How Cover Crops Build Soil Health

Part 2 (49 Slides)

North Valley Organics (Minor Morgan, Albuquerque, NM)

Close up of Cover Crops growing between vegetable rows at Minor’s Organic Farm

Soil Health & Assessments Training in NM

Rudy Garcia
USDA-NRCS Regional Soil Health Specialist (NM, CO, UT, AZ)

NOTE: this presentation is about how cover crops help to build soil health. Many NRCS Soil Health Specialists/Conservationists, Producers, University Specialists, Ag Consultants and other Soil Health Partners have shared their work on how cover crops build soil health and increase productivity. Many thanks to all of you.
How Cover Crops Build Soil Health

(1) Add Organic Matter
(2) Add Plant Diversity
(3) Enhance Mycorrhizal numbers
(4) Build Aggregates
(5) Increase Earthworms
(6) Add Lasting Residue/Cover
(7) Suppress Weeds
(8) Increase Infiltration of Water
(9) Reduce Erosion
(10) Minimize & Reduce Soil Compaction
(11) Manage Soil Moisture
(12) Capture & Recycle Nutrients (decrease nutrient loss)
(13) Add Nitrogen (Legumes)
(14) Add Nitrogen (Associative Nitrogen Fixers)
(15) Attract Beneficial Insects
(16) Disease Mgt./Suppression
(17) Enhance Pollinators
(18) Support Wildlife
(19) Catch Snow

Cover Crop Cocktail/Biological Primer (Photo: Jay Fuhrer, ND)

Sunflower 1 lb
Soybean 15 lbs
Cowpea 10 lbs
Turnip 1 lb
Radish 2 lbs
Proso Millet 3 lbs
Pearl Millet 3 lbs
Corn 1 lb
Squash 1 lb
Canola 1 lb

Other Benefits: Clean Air, Clean Water, Healthy & Nutritious Plants, and much more.
### Additional Considerations in Planting/Seeding Cover Crops:

- Fertility requirements? (test the soil)
- Seeding depths
- Planting methods will be consistent with applicable local criteria and soil/site conditions
- Select cover crop species that do not harbor pests or diseases of subsequent crops in the rotation
- Select cover crops that are compatible with the production system, well adapted to the region’s climate and soils, and resistant to prevalent pests, weeds, and diseases
- Cover crops may be used to improve site conditions for establishment of perennial species
- Termination at early vegetative stages may cause a more rapid release of nutrients compared to termination at a more mature stage
- If the cover crop is not meeting the purpose(s) adjust the management, change the species of cover crop, etc.
- Some cover crops may need a little shot of fertilizer especially if your soil is not functioning
- There are many cover crops that will over winter and only need a few inches of growth before winter. (winter wheat, winter barley, winter triticale, rye, peas, vetch, clovers, turnips, canola)
- Allelopathic effects to the subsequent crop should be evaluated when selecting the appropriate cover crop.
- Mix different seed prior to planting
- Pre-plant burndown?
- **NOTE on Increased Pest Risk:** “Overall, growing a cover crop rarely causes pest problems, but certain cover crops may contribute to particular pest, disease or nematode problems in localized areas, for example, by serving as an alternate host to the pest.” (quote: page 65 of Managing Cover Crops Profitably)

- Lack of local available cover crop seed/diversity; might need to ship cover crop seed mixes.
- Lack of knowledge of the right species, seeding rates, timing. Work with your Plant Materials Center to evaluate cover crops that are suitable for your areas cropping systems, climate, soils, etc.
- There are lots of videos to watch on YouTube on various cover crop issues.
- You can see lists and options on the cover crop periodic table provided by USDA-ARS in North Dakota.
- Contact your NRCS State Office for state-specific cover crop guides, technical notes and other resources.
- Some farmers have added full season multi species cover crops into their crop rotation and now added the 5th principle of soil health into his farming system (Integrating livestock into the cropping system).
- Terminate the cover crop at flowering (don’t let them go to seed).
- Remember that you will never get a perfect, cookie cutter cover crop mix. Each field is different, and we are the professionals writing a prescription for the concerns that need to be addressed in each specific field (Niels Hansen, NRCS UT).
Planting/Seeding Cover Crops:

Have a plan
- **Planting** – when, how?
- **Species** – how many, which ones, lbs/ac?
- **Termination** – how & when?
- **How much cover and what kind?**

