Reducing Risk through Best Soil Health Management Practices in Organic Crop Production

ORGANIC FARMING RESEARCH FOUNDATION

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Table of Contents

Introduction 3

Why Soil Health is Important to Production 4

Challenges and Opportunities in Co-Managing Soil Health and Production Risks 5

Concept #1: USDA Organic Standards Require Long-term Investment in Soil Health ... 7

Crop Rotation, Diversity, and Cover Crops 8

Concept #2: Idle, Bare Soil is Starving and at Risk 8

Concept #3: Choosing and Managing Cover Crops Where Rainfall is Limited: Not All "Drought Tolerant" Cover Crops Conserve Moisture 10

Nutrients, Compost, Manure, and Crop-livestock Integration 11

Concept #4: Nutrients and Compost: More is Not Always Better 12

Other Organic Amendments 14

Concept #5: Navigating the Organic Input Smorgasbord 15

The Tillage Dilemma and Integrated Systems 16

Soil Health in High Tunnels 16

Organic Transition 17

Human Health, Environmental, and Regulatory Risks; USDA Program and Resources 18

Practical Tips for Reducing Risk through Soil Health in Organic Systems 19

Worksheet 1: Evaluate Your Soil Resources 20

Worksheet 2: Reviewing Current Practices 21

Adding Crops 22

Concept #6: A Few Cover Crop Pitfalls to Avoid and a Few Tips to Reduce Risks 23

Concept #7: Elwood Stock Farm: A Crop-livestock Integrated System 24

Worksheet 3: Adding crops 26

Reducing Tillage 28

Adjusting Inputs 29

Managing Risk During Organic Transition 31

Recent Research on Selected Topics in Soil Health and Risk Management 31

Farmer Perceptions of Benefits and Risks Associated with Cover Cropping 32

Cover Crops in Moisture Limited Regions 32

Plant Breeding and Genetics 33

Conclusion 35

Information Resources and Decision Support Tools 36

Nationwide 36

Northeastern Region 38

North Central Region 39

Western Region 40

Southern Region 41

References 42

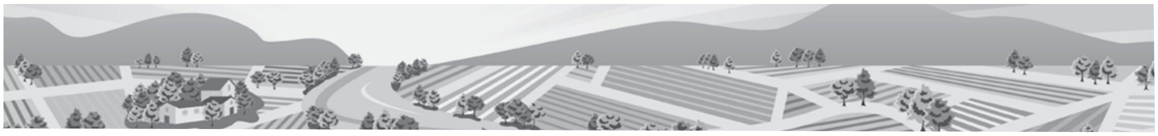
Introduction

The purpose of this guide is to provide farmers with research-based information and resources to help identify and implement effective soil health based risk reduction practices. The companion guide, *Introduction to Crop Insurance for Organic and Transitioning Producers*, provides information on how crop insurance works and how to determine which crop insurance options are right for your operation.

Farmers must manage an array of risks. Production risks include yield losses resulting from poor germination and establishment; drought, hail, and other adverse weather events; weeds, pests, and diseases; nutrient limitations; and long-term declines in productivity related to soil erosion, compaction, or degradation. Climate change is expected to exacerbate risks by intensifying weather extremes, modifying life cycles of crop pests and pathogens, and accelerating decomposition of soil organic matter (SOM) (IPCC 2014, Kirschbaum, 1995).

Financial risks arise when total costs of production, including seed, fertilizers and other inputs, labor, field operations, and fixed costs (e.g., loan payments), exceed gross proceeds as determined by yields and market prices. Careful evaluation of economic risks becomes especially important when you diversify crops or enterprises, adopt new practices for soil health or other objectives, or undertake transition to organic production. Farmers can also face legal, regulatory, and human health risks related to food safety, water quality and other environmental impacts of farming practices.

Strong market demand and high prices for certified organic farm products can help reduce economic risks for organic producers, and organic price elections (somewhat reflecting organic prices) are available for insurance of some crops in certain areas (Schahczenski, 2018a). However, without the use of synthetic fertilizers, herbicides, and pesticides, organic farmers face increased risks of crop losses to nutrient deficiencies especially nitrogen (N), weed competition, insect pests, and diseases. Compared to conventional systems, organic crop production depends more heavily on soil biological processes to provide crop nutrition and sustain yields. Building and maintaining a healthy soil—rich in organic matter and beneficial organisms—is a top management priority.



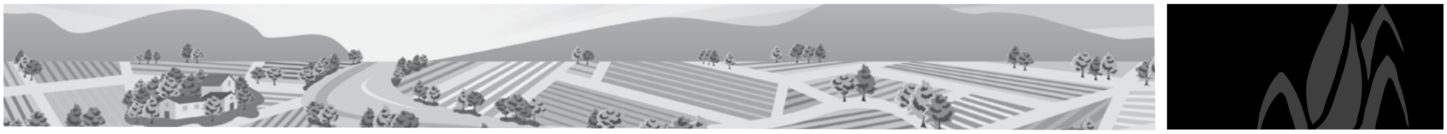
Why Soil Health is Important to Production

Soil health plays a key role in reducing production costs and risks (Table 1). Healthy soil enhances crop resilience to drought, pests, and other stresses; and thereby minimizes losses during "bad" years. For example, while organic and conventional crop rotations in the Rodale long term farming systems trials gave similar yields over a 35-year period, the organic systems sustained much better crop condition and 31% higher grain yield in corn during drought years (Rodale, 2011a, 2015). Higher soil organic matter, biological activity, and moisture infiltration and storage in the organic systems resulted in greater yield stability.

