Remediating compacted soils compromised by urban construction.

By Miles S. Sax & Nina Bassuk

Urban Horticulture Institute
Section of Horticulture
Strategies for protecting or remediating soil impacted by construction

- Protect soil prior to construction (CRZ).
- Calculate soil volume for plant ‘design size.’
- Create breakout zones (paths to better soil).
- Use raised landscape planting beds to create shared rooting space. Bury poor soil.
- Amend in place. “Scoop and Dump”
- Replace soil.
Critical Root Zone (CRZ)

- Typically, 1 foot radius protected for every 1” dbh
- Use 1.5 foot per every 1” dbh for specimen trees
How Much Soil Does a Tree Need?

2 cubic feet of soil for every 1 square foot of crown projection.
EX. Tree with expected 20' diameter crown spread

CP = $3.14 \times \text{radius (10')}^2$

= $314 \text{ ' squared} \times 2 \text{ (cubic feet)}$

20 ft. x 20 ft. x 18” (1.5 ft.) deep
For columnar trees, use ‘expected CRZ’ for soil preparation zone.
Volume effects on tree growth.
Honeylocust in Syracuse, NY.
*Tilia cordata* in restricted soil (right) and borrowed soil (left).
Detecting roots beyond the sidewalk
Sidewalk heaving
Break-out path in a sidewalk
Soil compaction during construction
Compacted soil showing loss of structure.
Soil Health Test

- Physical
  - Aggregate Stability (%)
  - Water Holding Capacity (%)
  - Bulk Density (g/cm³)
  - Texture
  - Resistance (PSI)

- Biological
  - Organic Matter (%)
  - Active Carbon (ppm)
  - Soil Respiration
  - Soil Protein

- Chemical
  - pH
  - Nutrients (P, K, Ca, Mg, Fe, Mn, Zn)
# Cornell Soil Health Assessment

**Sample ID:** J_151  
**Field/Treatment:** Musgrave Field E PLOW TILL  
**Tillage:** 7-9 inches  
**Crops Crown:** MIX, MIX, MIX  
**Date Sampled:** 5/21/2014  
**Given Soil Type:** Lima  
**Given Soil Texture:** Silt Loam  
**Coordinates:** Coordinates Not Provided

## Measured Soil Textural Class
- **Loam**
- **Sand:** 40%  
- **Silt:** 45%  
- **Clay:** 15%

## Test Report

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Value</th>
<th>Rating</th>
<th>Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available Water Capacity</td>
<td>0.11</td>
<td>17</td>
<td>Water Retention and Availability</td>
</tr>
<tr>
<td>Surface Hardness</td>
<td>210</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Subsurface Hardness</td>
<td>300</td>
<td>46</td>
<td>Aeration, Infiltration, Rooting, Crusting, Sealing, Erosion, Runoff</td>
</tr>
<tr>
<td>Aggregate Stability</td>
<td>19.1</td>
<td>20</td>
<td>Organic Matter Quality, Organic N Storage, N Mineralization</td>
</tr>
<tr>
<td>Organic Matter</td>
<td>3.4</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td>ACE Soil Protein Index</td>
<td>4.6</td>
<td>20</td>
<td>Organic Matter Quality, Organic N Storage, N Mineralization</td>
</tr>
<tr>
<td>Root Pathogen Pressure</td>
<td>5.3</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>Respiration</td>
<td>6.94</td>
<td>28</td>
<td>Soil Microbial Abundance and Activity</td>
</tr>
<tr>
<td>Active Carbon</td>
<td>411</td>
<td>14</td>
<td>Energy Source for Soil Biota</td>
</tr>
<tr>
<td>pH</td>
<td>7.9</td>
<td>0</td>
<td>High pH: Toxicity, Nutrient Availability</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>4.9</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Potassium</td>
<td>83.8</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

### Minor Elements
- **Mg:** 295  
- **Fe:** 0.7  
- **Mn:** 18.3  
- **Zn:** 0.4

## Overall Quality Score
- **44**  
- **Low**
Soil remediation and raised landscape beds
Study Sites

- Roberts 2009
- CCC 2012
- Plant Science 2007
- Mann 2010
- Centennial 2004
- Fernow 2001