Species Selection
- Start off 50/50 legume to grass
  - Haney Test Recommendation
- Adjust based on your soil needs and goals
  - What was the C:N of previous crop
    - High C:N need to increase legumes
    - Low C:N need to increase grasses
  - Trying to break up hard pan
    - Increase deep rooted crops
  - Scavenge residual N or P
    - Increase grasses
    - Reduce legumes
  - Soil moisture management
    - High biomass

Species
- Minimum 5 species (?)
- 3 crop types
- Planting time
  - Temperature & moisture
  - Seed issues
- Annuals, biennial, perennial
- Cost & availability
- Crop rotation
- Carbon: Nitrogen ratio
- Herbicide carryover

Placing
- Before or after harvest of cash crop?
- Equipment - drill, broadcast, airplane?
- Depth & seed size
- Mix seed before planting
- Inoculants - vary by species
- Pre-plant burndown
- Fertilizer?

Designing Cover Crop Mixes
- Always start with your goals!
  - Armor
  - Increase organic matter
  - Break up plow layer
  - N for next crop
  - Soil moisture management
- Helps determine species mix

If you get a 4 to 6 weeks of growth on your cover crop...you will get your money worth because of the “rotation” effect!
Planting/Seeding Cover Crops:

Matching objectives with species

http://www.sdnotill.com/Field_Facts_wheat_cover_crop.pdf

Grazing

*turnips, rape, radish, lentils, rye, oat, triticale, sorghum-sudan*

Reducing Compaction

*radish, canola, turnip (and hybrids), sugarbeet, sunflower, sorghum-sudan, sweet clover, alfalfa*

N-fixation

*clovers, vetches, lentils, cowpeas, soybean, field pea, chickling vetch*

Residue Cycling

*canola, rape, radishes, turnips, mustards*

Nutrient Cycling

*sunflower, sugarbeets, brassicas, small grains*
**Performance and Roles**

**LEGUME N Source:** Rates legume cover crops for their relative ability to supply fixed N.

**TOTAL N:** A quantitative estimate of the reasonably expected range of total N provided by a legume stand in lb. N/ac.

**DRY MATTER:** A quantitative estimate of the range of dry matter in lb./ac./yr.; this estimate is based on fully dry material.

**N SCAVANGER:** Rates a cover crop’s ability to take up and store excess nitrogen.

**SOIL BUILDER:** Rates a cover crop’s ability to produce organic matter and improve soil structure.

**EROSION FIGHTER:** Rates how extensive and how quickly a root system develops, how well it holds soil against sheet and wind erosion and the influence the growth habit may have on fighting wind erosion.

**WEED FIGHTER:** Rates how well the cover crop outcompetes weeds by any means through its life cycle, including killed residue. Note that ratings for the legumes assume they are established with a small-grain nurse crop.

**GOOD GRAZING:** Rates relative production, nutritional quality and palatability of the cover as a forage.

**QUICK GROWTH:** Rates the speed of establishment and growth.

**LASTING RESIDUE:** Rates the effectiveness of the cover crop in providing a long-lasting mulch.

**DURATION:** Rates how well the stand can provide long-season growth.

**HARVEST VALUE:** Rates the cover crop’s economic value as a forage or as a seed or grain crop, bearing in mind the relative market value and probable yields.

**CASH CROP INTERSEED:** Rates whether the cover crop would hinder or help while serving as a companion crop.

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**Cultural Traits**

**TOLERANCES:** How well a crop is likely to endure despite stress from heat, drought, shade, flooding or low fertility. The best rating would mean that the crop is expected to be fully tolerant.

**TYPE:** Biennial, Cool Season Annual, Long-lived perennial, Summer Annual, Short-lived Perennial, Winter Annual.

**HARDY THROUGH ZONE:** Refers to the standard USDA Hardiness Zones. Bear in mind that regional microclimate, weather variations, and other near-term management factors such as planting date and companion species can influence plant performance expectations.

**HABIT:** How plants develop (i.e., Climbing, Upright, Prostrate, Semi-Prostrate and Semi-Upright).

**pH PREFERRED:** The pH range in which a species can be expected to perform reasonably well.

**BEST ESTABLISHED:** The season in which a cover crop is best suited for planting and early growth. Note that this can vary by region and that it’s important to ascertain local planting date recommendations for specific cover crops. (Season: Spring, Summer, Fall & Winter; Time: Early, Late and Mid).

**MINIMUM GERMINATION TEMPERATURES:** The minimum soil temperature generally required for successful germination & establishment.