Healthy soils with optimum soil organic matter (SOM) content and biological activity develop good structure (tilth) with reduced surface crusting and compaction, and ample interconnected macro and micro pore spaces extending deep into the soil profile. Desirable soil test SOM levels vary with soil texture and climate, from ~2% in Southeastern U.S. coastal plain sandy loams, to ~6% or more in Northern Corn Belt clay loams (Magdoff and van Es., 2009). Such soils drain well, maintain sufficient aeration, and readily absorb, retain, and deliver plant-available moisture. In addition to sustaining crops through dry spells, healthy soils undergo less ponding, runoff, and erosion during heavy rains (Magdoff and van Es, 2009; Moncada and Sheaffer, 2010; Rodale, 2015).

Table 1. How healthy soil reduces risks in organic crop production

FUNCTIONS OF A HEALTHY SOIL	RISKS AND COSTS MITIGATED
Maintains good structure (tilth). Accrues and maintains stable organic matter.	Requires less tillage to make seedbed. Easy to work. Improves crop emergence and establishment. Cultivation for weed control is more effective.
Drains well.	Provides yield stability in wet years, and less root disease. Reduces delays in planting and other field operations.
Resists erosion, crusting, and compaction; recovers from tillage and other stresses.	Increases soil and crop resilience to weather extremes. Reduces risk of losing fertile topsoil.
Absorbs, retains, and delivers plant-available moisture.	Provides yield stability in drought years. Reduces need for irrigation. Reduces runoff and erosion; protects water quality.
Retains and recycles nitrogen and other nutrients. Maintains sufficient but not excessive levels of plant-available nutrients.	Maintains crop yield and quality. Reduces fertilizer needs. Reduces nutrient losses. Protects water quality.
Hosts abundant, diverse, beneficial organisms; harbors few pests or pathogens	Reduces risk of crop losses to diseases and pests.

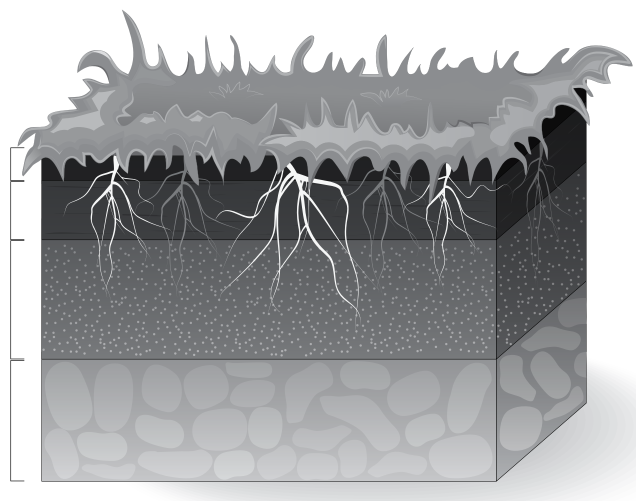


Good soil structure facilitates planting, crop emergence, and stand establishment; improves efficacy of cultivation for weed control, and may reduce the number of passes needed. In addition, as soil physical condition improves, crop roots extend deeper into the soil profile, thereby relieving subsurface hardpan and enhancing the soil's plant-available water holding capacity by building SOM below the plow layer (Rodale, 2015).

Abundant, active, and diverse soil life in healthy soils enhance the release of N and other nutrients from crop residues, active SOM, and organic amendments (Wander, 2015b; Wander et al., 2016). Healthy soils promote mycorrhizal (fungus-root) symbioses and other beneficial root-microbe associations that aid crop uptake of nutrients and moisture (Hamel, 2004). These biological processes, combined with deeper and larger root systems, reduce the amount of fertilizer and irrigation needed to sustain yields, and mitigate environmental and regulatory risks related to soluble N and phosphorus (P) losses to ground and surface waters (Kloot, 2018; Rosolem et al., 2017; Sullivan et al., 2017).

A diverse and balanced soil microbiota can suppress plant pathogenic fungi, bacteria, and nematodes, thereby reducing risks of crop losses to diseases (Baker, 2016). Beneficial soil fungi can also induce systemic resistance (ISR) to foliar pathogens, such as late blight and gray mold in tomato (Egel et al., 2018).

Challenges and Opportunities in Co-Managing Soil Health and Production Risks



While optimum soil health in itself generally reduces production costs and risks (Table 1), management practices adopted to improve soil health can add new costs and risks as well as benefits, especially for organic producers (Table 2). The National Organic Standards require certified organic producers to make a long term investment in soil health (see Concept #1). One challenge faced by all farmers is how to put a dollar value on soil health benefits, especially since financial returns (yield) on this investment can take five or ten years to accrue.

Table 2. Benefits, risks, and costs associated with soil health management practices in organic systems.

