Managing Risks in Organic Production through Soil Health Practices

eOrganic Soil Health and Risk Management Webinar
February 6, 2019

Developed and presented by Organic Farming Research Foundation, with funding from USDA Risk Management Agency

Presentation notes

Slide 1 – *Title Slide*

Slide 2 – *Farming is Risky!*

These are some of the production risks that all farmers face. Leading causes of yield losses include too little or too much rainfall, other weather adversities, inadequate crop nutrition, and the terrible trio of weeds, pests, and diseases. However, perhaps the greatest risk of all is the loss of the farm's working capital: healthy, fertile soil.

Another set of risks is water quality impacts – nutrient runoff and leaching, sedimentation, etc – which can affect farm family health and could potentially lead to strained community relations or environmental regulatory action.

Getting crops established is the season's first and often most worrisome hurdle. Poor seed quality, delays in planting (often wet conditions at planting time), soil crusting or poor tilth that hinders crop emergence, or unfavorable early season conditions can all result in a poor stand and hurt yields.

In addition to these direct threats to crop production, any decline in the farm's natural capital – healthy, fertile, soil – poses an overarching risk that can be less obvious but more costly in the long run. Farmers often work cropland soils hard in the daily struggle of making ends meet financially. Compaction, declining organic matter and soil life, and decreased fertility can gradually and silently undermine production potential.

Soil erosion is perhaps the greatest production risk of all. While hail destroys the current crop, and problems like soil compaction or low fertility can take a few years to correct, it takes Nature some 500 years to replace an inch of topsoil lost to wind or water erosion.

Slide 3 – *Climate change will increase risks*

In addition to intensifying weather extremes, especially drought, heat, and flood, changing climate will cause pest and disease life cycles to shift and weed competition to intensify. An unprecedented 7-inch rain on Sept 29, 2015 sent this small creek near Floyd, VA over its banks and across fertile bottomland crop fields. That same year, prolonged drought resulted in accelerated drydown and substantial yield reductions in this Pennsylvania field corn crop.

During 2013-2016, the most common causes of crop insurance indemnity payments to New York farmers resulted from drought or excessive rainfall.

Impacts and Opportunities of Climate Change on Northeast Crops and Livestock, part 1. Webinar delivered through the USDA Northeast Climate Hub on November 27, 2018.

Slide 4 – *Production risks in organic farming*

The organic farming approach, which excludes synthetic fertilizers, herbicides, and other inputs, and emphasizes soil building, may increase certain risks and mitigate others. Since the farmer cannot "fall back" on these inputs to mitigate weed, pest, or other production risks, organic is an inherently knowledge-intensive and management-intensive system, which makes for a longer learning curve to become a successful organic producer.

Organic producers most often cite nitrogen limitation and weed pressure as leading risks in crop production.

One major challenge that organic producers face is predicting and managing the release of plant-available nutrients from organic sources, especially ensuring sufficient and timely plant available nitrogen (PAN) to sustain yields. Organic crop yields are often N limited, and efforts to compensate by increasing application rates of compost and manure commonly build up excessive levels of P and sometimes other nutrients in the soil.

Another big challenge for organic farmers is managing weeds without herbicides and at the same time minimizing impacts of tillage and cultivation on soil health.

Other risks specific to organic systems include managing pests and diseases without synthetic crop protection chemicals, and the higher costs of NOP allowed nutrient sources, pest controls, and other inputs, compared to conventional inputs.

Organic crop yields average about 20% lower than conventional yields, especially for corn, cereal grains, and other commodity crops which have historically been extensively researched, bred, and selected for high input conventional systems. Since 2002, the USDA Organic Research and Extension Initiative (OREI) and Organic Transitions Program (ORG), and competitive grants programs offered by Organic Farming Research Foundation (OFRF) and other nonprofits have begun to address key research priorities, yet nationwide investments in organic agriculture still lag behind the 5% market share for organic foods.

Slide 5 – *Risk-mitigating factors in organic farming*

In addition, organic farmers do not have to worry about weeds developing resistance to herbicides. Insects can evolve resistance to both synthetic and NOP-allowed botanical or microbial pesticides – however, good organic IPM in which these materials are used only when absolutely necessary, and as one of many tactics within an integrated strategy, will minimize this risk.

Slide 6 – *Risk factors during organic transition*

Many fields undergoing transition to organic production may have soil health problems related to a history of conventional crop production, overgrazing or extractive hay harvest (which can "mine" P and K reserves to a state of depletion), or outright neglect (such as an urban farm established on abandoned city lot). Yields during transition are often markedly lower than in the preceding years with conventional inputs, and then gradually recover during 5 to 10 years under best organic management. Low yields without organic price premiums make the three year transition period highly risky, and too many farms either go under financially or give up on organic during this period.

N deficiency and weed pressure are especially common problems during organic transition.

Slide 7 – *Managing risk during transition*

Beginning farmers, and farmers new to organic methods can substantially reduce their risk by working with a mentor, consultant, or farmer to farmer learning network; attending sustainable agricultural conferences, and utilizing on-line resources at Organic Farming Research Foundation, eOrganic, National Sustainable Agriculture Information Service (ATTRA), Extension, etc.

The full URL for the newsletter issue cited above is: https://attra.ncat.org/newsletter/pdf/ATTRAnews_Nov-Dec06.pdf.

Transitioning gradually to organic can minimize risks related to the yield dip and learning curve during transition. If some fields have been successfully transitioned to certified organic and are producing good yields and earning organic price premiums, they can ease the farm over the transition period for additional fields.

However, one additional cost incurred on farms that are partly certified organic and partly conventional or in transition, is the labor and infrastructure required to keep the two product streams separate as required by NOP. Such a "split operation" may be easiest to manage if organic and non-organic production are taking place in separate locations, or produce different commodities.

During the transition, concentrate on restoring soil health and reducing weed populations as much as practical within the farm's cash flow constraints.

Slide 8 – *Subtitle – how healthy soil reduced risk*

Slide 9 – *How healthy soil reduces risk: physical properties*

The loose, crumbly structure of healthy soil makes it both easier to work (requiring less intensive tillage to prepare seedbeds, plant crops, and manage weeds) and more resilient to the negative effects of tillage as well as torrential rains and other weather extremes. Soil coverage (crops, residues), plant roots, beneficial soil organisms, and both active and stable organic matter all contribute to good physical soil condition, and thereby reduces costs of production as well as risks of soil loss, planting delays, and crop establishment failures.

Reduced need for tillage in turn reduces future stresses on the soil and helps maintain soil health.

Slide 10 – *How healthy soil reduces risk: plant-available water*

In addition to increased topsoil water holding capacity, healthy soil with a deep, open profile further enhances plant-available water by allowing full development of crop root systems that can access subsurface moisture reserves.

In irrigated systems, improving soil health reduces both frequency of irrigation and total amount of water needed to produce the crop, thereby reducing irrigation costs, which can be substantial, especially in water limited regions such as California.