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**Potential Advantages**

**SOIL IMPACT:** Assesses a cover’s relative ability to loosen subsoil, make soil P & K more readily available to crops, or improve topsoil.

**SOIL ECOLOGY:** Rates a cover’s ability to fight pests by suppressing or limiting damage from nematodes, soil disease from fungal or bacterial infection, or weeds by natural herbicidal (allelopathic) or competition/smothering action.

**OTHER:** Indicates likelihood of attracting beneficial insects, of accommodating field traffic and of fitting growing windows or short duration.

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**Potential Disadvantages**

**INCREASED PEST RISKS:** Relative likelihood of a cover crop becoming a weed, or contributing to a likely pest risk. Overall, growing a cover crop rarely causes pest problems, but certain cover crops may contribute to particular pest, disease or nematode problems in localized areas, for example by serving as an alternate host to the pest.

**MANAGEMENT CHALLENGES:** Relative ease or difficulty of establishing, killing or incorporating a stand. Till-kill refers to killing by plowing, disking or other tillage. Mature incorporation rates the difficulty of incorporating a relatively mature stand. Incorporation will be easier when a stand is killed before maturity or after some time elapses between killing and incorporating.
The front fluted coulter of a no-till drill slices an opening through hard sods for the “V” openers, seen middle, to open and deposit seed. The spring loaded press wheels then seal the opening.

The farmers are the real innovators, if we teach them the principles of soil health they will figure out the hard part of implementation. Many farmers will not invest in a no till drill until they rent one or have some custom planting done on their farm (Marlon Winger).

Ref.: Ray Archuleta (the Soil Guy)
The biggest difference between a drill and a planter is the row spacing. They both do a good job of planting and covering the seed. A planter is usually adjustable for row spacing’s of between 20 inches to 40 inches, and is used for row crops like corn and soybeans. A drill has much closer row spacing’s, around 4 to 6 inches, and used to plant small grains like wheat.
Broadcast cover crop seed while defoliating cotton

Seeded a multi-species cover crop mix
- Cereal rye
- Crimson clover
- Hairy Vetch

Broadcast seeding of cover crop as spray cotton defoliant using a multi-species cover crop mix. Great stand. Problem was farmer could spray more acres than he could broadcast, hopper not large enough (Ref.: Ray Archuleta).
Planting/Seeding Cover Crops:

Aerial Seeding

Earlier Planting Date & Growth

Advantage
• Seed most anytime
• Not affected by wet conditions
• Best Suited for small seed low seeding rate cover crops
• Less labor intensive

Disadvantages
• Limited on amount of seed they can carry
• Need to increase rates to compensate for poor seed to soil contact
• Cost
• Uniformity
• Seed to soil contact may not be as good
• Need gps systems- can drift onto neighbors property
Terminating Cover Crops (Crimping/Rolling):
Terminating Cover Crops (Frost Kill):

- Refer to your local cover crop chart or NRCS Specification and Jobsheet
- **Disadvantages**
  - Varies by species
  - Dependent on weather
  - Volunteer cool season annuals
- **Advantages**
  - No cost
  - Maximize growing season

Frost Killed: Mung bean; soybeans; sunn hemp, sorghum sudan, pearl millet, black oats, nitro radish; rapeseed, Ethiopian cabbage, flax and volunteer wheat.
Monocultures such as Turnips are excellent for grazing especially on high C:N residues. Supplemental grazing can mimic Nature’s grazing template: Mob tall grazing (250k-500k lbs./ac.) and help with nutrient cycling through density. Livestock integration can cut winter feed cost. Ref.: Burleigh County Conservation District, ND.
Improving Plant Health with High Density Grazing

- Graze fully recovered plants

Fully recovered plants have more biomass above- and below-ground. Plants with more root mass and depth can access water for longer periods of time. Deeper roots enable plants to allocate minerals from lower in the soil profile.
Terminating Cover Crops with Herbicide:

- Herbicide carryover (i.e., Check Label restrictions on herbicide use)

Cover Crop Herbicide Restrictions

- Forage and grain (food chain)
  - Herbicide must be labeled for all crops
  - Rotation/plant back restrictions (timeline)
  - Forage restrictions
- Ensure herbicides used with crops are compatible with cover crop selections and purpose(s).
- When a cover crop will be grazed or hayed ensure that crop selection(s) comply with pesticide label rotational crop restrictions.
- Be very aware of the herbicide carry over, many broadleaf herbicides have multiple month residual, consult label for correct information.
- There are also herbicides that are selective for example only kill the grasses and leave the broadleaf cover crop.
- There are several herbicides that will burn down the live plant with no herbicide residue.
- Burn down (concern with herbicide carryover; use as green manure, is the most common for vegetable production).
When appropriate for the crop production system, mowing certain grass cover crops (e.g., sorghum-sudangrass, pearl millet) prior to heading and allowing the cover crop to regrow can enhance rooting depth and density, thereby increasing their subsoiling and nutrient-recycling efficacy.