PRACTICE	BENEFITS	COSTS AND RISKS
Cover crop	Reduces erosion. Adds organic matter, feeds soil life. Fixes N (legumes). Recovers and retains nutrients. Suppresses weeds.	Consumes soil moisture. Can delay cash crop planting. Can tie up N (non-legumes). Can leach N (legumes, crucifers). Adds costs for seed and planting.
Diversified crop rotation	Enhances soil microbial diversity. Reduces weeds, pests, and diseases. Opens new market opportunities.	New crops entail marketing challenges. Increases system complexity. May require new equipment and skills.
Sod crop in rotation	Prevents erosion during sod phase. Depletes annual weed seed banks. Restores soil health and fertility.	Sod years may entail foregone income. Tillage usually needed to break sod.
Minimum tillage	Conserves soil organic matter. Conserves soil structure. Reduces erosion.	Often increases weed pressure. Can delay N release to cash crops. Can complicate crop establishment. Require new equipment and skills.
Compost and other organic amendments	Adds and stabilizes organic matter. Provides slow-release nutrients.	Can build excess P or other nutrients Some amendments can leach N. Manure can pose food safety risks. Adds purchase and shipping costs.

Organic farmers face a somewhat different suite of production risks from conventional farmers. Yields of organically produced corn, soybean, and other field crops average about 19% lower than conventional yields (Ponisio et al., 2014). Leading causes of this yield gap include insufficient plant-available N (Caldwell et al., 2012), increased weed pressure (Hooks et al., 2016), and challenges in managing pests and diseases without synthetic crop protection chemicals (Jerkins and Ory, 2016). The historical lack of research investment in organic agriculture and development of crop cultivars suited to organic systems have contributed to lower organic yields (Hultengren et al., 2016; Ponisio et al., 2014). Although USDA organic research funding still lags behind the 5% organic market share in the U.S. food system, the Organic Research and Extension Initiative (OREI) and Organic Transitions Program (ORG) have begun to address many organic farmers' research priorities (Schonbeck et al., 2016).

Exclusion of synthetic inputs from organic systems can reduce or offset certain production and economic risks. Consumer demand for food grown without pesticide sprays and with environmentally benign practices has led to higher prices for organic farm products. Non-use of pesticides and herbicides saves money on inputs, and eliminates risks from herbicide-resistant weeds, herbicide carryover in diversified crop rotations, and chemical impacts on water quality (Rodale, 2011a). Purchased organic fertilizers cost more per pound of nutrient than conventional soluble fertilizers, yet can pay for themselves when yields of high-value crops like broccoli respond to the input (Collins and Bary, 2017). In field crops, reduced total input expenditures and organic price premiums could result in competitive or higher net returns from organic (legume covers + manure) versus conventional (soluble fertilizer) systems (Delate et al., 2015b; Rodale, 2011a, 2015).

USDA Organic Standards Require Long-term Investment in Soil Health

The USDA National Organic Program (NOP) requires organic producers to use "tillage and cultivation practices that maintain or improve physical, chemical, and biological condition of soil, and minimize erosion," and to use cover crops and organic amendments to build SOM (USDA NOP Final Rule). In essence, NOP requires organic producers to make a long term business investment in soil health, with up-front costs and risks, and economic benefits (yield stability, input efficiency) that may take years to accrue. For example, corn grain yield benefits from cover cropping increase after four consecutive years of the practice (USDA, SARE, 2016).

NOP defines organic production as a system of practices that "foster cycling of resources, promote ecological balance, and conserve biodiversity." Toward this end, the Crop Rotation Standard requires organic farmers to "implement a crop rotation including … sod, cover crops, green manure crops, and catch crops that … maintain or improve soil organic matter, provide for pest management, manage deficient or excess plant nutrients, and provide erosion control"

(USDA NOP Final Rule).

CONCEPT #2

Idle, bare soil is starving and at risk

The long fallow periods in a typical corn-soy or vegetable rotation without winter cover crops subject the soil life to a protracted "fast" that can deplete populations of mycorrhizal fungi and other beneficial organisms (Kabir, 2018; Rillig, 2004; Six et al., 2006). In addition to increasing risks of erosion and depleting SOM (photo), prolonged bare fallows reduce efficacy of fertilizer inputs, and exacerbate leaching losses (Kabir, 2018, Rosolem et al., 2017). Growing cover crops during the off-season can sustain soil life, conserve nutrients, and reduce long term risks to fertility. When planting schedules or moisture limitations make a living cover impractical, crop residues or organic mulch can reduce the adverse effects of fallow.

In perennial fruit production, maintaining a bare orchard floor through tillage or herbicides can cut SOM levels by half compared to perennial cover with periodic mowing (Lorenz and Lal, 2016). In an organic orchard in Utah, alleys in a birdsfoot trefoil living mulch substantially enhanced SOM, microbial activity, tree root growth, and tree N nutrition over tilled bare fallow, with intermediate levels of soil and crop health under applied organic mulch (Reeve, 2014).

