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Soil & Water analyses
Farming in the 21st Century
“A practical approach to improve Soil Health”

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New Mexico Integrated Cropping Systems and Water Management Handbook
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/nm/technical/?cid=nrcs144p2_068965

USDA-NRCS: Unlock the Secrets in the Soil
All parameters are important; typically we focus on physical and chemical - but Biology is King or Queen!

Evaluate How Your Soil System is Functioning

We will first focus on the Biological component of soil health, as it relates to water & soil analyses and their interpretations.
Carbon is a “keystone” in nutrient cycling!

Soil carbon is the “Keystone” for all soil physical, chemical and biological processes and properties.

Management platform

Dr. D.C. Reicosky, ARS, Morris, MN.
Conventional Tillage in Pecans
(Wind erosion: a problem on this sandy soil)

Take plenty of photos of the before and after changes in soil health.
Bermuda grass planted in pecan orchard (1\textsuperscript{st} Irrigation).

5 tons of compost applied per acre before the 1\textsuperscript{st} irrigation.
Bermuda grass established in pecan orchard.

Irrigated with micro-sprinkler system.
Applying an Additional 5 tons of compost per acre.
(applied on top of dormant Bermuda grass)

Compost (i.e. to feed and prime the Soil Food Web in a no-till system)
Bermuda grass (2nd year early growth)

No more Wind Erosion and rejuvenating Soil Health
Soil is beginning to develop soil structure.

Managing the soil’s living organisms (Soil Food Web). This entails working to maintain favorable conditions of moisture, temperature, nutrients, pH, and aeration. It also involves providing a steady food source of raw organic material.
Creating a Soil Habitat is the first step to managing soil biota for long-term soil quality, soil health, and productivity.

Soil biological processes are responsible for supplying approximately 75% of the plant available nitrogen and 65% of the available phosphorus in the soil. Like all organisms, those inhabiting your soil need food and a favorable environment. Adequate organic matter content, ample aeration, moderate moisture, neutral pH, and warm temperatures all favor increased microbial activity.
Importance of maintaining a favorable habitat for the Soil Food Web.
Basic facts about the Soil food web

The soil food web:

1) Is complex
2) Individual organisms are small in size
3) Individual organisms are numerous
4) Is greatly impacted by temperature and moisture
5) Is most active near the soil surface
Managing for Soil Health

• Minimize Disturbance of the soil
• Maximize Diversity of plants in rotation/cover crops
• Keep Living Roots in the soil as much as possible
• Keep the soil covered at all times with plants and plant residues

• Create the most favorable habitat possible for the soil food web
SOIL CARBON is the key driver for the nutritional status of plants – and therefore the mineral density in animals and people.

SOIL CARBON is the key driver for soil moisture holding capacity (frequently the most limiting factor for production).

Soil carbon is the key driver for farm profit.
Soil Health Management System (Managing SOM)

- Biological
- Physical
- Chemical

(Emphasis on: Carbon, Carbon and Carbon in understanding the Bio-Geo-Chemical Nutrient Cycle)

Poor Nutrient Cycling & Water Use

Good Nutrient Cycling & Water Use
Evaluate How Your Soil System is Functioning

Next, we will focus on the **Physical** component of soil health, as it relates to water & soil analyses and their interpretations.

All parameters are important; typically we focus on physical and chemical- but Biology is King or Queen!
Influence of “Spheres” on Soil Function

- Detritusphere
- Drilosphere
- Porosphere
- Rhizosphere
- Aggregatusphere

Unsaturated Capillary water Soil Particle
Healthy soils are held together by soil glues, or glomalin, that are produced by fungi. Soils rich in soil biota hold together, while soils devoid of soil life fall apart and form a layer of sediment in the bottom of the jar. Pictured above, the soil on the left is from a field that has been managed using no-till for several years. The soil on the right is from a conventionally-tilled field.
Crumbly soils (left) have more pores and channels than cloddy soils (right). Pores and channels allow air and water to move into the soil.

Tillage and its impact on the nutrient and water cycle

Tillage destroys soil macro-aggregates, which is home to a diverse Soil Food Web.