**Terminating Cover Crops with Mowing:**

Mechanical termination (brush hog, flail mower: common for orchards).

- Mix clover/native grass cover in 7th leaf no-till pecans.
- Use mower and narrow glyphosate strip to control weeds.
- Decomposed pecan shell added.
- Antelco frame jet micro sprinklers.

South East Arizona (Photos: Brian Driscoll)
Harvesting Cover Crops vs Grazing them (Grazing improves the Soil Health):

Harvesting Cover Crops

Grazing 2007
- 91 bu/ac Corn ('08)
- 1 Herbicide Application
- Value of additional nutrients from manure?

Chopping 2007
- 68 bu/ac Corn ('08)
- 2 Herbicide Applications
- Value of nutrients hauled away?

Ref.: Jay Fuhrer, NRCS ND
Terminating Cover Crops (Green Manure Crop):

In most furrow irrigated cropland in the SW, cover crops are incorporated into the soil as a green manure crop. Consider using minimum-till in an irrigated system, to further improve soil health.

Green Manures

Usually grown to:
- help maintain soil organic matter and
- increase nitrogen availability
Get 4 Things Right
1. The Right Species
2. The Right Inoculants
3. The Right Seeding Rates
4. The Right Seeding Time

Answer 4 Main Questions
1. What Are The Goals/Concerns?
2. What Are The Environmentals?
3. What Is The Timeframe?
4. What Is The Budget?

What are your Goals/Resource Concerns?
1. Soil health – biological life
2. Supplemental grazing
3. Increased fertility/organic matter
4. Nitrogen capture/cycling
5. Additional lasting residue/cover
6. Weed suppression/disease cycle
7. Erosion control
8. Compaction breaking/deep roots

What are your goals/resource concerns? Generally speaking....
1. The more specific your goals/concerns, the less diverse your mixes will typically be.
2. The tighter your planting windows, the fewer species will work and thus the less diverse your mixes will be.

What is your timeframe?
1. Spring - fallow ground or prior to a spring crop (chemical/mechanical termination) (Check crop insurance implications!)
2. Early Summer - Right after wheat harvest (frost or chemical/mech. termination)
3. Late Summer – Delay after wheat harvest (frost termination)
4. Fall - After fall crops (frost termination or over-wintering)

What is your budget?
1. Low (less than $20/acre) (Low seeding rates – very few legumes)
2. Medium ($20 - $30/acre) (Average seeding rates – some legumes)
3. High ($30 - $40/acre) (High seeding rates – high legume %)
4. Higher ($40 - $60/acre) (special use: organic N production, nematode control, perennials, etc...)

What are your environmentals?
1. Rainfall or irrigation
2. Evapo-Transpiration (ET)
3. Growing season
4. Soil type and condition
5. Seeding method
6. Previous crop and next crop
7. Previous herbicides

Ref.: Keith Berns
Simplified Crop Classification

Cool Season Broadleaf
- Canola
- Clovers
- Mustards
- Pea
- Radish
- Turnips

Warm Season Grass
- Corn
- Millet
- Sudan
- Sudex
- Sorghum

(Fibrous Root)

* Broadleaf Perennial, Biannual, Annual.

(legumes, brassicas; Tap Root)

(legumes, non-legumes)
The Influence of Functional Diversity and Composition on Ecosystem Processes

David Tilman,* Johannes Knops, David Wedin, Peter Reich, Mark Ritchie, Evan Siemann
Cover Crop mixes and Yield Response

1 Year of Data From 2012

5 year No-till: David Brandt's Replicated Corn Test Plots (2012)

- Radish/Pea
- 10 Species mix
- 8 Species Mix
- 7 Species Mix
- 6 Species Mix

Total Rain from May to Sept (2012): 8.8 inches
2006 BCSCD data - at higher seed rate - diminishing returns
Traditional cropping systems only have a living root growing 90 to 120 days of the year.