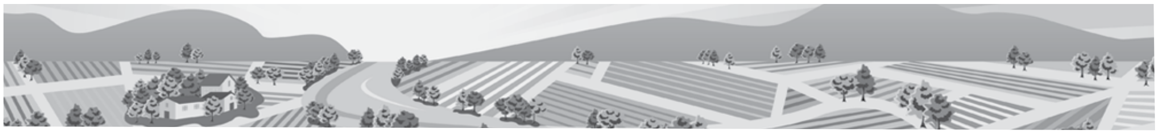
Stop, Thief! Exposed soil is highly prone to wind and water erosion, which rob fertility by selectively removing organic matter and clays, along with their adsorbed nutrients and microbiota. Nature creates only about an inch of new soil every 500 years; thus soil loss is one of the worst risks a farmer might face. You don't have to see rills deep enough to twist an ankle to be losing soil. Watch for signs of sheet erosion, such as water-flow or wind-blow patterns on the soil surface, a smooth or "sealed" surface, or "perched stones".

CROP ROTATION, DIVERSIFICATION, AND COVER CROPS

The USDA Natural Resources Conservation Service (NRCS) has developed four principles of soil health management:

- Keep the soil covered as much as practical.
- Maintain living roots in the soil.
- Build soil microbial diversity through crop diversity.
- Minimize soil disturbance.

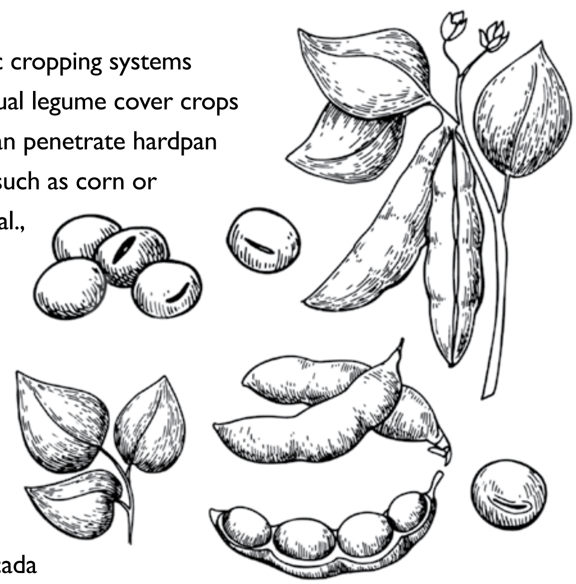
Research into organic and sustainable agricultural systems has largely validated these principles (Schonbeck et al., 2017). Organic producers face significant challenges in putting these principles into practice, and can incur costs and risks doing so. However, extended fallow periods without living cover and the erosion that can ensue constitute some of the gravest risks that any farmer can face (see Concept #2).



The importance of crop rotation in protecting soil quality and reducing risks related to pests, weeds, and diseases is well documented (Mohler and Johnson, 2009). Diversified rotations can reduce risks of catastrophic financial losses when one crop fails, and have been shown to enhance yield and soil health in organic systems (Moncada and Sheaffer, 2010; Ponisio et al., 2014). Adding a perennial grass-legume sod phase (one to three years) to the rotation can be especially effective in restoring SOM, tilth, and fertility, and reducing annual weed populations (Moncada and Sheaffer, 2010). In cash grain rotations, income foregone by rotating into perennial sod can sometimes be recovered in part by haying or grazing the sod. Rotationally-grazed livestock can also enhance the soil building effect.

Costs related to adding new crops to the rotation may include acquiring new skills, tools, and equipment. In addition, rotating into perennial sod phase to restore soil health in an intensive vegetable rotation could result in significant income foregone, and may not be practical for small-acreage market gardens. Diversifying cash crops requires careful market research and enterprise budgets to ensure that the expanded suite of crops is likely to maintain or improve net returns.

Cover cropping plays an essential role in soil health and fertility management in organic cropping systems (Hooks et al., 2015; Moncada and Sheaffer, 2010). For example, the roots of winter annual legume cover crops enhance both SOM and plant-available N (Hu et al., 2015). Deep rooted cover crops can penetrate hardpan and enhance rooting depth, moisture and nutrient acquisition, and yield by cash crops, such as corn or soybean after tillage radish, or cotton after winter rye (Gruver et al., 2016; Marshall et al., 2016; Rosolem et al, 2017).



Yet, adding cover crops can entail new risks (Moncada and Sheaffer, 2010). In selecting and managing cover crops, the organic producer must consider costs of seed, planting, and termination, as well as the cover crop's effects on planting dates, soil moisture, and nutrient availability for the following crop. In drier regions, a high biomass cover crop may not leave sufficient moisture for optimum yield in a subsequent grain crop (Thompson et al., 2016). In colder regions with short growing seasons, cover crops can hurt yields by delaying planting or slowing N mineralization (Liebman et al., 2017; Moncada and Sheaffer, 2010).

