Athletic Field Soils and How to Manage Them

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What’s Different about Athletic Field Soils?

• Turf Soils are different from Agricultural soils in that there is no opportunity to till them and open them up.

• Athletic Field Soils differ from most turf soils in the amount of traffic they are exposed to.

• We also have very high expectations, despite receiving excessive traffic, a high quality field is still expected.

A place to start Soil Web App

Role of soil in plant growth

• A quality soil is the foundation that a quality athletic field is built upon

• Water reservoir

• Supply of nutrients
  • N P K Ca Mg S Fe Mn B Cu Zn Mo Cl

• Support, anchor

• Oxygen, O₂
What makes a Healthy Soil?

- Soil quality and soil healthy are used interchangeably.
- To me they are different. The state of health of a soil depends on other things: an arid soils could be perfectly healthy for an arid soil but would not be considered healthy if productivity were taken into account.

Vital Soil Functions

- Sustaining biological activity, diversity, and productivity
- Regulating and partitioning water and solute flow
- Altering, buffering, degrading, immobilizing, and detoxifying organic and inorganic materials including agricultural, industrial and municipal by-products and atmospheric deposition
- Storing and cycling nutrients and other elements with the Earth’s biosphere
- Providing support of socioeconomic structures and protection of archeologic treasures associated with human habitation. (Karlen et al. 1997)

Soil Quality

- A simple definition would be “the capacity of soil to function.”
- It includes physical, chemical and biological characteristics.
- USDA has defined a simple kit for measuring soil quality

General soil respiration class ratings (Woods End Research, 1997)

<table>
<thead>
<tr>
<th>Respiration Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01</td>
<td>Very low soil activity, soil is depleted of organic matter and has little activity.</td>
</tr>
<tr>
<td>0.02</td>
<td>Moderately low soil activity, soil is approaching or declining from ideal state.</td>
</tr>
<tr>
<td>0.03</td>
<td>Ideal soil activity, soil in ideal state of biological activity.</td>
</tr>
<tr>
<td>0.04</td>
<td>Unusually high activity, very high soil activity due to application of large quantities of fresh OM.</td>
</tr>
</tbody>
</table>

Components of soil

- Mineral (inorganic)
- Organic (living and dead, plants and animals)
- Water (and dissolved salts)
- Air (N₂, O₂, CO₂, H₂O, CH₄, H₂S)
Thing 1 and Thing 2
Particle Size Distribution and Gradation

• Will give us a lot of information on how our soil will behave and give insights into Cultural Practices.

• Soil hydrometer test and sand sieving test.

• Many ways to interpret the results

Soil mineral matter

• Size separates and characteristics

• Clay (< 2 micron)
  • plate like structure
  • surface area - related to small size
  • mineralogy (secondary minerals)
  • negative charge
  • cation exchange capacity (CEC) - the sum of the exchangeable cations that a soil can adsorb
  • adhesion of water

• Sand (0.05 - 2 mm)
  • very coarse: 1 - 2 mm
  • coarse: 0.50 - 1 mm
  • medium: 0.25 - 0.50 mm
  • fine: 0.10 - 0.25 mm
  • very fine 0.05 - 0.10 mm
  • distribution of size range - packing
  • rounded vs angular (firmness)
  • mineralogy - mostly quartz (very stable)

Soil mineral matter

• Size separates and characteristics

• Silt (0.002 - 0.05 mm)
  • mineralogy

Grain Size Groups

<table>
<thead>
<tr>
<th>Size Group</th>
<th>Sieve Size</th>
<th>Passing</th>
<th>Retained On</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cobbles</td>
<td>No Maximum</td>
<td>3 inches</td>
<td></td>
</tr>
<tr>
<td>Gravel</td>
<td>3 inches</td>
<td>No. 4 (0.125 inches)</td>
<td></td>
</tr>
<tr>
<td>Sands</td>
<td>No. 4 (0.125 inches)</td>
<td>No. 200 (0.075 mm)</td>
<td></td>
</tr>
<tr>
<td>Fines (silt or clay)</td>
<td>No. 200 (0.075 mm)</td>
<td>No minimum size</td>
<td></td>
</tr>
</tbody>
</table>

In military engineering, the maximum size of cobble is accepted as 80 inches, based on the maximum jaw opening of a crushing unit.
Dry Sieve Analysis

Gradation
• Distribution of particles within a soil.

