SOIL SENSING FOR YIELD AND ENERGY-SMART FARMING – SOIL MANAGEMENT

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Outline

- Introduction to Soil Properties & Fertility
- Energy-Smart Farming: Soil Perspective
Soil as a $3 + 1$ phase system

Sensing for Soil Nutrients requires discrimination between the soil phases

- Solids
- Liquids
- Gas
- + Roots
Soil Composition

Solids
Bulk Density/Porosity

Soil Minerals (Physical)
• Particle Size Distribution
• Mineralogy of silicate clays
• Mineralogy of size-fractions

Soil Minerals (Chemical)
• Cation Exchange Capacity
• Exchangeable Cations and Ions
• pH

Liquids
Water-filled pore space

Water-filled pore space as a function of matric potential

Extractable water chemistry

Gasses
Air-filled pore space as a function of water content or potential

Gas Composition

Organic Carbon
Soil Minerals (Chemical)

- Cation Exchange Capacity
  - Sandy Soil: 3 to 5 meq 100g\(^{-1}\)
  - Clayey Soil: 30 to 40 meq 100 g\(^{-1}\)
- pH
  - 5.5 to 8.5 (Temperate Agricultural Soil)
Energy Inputs in Soil Management

Optimize On-Farm Soil Ecosystem Services

1. Plant-Soil-Nutrient Interactions
   1. On-Time and Spatially Precise Applications
      Knowledge Gaps: sensing when, what, and where
   2. Manage Soil Organic Matter for on-time delivery of nutrients
      Knowledge Gaps: Soil; Cropping System, Manager specific

2. Plant-Soil-Water Interactions
   1. Reduce Tillage and controlled traffic systems: available
   2. Manage for optimal Soil Structure
      Knowledge Gaps (quantify soil structure; identify optimal; identify management)
   3. Manage Compaction
      Knowledge Gaps (mapping; thresholds; pan-busting cover crop)
Optimize Off-Farm Soil Ecosystem Services

1. Non-Point Erosion
   Fills reservoirs; contributes to poor water quality; harms ecosystems
   Knowledge Gaps:
   1. Quantifying Off Farm Impacts linked to Soil Management
   2. Needs Hydrology Models that respond to Soil Health (Soil Structure)

2. Non-Point Nutrient loss
   Impact water recreation (human health, fishing, aquatic ecosystems)
   1. Knowledge Gaps: Same as above

3. Soil-Water Interaction
   Loss of water capture create flashiness in flooding
   Knowledge Gaps: Same as above
Soil Management for Farming Energy Smart?

1. Soil-Plant-Nutrient Management Timing
   (-) Minimal yield improvement
   (+) can reduce energy use requirements
   (+) can improve off-farm energy needs (Engineering solutions to pollution)
   **Technologies:** sensors that see soil water nutrients; good soil maps

2. Soil-Water-Plant Interactions
   (+) Yes yield improvements
   (+) Yes on-farm energy savings
   (+) Yes off-farm energy savings (probably 10 to 100xs) on farm
   **Technologies:** sensors that quantify soil structure; hydrology models that biophysically respond to soil health; compaction mapping strategies; compaction thresholds for yield
Thank You

Observe it, Measure it, Model it