= Study Site (n=6)  = Control (n=4)
Scoop & Dump method of soil remediation

- Apply a layer 6-8” of compost to compacted soil
- Use backhoe bucket to dig down to 18”
- Bucket is lifted with topsoil / compost mix 3 feet into the air
- Soil/compost mix is dropped onto the ground and smoothed
- Landscape plants are directly planted in the soil
- Surface mulch added every year to replenish organic matter
S&D not done under existing trees
Aggregate Stability

22% stability
Long-term plow till

72% stability
Long-term no till
Aggregate Stability (%) (n=30)

<table>
<thead>
<tr>
<th></th>
<th>Scoop &amp; Dump</th>
<th>Unamended</th>
<th>Std. Err.</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate Stability (%)</td>
<td>72.41</td>
<td>34.90</td>
<td>4.88</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>
Organic Matter

• Primarily refers to carbon derived from living sources:
  – Plant & animal residues
  – Living & dead microorganisms
Organic Matter (%) (n=30)

<table>
<thead>
<tr>
<th>Scoop &amp; Dump</th>
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<th>Std. Err.</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.43</td>
<td>3.23</td>
<td>0.58</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>
Active Carbon

Organic matter that is readily available as a food source for microorganisms
Active Carbon (mg/kg\(^{-1}\)) (n=30)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Mean (mg/kg(^{-1}))</th>
<th>Std. Err.</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scoop &amp; Dump</td>
<td>1022.47</td>
<td>361.60</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Unamended</td>
<td>361.60</td>
<td>51.51</td>
<td></td>
</tr>
</tbody>
</table>
Available Water Holding Capacity (n=30)

<table>
<thead>
<tr>
<th></th>
<th>Scoop &amp; Dump</th>
<th>Unamended</th>
<th>Std. Err.</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.23</td>
<td>0.15</td>
<td>0.01</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>
Potentially Mineralizable Nitrogen (mg/kg\(^{-1}\)) (n=30)

<table>
<thead>
<tr>
<th>Scoop &amp; Dump</th>
<th>Unamended</th>
<th>Std. Err.</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>27.53</td>
<td>3.11</td>
<td>4.41</td>
<td>.0005</td>
</tr>
</tbody>
</table>
Resistance (Penetrometer)

Root limiting resistance = >300 psi
Resistance (Penetrometer)

Average Depth of Root Limiting Resistance (300 PSI)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean</th>
<th>St. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scoop &amp; Dump</td>
<td>9.74</td>
<td>2.24</td>
</tr>
<tr>
<td>Unamended</td>
<td>3.44</td>
<td>1.65</td>
</tr>
</tbody>
</table>
Bulk Density
Weight/ Volume = Bulk Density
grams/cm³

Root Limiting Bulk Density

<table>
<thead>
<tr>
<th>Texture</th>
<th>Bulk Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>1.75 (g/cm³)</td>
</tr>
<tr>
<td>Silt &amp; Clay</td>
<td>1.40 (g/cm³)</td>
</tr>
</tbody>
</table>
The bar chart shows the bulk density (g/cm³) for two conditions: Scoop & Dump and Unamended. The chart indicates that the bulk density for Scoop & Dump is 0.89 g/cm³, and for Unamended it is 1.47 g/cm³. The table below provides the mean, standard error, and p-value for each condition:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Mean</th>
<th>Std. Err.</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scoop &amp; Dump</td>
<td>0.89</td>
<td>0.06</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Unamended</td>
<td>1.47</td>
<td>0.06</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>
Scoop & Dump Over Time
Bulk Density

Bulk Density (g/cm³) Over time ($R^2= 0.50$, $P<.0001$, $n=30$)

Years since Remediation

Bulk Density (g/cm³)
Active Carbon

Active Carbon (mg/kg\(^{-1}\)) Over Time (\(R^2 = 0.57\), \(P<.0001\), \(n=30\))
Potentially Mineralizable Nitrogen