Niches exist at both ends of the growing season that provide opportunity for cover crops to used to provide a living root.
Resources

• Burleigh County Soil Conservation District
  http://www.bcscd.com/?id=23

• Managing Cover Crops Profitably
  www.sare.org/publications/covercrops.htm

• Overview of Cover Crops and Green Manures
## Cover Crop Chart

### Growth Cycle
- A = Annual
- B = Biennial
- P = Perennial

### Plant Architecture
- γ = Upright
- * = Upright-Spreading
- ≈ = Prostrate

### Relative Water Use
- ○ = Low
- ◯ = Medium
- ● = High

### Chart

<table>
<thead>
<tr>
<th>COOL</th>
<th>WARM</th>
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<tbody>
<tr>
<td><strong>GRASS</strong></td>
<td><strong>BROADLEAF</strong></td>
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<tr>
<td><strong>GRASS</strong></td>
<td><strong>LEGUME</strong></td>
</tr>
<tr>
<td><strong>GRASS</strong></td>
<td><strong>BROADLEAF</strong></td>
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### Examples
- **Barley** (A, γ, A/B)
- **Oat** (A, γ, A/B)
- **Canola** (A, γ, A/B)
- **Cameolina** (A, γ, A/B)
- **Wheat** (A, γ, A/P)
- **Mustard** (A, γ, A/P)
- **Phacelia** (A, γ, A/P)
- **Field Pea** (A, A, A/B)
- **Berseem Clover** (A, B, A/B)
- **Vetch** (A, A, A/B)
- **Sunn Hemp** (A, A, A/B)
- **Cluster Bean** (A, A, A/B)
- **Quinoa** (A, A, A/B)
- **Proso Millet** (A, A, A/B)
- **Amaranth** (A, A, A/B)
- **Foxtail Millet** (A, A, A/B)
- **Pearl Millet** (A, A, A/B)
- **Buckwheat** (A, A, A/B)
- **Amaranth** (A, A, A/B)
- **Cereals** (Rye, A, γ, A)
2014 Cover Crop Mix: warm season or cool season

• #/acre    Species
  • 5        Super sweetsorg / sudan
  • 5        BMR grazing corn
  • 3        Soybean
  • 1        Cowpea
  • 1        Mong bean
  • 2        Forage collards
  • 1        Hunter turnips
  • 1        Wildlife grain sorghum
  • 1        German millet
  • 1        Berseem Clover, Crimson Clover, Arrowleaf Clover
  • 1        Sunflower
  • 1        Buckwheat, Oats, Safflower

Total 23#    Cost $27.00/ acre

Ref.: Willie Durham, NRCS TX (2016 Soil Health & Sustainability Course)
Growing season and whether a cover crop will overwinter must be considered. Cover crop jobsheet shows cold tolerance for various cover crops, some are: turnip 10 degrees, oats 32 degrees.
Producers must use a dynamic cropping approach, where management decisions are adjusted annually based on changing climatic & economic conditions. Also, use a net return per rotational acre to measure profitability of various crop rotations.

For Cover Crop planning, must use site-specific and case-by-case local considerations, to account for variability in soils, irrigation water availability, water quality, climate, cropping systems, etc.
Cover Crops Improve Soil Health

Benefits of Improving Soil Health

- Water Soluble Organic Carbon
- Aggregation & Infiltration
- Water & Nutrient Holding
- Productivity
  - Air & Water Quality
  - Soil Biota Habitat

New Equilibrium

Soil Health

Time

Biological

160 ppm C

Transition Period

347 ppm C
Agricultural Management Effects on Soil Health

<table>
<thead>
<tr>
<th>Tend to Reduce Soil Health</th>
<th>Tend to Promote Soil Health</th>
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<tbody>
<tr>
<td>Aggressive tillage</td>
<td>No-till or conservation tillage</td>
</tr>
<tr>
<td>Annual/seasonal fallow</td>
<td>Cover crops; Relay crops</td>
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<tr>
<td>Mono-cropping</td>
<td>Diverse crop rotations</td>
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<tr>
<td>Annual crops</td>
<td>Perennial crops</td>
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<tr>
<td>Excessive inorganic fertilizer use</td>
<td>Organic fertilizer use (manures)</td>
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<tr>
<td>Excessive crop residue removal</td>
<td>Crop residue retention</td>
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<tr>
<td>Broad spectrum fumigants/pesticides</td>
<td>Integrated pest management</td>
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<tr>
<td>Broad spectrum herbicides</td>
<td>Weed control by mulching, cultivation</td>
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Crop Insurance