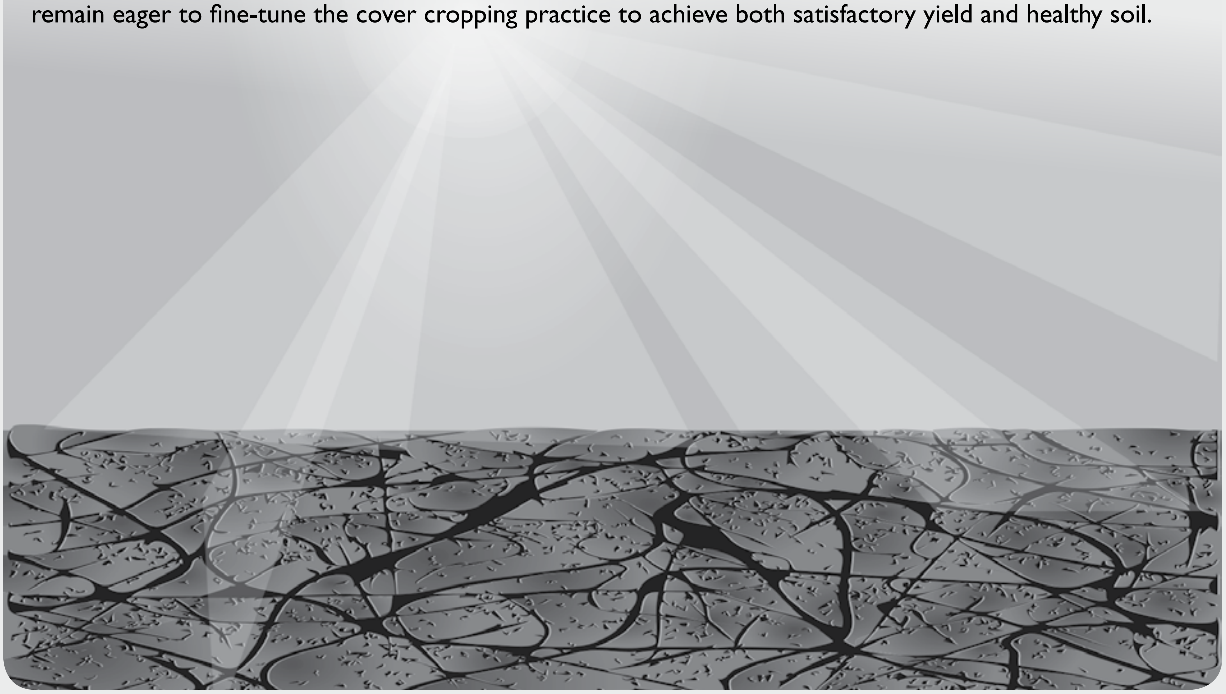
Annual nationwide farmer surveys have shown that, on average, cover cropping slightly enhances corn, soybean, and wheat yields, especially in drought years (USDA SARE). Farmers cite soil health benefits, followed by yield stability and weed management as their leading motivations for cover cropping, and a growing number perceive a net economic advantage from the practice (USDA SARE, 2017). Challenges include identifying the best cover crop species, mixes, and management practices for the grower's site, climate, soils, and management system; and, for organic producers, managing the cover crop without herbicides. In a survey of New York farmers, most participants reported that cover cropping reduced costs for soil erosion repairs; nearly half saved money by reducing fertilizer inputs, and slightly more than half reported improved crop yields (Mason and Wolfe, 2018). In semiarid regions such as Montana, the Dakotas, and interior Washington and Oregon, cover cropping can play a vital role in maintaining soil health in grain rotations, yet cover crop species must be selected and managed with care to realize benefits and minimize yield tradeoffs (see Concept #3).

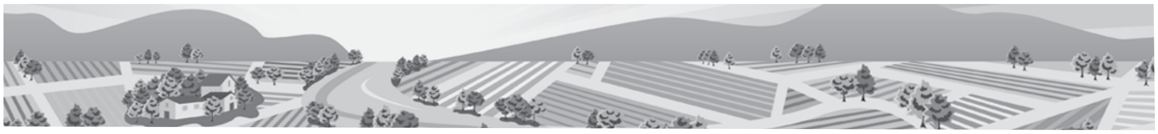
CONCEPT #3

Choosing and managing cover crops where rainfall is limited: not all "drought tolerant" cover crops conserve moisture.

Some drought tolerant cover crops are light users of soil moisture, and can be good choices for semiarid regions. These include barley, camelina, phacelia, medics, foxtail millet, pearl millet, amaranth, lablab, and pigeon pea (USDA ARS, 2018). However, the drought resilience of alfalfa, sainfoin, sunflower, rye, triticale, and tillage radish results from their deep, extensive root systems that consume large amounts of moisture throughout the soil profile. While alfalfa and perennial forage grasses can be excellent choices for soil building in moderate to high rainfall regions, their use during organic transition in semiarid regions like Montana can deplete moisture reserves throughout the soil profile, thus limiting subsequent crop yield for several years (Menalled et al., 2012).

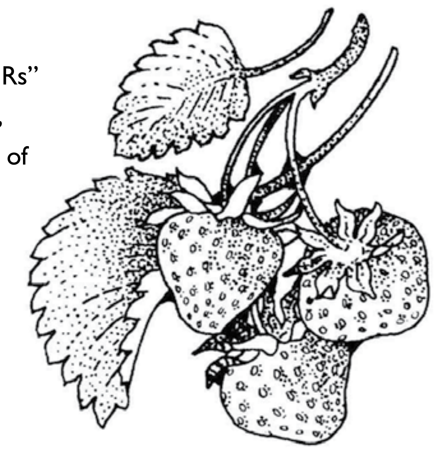
In addition, the contrasting rainfall patterns of the Dakotas (mostly in summer) and the interior Pacific Northwest (mostly in winter) may require different cover crop species and strategies for these two regions (Michel, 2018). NRCS scientists worked with 20 farmers for four years in eastern Washington to determine the best cover crops to use in lieu of the traditional wheat / herbicide fallow rotation, known to deplete soil health. Cover crops planted in late spring (not in fall immediately after wheat harvest, when the soil is driest) performed best. Surprisingly, cowpea and sunnhemp, noted for their vigor and resilience to heat and drought in the Southeastern US, did poorly in eastern Washington, whereas a cool season field pea (Pisum sativum) performed well as a N fixing rotation crop (Michel, 2018). Depending on soil moisture levels remaining after the cover crop, wheat yields varied from 20% higher to 60% lower than without cover; yet participant farmers remain eager to fine-tune the cover cropping practice to achieve both satisfactory yield and healthy soil.