Water-Stable Soil Aggregates

Soil Stability Test (Slake Test)

Poor aggregate stability
The maintenance of a high degree of soil aggregation is one of the MOST important goals of soil management (The Nature and Properties of Soil, 14th edition revised).
All parameters are important; typically we focus on physical and chemical— but Biology is King or Queen!

Finally, we will focus on the Chemical component of soil health, as it relates to water & soil analyses and their interpretations.
Soils, Water & Tissue Tests. Total Cost: $120 to $175
Integrated Nutrient Management

We are using various soil health assessments in order to better understand soil health function.

Irrigation Water Sample for Nutrient and Soluble Salts Analysis

Collecting Leaf Samples from Sorghum Crop for Nutrient Analysis

Collecting Soil Samples for Nutrient Analysis

Water Stable Aggregates in No-Till System

New Mexico: Clay Soil
Georgia: Silty Clay Soil

Tilled Soil
No-Till
No-Till
Tilled Soil

NRCS Soil Quality Test Kit

NRCS Active Carbon Field Kit
Select Plants adapted to your Climate (i.e., Temperature & Precipitation)

Net Irrigation Requirement = 48” for Pecans with mature cover

Know your water quality (Salinity, pH, SAR) & quantity (acre-feet/ac.) available

Abiquiu Reservoir, NM
Conventional Irrigation (soil salinity typically concentrates about 1.5 times the water EC)

Leaching Fraction (LF) = 0.3086/Fc^{1.702} (LF = 7.2%)

Fc = ECe(ct)/ECiw (i.e., ECe(ct) = 1.9 & ECiw = 0.81); Fc = 2.35

ECiw = 0.81 mmhos/cm
SAR = 1.71
pH = 7.9

Water Quality Analysis
Pounds per Acre:

- Nitrate-N = 12.2
- Potassium = 89.5
- Sulfate-S = 490.0
- Calcium = 591.0
- Magnesium = 146.2
- Sodium = 592.0
- Chloride = 783.0
- Bicarbonate = 1,911.4
- Carbonate = 26.1
- Iron = 9.3
- Mn = 0.22
- B = 1.31

Total Salts = 5,640.2 lbs./ac.
Calculations and Conversions: (48 ac-in of irrigation water applied/ac/yr.)

Water = 1.0 g/cm³
Cubic Foot = 28,316.85 cm³
28,316.85 g of Water/Cubic Foot
28,316.85 g x 1.0 lb./454.0 g = 62.37 lbs. of Water/ft³
62.37 lbs. of water/ft³ x 43,560 ft³ = 2,716,837.2 lbs. of water/ac-ft

2,716,837.2 ≈ 2.72 million lbs. of water/ac-ft. (Our conversion factor is 2.72. e.g., 2.72 x ppm = lbs. of nutrient/ac-ft. of irrigation water applied).

1.0”/12.0” = 0.0833

0.0833 x 2.72 = 0.227 (≈ 227,000 lbs. of Water/ac-in. Our conversion factor is 0.227. e.g., 0.227 x ppm = lbs. of nutrient/ac-in. of irrigation water applied).

Example: Calcium 54.32 ppm x 0.227 x 48” = 591.87 lbs. of Ca applied/ac./yr.

or

Example: Calcium 54.32 ppm x 2.72 x 4’ = 591.0 lbs. of Ca applied/ac./yr.

ppm = mg/l
TDS (ppm) = EC (mmhos/cm) x 640, for EC between 0.1 and 5.0 mmhos/cm
Example: 0.81 mmhos/cm x 640 = 518.4 mg/l
If we apply 4 acre-feet of water/ac./yr., how many pounds of salts will you apply in a year?

518.4 mg/l x 2.72 x 4 = 5,640.2 lbs./ac. of soluble salts applied per acre per year.
<table>
<thead>
<tr>
<th>Crop (name)</th>
<th>Yield loss 0%</th>
<th>Yield loss 10%</th>
<th>Yield loss 25%</th>
<th>Yield loss 50%</th>
<th>Maximum</th>
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<tbody>
<tr>
<td></td>
<td>ECe¹</td>
<td>ECw²</td>
<td>ECe¹</td>
<td>ECw²</td>
<td>ECe¹</td>
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<td>Barley</td>
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<td>Beans</td>
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<td>Beets</td>
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<td>Cabbage</td>
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<td>Corn, Grain &amp; Silage</td>
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<td>5.8</td>
<td>3.9</td>
<td>8.6</td>
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<td>4.1</td>
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<td>Lettuce</td>
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<td>Meadow Foxtail</td>
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<td>4.1</td>
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<td>Onion</td>
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<td>1.8</td>
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<td>Orchard Grass</td>
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<td>Peach</td>
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<tr>
<td>Pepper</td>
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<td>1.0</td>
<td>2.2</td>
<td>1.5</td>
<td>3.3</td>
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## Irrigation water quality guidelines