Slide 11 – *Drought resilience and yield stability*

In the Long Term Farming Systems Trials at Rodale Institute, rain infiltration into the organic systems averaged 15-20% greater than in the conventional systems, resulting in less runoff and erosion. In addition, the soil profile held considerably more plant-available moisture in the organic system, which led to the difference in crop health seen here. While average yields

(over the 35 years of the trials) have been similar for organic and conventional systems, organic yields in two drought years (1995 and 2012), exceeded conventional yields by 30%.
Farming Systems Trial Brochure. Summary after 35 years. 2015, 2 pp.
http://rodaleinstitute.org/assets/FST-Brochure-2015.pdf.
The Farming Systems Trial, Celebrating 30 Years. 2011, 21 pp.
http://rodaleinstitute.org/assets/FSTbookletFINAL.pdf.

Slide 12 – *How healthy soil reduces risk: crop nutrients*

As soil life converts plant residues, manure, and other organic inputs into active and stable organic matter, most of the nitrogen, phosphorus, and sulfur in the residues become integral parts of the organic matter, and are slow-released to plants through further action of soil organisms on the active fraction. Potassium, calcium, magnesium, and sodium are released from residues into the soil as soluble cations. Negative charges on stable organic matter contribute to the soil's *cation exchange capacity* – its ability to adsorb and hold the cations in a plant-available yet not readily leachable form.

In addition, soil minerals hold large nutrient reserves, particularly potassium (K), other cations, and micronutrients, which are gradually brought into the exchangeable (plant available) pools through the action of soil life and plant roots on the mineral component of the soil (biological weathering).

The capacity of the soil life to provide for crop nutrition through these processes is a key attribute of healthy agricultural soils. One notable aspect of soil health and plant nutrition is the depth of plant root accessible profile. While biological activity is slower at depths below 6 – 12 inches, plant roots and their associated microbiomes can grow as deep as five feet or more, retrieving leached nutrients (N, S, sometimes others), and accessing K and other nutrients from soil mineral reserves.

Slide 13 – "Living soil changes everything"

Fertilizer trials were conducted over a five year period with a corn-soy-wheat rotation with high biomass winter cover crops on an Orangeburg loamy sand soil in the coastal plain of South Carolina that initially tested sufficient in P and K. Full crop yields were sustained regardless of whether P or K were added.

Dr. Kloot noted that most soils, especially southeastern US coastal plain soils, have large subsoil K reserves that cover crop roots readily retrieve. This may explain the stable soil test K despite significant net withdrawals through harvest.

In a 2018 webinar, Dr. Kloot cited several farmers in a diversity of locations (NC, ND, IL, OH) who have greatly reduced fertilizer inputs and maintained high grain yields by building soil health with high biomass cover crops.

Kloot, Robin. 2017. *Rethinking P and K fertility in coastal plain soils.* Presentation at the 2017 Organic Agriculture Research Symposium, Lexington, KY, January 26, 2017.

Kloot, Robin. 2018. *Using adaptive nutrient management to answer "how much fertilizer do you actually need?"* NRCS webinar May 8, 2018. Science and Technology Training Library, http://www.conservationwebinars.net/listArchivedWebinars.

Slide 14 – Nitrogen dynamics in organic tomato fields

In a study of 13 organically managed tomato fields in central California, researchers at UC Santa Cruz identified three distinct patterns of nitrogen (N) cycling, plant nutrition, and yield.

In two fields, tomato yields were limited by insufficient plant-available N. The soils were relatively low in both active and total SOM and organic N. Fields received manure pre-plant (poor timing relative to crop demand), which did not release plant-available N when it was most needed later in the season.

Four fields with tightly coupled N cycling had higher levels of active and total SOM (1.5 X and 2X the N deficient fields, respectively). While crops received some in-row soluble N as fish emulsion or Chilean sodium nitrate, the bulk soil was amended with a yard waste compost with a moderate C:N ratio (15-18:1) that helped build SOM and released N slowly.

N saturated fields (seven) were amended with low C:N organic materials such as guano, poultry litter fertilizer, and all-legume cover crops. Their active and total SOM levels were intermediate between N-deficient and tightly coupled fields.

The researchers concluded that using a diversity of organic inputs with a range of C:N ratios (low to high) can promote tighter N cycling and overall soil health, thereby reducing risks of both N limitation and N leaching losses.

Bowles, T. M., A. D. Hollander, K. Steenwerth, and L. E. Jackson. 2015. *Tightly-Coupled Plant-Soil Nitrogen Cycling: Comparison of Organic Farms across an Agricultural Landscape*. PLOS ONE peer-reviewed research article. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0131888. Numerous other articles available at http://ucanr.edu/sites/Jackson_Lab/.

Jackson, L. 2013. *Researcher and Farmer Innovation to Increase Nutrient Cycling on Organic Farms.* Proposal and final report for OREI project 2009-01415. CRIS Abstracts.

Jackson, L. and T. Bowles. 2013. *Researcher and Farmer Innovation to Increase Nitrogen Cycling on Organic Farms* (Webinar). http://articles.extension.org/pages/67391/researcher-and-farmer-innovation-to-increase-nitrogen-cycling-on-organic-farms-webinar.

Slide 15 – *How healthy soils reduce risk: soil life*

Beneficial soil organisms enhance crop resilience by facilitating nutrient and moisture uptake and protecting plants from pathogens. While pathogens and root-feeding nematodes can be found in healthy soil, they are greatly outnumbered by beneficial organisms that perform these vital functions for crop health, and can also help stabilize soil organic matter (sequester carbon).

Soil microbial biomass and function played a central role in N cycling patterns in the UC Santa Cruz tomato study cited in the preceding slide. Microbial biomass was relatively low in the N-deficient fields, and contributed to the insufficiency of plant-available N when it was most needed. Both N-saturated and tightly-coupled fields had about twice the microbial biomass as the deficient fields. However, while the tightly coupled fields had high level of microbial enzymes involved in N mineralization in the immediate root zone of the crop, N-saturated fields had more enzyme activity associated with SOM breakdown and less activity related to N mineralization. In addition to microbial function, at least one plant root enzyme involved in crop N use efficiency showed enhanced activity in the tightly coupled fields.

UC Davis researcher Louise Jackson states in her 2013 report: "Since genetic pathways regulating N uptake are highly conserved across plant species, studies on these N metabolism genes in a model plant such as tomato are highly relevant to other crops."

Slide 16 – *Plant-soil-microbe partnerships*

Many crops, including legumes, cereal grains, tree and small fruits, and vegetables in the allium (onion), solanaceous (tomato), and cucurbit families form strong associations with arbuscular mycorrhizal fungi (AMF). These fungi grow both within root tissue and out into the soil, thereby greatly expanding the "reach" and efficacy of the root system, making N, P, and micronutrients more available from soil minerals and organic matter, enhancing moisture uptake, and deterring soilborne pathogens. Thus AMF can play a key role in risk reduction.

