Soil Building for Water Savings: Benefits & Practical Considerations

Agricultural Water Quality Alliance
8.13.14

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Director of Environmental Science & Resources

RIO FARMS
• Established in 1978 by Allen, David & Steven Gill
• King City and Oxnard, CA, & Yuma, AZ
• About 17,000 acres, including double-cropping
• 20+ vegetables, including spinach, lettuce, romaine, celery, broccoli, cauliflower, onions, peppers, tomatoes, baby greens and more
Sustainable Farming Practices

- Data analysis - baseline of resource use
- Tools - soil moisture sensors, water meters
- Science - Lab & field testing - soil, plant tissue and water
- Practices - Sprinkler & Drip Irrigation
- Waste - Drip tape re-use and recycling
- Energy - well pump efficiency tests, electrical conversion
Soil Building Practices

• Healthy soil = healthy food
• Basis of sustainable agriculture is maintaining fertility and productivity of land, year after year
Water Holding Capacity/Infiltration

- Water in - Irrigation + Precipitation
- Water present - water content/tension of the soil
- Water movement through soil
  - Texture, structure, and size of soil pores
  - Soil layers
  - Root penetration/preferential flow
  - Evapotranspiration

**SOIL WATER STORAGE**

**FIGURE 7-7** Water retention of several soil textures. (Adapted from Water: The Yearbook of Agriculture, USDA, 1955)
Soil Organic Matter

- Source of nutrients
- Cation exchange capacity
- pH buffering
- Feeds & restores soil microbial populations
- Aggregate formation - “Soil glue”
  - Polysaccharides – sugars produced by microbes
  - Glomalin - protein on arbuscular mycorrhizal fungi hyphae
- Suppresses plant pathogens
- Erosion prevention & reduction
- Reduced surface crusting
- Reduced compaction
- Carbon sequestration
- Soil water-holding capacity

Glomalin image from: http://www.ars.usda.gov/is/AR/archive/jul08/glomalin0708.htm
Organic Matter & Water Retention

Table 1
Observed effect of organic matter content on soil water retention at two water potentials

<table>
<thead>
<tr>
<th>Authors</th>
<th>— 33 kPa</th>
<th>— 1500 kPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bauer and Black (1981)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Bell and van Keulen (1995)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Beke and McCormick (1985)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Petersen et al. (1968)</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Calhoun et al. (1973)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Lal (1979)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Daralatos et al. (1994)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>De Jong (1983)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Jamison and Kroth (1958)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Riley (1979)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>McBride and MacIntosh (1984)</td>
<td>ND</td>
<td>Yes</td>
</tr>
<tr>
<td>Saltner and Haworth (1961)</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

5. Conclusion

(1) Relationship of soil water retention to organic carbon content is affected by proportions of textural components.
(2) Soil water retention at — 33 kPa is affected more strongly by the organic carbon than water retention at — 1500 kPa.
(3) Water retention of soils with coarse texture is substantially more sensitive to the amount of organic carbon as compared with fine-textured soils.
(4) The effect of changes in organic carbon content on soil water retention depends on the proportion of textural components and the amount of organic carbon present in the soil. At low carbon contents, an increase in carbon content leads to an increase in water retention in coarse soils and to decrease in water retention in fine-textured soils. At high carbon contents, an increase in carbon contents results in an increase in water retention of all textures.
(5) A comparable accuracy in estimating water retention has been achieved with regression trees and with polynomial neural networks of the group method of data handling.
(6) Test of the predictive ability of the GMDH equations resulted in the same accuracy of estimates for the independent data from soil quality studies as for the data set from the National Soil Characterization database.
(7) The developed equations can be used to evaluate effect of the soil carbon sequestration on soil hydraulic properties.
Compost Program

- Since 2000, windrow composting on 7 acres of land
- 8,000 tons/year in 2000 → 20,000 tons/year in 2012
- 4-6 tons/acre applied
- Keith Day Company manages, 1-2 full time staff
- Waste reduction strategy - reduces pathogens, fuel, GHG emissions
Compost Ingredients

- Culled onions
- Spent mushroom substrate from Monterey Mushroom Co.
- Grape pomace from Courtside Cellars, San Miguel
- Green Waste from Johnson Canyon, Gonzales
Composting Considerations

- Regulated by California Integrated Waste Management Board (CIWMB) Regulations (Title CCR, Chapter 3.1), enforced by Monterey County
- Food Safety / LGMA
  - Testing - fecal coliforms, salmonella, E. coli.
  - Temperature & turning frequency
  - Distance to harvested fields
  - Cleaning of equipment
  - Documentation
  - Pre-harvest interval
  - Mushroom mulch sterilization
- Air Resources Board: Compost is a source of GHGs, VOCs / reactive organic gases (ROG), particulate matter, and ammonia (NH₃).
Composting Considerations

- Cost
  - Take valuable land out of production
  - Staff time
  - Equipment – turner, loader, water truck, spreader
  - Fuel to turn and spread on fields
- Application timing: slow-release of nutrients may not available when plants may need it
- Onion skins - mobile in windy conditions
- Odor management
Cover Crops