<table>
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<tr>
<th>Potential irrigation water quality problem</th>
<th>Parameter</th>
<th>Degree of restriction on use</th>
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<tbody>
<tr>
<td><strong>Salinity</strong> (affects crop water availability)</td>
<td>ECiw (mmho/cm)</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>or TDS (mg/l)</td>
<td>$&lt; 0.7$</td>
</tr>
<tr>
<td></td>
<td>$&lt; 450$</td>
<td>$450 - 2,000$</td>
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<tr>
<td><strong>Infiltration</strong> (affects water infiltration rate, evaluated by using ECiw and SAR together)</td>
<td>SAR</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>$0 - 3$</td>
<td>$&gt; 0.7$</td>
</tr>
<tr>
<td></td>
<td>$3 - 6$</td>
<td>$&gt; 1.2$</td>
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<tr>
<td></td>
<td>$6 - 12$</td>
<td>$&gt; 1.9$</td>
</tr>
<tr>
<td></td>
<td>$12 - 20$</td>
<td>$&gt; 2.9$</td>
</tr>
<tr>
<td></td>
<td>$20 - 40$</td>
<td>$&gt; 5.0$</td>
</tr>
<tr>
<td><strong>Specific ion toxicity</strong> (affects sensitive crops)</td>
<td>SARadj</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>meq/l</td>
<td>$&lt; 3$</td>
</tr>
<tr>
<td><strong>(Na(^+)) surface irrigation</strong></td>
<td>meq/l</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>sprinkler irrigation</td>
<td>$&lt; 3$</td>
</tr>
<tr>
<td><strong>(Cl(^-)) surface irrigation</strong></td>
<td>meq/l</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>sprinkler irrigation</td>
<td>$&lt; 4$</td>
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<tr>
<td><strong>Boron (B)</strong></td>
<td>ppm/l</td>
<td>None</td>
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<td></td>
<td>$&lt; 0.7$</td>
<td>$0.7 - 3.0$</td>
</tr>
<tr>
<td><strong>(HCO(_3^-)) Bicarbonate</strong></td>
<td>meq/l</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>overhead sprinkler only</td>
<td>$&lt; 1.5$</td>
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</table>
Dr. Jamie Iglesias, with Texas Agrilife Center, discussing soil profile characteristics, drainage, water & salinity management, and water table.

Do you know your soils profile characteristics?
Emphasis on understanding the soil profile (texture & structure), stratification, root depth, water quality (ECiw, SAR, pH), crop salt tolerance, drainage, etc.
COLLECT 15-20 SOIL SUBSAMPLES PER FIELD
ECe = 0.36 mmhos/cm (No problem with Salts)
Sodium is 2.6% of total CEC (Satisfactory)
pH = 8.7 (Problem with pH; i.e. nutrient availability)

Soil Analysis:
- Organic Matter = 0.6% (Low)
- Nitrogen Mineralized = 12.0 lbs./ac.
- Nitrate-N = 8.55 lbs./ac. (Low)
- Phosphorus = 5.0 ppm (Low)
- Potassium = 122.0 ppm (Low)
- Sulfate-S = 20.7 ppm (Adequate)
- Calcium = 2,948.0 ppm (High)
- Magnesium = 187.0 ppm (Low)
- Zn = 0.4 ppm (Low)
- Iron = 4.6 ppm (Low)
- Mn = 4.2 ppm (Low)
- Cu = 0.6 ppm (Adequate)
- B = 0.4 ppm (Low)
- Sodium = 2.6% of total CEC (good)
Calculations and Conversions (ppm = mg/kg):

Soil Bulk Density of 1.472g/cm$^3$ ≈ 4,000,000 lbs./ac-ft

Cubic Foot = 28,316.85 cm$^3$

28,316.85 cm$^3$ x 1.472g/cm$^3$ = 41,682.4 g of soil/ft$^3$

41,682.4 g x 1.0 lb./454 g = 91.81 lbs. of soil/ft$^3$

91.81 lbs. of soil/ft$^3$ x 43,560 ft$^3$ ≈ 4,000,000.0 lbs./ac-ft.