Nitrogen fixation through the legume-*Rhizobium* symbiosis is perhaps the most widely known and utilized plant-microbe partnership. In addition, corn, pearl millet, and some other grains can meet some of their N requirement through N fixation by *Azotobacter, Azaspirillum*, and other "free living" soil N fixing microbes proliferating in their root zones.

In addition to suppressing root pathogens through direct competition for rhizosphere space or by direct antagonism, antibiosis, or predation, some beneficial soil microbes protect plants from *foliar* diseases through a plant immune system response called Induced Systemic Resistance (ISR). *Trichoderma harzianum* fungi in the root zone of tomato show potential to protect the crop from late blight (*Phytophthora infestans*) and gray mold (*Botrytis cinerea*) through ISR. Several soil organisms, including some strains of *Pseudomonas* bacteria, have been identified as carrot root endophytes (growing within the root tissue) that enhance carrot growth and protect the crop against a major foliar disease, *Alterneria dauci* leaf blight.

In order to realize the full potential for beneficial plant-soil-microbe partnerships, the desired organisms must be present and active. Healthy soil provides sufficient "food" – active SOM, and the living roots and residues of a diversity of plants – to sustain the desired microbial community. Moderate (non-excessive) levels of plant available N and P promote plant partnership with mycorrhizal fungi and N fixing microbes, while very high nutrient levels render these organisms dormant, making crops less resilient and more dependent on fertility inputs.

Different crop cultivars and breeding lines show contrasting capacities for beneficial microbial interactions, which indicates that plant breeding can play an important role in crop resilience and risk reduction in organic production.

Silva, E. 2016. OFRF project summary. https://ofrf.org/research/grants/creating-climate-resilient-organic-systems-enhancing-arbuscular-mycorrhizal-fungi.

Abdelrazek, S., and L. A. Hoagland. 2017. *Potential functional role of carrot endophyte communities*. Tri-Societies Meetings, Tampa, FL, October, 2017.

Goldstein, W. 2015. *Breeding corn for organic farmers with improved N efficiency/N fixation, and protein quality*. Proceedings of the Organic Agriculture Research Symposium, LaCrosse, WI February 25-26, 2015. http://eorganic.info/node/12972.

Goldstein, W. 2018. *High Methionine, N Efficient Field Corn from the Mandarin Institute/ Nokomis Gold Seed Co.* Proceedings of the 9th Organic Seed Growers Conference, Feb 14-17, 2018, Corvallis OR, pp 25-26. https://seedalliance.org/all-publications/.

Hamel, C. 2004. *Impact of arbuscular mycorrhizal fungi on N and P cycling in the root zon*e. Can J Soil Sci. 84(4):383-395.

Zubieta, L. and L. A. Hoagland. 2017. *Effect of Domestication on Plant Biomass and Induced Systemic Resistance in Tomato (Solanum lycopersicum L.).*
Poster Number 1209, Tri-Societies Meetings, Tampa, FL, Oct 24, 2017.

Slide 17 – *Subtitle – soil health and risk reduction – challenges and opportunities*

Slide 18 – *The journey to soil health: NRCS Four Principles*

The NRCS principles of soil health provide a roadmap for cropland soil management. Research has abundantly validated these four principles as guidelines for building SOM, sequestering carbon, and developing healthy, resilient soils for long term system sustainability and risk reduction.

Slide 19 – *The journey to soil health: investments and risks*

While *optimum soil health* in itself generally reduces production costs and risks, *management practices adopted to improve soil health* can add new costs and risks as well as benefits, especially for organic producers. These include:

- Direct costs for seeds, amendments, fuel, and labor'; and potentially capital investment in new equipment such as roller crimper or new planting or harvest equipment for new cover or cash crops.
- The learning curve associated with new practices or systems requiring new skills, and management of more complex systems
- Income foregone by rotating out of production crops into cover crops or perennial sod crops to restore the soil.
- Potential tradeoffs between soil health and maximum crop yield, especially in the short term.

Slide 20 – *National Organic Standard require investment in soil health*

Text on slide is excerpted and paraphrased from the Soil Fertility and Crop Nutrient Management Practice Standard (Section 205.203), and the Crop Rotation Practice Standard (Section 205.205) of the National Organic Program Final Rule.

Slides 21 and 22 – *Cover crops*

Cover crops offer tremendous benefits and exemplify three of the four NRCS principles – soil coverage, living root, and diversified rotation. However, effective cover cropping requires skill, and cover crop species selection and management practices require site-specific considerations.

Slide 23 – *Diversified crop rotation*

Even when crop intensity (average annual plant biomass production, percentage of the year in living cover) is unchanged, adding one or two new crops to a low diversity rotation has been found to enhance active and total SOM and soil food web functional diversity, which in turn improve overall system resilience and sometimes crop yields.

One challenge in a diversified rotation is to develop and maintain profitable markets for each of the production crops individually and for the rotation as a whole. Another is the need to acquire needed skills, equipment, and infrastructure to produce the additional crops and bring them to market.

Slide 24 – *Sod phase in crop rotation*

Multiple studies show that adding a 1 – 3 year perennial sod phase to annual crop rotations can be especially effective for restoring soil organic matter, tilth, and fertility, and for reducing annual weed pressures in subsequent cash crops. The greatest constraint on this practice is the income foregone by rotating fields out of high value cash crops; the grazing option can offest this cost in crop-livestock integrated farming systems. In addition, vigorous tillage is usually needed to terminate the sod for transition back to annual crop production; and sod crops may regrow if organic reduced tillage is attempted during the first year of cropping after sod. Soil moisture consumption by the sod crop can be a concern in limited-rainfall regions.

Slide 25 – *No-till planting in rolled cover crop*

Organic rotational no-till systems, in which cover crops are terminated by roll-crimping or mowing, followed by no-till planting of cash crops, address all four NRCS soil health principles and usually give the best soil health outcomes in comparative farming system trials (better than either organic with tillage or conventional no-till). However yield tradeoffs are often severe, especially in colder climates and shorter growing seasons of the northern half of the US, where corn and cereal grain yields may be 63% lower and soybean yields 30% lower than in tilled systems. Planting delays, problems with planting through roll-crimped crop residue resulting inadequate seed-soil contact and poor stands, delayed N mineralization, and increased perennial weed pressure all contribute to the yield losses.

Barbercheck, M. E., D. A. Mortensen, H. Karsten, E. S. Sanchez, S. W. Duiker, J. A. Hyde, and N. E. Kiernan. 2008. *Organic Weed Management: Balancing Pest Management and Soil Quality in a Transitional System.* Final report on ORG project 2003-04619. CRIS Abstracts.