• Soils are either:
  • Well graded – good distribution of particle sizes
  • Poorly graded – bad distribution of particles sizes
    • Uniformly graded – only one soil size
    • Gap graded – missing soil sizes

Soil Gradations

Grain Shape
• Influences a soil's strength and stability

• Two general shapes:
  • Bulky – three dimensional
    • Angular – recently been broken
    • Sub angular – sharper points and edges are worn
  • Sub rounded – further weathered than sub angular
  • Rounded – no projections and smooth in texture
  • Platy – two dimensional

Soil Particle Shapes

Soil mineral matter
• Soil texture - percentage of sand, silt and clay in soil
  • influenced by parent material, weathering (clay formation), transport of clay, erosion/sedimentation
  • textural classes
    • textural triangle
    • profile textural differentiation
importance of texture

- pore space
- aeration
- water retention, available water
- water infiltration and percolation
- runoff, erosion
- cohesion, plasticity
- shrink-swell character

Management

- Soil Texture can be improved over time with a topdressing and hollow tined aerification approach.

- Often we have to manage what we are given, but knowing what we are dealing with is helpful.

- Perhaps we can manage this up front by choosing sites with good soils or building our turf rootzone from quality materials.

importance of texture

- soil structure
- management - tillage
- microbial activity, o.m. content
- soil pH (acidity)
- soil temperature
- fertility, productivity

Thing 3  Bulk Density/Compaction
Measuring Bulk Density

• Most common method is to use a core sampler. Takes core of a known volume.
• Sample is usually then weighed wet, then oven dried to a constant weight at 105°C (usually 24 hrs).
• You now have a mass and a volume of soil
• BD = mass of OD soil (g) / vol. soil (cm³)

Bulk density

• dry weight of a given volume of soil
• Used to characterize structure
• More porespace = less weight = lower BD
• Texture influences structure and density
• Range for mineral soils: 1.1 - 1.5 g/cm³ (68.7 - 93.6 lbs/cf)
• organic soils: 0.1 - 0.6 g/cm³ (6.2 - 37.4 lb/cf)

Effect Of H2O on Density

Typical H2O-Density Relationship

General relationship of BD to root growth based on soil texture

<table>
<thead>
<tr>
<th>Soil Texture</th>
<th>BD (g/cm³)</th>
<th>Root Growth</th>
<th>Optimum BD Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandy loams</td>
<td>&gt; 1.60</td>
<td>Poor</td>
<td>1.60 - 1.80</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>&gt; 1.60</td>
<td>Poor</td>
<td>1.60 - 1.80</td>
</tr>
<tr>
<td>Loamy sands</td>
<td>&gt; 1.60</td>
<td>Poor</td>
<td>1.60 - 1.80</td>
</tr>
<tr>
<td>Silty clay</td>
<td>&gt; 1.50</td>
<td>Poor</td>
<td>1.50 - 1.75</td>
</tr>
<tr>
<td>Sandy loams</td>
<td>&gt; 1.55</td>
<td>Poor</td>
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<td>Poor</td>
<td>1.50 - 1.55</td>
</tr>
<tr>
<td>Loam</td>
<td>&gt; 1.60</td>
<td>Poor</td>
<td>1.60 - 1.70</td>
</tr>
<tr>
<td>Clay</td>
<td>&gt; 45%</td>
<td>Poor</td>
<td>45% - 1.47</td>
</tr>
</tbody>
</table>

Compaction Characteristics of Various Soils
Hollow-tine Core Aeration

- Physical removal of a core of various diameters and depths from the soil.
  - Typical tine size and depth: \(1/4 - 1"\) diameter, \(3 - 12"\) deep

- The Most Critical Tool in a Cultivation Program!

- HTC is also the most surface disruptive procedure—must be scheduled around events—Cores can affect footing—Holes can catch cleats

- If cores removed, what to do with them? What good does it do?
  - Punches a hole YES
  - Decreases compaction YES
  - Returns loosened material to surface YES
  - Potential to break down thatch YES
  - Creates a large pore YES
  - Breaks through layers YES
  - Adds Material to Profile YES

- Soil pH

<table>
<thead>
<tr>
<th>pH</th>
<th>([\text{H}^+])</th>
<th>([\text{OH}^-])</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>(10^{-7}) or 0.0000007</td>
<td>(10^{-7}) neutral</td>
</tr>
<tr>
<td>3.5</td>
<td>(10^{-3.5}) or 0.00032</td>
<td>(10^{-10.5}) acidic</td>
</tr>
<tr>
<td>9</td>
<td>(10^{-9}) or 0.00000001</td>
<td>(10^{-9}) alkaline</td>
</tr>
</tbody>
</table>

*note that the exponents of \([\text{H}^+]\) and \([\text{OH}^-]\) add to -14.
*When both are -7 the ions are in equal concentration, therefore the system is neutral.