≈ 4,000,000 lbs. of Soil (dry weight)/ac-ft

4,000,000 (our conversion factor is 4.0; e.g., 4.0 x ppm = lbs./ac-ft.)

Example: Nitrate-Nitrogen 4.5 ppm x 4.0 = 18.0 lbs. of Nitrate-Nitrogen/ac-ft

Example: Nitrate-Nitrogen 4.5 ppm x 2.0 = 9.0 lbs. of Nitrate-Nitrogen/ac (6” depth)

Example: 4,000,000 lbs. of Soil x 0.012 (1.2% Organic Matter) = 48,000 lbs. Organic Matter/ac-ft

48,000 lbs. Organic Matter x 0.05 (5% is Organic N) = 2,400 lbs. of Organic N.

2,400 lbs. of Organic N x 0.025 (about 2.5% is mineralized/yr.) = 60 lbs. of N mineralized/ac/yr.
A schematic look at cation exchange

CEC 25
More clay, more positions to hold cations

CEC 5
Low clay content, fewer positions to hold cations

Soils with CEC 11-50 Range:
- High clay content; Greater capacity to hold nutrients in a given soil depth; high water-holding capacity; physical ramifications of a soil with a high clay content.

Soils with CEC 1-10 Range
- High sand content; Nitrogen and Potassium leaching more likely, low water-holding capacity, physical ramifications of a soil with a high sand content.

Cation Exchange Capacity (CEC): Aridisols
CEC: Typical proportions of major adsorbed cations: Ca (65%), Mg (20%), K (10%) and Na (5%) (Table 8.1, Nature & Properties of Soil, 11th Edition)
e.g., Soil CEC = 25 meq/100 g of soil. 65% of CEC is Calcium.
0.65 x 25 = 16.25 meq of Ca/100 g of soil
20.04 mg of Calcium/meg
16.25 meq x 20.04 mg/meg = 325.65 mg of Ca/100 g of soil
Macroaggregate (2.0 – 5.0 mm dia.)

- Healthy Soil (Optimum growing conditions)
- Soil Solution
  - Soluble Nutrients
  - Soil Microorganisms
  - Temperature
  - pH
  - Matric Potential (Bars)
  - Electrical Conductivity (ECss; Salinity)
  - CEC
  - SAR
  - Dissolved O₂ & CO₂
  - Soil Microorganisms
  - Mineralization
  - Immobilization

Microaggregate (< 0.3 mm dia.)

- Consisting of Clay, silt, humus, particulate organic matter, very fine sand.
- White areas indicating presence of glomalin (Dr. Kris Nichols, USDA/ARS Mandan, ND)
Pecan Plant Tissue Analysis:

- **N** = 2.66% **Optimum**: Sufficiency Range: 2.49 – 2.8%
- **P** = 0.12% **Optimum**: Sufficiency Range: 0.11 – 0.3%
- **K** = 0.95% **Optimum**: Sufficiency Range: 0.74 – 1.25%
- **S** = 0.22% **Optimum**: Sufficiency Range: 0.19 – 0.4%
- **Ca** = 1.21% **Optimum**: Sufficiency Range: 0.89 – 1.5%
- **Mg** = 0.31% **Optimum**: Sufficiency Range: 0.29 – 0.6%
- **Zn** = 58.22 ppm **Optimum**: Sufficiency Range: 49 – 100 ppm
- **Fe** = 135 ppm **Optimum**: Sufficiency Range: 49 – 300 ppm
- **Mn** = 58.1 ppm **Low**: Sufficiency Range: 99 – 800 ppm
- **Cu** = 5.8 ppm **Low**: Sufficiency Range: 9 – 30 ppm
- **B** = 105.4 ppm **High**: Sufficiency Range: 29 – 45 ppm
- **Na** = 0.02% **Optimum**: Sufficiency Range: 0 – 0.1%