Caldwell, B., J. Liebert, and M. Ryan. 2016. *On-Farm Organic No-Till Planted Soybean in Rolled Cover Crop Mulch*. What's Cropping Up Blog vol 26, no. 5 (Sept-Oct, 2016). http://blogs.cornell.edu/whatscroppingup/2016/09/29/on-farm-organic-no-till-planted-soybean-in-rolled-cover-crop-mulch/.

Delate, K. 2013. *Developing Carbon-positive Organic Systems through Reduced Tillage and Cover Crop Intensive Crop Rotation Schemes.* Final report for ORG project 2008-01284. CRIS Abstracts.

Delate, K., C. Cambardella, and C. Chase. 2015. *Effects of cover crops, soil amendments, and reduced tillage on Carbon Sequestration and Soil Health in a Long Term Vegetable System.* Final report for ORG project 2010-03956. CRIS Abstracts.

Reinbott, T. 2015 .*Identification of factors affecting carbon sequestration and nitrous oxide emissions in 3 organic cropping systems*. Final report on ORG project 2011-04958. CRIS Abstracts.

Shapiro, C. 2013. *Organic Farming Systems Research at the University of Nebraska, Part 2 Nutrient Management in Organic Systems* (Webinar). http://articles.extension.org/pages/67368/organic-farming-systems-research-at-the-university-of-nebraska.

Silva, E. 2015. *Implementing cover crop-based reduced tillage in small scale organic vegetable production*. 2015 Organic Agriculture Research Symposium, recording at http://eorganic.info/node/12972.

Slide 26 – Organic no-till success

This example is from a trial at Virginia Tech, near Blacksburg, VA.

Slide 27 – *Bare soil is at risk!*

The costs, complexities, and risks associated with adding soil building crops and reducing tillage can deter farmer adoption. However, it takes nature 50 years to build *one tenth of an inch* of new topsoil … and one untimely downpour or windstorm on unprotected soil to take that much away.

Even when surface residues left by no-till practices are sufficient to check erosion, organic matter may decline during fallow. Without daily inputs of plant root exudates, the soil life loses its primary source of nourishment, and key organisms go dormant or die out. Without the "green bridge" provided by legume and grain cover crops, mycorrhizal fungal populations decline sharply in rotations consisting of warm season annual crops and winter fallows.

Slide 28 – *The soil test paradox*

The soil test is a double edged sword. Not having it done increases production risks, yet taking the report and recommendations too literally can increase costs and risks as well.
The standard soil test provides essential information, and can help identify pH issues (need for lime), and potential nutrient deficiencies ("low" or "very low" ratings), surpluses ("very high") or imbalances. For example, a depleted soil poor in organic matter and biological activity may be very low in P and K, or very high, depending on field history – these two scenarios require different restoration strategies.

In this example from an organic vegetable farm in Floyd County, VA, the soil test indicates ideal pH, a "high" level of phosphorus (considered optimum, with low probability of crop yield response to added fertilizer P, a "very high" level of potassium (ample, little chance of crop response, possibly excessive), a low boron (B) level of 0.4 ppm, and sufficient levels of all other nutrients (not shown). Low B can affect tomato yield or quality, and a boron supplement is warranted.

Soil tests can also be misleading. Both lab procedures and interpretation protocols (what constitutes low, sufficient, or surplus levels of each nutrient) have been developed for conventional production systems, based on research in soils managed with synthetic fertilizers. Nutrient dynamics in biologically active, organically managed soils can be significantly different, providing sufficient nutrients to crops even when soil test levels are "low."

In this example, the lab recommended 100 lb phosphate (44 lb elemental P) and 50 lb potash (42 lb elemental K) for tomato, as well as 90 lb N (a standard recommendation for tomato independent of soil test report, which does not include soluble N). Historically, these "maintenance" applications have been considered essential for replenishing nutrients harvested off or lost to leaching or immobilization (tieup in soil minerals or organic matter) and sustaining long term productivity. However, with a low probability of any crop need for, or response to, the P and K, their application at this time may be an unneeded expense that adds to risks of a negative cash flow. In addition, "very high" nutrient levels can present risks to soil, crop, and livestock health; for example, excessive soil P deters mycorrhizal fungi, and excessive K can promote blossom end rot in tomato and grass tetany in grazing livestock.

Several factors contribute to higher NPK recommendations than is actually needed in healthy soil. The biggest is that the role of soil life has historically been ignored in estimating crop access to nutrients – an omission that is now being corrected as the roles of soil life and soil health become widely embraced by mainstream agricultural professionals, especially NRCS and Extension. Second, soil tests measure only the top six inches of soil, while plant roots typically extend 2 to 5 feet down. Soil is assumed to be "leaky" (which is true for depleted soil, less so for healthy soil), and the potential for deep rooted crops to retrieve nutrients is also ignored.

Slide 29 – *Compost and manure*

Comparative responses of crops (field corn, kale) and weeds (lambsquarters, Powell amaranth, common ragweed, foxtails) to composted poultry litter (5-4-3 analysis) shown in the diagram were documented in organic vegetable and field cropping systems trials at Cornell University by by Dr. Charles Mohler and colleagues. In these trials, high poultry litter compost rates stimulated <u>more</u> weed growth than equivalent amounts of N (feather meal) or K (potassium sulfate), which suggests that weeds were responding to all three major nutrients in the high analysis compost.

Tilling-in an all-legume cover crop can stimulate a flush N responder weeds.

Note that the majority of crops form strong, beneficial arbuscular mycorrhizal fungal (AMF) associations that assist nutrient and moisture uptake and reduce soilborne crop diseases (exceptions: brassica family, beet-spinach family, and buckwheat), while many agricultural weeds – including pigweeds, lambsquarters, smartweeds, wild mustard, and nutsedges – do not benefit from AMF. As noted earlier, the P excesses that can accrue with regular use of manure and compost may deter AMF activity, thereby eliminating this crop advantage over weeds.

Strong N fixers like soybean can gain an edge over N-responsive weeds when plant available soil N is low.

Uncomposted or cool-composted (<130 F) manure can pose food safety risks. The NOP-required 120 day interval between manure application and food crop harvest is a good guideline for all farms to minimize this risk.

Clark, K. 2016. *Organic weed management systems for Missouri.* Proposal and progress report on OREI project 2014-05341. CRIS Abstracts.*

Cornell University, 2005. *Organic Cropping Systems Project: Compost Experiment*. Protocol at http://www.hort.cornell.edu/extension/organic/ocs/compost/index.html. Results summary at http://www.hort.cornell.edu/extension/organic/ocs/compost/pdfs/20042005results.pdf.

Little, N., C. Mohler, A. DiTommaso, and Q. Ketterings. *Partitioning the Effects of Nutrients from Composted Manure on Weeds and Crops: A Step Toward Integrated Crop-Weed Management*. In Northeast Organic Farming Association of New York, 2012, *Northeast Organic Research Symposium Proceedings*, pp 46-47.