- Soil Reaction (pH)

  - measure of the acidity or alkalinity of the soil solution
  - \(\text{pH} = -\log[\text{H}^+]\)
The importance of soil pH

- indication of weathering (parent material, leaching)
- availability of nutrients
- toxicity of metals, esp, Al³⁺
- oxidation of reduced S

Active acidity in soil solution

- H⁺ [measured as pH]
- Exchangeable acidity (Reserve)
- Residual acidity (Bound)

Processes increasing soil acidity

- CO₂ (from respiration) + H₂O + HCO⁻ → H⁺
- Organic acids
- H⁺ releases upon cation uptake by the root
- leaching of anions (Cl⁻, SO₄²⁻) requires leaching of equal + change
- Oxidation of reduced substances (e.g. sulfide minerals, organic matter, ammonia fertilizers)
- Acid rain

Buffering capacity of soils

- Resistance to change in pH of soil solution
- Exchange site equilibrium with soil solution
- Higher the CEC, the greater the buffering capacity
Processes increasing alkalinity

• Reduction of Fe$^{3+}$, Mn$^{4+}$ consumes H$^+$ or releases OH$^-$
• Fe(OH)$_3$ + e$^-$ → Fe(OH)$_2$ + OH$^-$ (anaerobic situations)
• Recycling of basic cations by deep-rooted plants - maintains B.S.
• Liming

Modifying Soil pH

• Raise pH – add lime (carbonates, oxides or hydroxides of Ca, Mg)
  - Limestones (carbonates) – calcitic, dolomitic, dolomite
    - CaCO$_3$ + 2H$^+$ → Ca$^{2+}$ + H$_2$O + CO$_2$
    - MgCO$_3$ + 2H$^+$ → Mg$^{2+}$ + CO$_2$ + H$_2$O
  - Burned or Quicklime (oxides) – produced by heating limestone
  - Hydrated lime (hydroxides) – water added to burned lime

Liming

• Lime is an amendment used to raise soil pH
• Calcium carbonate (CaCO$_3$): Lime
• Mg(CaCO$_3$): dolomitic lime

Approx. Lime Amounts to Raise pH to 6.5

<table>
<thead>
<tr>
<th>pH</th>
<th>Sandy</th>
<th>Loamy</th>
<th>Clayey</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.0</td>
<td>20</td>
<td>35</td>
<td>50</td>
</tr>
<tr>
<td>5.5</td>
<td>45</td>
<td>75</td>
<td>100</td>
</tr>
<tr>
<td>5.0</td>
<td>65</td>
<td>110</td>
<td>150</td>
</tr>
<tr>
<td>4.5</td>
<td>80</td>
<td>150</td>
<td>200</td>
</tr>
<tr>
<td>4.0</td>
<td>100</td>
<td>175</td>
<td>230</td>
</tr>
</tbody>
</table>

Finer the lime, the quicker it reacts, but harder to apply

Lime Requirement – Factors determining amount to add

• pH change desired
• soil’s buffer capacity
• chemical composition and purity – guarantee
  – Compare H$^+$ neutralizing power per weight
• Calcium Carbonate Equivalent (CCE)
  – fineness of lime

Lower pH

• Add organic matter
• Elemental sulfur
  – 2S + 3O$_2$ + 2H$_2$O → 4H$^+$ + 2SO$_4^{2-}$
  – FeSO$_4$ + H$_2$O → Fe$^{2+}$ + SO$_4^{2-}$
  – Fe$^{2+}$ + 2H$_2$O → Fe(OH)$_2$ + 2H$^+$
  – Ferrous sulfate
  – 4Fe$^{2+}$ + 6H$_2$O + O$_2$ → 4Fe(OH)$_3$ + 4 H$^+$
• Aluminum sulfate
  – Al$^{3+}$ + 3H$_2$O → Al(OH)$_3$ + 3H$^+$
Surface Hardness

• Different from compaction. Especially with sands a soil may be firm without necessarily being compacted.
• Surface Hardness – Safety Issue
• Compaction - Plant growth

Clegg Impact Soil Tester

Surface Hardness Management

• Water if dry
• Aerification with small solid tines
• Grow more grass
• Topdressing

Soil organic matter

• organically derived fraction of soil, including plant, animal, & microbial residues in various stages of decomposition
• Organic residue degradation and formation of humus
  — residue addition to soil – plant, animal, microorganisms
  — microbial activity (decomposition)
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How to measure – Most soil testing labs have a CN or CNS analyzer. For a minimal fee you can know your soil organic matter content and its C:N ratio.