Zone 1 - Terminate cover crop 35 days or earlier before planting, except for the RMA summer fallow practice*

Zone 2 - Terminate cover crop 15 days or earlier before planting, except for the RMA summer fallow practice*

Zone 3 - Terminate cover crop at or before planting, except for the RMA summer fallow practice*

Zone 4 - Terminate cover crop at or within 5 days after planting, but before crop emergence
Healthy Soil or Poor Soil Health?
Emphasis on Soil Organic Matter Mgt.
(Earthworms in a Chile field at Deming, NM)

Healthy Soil (i.e., a diverse Soil Food Web (SFW))

- Higher water-holding capacity
- Lower evaporation
- Higher water-use efficiency
- Lower soil temperature
- Higher infiltration rate & less runoff
- Water-stable aggregates
- Good drainage/permeability
- Optimal nutrient cycling (i.e., soil has a diverse SFW)
- Higher drought tolerance
- Higher buffering capacity
- Good Soil Tilth
- All Biological Spheres are present
- Earthworms are present
- No Compaction

Poor Soil Health (i.e., a bacterial-dominated Soil Food Web)

- Lower water-holding capacity
- Higher evaporation
- Lower water-use efficiency
- Higher soil temperature
- Lower infiltration rate and more runoff
- Unstable aggregates
- Poor drainage/permeability
- Poor nutrient cycling (i.e., soil has a bacterial-dominated SFW)
- Lower drought tolerance
- Lower buffering capacity
- Poor Soil Tilth (Crusting)
- Some Biological Spheres not present or are in poor condition
- No Earthworms
- Compaction Present

Tillage disrupts ecosystem processes

Cover Crops Improve Soil Health: Soil Health Indicators are at Optimal Levels

rudy.garcia
An average soil is composed of mineral matter, organic matter, and pore space, which may be occupied by air and/or water. The percentage of these four components can vary depending on how and where the soils were formed.

50% solids and 50% pore space; obviously, these are mixed in a natural environment and fluctuate greatly throughout the year.
What things change when you stop tilling the soil?

- Soil pores remain continuous
- Soil aggregates form and are not destroyed
- Soil Food Web increases and diversifies
- Weed seeds are not planted
- Water is captured and stored
- Bulk density increases slightly; then stabilizes
- Soil fungi and earthworms increase
- Microarthropods increase (>20% of nutrient cycle)

Ref.: Cover Crops and Ecosystem Services: Insights from Studies in Temperate Soils
Humberto Blanco-Canqui,* Tim M. Shaver, John L. Lindquist, Charles A. Shapiro,
Roger W. Elmore, Charles A. Francis, and Gary W. Hergert
**Root Exudates**: Diverse roots is why you have a diverse Soil Food Web.

**Nature and amounts of exudates** are dependent on plant species, plant age, inorganic nutrients, soil and air temperature, light intensity, moisture content, $O_2/CO_2$ levels, transpiration rate, plant health and soil health.

- **Organic Acids (OA)**: Increase available insoluble nutrients, metals, mobilization & transport of minerals.
- **Carbohydrates/sugars (CS)**: Is food for microbes, stimulate their activity and improve plant resistance to diseases and pests.
- **Amino Acids (AA)**: Basic compounds of living cells in plants and microorganisms.
- **Nucleic Acid Derivatives (NAD)**: Large molecules that carry genetic information (DNA & RNA).
- **Growth factors (GF)**: Known as phytohormones; chemical messengers that regulate plant growth.
- **Other compounds (OC)**: Assist in plant health; in some cases they may attract, repel, or inhibit microorganisms.
- **Enzymes (EZ)**: Multi-protein complexes that aid catalyzing reactions that might not otherwise occur.
- **Water soluble vitamins (WSV)**: Vary with plant species; aid in the nutrition of microorganisms.

Greater populations of microorganisms exist near the roots; they decrease with distance and depth of the root system.

**Liquid Carbon**: A major Food Source that feeds the Soil Food Web.

Clarence Chavez 5/2014
And those principles are simple. They simply protect and enhance the habitat of the microorganisms that give our plants—and by extension us—life. It’s not rocket science. It’s soil science.