Mohler, C, T. Bjorkman, and A. DiTommaso. 2008. *Control of weed size by compost application rate in an organic cropping system.* Weed Science Society of America 2008 Proceedings, Presentation No. 261.

Slide 30 – *Nutrient strategies and risks*

One of the greatest challenges in organic production is “translating” conventional soil test reports and recommendations into organic, and determining how much added N, P, and K is actually needed. Compared to conventionally managed fields, nutrient dynamics are very different for organic nutrient sources and in biologically active, organically managed soils. Thus, organic producers face risks related both to insufficient nutrient applications (especially early in process of soil restoration), and excessive or unnecessary applications (especially in healthy, fertile soils).

Some common pitfalls are:

- Assuming that the organic principle of "feeding the soil" will meet all of the crop's nutrient needs without fertilizer. This approach commonly results in low, N-limited yields, especially if soil health is not yet optimal.
- "Input substitution" – trying to get the nutrients recommended on a standard soil test from NOP allowed sources calibrating rates based on N, P, and/or K content. The organic fertilizers are more expensive, and may or may not pay for themselves in increased marketable yields.
- Using compost or manure to meet crop N needs is likely to build up excess P, especially if rates are based on "available N" (estimated at 10-25% of total compost N, and 50% of total manure N). The surplus P could, in turn compromise the soil's capacity to deliver nutrients to crops by rendering AMF community dormant and nonfunctional. This can in turn increase the need for applied nutrient in future seasons.

Recent research indicates that crops often need less N, P, and K than recommended by private or Extension soil labs. The costs to farm profits, soil health, and water quality of overapplying N and P are widely known. In a review of multiple long term field trials, Khan and colleagues at University of Illinois found that exchangeable K levels (soil test K) does not clearly indicate crop need for this nutrient. In many soils, exchangeable K levels remain stable for years or decades, even when K inputs are considerably less than K removal by crop harvests. Higher K application rates often do not improve crop yield, and rates exceeding K removal can adversely affect soil, crop, and livestock health. These findings have led some researchers to question whether even replacement rates of K might incur more costs than benefits for many farmers.

Khan, S. A., R. L. Mulvaney, and T. R. Ellsworth. 2013. *The potassium paradox: implications for soil fertility, crop production, and human health.* Renewable Agriculture and Food Systems: doi:10.1017/S1742170513000318. 25 pp.

The balance sheet approach aims to replenish the nutrients actually removed in harvest. Nutrient use patterns differ among grain, forage, and horticultural crops, with the greatest potential for P and K depletion with repeated hay harvests without sufficient fertility inputs. Hay field soils often show good SOM and physical properties, but extremely low soil test P and K. Grazing the same forages results in far less nutrient depletion, as nutrient are returned in dung and urine. Vegetable crops are considered "heavy feeders" yet remove much less NPK than forages; thus intensive organic vegetable production can build up nutrient excesses, especially P. Grain harvests remove little K relative to N and P, because most of the K remains in straw or stover, and normally returns to the soil. Crop rotations that include all three crop types can help balance nutrient flows, especially in crop-livestock integrated systems.

The rough estimates of typical nutrient removals by the three crop types are based on the following information resources:

- Wander, M., 2015. *Nutrient Budgeting Basics for Organic Systems.* https://articles.extension.org/pages/18794/nutrient-budget-basics-for-organic-farming-systems.
- Dunne, L., 1990. *Nutrition Almanac, 3rd Edition.* This reference gives nutrient concentrations in the edible portions of food crops.
- Virginia Tech Extension bulletins with estimates of nutrient removals by grain and forage crops.

At least some of the N harvested off can be replenished through N fixation by the legume-Rhizobium symbiosis and by free living / rhizosphere N fixing bacteria. In organic production, the challenge with P in intensive organic production is not to overshoot, as shown by the figures for nutrients added in compost and poultry litter fertilizer.

"Maintenance" applications recommended for a "high" soil test often exceed actual replacement rates, especially for P. For example, in its *2018 Mid-Atlantic Commercial Vegetable Production Recommendations*. (https://www.soiltest.vt.edu/Files/handbooks.html), Virginia Extension recommends 50 – 100 lb/ac each phosphate (P_2O_5 = 22 – 44 lb elemental P) and potash (K_2O = 42 – 83 lb elemental K) in soils testing "high" (optimum – no crop response expected) – applications that simply cost money and may accrue nutrient excesses..

Based on these findings and a growing understanding of the role of soil life and soil health in crop nutrition, Oregon State Extension now recommends no P or K application on vegetable crops in soils testing high in these nutrients. N recommendations have also been reduced to take more complete account of N provided by legumes, manure and compost inputs, N mineralization from active organic matter, and even dissolved nitrate-N in irrigation water.

Oregon State U. Extension bulletin EM 9165, *Nutrient Management for Sustainable Vegetable Cropping Systems in Western Oregon*, by D.M. Sullivan, E. Peachey, A.L. Heinrich, and L.J. Brewer, May, 2017.

Pacific Northwest Extension bulletin PNW 646, *Soil Fertility in Organic Systems: A Guide for Gardeners and Small Acreage Farmers*, by Doug Collins, Carol Miles, Craig Cogger, and Rich Koenig, 2013.

Slide 31 – *The organic input smorgasbord*

Lime or sulfur may be needed to correct soil pH, and specific micronutrient supplements may be essential (based on soil and foliar tests – see boron example above). Research has indicated both fertilizer value and more subtle (microbial) benefits from worm castings.

In addition to nutrient sources, today's input catalogues for organic producers offer a dizzying array of special products claimed to build SOM, soil health and fertility; enhance crop resilience, yield and quality; and/or directly fight plant pathogens or pests. These include biochar, humates and other organic amendments, and microbial preparations including specific biofungicies, compost teas, biodynamic preparations, bokashi, effective micro-organisms (EM), mycorrhizal inoculants, and special mixtures of specific microbes claimed to enhance overall soil food web function. The efficacy of *Rhizobium* inoculants applied to legume seeds at planting in ensuring effective N fixation has been well established, and some studies have shown benefits of mycorrhizal fungal inoculants applied to host crop root balls or seeds. However, research results with most other microbial products and soil conditioners have been inconclusive

A research team at Ohio State University is testing a range of microbial biostimulant and biofertilizer products in organic production of various crops, and has thus far not documented significant benefits from any of the products. The indigenous soil biota usually outcompetes and neutralizes applied inoculants, especially in healthy, biologically active soils under sound organic management.

The greatest risk from this "organic amendment smorgasbord" lies in the cost of purchase, which may not be repaid in increased crop yield or marketability or reduction in other production costs. Most of these materials are relatively harmless to soil and water resources.

Try them out in a side by side comparison trial to see if they confer production benefits that justify the cost and labor of application.