Area yield is about 2,300 lbs./ac.
Conversions and Calculations (ppm = mg/kg):

Parts Per Million (ppm) = milligram/kilogram (mg/kg)

Example: 10,000 ppm ÷ 1,000,000 ppm = 1.0%
Example: 5,000 ppm ÷ 1,000,000 ppm = 0.5%
Example: 1,000 ppm ÷ 1,000,000 ppm = 0.1%
Example: 500 ppm ÷ 1,000,000 ppm = 0.05%
Example: 100 ppm ÷ 1,000,000 ppm = 0.01%

1.0 gram = 1,000 milligrams
1.0 kilogram = 1,000 grams = 1,000,000 mg

Example: 100 mg/1,000,000 mg = 100 mg/kg
100 mg ÷ 1,000,000 mg = 0.01%
100 ppm ÷ 1,000,000 ppm = 0.01%

ppm = mg/kg
### Nutrients

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Irrigation Water Analysis (ppm x 0.227 x 48&quot; = lb/ac.)</th>
<th>Soil Analysis 0-6&quot; depth</th>
<th>Soil Structure: to be evaluated at workshop</th>
<th>Aggregate Stability: to be evaluated at Workshop</th>
<th>Should I Apply Nutrients?</th>
<th>Conservation Practices to consider for achieving sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ppm or mg/l</td>
<td>Pounds per Acre</td>
<td>ppm or mg/Kg</td>
<td>Low Adequate High</td>
<td>Nutrient Inputs (recommendations)</td>
<td>Plant Tissue Analysis</td>
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<tr>
<td>Organic Matter</td>
<td></td>
<td></td>
<td>0.6%</td>
<td>11,400 Low</td>
<td>Manure?</td>
<td>Yes (Y) No (N)</td>
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<tr>
<td>N mineralized</td>
<td></td>
<td></td>
<td>ON</td>
<td>12.0 Low</td>
<td>n/a</td>
<td>n/a</td>
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<tr>
<td>Nitrate-Nitrogen</td>
<td>1.12</td>
<td>12.2</td>
<td>4.5</td>
<td>8.55 lbs./ac.</td>
<td>55.0 N</td>
<td>2.66% Q</td>
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<td>Phosphorus</td>
<td>8.23</td>
<td>89.5</td>
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<td>Low</td>
<td>22.5 P₂O₅</td>
<td>0.12% Q</td>
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<td>Potassium</td>
<td>45.03</td>
<td>490.0</td>
<td>20.7</td>
<td>Adequate</td>
<td>none</td>
<td>0.95% Q</td>
</tr>
<tr>
<td>Sulfate-Sulfur</td>
<td>54.32</td>
<td>591.0</td>
<td>2,948.0</td>
<td>High</td>
<td>none</td>
<td>0.22% Q</td>
</tr>
<tr>
<td>Calcium</td>
<td>13.44</td>
<td>146.2</td>
<td>187.0</td>
<td>Low</td>
<td>9.4 MgO</td>
<td>1.21% Q</td>
</tr>
<tr>
<td>Magnesium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.31% Q</td>
</tr>
<tr>
<td>Zinc</td>
<td></td>
<td></td>
<td>0.4</td>
<td>low</td>
<td>3.3</td>
<td>58.22 ppm Q</td>
</tr>
<tr>
<td>Iron</td>
<td>0.85</td>
<td>9.3</td>
<td>4.6</td>
<td>low</td>
<td>5.1</td>
<td>135 ppm Q</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.02</td>
<td>0.22</td>
<td>4.2</td>
<td>low</td>
<td>3.3</td>
<td>58.1 ppm L</td>
</tr>
<tr>
<td>Copper</td>
<td>0.12</td>
<td>1.31</td>
<td>0.4</td>
<td>adequate</td>
<td>none</td>
<td>5.8 ppm L</td>
</tr>
<tr>
<td>Boron</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.9</td>
</tr>
<tr>
<td>Molybdenum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>none</td>
</tr>
<tr>
<td>Sodium</td>
<td>54.41</td>
<td>592.0</td>
<td></td>
<td>use SAR</td>
<td></td>
<td>0.02% Q</td>
</tr>
<tr>
<td>Chloride</td>
<td>71.96</td>
<td>783.0</td>
<td></td>
<td></td>
<td></td>
<td>not analyzed</td>
</tr>
<tr>
<td>Bicarbonate</td>
<td>175.68</td>
<td>1,911.4</td>
<td></td>
<td></td>
<td></td>
<td>0.26% Q</td>
</tr>
<tr>
<td>Carbonate</td>
<td>2.40</td>
<td>26.1</td>
<td></td>
<td></td>
<td></td>
<td>0.95% Q</td>
</tr>
</tbody>
</table>