- Started in 2010 with 22 acres, 320 acres in 2013-14 winter
- Site selection
  - Sandy lots - goal to build SOM, reduce leaching
  - Hilly lots - goal to reduce soil erosion, reduce leaching
- Species used: triticale, Merced rye, wheat forage mix
- Drill seeded
- Disked under or harvested for cattle feed
Cover Cropping Benefits

- Protects water quality
- reduces soil erosion & runoff
- decreases leaching of nitrates
- “Banks” nitrogen until the spring
- Natural biofumigant - mustards
- Fixes atmospheric nitrogen - legumes
- Habitat for beneficial insects
- Potential revenue if crop is sold
Cover Crop Considerations - Environmental

Figure 6. Total runoff in the three cover crop treatments

Figure 11. Nitrate and ammonium concentrations in the soil profile. Upper graph: November 23, 2009 prior to cover crop germination and lower graph: March 8, 2010 prior to tillage operations. Error bars represent the SE n=6.

The role of cover crops in irrigated systems: Water balance, nitrate leaching and soil mineral nitrogen accumulation

J.L. Gabriel\textsuperscript{a}, R. Muñoz-Carpeta\textsuperscript{b}, M. Quemada\textsuperscript{a,*}

Barley greatly reduced the \textit{NO}_3^- leaching throughout the experimental period relative to fallow. The main effect appeared during the intercrop period and in the years when the drainage was abundant. Only in the unusually dry autumn of 2007/08, in which the precipitation from October to March was 101 mm, were the drainage and \textit{NO}_3^- leaching similar (nonexistent) for all of the treatments. This large variability is characteristic of Mediterranean semiarid regions, in which soil \textit{N}_{\text{min}} accumulates during the dry intercrop periods and is leached out of the soil profile when an unusually heavy rainy season occurs (Ruiz-Ramos et al., 2011). At the beginning of the experiment, the \textit{N}_{\text{min}} content just before sowing the CC was high (~300 kg N ha\textsuperscript{-1}) and similar for all the treatments; therefore, the CC had an opportunity to show their ability to reduce \textit{NO}_3^- leaching. Both the barley and vetch cut the \textit{NO}_3^- leaching losses by more than half relative to fallow. At the same time, the barley greatly reduced the \textit{N}_{\text{min}} content in the soil profile, as it captured most of the available N, whereas the \textit{N}_{\text{min}} content in the vetch soil was midway between those of the fallow and the barley owing to atmospheric N\textsubscript{2} fixation. After the 2007 maize cropping, all of the treatments converged.
Cover Crop Considerations - Timing

- species - timeframe to grow & provide desired benefit
- weather - field access
- decomposition time
- uptake of N in subsequent crop may not match N release
- prolonged wet, cold soils
- depletion of soil moisture
## Cover Crop Considerations - Agronomic

<table>
<thead>
<tr>
<th>Cover crop example</th>
<th>%N in cover crop</th>
<th>C:N ratio</th>
<th>Effect of N release</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereal straw, cereal at heading</td>
<td>0.5 – 1.5%</td>
<td>&gt; 25:1</td>
<td>Immobilization</td>
</tr>
<tr>
<td>Cereal at or before heading. Mustards at heading.</td>
<td>1.5 – 2.5%</td>
<td></td>
<td>May tie up N</td>
</tr>
<tr>
<td>Legumes, mustards, juvenile cereal</td>
<td>2.5 – 4%</td>
<td>10:1 to 15:1</td>
<td>Mineralization</td>
</tr>
</tbody>
</table>

### Chart 4B: POTENTIAL DISADVANTAGES

<table>
<thead>
<tr>
<th>Species</th>
<th>Orthogonal Pest Risks</th>
<th>Management Challenges</th>
<th>Comments Pro/Con</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plant</td>
<td>Aerial</td>
<td>Root</td>
</tr>
<tr>
<td>Annual ryegrass</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Barley</td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Oats</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Rye</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Wheat</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Buckwheat</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Sorghum-sudangrass</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Mustards</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Radish</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Rapeseed</td>
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<td></td>
<td>1</td>
</tr>
</tbody>
</table>

Cover Crop Considerations - Economic

- Harvest & sell vs. incorporate for full agronomic benefit
- Availability of labor in off-season
- Cost
  - seeds
  - labor
  - irrigation in dry years
  - weed control/herbicides
  - diesel/electricity for planting, irrigation
  - land rent
- Cover crops as weeds
Resources - Compost

CDFA - Compost Production and Utilization: A Grower's Guide
http://www.cdfa.ca.gov/is/ffldrs/frep/Nutrient_Mgmt Tools.html

Leafy Greens Marketing Agreement - Food Safety Practices
http://www.lgma.ca.gov/food-safety-practices#downloads

Cal Recycle Composting Operations - Regulatory Requirements
http://www.calrecycle.ca.gov/laws/Regulations/Title14/ch31a5.htm

Cal Recycle - On Farm Composting
http://www.calrecycle.ca.gov/organics/farming/OnFarm.htm

Air Resources Board – Compost Emissions Work Group
http://www.calrecycle.ca.gov/organics/farming/OnFarm.htm

