribbon
- Loam: thick 1 inch ribbon
- Silt: makes flakes rather than ribbon
- Silty clay loam: thin, breaks easily, has floury feel
- Sandy clay loam: stronger, has grainy feel
- Clay: long (3 inch) ribbon, has smooth feel

See video at www.puyallup.wsu.edu/soilmgmt/Soils.html
Don’t grind up your soil! Mix loosely to preserve the peds.
Organic amendments (compost) improve structure in all soil types, through biological activity and bio-chemical modifications.
Density or Compaction
As compaction increases, pore space for water and air decreases.
Plant-available water depends on pore spaces and organic matter.

Adding compost increases plant-available water capacity.
Examining a soil profile with a soil probe / core sampler

*Only works 6-12” deep, so better for lawns than trees.*

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**Compacted vs. Amended**

Examining soil profile with shovel

*To verify scarification of subsoil and amendment of upper 8” with compost.*
Chemical properties of soil

Texture
- sand / silt
- clay

Structure
- Clumps / clods
- peds

Nutrients
- N P K +

pH
- Acidity

Density
- weight / volume
- pore space

Organic matter
- Carbon

Soil Biology

Air and water movement / soil profile
### Elements Required by Plants

<table>
<thead>
<tr>
<th>Base elements</th>
<th>Macronutrients</th>
<th>Micronutrients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen (O)</td>
<td>Nitrogen (N)</td>
<td>Boron (B)</td>
</tr>
<tr>
<td>Hydrogen (H)</td>
<td>Phosphorus (P)</td>
<td>Chlorine (Cl)</td>
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<tr>
<td>Carbon (C)</td>
<td>Potassium (K)</td>
<td>Cobalt (Co)</td>
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<tr>
<td></td>
<td>Calcium (Ca)</td>
<td>Copper (Cu)</td>
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<tr>
<td></td>
<td>Magnesium (Mg)</td>
<td>Iron (Fe)</td>
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<tr>
<td></td>
<td>Sulfur (S)</td>
<td>Manganese (Mn)</td>
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<tr>
<td></td>
<td></td>
<td>Molybdenium (Mo)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Zinc (Zn)</td>
</tr>
</tbody>
</table>

Adding compost increases nutrient availability to plants!
The smaller the particle the greater the CEC. *Humus/clay colloids have the most!*

**Cation Exchange Capacity (CEC) for planting soil mixes**
- Low fertility soil: Less than 5
- Medium fertility: 5-10
- High fertility: 10-30
- Compost/humus: up to 200!

Adding organic (mulch & compost) increases CEC and nutrient capacity of all soil types.
### USDA pH Classification

<table>
<thead>
<tr>
<th>pH range</th>
<th>pH range</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultra acid</td>
<td>1.8 - 3.4</td>
<td>Toxic to most plants</td>
</tr>
<tr>
<td>Extremely acid</td>
<td>3.5 - 4.4</td>
<td>Restrictive to most plants</td>
</tr>
<tr>
<td>Very strong acid</td>
<td>4.5 - 5.0</td>
<td>Acid-tolerant plants</td>
</tr>
<tr>
<td>Strongly acid</td>
<td>5.1 - 5.5</td>
<td>Acid-tolerant plants</td>
</tr>
<tr>
<td>Moderately acid</td>
<td>5.6 - 6.0</td>
<td>Acid-tolerant plants</td>
</tr>
<tr>
<td>Slightly acid</td>
<td>6.1 - 6.5</td>
<td>Best nutrient availability for most plants</td>
</tr>
<tr>
<td>Neutral</td>
<td>6.6 - 7.3</td>
<td>Best nutrient availability for most plants</td>
</tr>
<tr>
<td>Slightly alkaline</td>
<td>7.4 - 7.8</td>
<td>Alkaline-tolerant plants</td>
</tr>
<tr>
<td>Moderately alkaline</td>
<td>7.9 - 8.4</td>
<td>Alkaline-tolerant plants</td>
</tr>
<tr>
<td>Strongly alkaline</td>
<td>8.5 - 9.0</td>
<td>Restrictive to most plants</td>
</tr>
<tr>
<td>Very strongly alkaline</td>
<td>9.1 - 11.0</td>
<td>Toxic to most plants</td>
</tr>
</tbody>
</table>

Lower or higher pH decreases availability of different nutrients.

Adding humus (compost) buffers soil pH towards 6.3 to 6.8, best for nutrient availability to plants.
Organic & Biological properties of soil

- Texture: sand / silt / clay
- Structure: clumps / clods / peds
- Nutrients: N P K +
- Density: weight / volume / pore space
- Organic matter: Carbon
- pH: Acidity

Soil Biology

Air and water movement / soil profile
Soil development from parent “dirt” & rock – *biology in action!*

Soil horizons & their evolution

- Substratum (C) or bedrock (R) weathers physically & chemically to subsoil (B)

- Primarily **biological** processes create topsoil (A) and organic (O) horizons

USDA - NRCS
http://soils.usda.gov
Understanding Soil Biology

Soil life provides essential functions

Soil is alive!