**Additional Assessments to Consider in evaluating your Cropping System (soil pH, free lime & CEC):**

- **Electrical Conductivity of Irrigation Water (ECiw)** = 0.81 mmhos/cm
- **Sodium Adsorption Ratio (SAR) from water test** = 1.71 & pH = 7.9
- **Irrigation Water Quality infiltration assessment (degree of restriction on use is none). Total Dissolved Solids** = 518.40 mg/l
- **Soluble salts applied** = 5,640.2 lb/ac./yr.
- **Soluble Salts** = 0.36 mmhos/cm (Satisfactory)
- **Soil pH** = 8.7 (Problem. e.g., nutrient availability)
- **Soil pH** = 8.7 (Problem. e.g., nutrient availability)
- **Sodium** is 2.6% of Total Cation Exchange Capacity (Satisfactory)
- **Refer to Crop Salt Tolerance Table (Section 2)** to evaluate for potential yield reduction (No yield reductions due to existing salinity levels)
Plan, Design, Implement & Monitor/Adjust a Dynamic Soil Health Management System
Create Quality Microbial Habitat

Living Roots

Water-stable Macro-aggregates

Living Roots
A single spade full of rich, garden soil contains more species of organisms than can be found above ground in the entire Amazon rain forest.
Fungi and Bacteria
(solubilize mineral elements)

- Various species of **fungi** can solubilize mineral elements from the mineral soil, not one species can solubilize ALL minerals (Diversity is needed)

- Various species of **bacteria** can solubilize mineral elements from the mineral soil, not one species can solubilize ALL minerals (Diversity is needed)
Rhizosphere

• Narrow region of soil directly around roots.
• Living roots release many types of organic materials.
• These compounds attract Bacteria that feed on the proteins & sugars.

Rhizosphere is:
• Area immediately surrounding [0.5-1 inches (1-2 cm)] the plant roots.
• Has the highest biological activity due to the high concentration of photosynthetically-derived carbon (approx. 70%) – Juma, 1993.
• Has some of the greatest impact on soil structure.
• Most impacted by aboveground management.
Fungal hyphae binding soil particles together into aggregates. Arbuscular Mycorrhizal fungi produces Glomalin that glues soil particles together.
Glomalin is naturally brown. A laboratory procedure reveals glomalin on hyphae and soil aggregates as the bright green material shown here.

Fungal Hyphae

- A microscopic view of an arbuscular mycorrhizal fungus growing on a corn root.
- The round bodies are spores, and the threadlike filaments are hyphae.
- The substance coating them is glomalin, revealed by a green dye tagged to an antibody against glomalin.
- Emphasize of the hyphae in comparison to root hairs.
- Hyphae can grow several centimeters (1 to 2 inches) beyond roots (Fig. 1) and access more soil to acquire nutrients more efficiently.
- This is similar to a tree, where the branches (i.e. hyphae) grow out of the trunk (i.e. root). A tree forms branches to reach more of the sun’s rays. Without enough sunlight, the tree would die.
- Belowground the plant forms a beneficial relationship with AMF or produces many fine roots to get the nutrients that it needs.
- Hyphae are not covered with bark like tree branches. Instead AMF produce glomalin to coat hyphae to keep water and nutrients from getting lost on the way to and from the plant.

