Farming for Success in the 21st Century: Soil Building

Scientists predict that climate change impacts on California agriculture will include less available water, drier and hotter conditions, more unpredictable and extreme weather events, and new pest and disease pressures. Building healthier soils can help growers enhance the resilience of farm operations and cope with a changing climate while improving crop yields, increasing soil water holding capacity and water infiltration rate, increasing soil fertility, and decreasing input costs.

Keeping nutrients such as carbon (C) and nitrogen (N) in balance is important for not only for healthy soils, but also for environmental protection. Microorganisms can convert C into carbon dioxide (CO_2), a greenhouse gas. Excess N can become nitrous oxide (N_2O), an even more potent greenhouse gas, or nitrate that can leach into groundwater. The presence of excess nutrients can be an indication of inefficiency in the farm system and an opportunity to reduce input costs.

Maintaining high levels of soil organic matter (SOM) is also essential for soil health. SOM consists of: (1) living microorganisms; (2) fresh and partially decomposed plant roots and residues; and (3) humus, well-decomposed and highly stable organic material.

Synthetic fertilizers deplete SOM and are linked to N_2O emissions and nitrate groundwater contamination (as is raw manure application). Alternatively, SOM levels can be increased by adding plant material (from compost, cover crops, dry manure, etc.) and/or by reducing soil disturbance to slow down the rate of SOM decomposition. Growers interested in these practices can get technical and financial support from the California Natural Resource Conservation Service.

Benefits of Soil Organic Matter (SOM)

The ability to cycle nutrients and provide 'free' fertilizer is a major benefit of building healthy soil. When microbes consume SOM they give off nutrients that are available for plant use.

Increasing SOM can:

- Increase the ability of soil to store and supply nutrients to crops
- Increase nutrient cycling and the availability of soil N to plants
- Improve water infiltration and reduce surface crusts
- Stabilize soil against erosion and reduce runoff
- Minimize soil temperature fluctuations
- Provide habitat for beneficial soil microorganisms
- Sustain or enhance soil fertility and crop productivity
- Store (or "sequester") C that could otherwise accumulate in the atmosphere as CO_2

"If I use cover crops to provide nitrogen, I don't have to buy any fertilizer. That's money in the bank."
— John Teixeira, Lone Willow Ranch, Firebaugh, CA

This is one in a series of fact sheets providing practical information on enhancing the resilience of California farms to climate change. For fact sheets or technical resources on soil building, water stewardship or biodiversity, see www.calclimateag.org.

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Soil Building Techniques

The following practices increase the amount of SOM in the soil.

Cover & Green Manure Crops – *Grasses or legumes grown in same year as cash crop, during fallow period*

Benefits

- Reduce nutrient losses, winter runoff, surface compaction
- Can suppress some weed growth
- Leguminous cover crops can substitute for some synthetic N fertilizer
- Maintain &/or increase soil C, N levels
- Cover crops can scavenge excess N & reduce N_2O emissions, nitrate leaching

Case Studies – *(from SARE's "Saving Soil Nutrients and Money with Cover Crops")*

- Well-established buckwheat stand eliminated 98% of summer weeds
- Vetch cover crop replaced 110 lbs feather meal/acre on broccoli crop, saving $500/acre
- Cover crops & no-till in Ohio corn-soybean rotation eliminated most runoff of N & P
- Forage radish can capture & hold up to 150 lbs. N/acre that stays in soil after fall harvest.

Considerations

- May need extra irrigation; can compete for moisture
- May need more tractor work to incorporate
- Could delay field entry
- Timing of incorporation is important for nutrient availability to crops
- Non-leguminous cover crops may require supplemental N after incorporation

Compost & Animal Manures

Benefits

- Increase SOM levels over a longer time period
- Higher levels of lignin & humus increase soil aggregation & help with slow release of nutrients
- Compost has relatively low levels of N in a stable form
- Manure provides readily available & slow-release N

Case Studies – *(from SARE's "Building Soils for Better Crops")*

- Over 70% of the N, 60% of the P, and 80% of the K in animal feed may end up in manure
- Soil in long-term study plots receiving manures were better aggregated, less dense & had more pore space than fields receiving no manure
- Severity of root rots and leaf diseases can be reduced with composts that have low levels of available N but still have some active organic matter

Considerations

- Manure typically provides more readily available nutrients than compost which is more decomposed
- Raw manure can cause nitrate groundwater contamination & high N_2O emissions
- Over time, high manure use can cause P & K buildup & salt damage if insufficient leaching by rainfall or irrigation

Conservation Tillage – *Practices that minimize or eliminate tillage operations (e.g., disking, plowing, ripping)*

Benefits

- Conserve SOM & improve soil structure
- Reduce soil compaction and erosion
- Reduce fuel use, labor, wear on machinery
- Good match for subsurface drip irrigation & overhead sprinklers
- Lower CO_2, dust, particulate emissions from reduced tractor use
- Combined with cover crops, can reduce N_2O emissions & sequester C in soil

Case Studies

From UC Conservation Agriculture Systems Innovation:

- Conservation tillage in Central Valley tomatoes led to profit increase of $736/acre

From the Conservation Technology Innovation Center:

- Fuel savings = average 3.5 gallons/acre
- Machinery wear & maintenance savings = estimated $5/acre
- Soil erosion can be reduced by up to 90%

Considerations

- Residues may interfere with furrow irrigation
- Higher rates of N may be required initially
- Placing fertilizer below surface residue can help avoid immobilization of N by soil microbes
- Effect of no-till on N_2O emissions over time varies depending on soil, moisture conditions