C:N Ratios

- Fungi 9:1
- Actinomycetes 5:1
- Bacteria 4:1
- Young Legumes 12:20:1
- Young Grasses 20:40:1
- Oat/Wheat Straw 80:90:1
- Tree Leaves 60:100:1

With additions of residue, N becomes the limiting nutrient
- If residue C:N < 20:1, excess N is released as residue decomposes
- If residue C:N > 30:1, microorganisms require soil N, (competing with plants)
- Residue C is respired (CO₂↑) during decomposition, but N is recycled as microorganisms die; so C:N decreases

Characteristics of Soil Organic Matter

- low bulk density
- negative charge; high CEC compared to mineral fraction
- buffering capacity
- water holding capacity
- source of N, P, S, micronutrients

• residue is transformed
• humus results – relatively stable modified organic molecules resistant to further breakdown
  - C 50-60%
  - N 5%
  - P 0.6-1.2%
  - S 0.5%
Organic matter in soils

- Amount
  - range in A horizon: 0.5–7.0%
  - subsoils have less: 0.25–1.75%

Significance of Soil OM

- Soil bulk density, porosity
- Soil structure stability, resilience
- Water holding capacity
- Fertility (N, P, S contents, CEC, chelates)
- pH buffer
- Supports microbial biomass
- Adsorbs some pesticides
- Heat absorption (color)

Thing 6 Water Infiltration Rate

Infiltration Rate

- Soil texture and compaction will give us an idea.
- Gold Standard is the double ring infiltrometer but even those can be squirrely.
- Pounding a coffee can with ends removed into soil works ok except in sand based soils.
- Best is to watch your field drain and look for trouble spots. Then look for source of bad drainage/standing water.

Thing 7 Nutrient Levels
Soil Testing Nutrient Levels

- Stick with the same lab using the same procedure
- Use a lab without skin in the game
- Keep track of numbers. Should be able to build fertility into fine textured soils. In sandy soils you may end up chasing numbers you cannot attain. Best is to watch your field drain and look for trouble spots. Then look for source of bad drainage/standing water.

MLSNI Guidelines

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>MLSNI Guidelines</th>
<th>SLAN Carrow et al 2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium (K ppm)</td>
<td>74 1.7 &gt;234 &gt;5.4</td>
<td></td>
</tr>
<tr>
<td>Phosphorus (P ppm)</td>
<td>42 1.0 &gt;110 &gt;2.5</td>
<td></td>
</tr>
<tr>
<td>Calcium (Ca ppm)</td>
<td>696 16.0 &gt;1500 &gt;35</td>
<td></td>
</tr>
<tr>
<td>Magnesium (Mg ppm)</td>
<td>94 2.1 &gt;242 &gt;5.5</td>
<td></td>
</tr>
<tr>
<td>Sulfur (S ppm)</td>
<td>14 0.3 &gt;82 &gt;2</td>
<td></td>
</tr>
</tbody>
</table>

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Thing 8 Grade

Figure 12.1. Crossed field with level sidewalk—elevations noted in feet.

Figure 11.1. The simplest and most common (good) field design—elevations noted in feet.
Thing 9 What does my soil profile look like?

Layering

- Deep tine aerification.
- Other aerification that goes deep.
- If you are doing things correctly your drainage should improve.
Thing 10 Thatch Thickness

CEC Cation Exchange Capacity

• Usually calculated by sum of cations from soil test.
• Dedicated CEC test using a double wash method would be more accurate—especially for sandy soils.
• Best way to manage would be to add organic matter such as compost or peat. These will increase CEC. I’ve never heard of someone trying to decrease CEC.

2020 Events

2020 Events
MTA Roadshow—January 7 NWMCC Senatobia Field Day—August 18 (Tentative)
Deep South—November 2-5
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