Kleinhenz, M. 2018. *Assessing the Influence of Microbe-containing Crop Biostimulants on Vegetable Crops and Farms through On-station and On-farm Study*. Presentation at Annual Meetings of the American Society for Horticultural Science; Aug 1, 2018; Washington, D.C.

Slide 32 – *Subtitle Reducing risk through soil health management – practical steps and resources*

Slide 33 – *Step 1: Assess the farm's soil resources*

The soil survey provides valuable information on inherent soil properties – what nature has given the farmer. These properties include texture, depth, drainage, slope, mineralogy, and soil profile features such as naturally occurring hard layers. Understanding these inherent properties can inform best management of soil health and production risks

Be sure to look at soil tests through the lens of soil as a *living system*. Even a depleted soil is alive, though its vitality is below par so that crops may need more fertility inputs to thrive and yield until soil is restored. Consider the soil test report in the context of field observations, crop foliar analysis, soil survey information, and (if performed) soil health evaluations.

The foliar analysis can be helpful in revealing what the crop actually "sees", which can differ greatly from what the soil test report indicates, depending on soil biology, depth of root-accessible soil profile, etc. The crop foliar analysis can be valuable for identifying causes of below-par crop performance, and detecting subtle deficiencies or imbalances ("hidden hunger") that are not yet visible but need to be corrected to maintain yield and quality..

Soil health tests include the Solvita respiration test (microbial activity), permanganate oxidizable carbon (active SOM), aggregation (structure), and composite soil health scores based on several parameters, such as the Cornel Comprehensive Assessment of Soil Health (CASH). Interpretation of data from these tests is soil- and site-specific, and can be tricky. Over the past year, NRCS has worked with a network of soil scientists to develop standardized lab procedures for active and total SOM, mineralizable organic N, aggregation, microbial activity and microbial community functional diversity – an endeavor that can enhance availability and utility of these measures.

Slide 34 – *NRCS Soil Survey: land capability*

Land capability classes and soil series descriptions outline the inherent strengths and constraints of different soils. Land capability class 1 is best – few constraints on crop production; 2 indicates moderate constraints but can sustain excellent production if managed with care. Classes 3 and 4 impose more severe constraints and require diligent conservation to maintain productivity and protect the soil resource. The letter *e* indicates risk of erosion, related primarily to slope and also soil texture and structure; *s* indicates shallowness or stoniness that limits fertility and moisture reserves; *w* indicates wet conditions. Land capability classes 5 through 8 are unsuitable for crop production.

Slide 35 – *Step 2: Review your practices*

A quick overview of your production system and its key components, strengths, and weaknesses can often reveal easy, low-cost steps you can take to improve soil health and/or reduce risks.

Slide 36 – *Step 3: Build a resilient production system for your site*

Just as it takes time to build soil health, it takes time to build a site-appropriate, profitable, risk-resilient organic farming system. More than one farm has “gone under” by trying to launch too many new enterprises, or to adopt too many new practices at once.

For example, if a farm is not using cover crops and has a low-diversity rotation, it is probably too much to add two new enterprises, several cover crops, and no-till cover crop termination and cash crop planting all at once. Keep the learning curve manageable – add the cover crops first, then gear-up for trying rotational no-till or reduced till in a future season.

It is also advisable to try things out first on a small scale, and test a new cover crop, amendment, or management practice in a side by side comparison with current practice. Gradually scale-up promising practices year to year, and conduct a budget analysis to ensure new costs are sufficiently offset by savings, improved production, and long term soil health benefits.

Slide 37 – *Step 4: Defray costs*

NRCS working lands program – including Environmental Quality Incentives Program (EQIP), EQIP Organic Initiative, Conservation Stewardship Program (CSP), and Regional Conservation Partnership Program (RCPP) – offer financial assistance to defray some of the up front costs of practices to build soil health and agricultural resilience (yield stability, etc), and technical assistance to help farmers identify and implement the best practices for their farm. EQIP offers cost-share for newly adopted basic soil health practices like cover cropping and conservation tillage. CSP provides financial and technical support for whole farm conservation, with additional payments for adopting high-level soil health and resource stewardship enhancement activities.

Some state departments of agriculture also offer financial incentives for cover cropping and other conservation practices, sometimes in collaboration with private non-profit organizations. For example, Iowa Department of Agriculture and Land Stewardship. IDALS is working with USDA Risk Management Agency (RMA) to offer a $5 per acre discount on crop insurance premiums for planting cover crops during the 2017 – 2019 growing seasons. This program is part of the Iowa Water Quality Initiative to reduce nutrient pollution in the state’s ground and surface waters; the cover crop program will also help participants co-manage . Farmers and conservationists in several other Midwest states are exploring the possibility of State-RMA collaboration on similar initiatives.

In 2014, a Maryland Department of Agriculture cost-share program facilitated farmer adoption of cover cropping on an additional 478,000 acres within the state.
Hooks, C. R., K. H. Wang, G. Brust, and S. Mathew. 2015. *Using Winter Cover Crops to Enhance the Organic Vegetable Industry in the Mid-Atlantic Region.* Final report for OREI project 2010-01954. CRIS Abstracts.*

Slide 38 – *Information resources*

This is a sampling of the nationwide resources listed in the new Soil Health and Risk Management Guidebook. Other Guidebooks in the OFRF series explore the following soil health related topics in greater depth: soil organic matter, cover crops, conservation tillage, weed management, nutrient management, water management and water quality, and crop genetics for organic systems.

eOrganic is an OREI-funded community of practice that has developed extensive informational materials including decision tools and other practical guidance for organic soil, nutrient, crop, livestock, weed, pest, and disease management.

In addition to the book cited here, SARE offers other manuals and bulletins on soil related topics, as well as "learning rooms" with extensive resources on cover crops and other topics.

ATTRA offers bulletins on a wide range of topics as well as individual consulting services.

The NRCS soil health resource provides a number of videos and articles on practical soil health management practices.

Farmer networks, often coordinated through state or regional sustainable / organic agriculture non-profits or through USDA Organic Research and Extension Initiative (OREI) project teams, can provide invaluable support to individual producers seeking to improve soil health and profitability, and reduce risk. Examples include Practical Farmers of Iowa, the Soil Builders Network within the Land Stewardship Project, the Soil Institute of Pennsylvania Association for Sustainable Agriculture, and the Northern Vegetable Improvement Collaborative (OREI project).

Slide 39 – *Subtitle – adding crops*

Slide 40 – *A few cover cropping tips*

Seek out regional information resources or local expertise on cover crops to help you select the best species and management practices for your locale, soil, climate, and the season or "rotation niche" for the cover crop.

Fresh seed, timely planting, and best planting methods improves chances for getting a good stand. If the soil is dry at planting, irrigate once to get the crop up and established, if practical. Grass alone can tie up N; legume alone may leach N after termination. Grass + legume combination can increase benefits and reduce risks.