Of the 4 major factors to improve soil health, cover crops form a part of 3 of the factors: cover crops provide diversity of timing and vegetation, they keep the soil covered, and they increase the living root mass in the soil.

**Keys to Achieving a Healthy Soil**

- Minimize soil disturbance.
- Maximize diversity (plants, animals, amendments, inoculants...).
- Keep the soil covered.
- Maximize living roots.

**Integration Of Livestock On Cropland**

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**Soil Health**

The continued capacity of the soil to function as a vital living ecosystem that sustains plants, animals, and humans

- Nutrient cycling
- Water (infiltration & availability)
- Filtering and Buffering
- Physical Stability and Support
- Habitat for Biodiversity
- Microbes Mitigate 90% of these functions
Cover Crops capture as much *free* solar energy as possible

- Every plant has a solar panel that is far less expensive than an artificial solar panel.
- The more natural solar panels there are per unit area, the more efficient that land is at capturing free energy.
- Bare ground doesn’t capture any energy.
Fruit Orchard with New Zealand White Clover as a permanent ground cover. (Plant Material Center, Los Lunas, NM)

In NM, we have found soil temperature difference of about 20 degrees Fahrenheit (cover crops had lower temp. vs. bare soil)
A Sunflower, sorghum-sudan, rapeseed, turnip, radish, millet, pea, lentil @ 25 lbs/ac no-tilled into wheat stubble to feed the soil foodweb & build soil health in Montana.

Ref.: Daniel Palic, NRCS District Conservationist, CO
The Soil Health Mgt. System (SHMS) Gear (i.e. Conservation Plan), that you designed, drives the Biological, Physical & Chemical gears (i.e., components of the living soil).

The Soil Health Journey: Attaining Balance/Synergy & Understanding Your Local Context

Abiquiu Lake, NM

Physical

Biological

Chemical

Soil Health Gearbox

“I’m the ultimate driver of soil Health”

Abiquiu Lake, NM

Soil Health Gearbox

Chem.

BIO.

Phys.

SHMS

Cover Crop Challenge: must be Site-Specific and Case-by-Case to account for local conditions.

IMPORTANT! You are riding on the management decisions you’ve made. Your actions will have Productivity & Soil Health consequences.

Nambe, NM

Living Soil

(Ref.: Building Soils For Better Crops – Sustainable Soil Management 3rd Edition)
We began by developing a Soil Health Management Roadmap to Guide our decisions.

**Soil Improving Practices**
(1) Build soil carbon: Apply High Quality Compost & grow Cover Crops
(2) Precision irrigation & laser leveling
(3) Monitor Soil Conditions (lab analyses & Soil Health)
(4) Nutrient Mgt. (Manage N/P/K)

**Soil Health Planning Principles:**
1) Crop diversity
2) Living Roots
3) Cover the Soil
4) Less Disturbance

**Decrease soil-borne pests/diseases/insect pressures**
Build aggregates, feed soil food web
Reduce extremes in soil temperature; reduce evaporation
Reduce soil disturbance (i.e., Physical, Chemical, & Biological)

Diaz Pecan Orchard, NM
Cover Crops Improve Nutrient Cycling Dynamics

Soil Solution

Factors affecting nutrient cycling (availability):
- Quantity & Quality of Organic Matter inputs (C:N ratio)
- Soil Moisture content (& its pH and Salinity/SAR)
- Aeration
- Temperature

Soluble OC, ON

Dissolved O₂ & CO₂

Relative Humidity approximately 100%

CO₂ recycled by plants

Root hair

Bacteria

Fungal hyphae

Immobilization

Mineralization: the conversion of an element from an organic form to an inorganic state as a result of microbial decomposition.

Various species of fungi and bacteria can solubilize mineral elements from the mineral soil.

Free-living N-fixing Bacteria

Formation

Decomposition

Humus

Exchangeable Cations

CEC (Clay & Humus)

Surface Area

Adoption

P fixation

Dissolution

Precipitation

Irrigation Water (iw)

ECiw (TDS), SAR, pH

Precipitated Minerals

Irrigation Water is held within the pores of macro- and micro-aggregates (this water is the Soil Solution)

CO₂

O₂

Healthy Soil = a diverse SFW (i.e. above & below the soil surface)

Water-Stable Soil Aggregates

Slake Test

Minerals

Precipitated Precipitation

Dissolution

Various species of fungi and bacteria can solubilize mineral elements from the mineral soil.