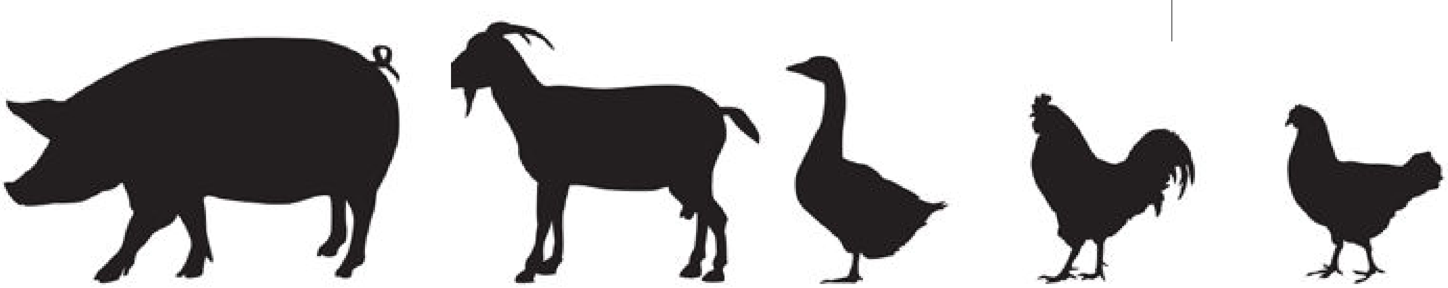
NUTRIENTS, COMPOST, MANURE, AND CROP-LIVESTOCK INTEGRATION

"Feed the soil, and let the soil feed the crop," is a founding principle of organic agriculture. While it provides a good starting point, it does not eliminate production risks related to deficient or excess nutrients, particularly nitrogen (N) and phosphorus (P). Organic crop yields are often limited by insufficient N, especially in soils recently transitioned from conventional to organic management, in which SOM, soil life, and N mineralizing capacity are initially below optimum. Increasing organic fertility inputs can help maintain yields, but may also incur risks (see Concept #4).



The NRCS Nutrient Management conservation practice standard (CPS 590) outlines the "four Rs" of nutrient management for crop yields and resource protection: right placement, right amount, right nutrient source, and right timing (USDA NRCS). However, because of the complex nature of biologically mediated nutrient cycling, nutrient release from manure, cover crops, and other organic nutrient sources can be difficult to predict and manage precisely, especially for N. As a result, organic systems can be challenged by crop N deficiencies, N surpluses subject to leaching, and sometimes both within the same growing season (Muramoto et al., 2015; Sullivan et al., 2017).

Finding the optimal N rate can be tricky for certain crops, such as broccoli and strawberry. In the Pacific Northwest and California, broccoli gave highly profitable yield responses to organic N fertilizers such as feather meal ($4 – 10 per $1 on fertilizer) at rates up to 200 lb N/ac or more, yet harvest removed less than half this much N, with much of the balance leached to groundwater or converted into the potent greenhouse gas nitrous oxide (Collins and Bary, 2017; Li et al., 2009). In organic strawberry production, preplant applications of organic N from compost, cover crops, or broccoli residues are mineralized and leached months before the strawberry crop can utilize it (Muramoto et al., 2015). On the other hand, an organic lettuce trial in Colorado showed optimum yield and N use efficiency at just 25 lb/ac (Toonsiri et al., 2016). Because of the complex and site specific nature of N cycling, farmers may need to conduct simple trials to fine-tune fertilizer rates for best economic and soil health outcomes. For example, a Virginia organic farmer planted fall broccoli and cauliflower after a summer cover crop of pearl millet and cowpea was mowed and solarized for two days under clear plastic, and applied 0, 90 or 180 lb N per acre. The brassicas gave excellent yields after the cover crop alone, with no further response to added N (Anthony Flaccavento, 2015, personal communication).



Nutrients and Compost: More is not Always Better

Farmers often use a little extra fertilizer as "insurance" against yield losses to nutrient deficiencies, and soil test labs have historically recommended more N, P, and potassium (K) than crops actually utilize or remove through harvest. Similarly, organic producers often use compost liberally to ensure sustained yields from intensively-cropped systems such as high tunnels or small-acreage vegetable operations. This approach can lead to P surpluses in the soil.