PMN (mg/kg\(^{-1}\)) Over Time (\(R^2=0.61\), \(P<.0001\), \(n=30\))
Scoop & Dump

This method has shown:

• Soil resistance decrease
• Pore volume increase
• Reduction in bulk density
• Increased C & N
• Improved soil structure
• Improved aggregate stability
• Improved plant growth response
• Long term improvement of soil conditions and plant growth (13 years)
Treatments:
0% compost (100% soil)
33% compost
50% compost
100% compost
### Compost Specification for Compaction Remediation in a Landscape Bed

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units of Measurement</th>
<th>Recommended Range</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>pH units</td>
<td>6.5 - 8.0</td>
<td>Depending on pH of soil</td>
</tr>
<tr>
<td>Soluble Salt Content</td>
<td>dS/m (mmhos/cm)</td>
<td>1 - 4</td>
<td></td>
</tr>
<tr>
<td>Organic Matter</td>
<td>% dry weight basis</td>
<td>&gt;20</td>
<td></td>
</tr>
<tr>
<td>C:N</td>
<td>Ratio</td>
<td>10:1 - 20:1</td>
<td>Depending on soil texture and moisture level</td>
</tr>
<tr>
<td>Total N</td>
<td>% dry weight basis</td>
<td>1.0 - 4.0</td>
<td></td>
</tr>
<tr>
<td>Total Phosphorous</td>
<td>% P2O5 dry weight basis</td>
<td>0.5 - 2.0</td>
<td></td>
</tr>
<tr>
<td>Total Potassium</td>
<td>% K2O dry weight basis</td>
<td>1.0 - 5.0</td>
<td></td>
</tr>
</tbody>
</table>
Scoop & Dump vs. Unamended

**Study Site:** In garden bed

**Control Site:** In turf

- Mulch
- Scoop & Dump
- Resident Subsoil

- Turf
- Unam.
Soils Collected
Leaf Area (cm²) by Treatment (n=30)  
(P<0.0002)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Leaf Area (cm²)</th>
<th>Std. Err.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scoop &amp; Dump</td>
<td>933.18</td>
<td></td>
</tr>
<tr>
<td>Unamended</td>
<td>579.89</td>
<td>59.14</td>
</tr>
</tbody>
</table>
Dry Weight Shoots (g) by treatment (n=30) (p=0.0015)

<table>
<thead>
<tr>
<th>Scoop &amp; Dump</th>
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<th>Std. Err.</th>
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</thead>
<tbody>
<tr>
<td>10.17</td>
<td>7.03</td>
<td>0.63</td>
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Bulk Density (g/cm³) by Treatment (n=30) (p<.0001)

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Avg. Bulk Density

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<th>Avg. Bulk Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scoop &amp; Dump</td>
<td>0.97</td>
</tr>
<tr>
<td>Unamended</td>
<td>1.68</td>
</tr>
</tbody>
</table>

Root Limiting Bulk Density

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</tr>
</tbody>
</table>
Linear Regression Dry Weight Shoots (g) by Bulk Density (g/cm³)

\( R^2 = 0.52 \) (n=30) (p < .0001)

- Scoop & Dump
- Unamended
Destructive Harvest Observations

Root avoidance of compacted soils
Destructive Harvest Observations

Root Growth in ‘Scoop and Dump’ Soil
Radial Trenching

Radial trenching--plan view

Radial trenching--section
Questions?

Additional Resources

• Cornell Urban Horticulture Institute
  https://blogs.cornell.edu/urbanhort/

• Cornell Soil Health Test
  http://soilhealth.cals.cornell.edu/extension/manual.htm

• Cornell Nutrient Analysis Lab (Compost Testing)
  – http://cnal.cals.cornell.edu/

Publication

Long-Term Remediation of Compacted Urban Soils by Physical Fracturing and Incorporation of Compost
MS Sax, N Bassuk, H van Es, D Rakow - Urban Forestry & Urban Greening, 2017