Don’t treat your soil like dirt!

“Soil 101”

Forbes Walker, Environmental Soils Specialist, UT Extension

Overview

• What is soil?
• How is it formed?
• Importance of texture and structure
• What can your color soil tell you?
• Soil pH
• Soil organic matter
• Essential plant nutrients
• Soil testing
• Tillage

What is Soil?

• Unconsolidated mineral and organic material that serves as a natural medium for the growth of plants
  – Anchors plants
  – Pores: gaseous exchange (CO₂ ⇌ O₂); water infiltration and storage
  – Moderates temperature
  – Supplies nutrients
• Recycling system for nutrients, wastes
• Habitat for numerous soil organisms
• System for water supply and purification

What is in Soil?

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Organic</th>
<th>Water</th>
<th>Air</th>
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</thead>
<tbody>
<tr>
<td>25%</td>
<td>25%</td>
<td>3%</td>
<td>47%</td>
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Soil Forming Factors

• Parent Material
  - Geology; wind-blown, glacial or river deposits
• Climate
  - Temperature; rainfall
• Topography / landscape position
  - Erosion
• Biota
  - Plants, animals, humans
• Time
  - Weathering; availability of nutrients

Soil Horizons

• Vertical section of soil exposing all layers of the soil
• Soils vary in number of layers and their thickness

Grassland

Deciduous forest

Coniferous forest
Soil Texture

- Percentage of sand, silt and clay particles
- Does not include material > 2 mm diameter (gravel, rocks etc.), or organic material
- Permanent characteristic of soil
- Important for many properties:
  - water holding capacity
  - water movement into and off soil
  - nutrient holding capacity
  - resistance to erosion
  - influences crop management
  - engineering applications

Soil Texture

- Sand: 0.05 - 2 mm diameter
  - single grained, gritty feel, SiO₂ (silicates)
- Silt: 0.002 - 0.05 mm diameter
  - smooth, floury feel, slightly cohesive, quartz, feldspars
- Clay: < 0.002 mm diameter
  - stiff, sticky, very cohesive
  - secondary minerals (weathered)

Soil Structure

- Definition:
  - Aggregation of primary soil separates into compound particles that are separated from adjoining aggregates by planes of weakness
- Helps to determine drainage of soil; Influences erosion; Rooting medium; Aeration of subsoil
- Five structure types
  - Granular
  - Platy
  - Prismatic / columnar
  - Blocky: angular / sub-angular
  - “Structureless”

Soil Color

- Black - organic matter
- Grey - REDUCED IRON (Fe²⁺), indicates poor drainage, saturated conditions, low oxygen
- Reds, browns, yellows, tans - OXIDIZED IRON (Fe³⁺), good drainage, adequate oxygen
- White - high silica content or salts
Soil pH

- Concentration of hydrogen ions
- Measured on pH scale (1 to 14)
- Most crops need pH 5.7 to 6.5
- Micro-nutrient availability less at high pH
- Nutrient uptake; nitrification; acid rain
- Low pH (<5.5) = Al toxicity
  - Correct with calcitic or dolomitic lime
  - Determine with soil test

Soil Organic Matter

- Source of plant nutrients: N, P, S
- Soil aggregation
- CEC and buffering capacity
- Water holding capacity, air movement, etc.
- Chelation of metals (Zn, Cu)
- C supply for microorganisms
- Surface mulches regulate temperature, moisture

Humus

- Humic Substances
  - high molecular weight
  - highly aromatic ring structure
  - formed by decomposition and synthesis processes, microbial and chemical
  - Very high specific surface area
- Very high Cation Exchange Capacity
  - pH dependent
  - 200 to 300 cmolc/kg
- High water holding capacity
  - 4 to 5 times its mass

18 Essential Plant Nutrients

- Oxygen
- Hydrogen
- Carbon
- Nitrogen
- Phosphorus
- Potassium
- Calcium
- Magnesium
- Sulfur
- Copper
- Zinc
- Manganese
- Molybdenum
- Iron
- Chlorine
- Boron
- Nickel
- Cobalt

Role of Nitrogen

- Importance: proteins, chlorophyll, nucleic acids
- Low N = low yields
- Total soil N: < 400 to >8000 kg/ha
  - Available soil N = < 5% of total at any time
  - Available N = NH₄⁺ and NO₃⁻
  - only nutrient taken up as cation and anion
  - Remainder = organic forms and NH₄⁺ “fixed” by clays