National Center For Appropriate Technology – Sustainable Agriculture Information Service
https://attra.ncat.org/publication.html
### Table 2.1. Cover crop production and cultural information

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name</th>
<th>Common varieties</th>
<th>Growing season *</th>
<th>Seeds per pound</th>
<th>Typical seeding rate * (lb/ac)</th>
<th>Rhizobium inoculant</th>
<th>Seedling vigor</th>
<th>Vigor of winter growth</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GRASSES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Avena sativa</em></td>
<td>oat</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Hordeum vulgare</em></td>
<td>barley</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Secale cereale</em></td>
<td>cereal rye</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td><em>Sorghum bicolor</em> × <em>S. bicolor</em></td>
<td>sorghum-sudangrass</td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td><em>Sorghum bicolor</em> ssp. <em>drummondii</em></td>
<td>sudangrass</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Triticum aestivum</em></td>
<td>wheat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>× <em>Triticosecale rimpau</em></td>
<td>triticale</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>LEGUMES</strong></td>
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<td></td>
</tr>
<tr>
<td><em>Crotalaria juncea</em></td>
<td>sunn hemp</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td><em>Pisum sativum</em></td>
<td>field pea</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td><em>Trifolium spp.</em> and <em>Medicago spp.</em></td>
<td>clovers an medicis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Vicia benghalensis</em></td>
<td>purple vetch</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Vicia faba</em></td>
<td>common vetch</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Vicia sativa</em> ssp. <em>sativa</em></td>
<td>woollypovetch</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

### Table 2.2. Characteristics of cover crops

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name</th>
<th>Nitrogen fixation</th>
<th>Nitrogen scavenging</th>
<th>C:N ratio at maturity</th>
<th>Seeding hazard</th>
<th>Weed suppression</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GRASSES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Avena sativa</em></td>
<td>oat</td>
<td>—</td>
<td>excellent</td>
<td>high</td>
<td>low</td>
<td>moderate</td>
<td>Some varieties are the latest maturing of the cereals.</td>
</tr>
<tr>
<td><em>Hordeum vulgare</em></td>
<td>barley</td>
<td>—</td>
<td>excellent</td>
<td>high</td>
<td>high</td>
<td>good</td>
<td>Fast growing; many varieties are early maturing.</td>
</tr>
<tr>
<td><em>Secale cereale</em></td>
<td>cereal rye</td>
<td>—</td>
<td>excellent</td>
<td>high</td>
<td>moderate</td>
<td>excellent</td>
<td>At appropriate seeding rates, the variety Merced suppresses weeds well. AG 104 is resistant to rust.</td>
</tr>
<tr>
<td><em>Sorghum bicolor</em> × <em>S. bicolor</em></td>
<td>sorghum-sudangrass</td>
<td>—</td>
<td>excellent</td>
<td>high</td>
<td>moderate</td>
<td>good</td>
<td>Residues are allelopathic to tomatoes, lettuce, cole crops, and possibly other vegetables. Need to allow 6–8 weeks following incorporation of residue for allelochemicals to leach and/or break down.</td>
</tr>
<tr>
<td><em>Sorghum bicolor</em> ssp. <em>drummondii</em></td>
<td>sudangrass</td>
<td>—</td>
<td>excellent</td>
<td>high</td>
<td>moderate</td>
<td>good</td>
<td>Is tolerant of mowing and can produce large amounts of biomass.</td>
</tr>
<tr>
<td>× <em>Triticosecale rimpau</em></td>
<td>triticale</td>
<td>—</td>
<td>excellent</td>
<td>high</td>
<td>high</td>
<td>good</td>
<td>Its use as a cover crop is typically dependent upon seed price.</td>
</tr>
<tr>
<td><strong>LEGUMES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Crotalaria juncea</em></td>
<td>crotalaria</td>
<td>excellent</td>
<td>poor</td>
<td>low</td>
<td>low</td>
<td>moderate</td>
<td>Upright growth to 6 feet tall. Can be highly productive, but susceptible to root rot on heavy, wet soils.</td>
</tr>
<tr>
<td><em>Pisum sativum</em></td>
<td>field pea</td>
<td>excellent</td>
<td>poor</td>
<td>low</td>
<td>moderate</td>
<td>poor</td>
<td>Tolerant of wet soils; a high nitrogen producer.</td>
</tr>
<tr>
<td><em>Vicia benghalensis</em></td>
<td>purple vetch</td>
<td>excellent</td>
<td>poor</td>
<td>low</td>
<td>moderate</td>
<td>moderate</td>
<td>A reliably productive legume. Because of its upright growth it mixes well with grasses.</td>
</tr>
<tr>
<td><em>Vicia faba</em></td>
<td>bell bean</td>
<td>excellent</td>
<td>poor</td>
<td>low</td>
<td>moderate</td>
<td>poor</td>
<td></td>
</tr>
</tbody>
</table>
Resources - Cover Crops

Managing Cover Crops Profitably, Western SARE (2012)
http://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition

http://www.sare.org/Learning-Center/Project-Products/Western-SARE-Project-Products/Estimating-Plant-Available-Nitrogen-Release-from-Cover-Crops