Recent research has shown that crops may need much less fertilizer than recommended by soil tests, especially in biologically active soils that cycle nutrients effectively (Kabir, 2018, Kloot, 2018, Wander, 2015a). Vegetable harvests remove, 7 – 12 lb P (16 – 28 lb P2O5) and 64 – 93 lb K (77 – 112 lb K2O) per acre (Sullivan et al., 2017; Wander, 2015a). Grain harvests may remove somewhat more P (25 lb/ac for a 150 bu/ac corn crop), but most of the K returns to the soil in stover, and only about 35 lb/ac is removed in the grain (Virginia Cooperative Extension). As little as one or two tons of compost or manure per acre can replenish the P, compost and legumes in the rotation replenish N, and many soils have large subsurface mineral reserves of K, from which deep rooted crops can replenish the topsoil. Even in the southeastern US coastal plain where native fertility of the sandy soils is low, organically managed fields with good biological activity may show no crop response to added P and K, and little or no decline in P or K even when crops are produced without fertilizer (Kloot, 2018). However, failure to replenish nutrients removed in harvest over many years can eventually deplete the soil and lead to declining yields in organic crop production (Olson-Rutz et al., 2010).

Based on recent research findings, Oregon State Extension no longer recommends P or K applications for "high" soil test levels, and subtracts N credits for SOM mineralization, cover crops, and organic amendments to determine N recommendations (Sullivan et al., 2017).

While ensuring sufficient N for crop production is a risk management imperative for all farmers, providing more nutrients than needed can also pose risks, including:

- Increased cost for inputs.
- Increased nutrient losses, nutrient pollution of groundwater and surface waters.
- Reduced soil food web function; mycorrhizal fungi suppressed by high soil P.
- Reduced yield, delayed maturity (excess N on pepper and other fruiting vegetables).
- Reduced crop quality, increased blossom end rot or tip burn (excess N and K).
- Increased crop susceptibility to certain pests and diseases.
- Increased weed growth.
- Grass tetany in pastured livestock (excess K and low magnesium in forage).

Manure is an important nutrient source for many organic growers, but its use requires care to minimize food safety risks. NOP Standards require a 120-day interval between application of manure (raw, aged, or composted at <130°F) and harvest of most organic food crops. In addition, the Food and Drug Administration (FDA) has recently implemented food safety regulations for all produce growers. Preliminary studies indicate that foodborne pathogens in soil decline to undetectable levels by 120 days after manure deposition by grazing livestock (Patterson et al., 2016), and FDA has accepted the NOP rule as an interim guideline pending additional research. The hypothesis that healthy, biologically active soil can speed the attenuation of human foodborne pathogens in manure requires verification, and is currently under investigation (Pires, 2017).

Integrating crop and livestock production within the same farming system and returning manure to the fields is an excellent and time-honored nutrient management strategy that can optimize nutrient cycling within the farm and minimize the need for purchased nutrient inputs. Crop-livestock operations that market fresh produce, must take special care to prevent contamination of produce from pasture runoff, dust (particulates) that may contain manure pathogens, and manure storage or composting operations.

Finished compost can be especially effective for building stable SOM, water holding capacity, and soil fertility (Lewandowski, 2002; Reeve and Creech, 2015). However, relying on compost or manure as the primary means to build SOM or meet crop N needs can build surpluses of P and other nutrients in the soil. Excessive soil P ("very high" on soil tests) inhibits the mycorrhizal symbioses so vital to soil health and crop nutrition (Rillig, 2004; Van Geel et al., 2017), and can threaten water quality (Osmond et al., 2014). Soils that have been "built up" with manure and compost often mineralize more N from the active organic matter than crops can utilize, and the excess leaches (Sullivan et al., 2017). Nutrient-rich organic amendments such as poultry litter can also intensify weed competition when application rates exceed crop needs (Cornell, 2005; Mohler et al., 2008).

Producers must also consider direct costs of purchasing and applying amendments. For example, in organic dryland wheat production in Utah, a single heavy application (22 tons dry weight per acre) of dairy manure/bedding compost doubled topsoil SOM and grain yields for 16 years after application, yet returns on the enhanced organic wheat harvest did not fully pay for the compost application (Reeve and Creech, 2015).

OTHER ORGANIC AMENDMENTS

In some cases, purchased organic or natural mineral amendments can reduce risk by remedying acidic or alkaline pH, deficiencies in specific micro- or macro-nutrients, or other soil health concerns. However, today's farm input catalogues offer such a dizzying array of products that certain risks may arise in trying to sort out what is actually needed to optimize soil health and crop production (see Concept #5). The main risks include the costs of purchasing and applying materials that are not needed or not effective on a particular soil, and inadvertently using a material that NOP has not approved for organic production. Some of the most "tried and true" materials include:

- Rhizobium inoculants for legume seed. These are vital when the right species of rhizobia for the legume planted are not already present in the soil. At a cost of just a few dollars per acre, legume inoculants are often inexpensive insurance for effective N fixiation.
- Liquid fish and seaweed based fertilizers for in-line fertigation. Risks include problems with clogging drip systems, but a number of growers and researchers have used these materials successfully, realizing high nutrient use efficiency and low environmental risks (Toonsiri et al., 2016).
- Mycorrhizal fungal inoculants applied to root balls just before transplanting. Most often used for perennial stock, this practice can enhance establishment of fruit and nut crops in soils where the desired mycorrhizal symbionts are not already present.