In dry regions, moisture consumption by the cover crop can pose major risks to subsequent dryland cash crop production. Select cover crops with low water use, and adjust planting and termination dates to allow soil moisture to be recharged in time for the cash crop. Use a blade plow (= sweep plow undercutter) to terminate the cover crop and knock out any emerging weeds. This implement leaves residues on the surface and most of the soil profile undisturbed, thus helping to conserve moisture and soil structure.

Slide 41 – *SARE Cover Crop Surveys 2012-2016*

Annual surveys conducted through the USDA Sustainable Agriculture Research and Education (SARE) program document a steady increase in successful implementation of cover cropping by both organic and non-organic farmers, most of whom see evidence of improving soil health, often within a year or two of adopting the practice. Yield benefits become larger after four or more years of cover cropping, and were most pronounced in the severe drought year of 2012, which reflects the capacity of cover crops to build soil moisture holding capacity.

Both number of farmers using cover crops, and acres cover cropped per farm rose steadily through the five years of survey. Farmers surveyed in 2017 cover cropped average of 400 ac in 2016 with plans to expand to 450 ac in 2017.

Slide 42 – *Resources for cover cropping*

The Cover Crop Economic Decision Support Tool can help clarify economic costs and savings associated with adopting the cover cropping practice and specific cover crops.

The SARE learning center includes extensive information for all regions.

The USDA cover crop chart provides key information on cover crop regional adaptation, growth habit, season, rooting depth, and water use intensity.

Regional Cover Crop Councils include Midwest (most established), Northeast and Southern (in development), and a new Western Cover Crop Council most recently launched.

Slide 43 – *Adding production crops*

Slide 44 – *Resources for crop diversification*

Slide 45 – *Process for adding new crops*

Slides 46 – 49 – *Example: adding cover crops to a corn-soy rotation*

In this example, adding the cover crops reduced risk in several ways: better corn yields, better nutrient cycling and possibly less applied N needed to sustain corn yield, less weed control needed for soybean, and partial mitigation of erosion losses. It can be difficult for farmers to quantify N recovery and mitigation of leaching by the rye crop, or the long term benefits of building soil organic matter; however extensive research indicates that adding the cover crops to a corn-soy rotation will benefit water quality, soil health, and long term fertility.

Fine tuning steps might include mixing oats or radish with the fall planting of hairy vetch to improve early season cover and erosion control, and retooling the planter for improved seed-soil contact when planting into the higher residues left by the winter rye cover crop.

It may take several years to assess the benefits in terms of yield or yield stability, and a longer period to realize the long term risk reduction related to soil health and water quality. In the short to intermediate term, assess the net financial benefit. Even if the figure is zero or *slightly* negative, it may pay in the long term to adopt the improved soil health practices – and a growing number of farmers are adopting cover cropping primarily for their soil health benefits even when positive financial returns do not begin immediately.

Slide 50 – *Subtitle – Reducing tillage*

Several long term farming system trials have demonstrated similar or superior SOM building and soil health in organic systems that include tight, diversified rotations, cover crops, and some tillage versus continuous no-till with conventional inputs and lower diversity rotations.

Cavigelli, M. A., J. R. Teasdale, and J. T. Spargo. 2013. *Increasing Crop Rotation Diversity Improves Agronomic, Economic, and Environmental Performance of Organic Grain Cropping Systems at the USDA-ARS Beltsville Farming Systems Project.* Crop Management 12(1) Symposium Proceedings: USDA Organic Farming Systems Research Conference. https://dl.sciencesocieties.org/publications/cm/tocs/12/1.

Wander, M. M., S. J. Traina, B. R. Stinner, and S. E. Peters. 1994. Organic and Conventional Management Effects on Biologically Active Soil Organic Matter Pools. Soil Sci. Soc. Am. J. 58:1130-1139.

Wander, M. M., C. Ugarte, E. Zaborski, and E. Phillips. 2014. Organic systems and climate change. Proposal and final report for ORG project 2010-03954. CRIS Abstracts.*

Slide 51 – *When organic rotational no till is most likely to succeed*

A sufficiently heavy, weed-free cover crop grown to the right developmental stage (late bloom to early seed set) and suitable equipment (roller crimper or flail mower for cover crop, no-till planter for cash crop are essential for successful organic no-till. Farmer experience with cover cropping and conservation tillage is very helpful; less experienced farmers can negotiate the learning curve on a small scale before attempting this system on a larger area or the whole farm.

In warmer regions with longer growing seasons, it is easier to ensure sufficient time for both cover and cash crop. No-till yields are often equal and sometimes better than after cover crops are tilled in, especially when a combination of hot rainy climate and sandy soil might mineralize N <u>too</u> quickly after a cover crop is tilled in.

Organic soybeans planted no-till into roll-crimped rye show less "yield drag" than organic no-till corn, and in central or southern regions often yield as much or more than organic soybean planted into a tilled seedbed. This is largely because soybean is a strong N fixer and is little affected by the slower N mineralization or N tie-up under a roll-crimped cereal grain cover, while many weeds, especially "N-responders" like pigweed, lambsquarters, ragweed, and foxtails, are hindered or even stunted.

Chen, G., C. R. Hooks, M. Lekveishvili, K. H. Wang, K. H., N. Pradhan, S. Tubene, S., R. R. Weil, and R. Ogutu. 2015. *Cover Crop and Tillage Impact on Soil Quality, Greenhouse Gas Emission, Pests, and Economics of Fields Transitioning to Organic Farming.* Final report for project ORG 2011-04944. CRIS Abstracts.

Clark, K. 2016. *Organic weed management systems for Missouri.* Proposal and progress report on OREI project 2014-05341. CRIS Abstracts.*

Delate, K., C. Cambardella, and C. Chase. 2015. *Effects of cover crops, soil amendments, and reduced tillage on Carbon Sequestration and Soil Health in a Long Term Vegetable System.* Final report for ORG project 2010-03956. CRIS Abstracts*

Morse, R. D., H. L. Warren, M Schonbeck, J. C. Diaz, J Ruberson, and S. Phatak. 2007. *Integrating No-tillage with Farmscaping and Crop Rotations to Improve Pest Management and Soil Quality in Organic Vegetable Production.* Final report for ORG project 2003-04625. CRIS Abstracts.*

Slide 52 – *Practical options for reducing tillage intensity in organic systems*

Strip tillage, zone tillage, and ridge tillage concentrate soil disturbance and accelerated SOM mineralization and nutrient release in the crop row, leaving alleys undisturbed, thus conserving SOM, providing a refuge for soil biota and checking erosion and nutrient leaching. A Cornell U team of researchers has developed tool combinations for zone till that show great promise for reduced soil disturbance in organic systems in the Northeast.

The spading machine is powerful enough to break sod or incorporate a high biomass cover crop, yet is gentler on soil structure, does not invert the profile, and has been shown to reduce compaction and sometimes increase vegetable yields compared to plow-disk in a mulit-year farming systems trial.