Role of Phosphorus

- The energy currency in the cell
  - ATP -- adenosine triphosphate
  - DNA--deoxyribonucleic acid
  - RNA--ribonucleic acid
- Enhances many aspects of plant physiology
  - photosynthesis, maturation
  - N-fixation, flowering, fruiting, seed production
Role of Potassium

- Enzyme activation
- Water relations - osmotic regulation
- Energy relations
  - Photosynthesis
  - Translocation
  - Protein synthesis
- Stress resistance

Nutrient Management

- Supply essential nutrients
- Effective & efficient use of nutrients
- Minimize environmental degradation
- Maintain or improve soil quality

Major Nutrient Cycles

- Nitrogen: organic nitrogen, ammonium (NH$_4^+$), nitrate (NO$_3^-$), ammonia (NH$_3$)
- Phosphorus: phosphorus or phosphate (sold as “P$_2$O$_5$”); taken up as PO$_4^{3-}$, HPO$_4^{2-}$, H$_2$PO$_4^-$
- Potassium: potash (sold as “K$_2$O”); taken up as K$^+$

Nutrient Cycling

Plants $\rightarrow$ Soil $\rightarrow$ Nutrients

The Nitrogen Cycle

Nitrogen Mineralization

Organic Nitrogen $\rightarrow$ Inorganic Nitrogen

Note: Biosolids not allowed for use as soil amendment in Certified Organic production.
Fate of NH₄ and NO₃

NH₃ → Immobilized → Plant Uptake → N₂O / N₂

NH₄⁺ → "Fixed" → Runoff → Leached

The Phosphorus Cycle

Crop Uptake

Minerals: Ca-P, Fe-P, Al-P, Mn-P
Soluble P (depends on pH)
PO₄³⁻ → HPO₄²⁻ → H₂PO₄⁻ → H₃PO₄

Organo-phosphorus: problematic emission

Organic phosphorus: mineralization

Minerals: orthophosphate

Organic phosphorus: mineralization

Organic phosphorus: mineralization

Transport Mechanisms

Surface Water Runoff: N, P, K
Soil Erosion: N, P, K
Groundwater: N, K
Gas: N
Environmental Concerns
Nitrogen: Air & Water quality
Phosphorus: Water quality
Potassium: Feed Quality

Best Management Practices
Reduce Surface Runoff & Erosion
Avoid over application
Maintain soil pH

Soil Testing
• “Don’t guess soil test!”
• Sampling
  – 0 - 6”
  – Random
• Lab analyses
  – Basic: P, K, pH
  – Cost: $7
  – http://soilplantandpest.utk.edu/
• Interpretation of results
• Sufficiency vs. Maintenance

Yield and Nutrient Concentration

To Till or Not to Till?
• Tillage – “a weakness in organic systems?”
• Minimize the negative consequences:
  - Timing of tillage
  - Equipment operation
  - Soil conditions
  - Crop rotation
• Primary (plows) & secondary (harrow)
tillage
• No-till – 30% residue cover

Organic Certification and Tillage
• Must document tillage practices as part of
  Organic System Plans [NOP section §205.201(a)(1)]
• Hand weeding and mechanical cultivation are
  allowed weed control measures [NOP section §205.206(c)(4)]
• Records must document the frequency of tillage
• Organic inspector will consider whether tillage
  practices are being used in ways that maintains
  or improves the physical, chemical, and
  biological condition of the soil and that minimize
  soil erosion [NOP section §205.203(a)].
Tillage

- Weed management
- Destroys soil structure
- Reduces soil organic matter
- Energy intensive
- Increases erosion: 30% cover = 80% less erosion

Figure credit: Ed Zaborski, University of Illinois. Adapted from House and Parmelee (1995).

Tennessee Soils

Topography very variable:
- Mountains (east)
- Flat alluvial plains (west)

Parent materials: limestone to loess
- Loess derived soils in west (very prone to erosion)

Soil erosion, degradable soils and runoff

Losses up to 250 tons per hectare per year
Summer drought: low organic matter, poor structure, low water holding capacity, lower yields

No-Till vs “Conventional”

0.2 ton v. 13.1 ton per acre (in one storm!)

UT No-Till Organic Research

- Winter cover crop
  - Oats and crimson clover
- Crop roller
  - May 14, 2008
- Planted corn
  - May 23, 2008
- No weeding
- Harvested
  - Sept 24, 2008
- Weed suppression??

Nutrient enrichment & eutrophication
Harvesting

Oat Mulch Prior to Harvest

October 2008