Cyst
Amoeba
Flagellate
Bacterial Colonies
Nematode
Ciliate
Clay-Organic Matter Complex
Decomposing Plant Cells
Fungal Hyphae and Spores
Actinomycete hyphae and Spores

USDA-NRCS
“Soil Biology Primer”
http://soils.usda.gov/sqi/
Common organisms in the soil food web:

- Bacteria
- Fungi
- Protozoa
- Nematodes
- Arthropods
- Earthworms
Restoring soil life, to restore soil functions

Soil organisms create:
- soil structure
- fertility = nutrient cycling
- plant disease protection
- Bio-filtration
- erosion control
- stormwater detention & moisture capacity

Compost kickstarts the soil ecosystem! (Provides food and home for organisms)
How can we enhance & restore soil biodiversity, to improve plant growth, water quality, and reduce runoff?

- Prevent /reduce compaction (keep heavy machinery off)
- Reduce intensive use of pesticides & soluble fertilizers
- Incorporate compost into soil, and mulch regularly, to feed soil life

organic matter + soil organisms + time creates ⇒ soil structure, biofiltration, fertility, & stormwater detention
Plants as indicators of soil differences and problems
WSDOT
I-5 Marvin Rd.
Interchange

Which site is selling the next job?
Which needs more water, fertilizer, weed control?

Compost

UW trials:
up to 50% reduction in storm water runoff when glacial till soil is amended with compost.

No Compost
Grey color, poorly draining soil

Constantly smell the soil! Sour odor indicates poor drainage
Regulatory requirements for new construction, in WA Dept. of Ecology’s Stormwater Mgmt. Manual for Western WA

BMP T5.13 “Post-Construction Soil Quality and Depth”

- Retain native soil and duff wherever possible
- All areas cleared and graded require 8 inch soil depth:
  - Organic matter content $\geq 10\%$ dry weight (5% for turf)
  - Use native topsoil, amend existing soil with compost, or import topsoil blend
  - Subsoil scarified 4 inches below 8-inch topsoil layer
  - Protect amended soil from compaction
  - Mulch after planting
  - Maintenance practices to replenish organic content
Soil Interfaces

Topsoil over smooth compacted layers causes drainage and root growth problems

Better: Scarified subsoils
Loss of organic matter

• Plan to preserve existing soil & vegetation where possible
• Minimize grading, cut and fill
• Minimize traffic off road bases
• Even a low-organic subsoil can be substantially restored by amending 10-25% (by volume) with mature, stable compost.
Chemical changes

- pH (sometimes due to compacted, anaerobic conditions)
- Nutrient deficiencies (loss of topsoil)
- Toxins: oil, metals, chemicals

Compost amendment tends to correct all of these

Visually examine and smell, then test for suspected deficiencies, toxins, & pH

Chose well-adapted plants, tolerant of your soil conditions (pH etc.)
Protect soil & vegetation during construction

• Fence vegetation & soil protection zones
• Inform all contractors & subs: no stockpiles etc.
• If temporary vehicle access required, place steel plates over 6” coarse wood chip.
Restoring soil in place

- Place sub-drainage if req’d
- Range of equipment for different-sized sites
- If compacted, rip (scarify) to 12-18” depth before or while amending
- 2-4” compost mixed into upper 8-12” of soil
Soil harvesting, storage, & re-installation

- Harvest at start of grading
- Store covered with breathable fabric, coarse wood chips, or sterile annual grass to prevent erosion and weeds
- Amend with compost just before re-spreading
- Rip in first lift to avoid sharp soil interfaces (which can limit air and water movement)
- Don’t work soil when saturated
Soil Installation
Working with soils with retained peds

Constantly loosen soil while installing to avoid buildup of deep compaction. Back drag over loader tracks each time.

Require all equipment to have teeth on bucket to scarify soil.

Require low ground pressure equipment (4 psi preferred - 5 psi max).

Teeth on loader bucket
Amending soils on site

- Place sub-drainage if req’d
- Range of equipment for different-sized sites
- If compacted, rip (scarify) to 12-18” depth before or while amending
- 2-3” compost mixed into upper 8-12” of soil
Add Compost: Most of it in the top layer of the soil profile – mimic natural profile!
How to Select Compost

Know your supplier!