The sweep-plow undercutter is an excellent tool for terminating cover crops, leaving topgrowth to protect the soil surface and conserve moisture, and leaving most of the soil profile undisturbed.

Most of these reduced tillage options do entail capital investments in new equipment, modifications of current equipment, and/or learning new skills. A no-cost approach, developed by Rick Felker of Mattawoman Creek Farms in Virginia, is simply to set the PTO on a low gear and increase tractor forward speed so that the rototiller makes a seedbed without pulverizing soil aggregates.

Maher, R. 2018. *Designing zone tillage systems for organic vegetables – summer 2018*. Cornell Small Farms Program. Pages 12-15 in Reduced Tillage in Organic Systems Field Day Program Handbook, https://rvpadmin.cce.cornell.edu/uploads/doc_699.pdf.

Williams, A., A. S. Davis, A. Jilling, A. S. Grandy, R. T. Koide, D. A. Mortensen, R. G. Smith, S. S. Snapp, K. A. Spokas, A. C. Yannarell, and N. R. Jordan. 2017. *Reconciling opposing soil processes in row-crop agroecosystems via soil functional zone management*. Ag Eco Env 236: 99-107.

Cogger, C. G. M. Ostrom, K. Painter, A. Kennedy, A. Fortuna, R. Alldredge, A.; Bary, T. Miller, D. Collins, J. Goldberger, A. Antonelli, and B. Cha. 2013. *Designing Production Strategies for Stewardship and Profits On Fresh Market Organic Farms.* Final report for OREI project 2008-01247. CRIS Abstracts.*

Wortman, S., C. Francis, R. Drijber, and J. Lindquist. 2016. *Cover Crop Mixtures: Effects of Diversity and Termination Method on Weeds, Soil, and Crop Yield*. Midwest Cover Crop Council, http://mccc.msu.edu/wp-content/uploads/2016/12/NE_2016_Cover-Crop-Mixtures_-Effects-of-Diversity-and-Termination.pdf

Slide 53 – *Subheading - Adjusting inputs*

Slide 54 – *Input frugality*

Healthy soil, good rotation, and nutrient cycling via on farm organic residues and crop-livestock integration can reduce nutrient needs.

The challenge is to know when these on-farm processes are sufficient and when you need to add one or more nutrients to sustain crop yields and soil reserves. Unfortunately, the standard soil test by itself often cannot reliably answer this question. Supplement with a crop foliar nutrient analysis to find out what the crop actually "sees" – and what supplements it might need.

Fertilizer rate trials – either with versus without a given nutrient or amendment, or different rates – can save on fertilizer costs in the future. Lay out side by side plots planted to the same crop and cultivar on a fairly uniform part of the field, apply the amendment to one and not the other. Measure yields and note any quality issues with or without the input.

More and more evidence suggests a conservative approach to P and K. Although harvests can remove a lot of K, it may not always be necessary to fully replenish K removed, especially if soil and foliar tests both show sufficient or ample K.

Slide 55 – *N response economics: three examples*

In Oregon trials on five working farms (maritime to semiarid), each lb feather meal N (cost $6.36) increased broccoli yield 11 to 88 lb (market value $2.50/lb), which works out to a 4 to 35 fold return on investment. N leaching potential in the OR trials was significant at the 220 lb N/ac (as feather meal); in CA trials, broccoli responded similarly to organic N rates, but the higher rates leached well over 100 lb N/ac during and after broccoli production.

Organic N fertilizers were broadcast applied – banding might have been more efficient (plateau at lower rate, less leaching).

In the Utah dryland wheat trial, grain yields and wheat prices were insufficient to fully pay for compost ($45 per ton) even after 15 years of doubled harvests.

These disparate results illustrate the need for a site- and crop-specific approach to inputs, and the value of side by side fertilizer trials and sound economic analysis.

They also suggest a need to breed and select broccoli and other heavy N feeders for improved nutrient uptake and utilization efficiency, to band apply N even from organic sources – and to pay farmers a decent price for wheat!

Collins, D. P. and A. Bary. 2017. *Optimizing nitrogen management on organic and biologically intensive farms.* Proceedings of the Special Symposium on Organic Agriculture Soil Health Research at the Tri-Societies Annual Meeting, Tampa, FL, October 22-25, 2017. http://articles.extension.org/pages/74555/live-broadcast:-organic-soil-health-research-special-session-at-the-tri-societies-conference.

Li, C., Salas, W. and Muramoto, J. 2009. *Process Based Models for Optimizing N Management in California Cropping Systems: Application of DNDC Model for nutrient management for organic broccoli production*. Conference proceedings 2009 California Soil and Plant Conference, 92-98. Feb. 2009. http://ucanr.edu/sites/calasa/files/319.pdf.

Reeve, J., and E. Creech. 2015. *Compost Carryover Effects on Soil Quality and Productivity in Organic Dryland Wheat*. http://articles.extension.org/pages/73247/compost-carryover-effects-on-soil-quality-and-productivity-in-organic-dryland-wheat.

Toonsiri, P., S. J. Del Grosso, A. Sukor, and J. G. Davis. 2016. *Greenhouse Gas Emissions from Solid and Liquid Organic Fertilizers Applied to Lettuce* J. Environmental Quality Vol. 45 No. 6, p. 1812-1821.

Slide 56 – A balanced approach to NPK

In addition to getting a soil test to identify your "starting point," be sure to get a full nutrient analysis on any compost, manure, or other nutrient-rich amendment you use regularly, in order to budget nutrients more precisely and avoid overapplying P. Crop nutrient testing (nitrate-N or complete nutrient analysis) can help fine tune inputs.

Legume N is about half as costly per pound as organic fertilizer N. In healthy, biologically active soil, N mineralization from compost, other amendments, and from active soil organic matter can further reduce the need for added N.

If N supplement is needed, it is much more efficient on wider-spaced row crops (e.g. tomato, sweet corn, head brassicas) to band the N near the crop row, or deliver it via in-row drip, than to broadcast apply it. For crops grown in double or triple rows on raised beds, this can be done by broadcasting before running a bed shaper through the field, which will move the fertilizer out of the alleys and concentrate it on bed tops.

Remember that different crops have very different needs for N and ability to access soil N resources. For example, in contrast to broccoli, pepper is one crop whose fruit set and yield can be hurt by too much soluble soil N – even from a legume green manure.

A light compost application can offer real benefits, including beneficial microbial inoculum, and stabilizing SOM – adjust the rate to maintain "medium" to "high", but *not* "very high" soil test P levels.

Compost and other amendments will add some K – you probably do not need more unless both soil test and plant foliar analysis show low K levels.

Oregon State University has developed a cover crop and organic fertilizer calculator for Pacific Northwest, available at http://smallfarms.oregonstate.edu/calculator.

Slide 57 - *Questions*