Dr. Kris Nichols – Microbiologist – USDA ARS
Above: USDA-ARS research microbiologist Wendy Taheri found that arbuscular mycorrhizal spores were sparse from a tilled farm field (top), but abundant in an undisturbed prairie soil.
Figure 6
Linkage of mycorrhizal roots

Using energy gained from previously colonized roots, the mycorrhizal mycelium connects to additional roots of this and nearby plants. Roots of many species may be linked by the same network. The mycelium intensively exploits the soil, supporting key parts of the soil microflora, binding soil aggregates, and extracting nutrients for use by the plants.
Fig. 1. Hyphae of arbuscular mycorrhizal fungi grow beyond nutrient depleted zones found around roots and root hairs. Hyphae form a frame for soil particles to collect into aggregates which are coated with glomalin.
Fig. 2. Glomalin is extracted from soil with high heat. After removal of glomalin, soil is transformed from a rich brown color to a grey mineral color.
Cover crops can enhance mycorrhizal numbers, add N (legume), suppress weeds, suppress nematodes, reduce erosion, increase infiltration of water, decrease nutrient loss, attract beneficial insects, and add organic matter.
Rio Grande Community Farms (RGCF) in Albuquerque, NM:

- 8-Way cover crop planted to a soil with very poor soil health. Reactive Carbon increased 50% following CC.
- Cover Crop growing in a Certified Organic Subsurface Drip irrigation (assisted with EQIP) for growing vegetables
- This drip is using a CIG to demonstrate the integration on crop rotations, cover crops, no-till/minimum-till, IWM and other practices that build soil health & crop productivity
- Various soil health trainings have been conducted at this site
- Improved wildlife habitat
- This site is a training site partnership between RGCF, NRCS and other partners to educate farmers in the principles of soil health
C:N Ratio for Various Crops

<table>
<thead>
<tr>
<th>Material</th>
<th>C:N Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>rye straw</td>
<td>82:1</td>
</tr>
<tr>
<td>wheat straw</td>
<td>80:1</td>
</tr>
<tr>
<td>oat straw</td>
<td>70:1</td>
</tr>
<tr>
<td>corn stover</td>
<td>57:1</td>
</tr>
<tr>
<td>rye cover crop (anthesis)</td>
<td>37:1</td>
</tr>
<tr>
<td>pea straw</td>
<td>29:1</td>
</tr>
<tr>
<td>rye cover crop (vegetative)</td>
<td>26:1</td>
</tr>
<tr>
<td>mature alfalfa hay</td>
<td>25:1</td>
</tr>
<tr>
<td>Ideal Microbial Diet</td>
<td>24:1</td>
</tr>
<tr>
<td>rotted barnyard manure</td>
<td>20:1</td>
</tr>
<tr>
<td>legume hay</td>
<td>17:1</td>
</tr>
<tr>
<td>beef manure</td>
<td>17:1</td>
</tr>
<tr>
<td>young alfalfa hay</td>
<td>13:1</td>
</tr>
<tr>
<td>hairy vetch cover crop</td>
<td>11:1</td>
</tr>
<tr>
<td>soil microbes (average)</td>
<td>8:1</td>
</tr>
</tbody>
</table>

Rye
- High C:N
- Ties up N
- Compounds problem following another high C:N crop

Hairy Vetch
- Low C:N
- Release lots of N
- Decomposes Fast

Rye & Hairy Vetch Mix
- Balance C:N ratio
- Control decomposition
- Ideal cover crop mix

- Cover crops added to a cash crop rotation can help manage nitrogen and crop residue cover in a cropping sequence.
- A low C:N ratio cover crop containing legumes (pea, lentil, cowpea, soybean, sunn hemp, or clovers) and/or brassicas (turnip, radish, canola, rape, or mustard) can follow a high C:N ratio crop such as corn or wheat, to help those residues decompose, allowing nutrients to become available to the next crop.
- Similarly, a high C:N ratio cover crop that might include corn, sorghum, sunflower, or millet can provide soil cover after a low residue, low C:N ratio crop such as pea or soybean, yet decompose during the next growing season to make nutrients available to the following crop.
- Understanding carbon to nitrogen ratios of crop residues and other material applied to the soil is important to manage soil cover and crop nutrient cycling.
- Providing quality habitat for soil microorganisms should be the goal of producers interested in improving soil health.
- Soil is a biological system that functions only as well as the organisms that inhabit it.
Solvita test taken at the Los Lunas, NM Plant Materials Center (field test was done on July 31, 2013).

Jar on the left is from an alfalfa field and jar on the right is from a cultivated bean field.

This is one of several soil health assessment tools that can be used to educate and increase our understanding on soil health.