Field tests:
- earthy smell - not sour, stinky, or ammonia
- brown to black color
- uniform particle range
- stable temperature (does not get very hot if re-wetted)
- not powdery or soaking wet

Soil/compost lab test info:
- Nutrients
- Salinity
- pH
- % organic content (OM)

Mfr.-supplied info:
- State permitted composting facility
- Meets US Compost Council (STA) “Seal of Testing Assurance”
- TMECC lab test methods, specs:
  - C:N ratio
  - Weed-seed trials
  - Nutrients, salinity, contaminants
  - Size: “screen”, % fines

Stability /Maturity:
- use Solvita test on-site (> 6)
- rely on mfr’s TMECC tests: CO\textsuperscript{2} evolution and seedling growth
Compost Based Erosion Control BMPs

- EPA-approved BMPs: **blankets**, **berms**, and **socks**
  - see www.buildingsoil.org

- “2 for 1” value – use compost for erosion control, then till in at end to restore soil:
  - No disposal costs
  - Faster planting, better growth

- Costs: blankets similar to rolled products, but savings on disposal, plus 2 for 1 benefits

More info at www.BuildingSoil.org
Soil biological additive products

Compost teas – useful in remediation, but just use good compost for soil preparation

Mycorrhizal inoculants – species specific, also in soil from healthy trees

Kelp & other organic additives – match plant nutrient needs – good for micronutrients

Fertilizers – stick with organic sources, match plant needs – compost often supplies most needs for establishment.

*Base fertilization on soil test results!*
Soil chemistry & pH modifications

- **Match plant selection to site soils**, rather than trying to modify chemistry
- Compost buffers pH, acid or alkaline towards optimal 6.3-6.8
- Compost increases cation exchange capacity (CEC) = nutrient storage & avail
- Lime as needed for Ca & Mg plant needs
- Sulfur applications only lower pH temporarily

Plant problems? Get a soil test.
Rationale for less fertilizer for urban trees and landscapes

Not crops – Fruit production or crop yields not required

Sufficient required nutrients available to support plant goals

No yearly harvest/removal of biomass

Slower growth may be a desirable trait

Too much N increases sucking insects and foliar diseases, and annual weeds

Feed the soil, not the plant by mulching and leaving fallen leaves.
Plant problems? Get a soil test.
Soil Maintenance

Using mulches after planting and for annual maintenance

BENEFITS:

Mulches limit weed growth, and make weeds that sprout easier to pull or cultivate.

Mulches conserve water, moderate soil temperature, and reduce erosion.

Mulches replenish soil organic matter, enhancing soil biodiversity, structure, and nutrient cycling = increased plant vigor.
Mulching

WHEN  After planting, and once every year or two:
- Spring or fall on trees and shrubs to prevent weeds.
- Early summer on gardens. (Let soil warm up.)
- Fall on beds to prevent erosion and compaction.

WHERE  Whole beds, paths, 3 ft. or larger ring around trees & shrubs in lawns.

HOW  Remove weeds & grass before spreading mulch. Keep mulch away from plant stems. Use cardboard weed barrier (not fabric) to control aggressive weeds.
Mulching

WHAT

Woody mulches (arborist wood chips, bark) for woody plants (trees & shrubs).

Non woody mulches (compost, leaves, grass clippings, composted manure or biosolids) for non-woody plants (annuals, perennials, berries, roses).

HOW MUCH

Compost, leaves, sawdust, fine bark, grass clippings: 1-2” deep.

Wood chips or coarse bark: 2-4” deep.
Other Soil Maintenance Practices

• Leave plant litter, recycle fall leaves and chipped prunings into mulch on site.

• Mulch-mow lawns (leave the clippings)

• Base all fertilizer applications on soil tests (every 1-3 years on most sites). Learn about soil testing at [www.puyallup.wsu.edu/soilmgmt/Soils.html](http://www.puyallup.wsu.edu/soilmgmt/Soils.html)

  See videos and factsheets on “Collecting a soil sample”, “Determining soil texture by hand”, and “Understanding soil test results”.

• More urban soil remediation & maintenance strategies in *Up by Roots* by James Urban.
Soil Goals and Requirements – *Right plant, right place, right soil!*

**Tree Issues**
- Expected canopy size
- Maintenance?
- Tree stability
- Soil drainage
- Sufficient soil volume
- Existing soil conditions
- Importing soil sources
- Grading
- Space for roots and trunk flare

**Use Issues**
- Use intensity
- Irrigation or rain harvesting?
- Storm water?
- Lawn?
- Maintenance?
- Food?

**Soil Issues**
- Soil growth
Resources to learn more:

WSU Soil Management – testing & more
www.puyallup.wsu.edu/soilmgmt/Soils.html

www.sustainablesites.org

Up By Roots: Healthy Soils and Trees in the Built Environment
By James Urban, available at Amazon

Building Soil Manual www.buildingsoil.org

Natural Landscaping: Design, Build, Maintain and other resources in English and Spanish at
www.seattle.gov/util/landscapeprofessionals