Leaching to maintain salt balance

Soluble Salts

O₂ (free-living N-fixing Bacteria)

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Resource Inventory and Concerns for our SW semi-arid climate:

- On-going drought; aquifer depletion, reduction in reservoir capacity
- Needing adaptive grazing management for improving rangeland health
- Improving wildlife and restoration efforts on watersheds
- Dry cropland soils that have been eroded; with substantial decrease in yields, need soil health improvements
- Pastureland with little diversity and cover
- Dry cropland with no cover, excessive tillage and lack of diversity; need more diversity and less disturbance
- What are the economics of growing Cover Crops and water use?
- What are the benefits of inoculating seeds with mycorrhizae spores and appropriate nitrogen-fixing bacteria
- Improved irrigation systems and water management on vegetable crop production (to better conserve water, this approach must include soil health mgmt. practices)
- Water quality and salinity management; due to drought, we are seeing more incidence of salinity (need healthier soils)
- Appropriate use of soil amendments to improve soil health

Barriers Identified:

- Planting times, seed mixes, cover crop mixes: what are the details necessary for local site-specific conditions, water requirements, drought, et.
- Are cover crops taking away necessary moisture from the cash crop?
- NRCS Field Offices lack necessary demonstration tools (field equipment) and the necessary skill/training and confidence needed to sell the soil health management systems approach.
- Field Office staff feel that they need more in-depth soil health training (e.g., how to develop site-specific soil health management systems; how to properly assess the pertinent soil health indicators, in order to properly plan the most appropriate conservation practices, etc.)
- Lack of experience to share soil health information and its practical application.
- Current Field Office workload makes it difficult to commit quality time to building local Field Office technical capacity in delivering soil health information, technology.
- Lack of cost share opportunities to advance soil health.
- Field Office indicating that it is not their top priority; i.e., programs, contracting, toolkit, and other required activities use up all the employees time. Thus, difficult to give quality time to soil health activities.

NOTE: the above issues/concerns are some of the main topics addressed and does not include other valid issues/concerns/training needs that need equal attention.

The Soil Health Division is here to help advance the art and science of implementing Soil Health Mgt. Systems in our conservation planning process.
May 4, 2016  (Year 6; Biologically Enhanced Agricultural Management)

46" height (3 vetches, bell beans, field peas and Cayuse oats mix)

David C. Johnson Ph.D.  davidcjohnson@nmsu.edu  575-646-4163
Cover Crop Purpose: Build Soil Health

8-way Cover Crop Cocktail mix is quickly Improving soil structure & soil health. Fall cover crop was planted on 9/15/2010 & consisted of: red winter wheat, grain rye, triticale, winter peas, bell beans, common vetch, daikon radish and mustard mix.

57-Days of total growth before 1st major frost (Albuquerque, NM)

Photos taken on November 11, 2010
Cover Crops in Northern NM: Cover Crop mix; this field planted into Chile

Cover Crop Purpose: Suppress Weeds
(Ref./photo: Ana Gomes, NRCS NM)

The more diverse the crop rotation/cover crops, the better at managing diseases, pests and weeds.

Nambe, NM
(vegetables planted into a winter pea cover crop)

Cover Crop Termination

Terminate the cover crop before or during soil preparation for next main crop.
- At blooming- before seeds
- Wait 1-2 weeks for next crop planting after killing the cover crop.
Microbes exist in the most extreme environments possible but most agricultural soils benefit from conditions:
- Near-neutral pH
- Soil water at field capacity
- Warm soil temps (60-90F)
- Good aeration (low bulk density)
- Lots of food sources
- Array of hiding places to avoid predation
- Minimal contaminants, salts
The PLANTS Database provides standardized information about the vascular plants, mosses, liverworts, hornworts, and lichens of the U.S. and its territories.

**Plant of the Week**

*Silky Camellia*

*Swarthia malacodendron L.*

Click on the photo for a full plant profile.

**Spotlights**

- **Slide show for images**
  PLANTS now presents images in a "slide show", enabling PLANTS users to scroll through photos and line art, providing a faster and easier way to review images.

- **PLANTS has new maps**
  Plants is trying out a new, more modern mapping system. Our new system allows users to scroll side to side and zoom in and out. At higher scale zoom levels users can see county-level data.

- **2014 National Wetland Plant List**
  The wetland indicator status ratings from the 2014 National Wetland Plant List (NWPL) are now on our species profile pages and are fully searchable.

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