Navigating the Organic Input Smorgasbord

In addition to organic and natural mineral fertilizers and amendments, commercial vendors offer a large and growing plethora of other products claimed to enhance soil health and fertility, crop yield, or nutritional and market quality of produce. These include:

- Compost teas, bokashi, Effective Micro-organisms, Biodynamic preparations, and other microbial inoculants or biostimulants applied to soil, seeds, root balls, or foliage.
- Humic acids and humate products.
- Biochar.
- Rock powders and other natural mineral products with multiple trace elements.
- High calcium limestone, gypsum, and other minerals applied to achieve specific ratios of cations (Ca, Mg, K, Na) or other nutrient claimed to improve soil and crop health.

Many organic farmers use one or more of these products or methods, and consider them a vital part of their production and soil health management strategies. While most of these products are unlikely to harm soil, crops, or the environment, not all have been approved by NOP for organic production, and many lack scientific evidence that their benefits justify their purchase costs. Rigorous field evaluations of biochar, humates, and formulaic nutrient management systems such as the "base cation saturation ratio" (BCSR) have given mixed and often highly site-specific results. In other words, they may or may not work on your farm.

Considerable research has gone into the development of some of the newer mycorrhizal inoculants and other microbial products now commercially available. Yet, they often have little impact when applied to the soil (Kleinhenz, 2018), likely because the indigenous soil microbiota overwhelms the added inoculum. Mycorrhizal or other inoculants applied to seeds or root balls can improve crop performance in depleted soils, but may have no effect in healthy soils whose biota already perform the functions for which the inoculant has been selected.

Tips for avoiding unnecessary costs and risks when visiting the "inputs smorgasbord":

- Beware sweeping claims that a given product can solve all your soil problems.
- Select a product with specific objectives in mind.
- Select a product whose development was based on sound research and field trials.
- Make sure the product is NOP-approved for organic production.
- Try the material on a small scale first, in a side by side comparison trial.

THE TILLAGE DILEMMA AND INTEGRATED SOIL HEALTH STRATEGIES.

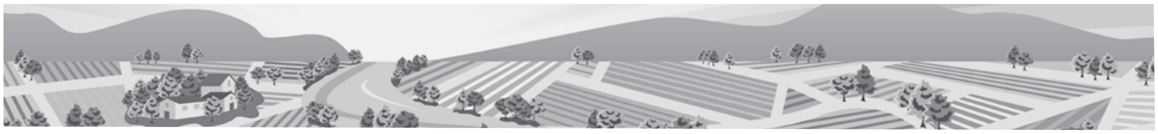
Over the past 30 years, organic researchers and farmers have attempted to save soil through rotational no-till systems, in which high biomass cover crops are roll-crimped or mowed before no-till cash crop planting. These systems save fuel and labor on field operations, consistently enhance SOM and soil health, and—with optimum tools and management technique and favorable weather—can give excellent results (Rodale, 2011b). However, problems with crop establishment, weed pressure, and N limitation can reduce organic crop yields and net returns, especially in northern regions where the organic no-till system reduced corn and oat grain yields by 63% and soybean yields by 31% in multiple-site field trials (Barbercheck et al., 2008; Delate, 2013). In Missouri and the mid-Atlantic region, organic no-till soybean in roll-crimped rye gave full yields, while organic corn showed significant yield decreases when planted no-till in roll-crimped legume + rye covers (Barbercheck et al, 2014; Clark, 2016). In warm-temperate or tropical regions, vegetable crops gave similar yields for the full-till and rotational no-till systems (Delate et al., 2015a; Morse et al., 2007).

Several strategies for reducing tillage intensity in organic systems have been shown to protect soil quality while maintaining crop yields. For example, strip tillage speeds soil warming and N mineralization in the crop row while leaving alleys undisturbed and residue-covered, and shows promise for organic vegetable and row crop production (Caldwell and Maher, 2017; Rangarajan, 2018). Other promising approaches include using a spading machine in lieu of a plow-disk (Cogger et al., 2013), chisel plow in lieu of inversion (turn plow) (Zuber and Villamil, 2016), shallow (3 in.) tillage (Sun et al., 2016), ridge tillage (Williams et al., 2017), and sweep plow undercutter in lieu of disking to terminate cover crops (Wortman et al., 2016). Integrated organic weed management can reduce the number of cultivations needed, thereby protecting soil and reducing direct costs for field operations (Michigan State University, 2008).

Integrated soil health strategies that include diversified rotation, cover crops, compost or manure application, and practical measures to reduce tillage intensity often yield greater soil benefits and sometimes higher crop yields than any one of these practices alone (Cogger et al., 2013; Delate et al., 2015a; Wander et al., 2014). Long term grain-forage farming systems trials have shown equal or greater SOM and soil microbial activity in integrated organic systems with routine tillage compared with conventional continuous no-till (Cavigelli et al., 2013; Wander et al., 1994). However, integrated systems can be more complex and costly to implement, and require greater management skills.

SOIL HEALTH IN HIGH TUNNELS

High tunnels can be especially important for organic specialty crop growers in cold-temperate climates (season extension) or high rainfall climates (reduce disease in tomato, tree and vine fruit, etc.). However, the high tunnel environment presents unique challenges in co-managing production risk and soil health. Greater capital and labor investments in a small production area, and the opportunity for year-round production, impel producers to crop the high tunnel intensively, and to apply compost frequently to maintain SOM and fertility. Exclusion of natural rainfall results in net upward movement of soil moisture, which can accentuate accumulation of P, some other nutrients, and soluble salts in the topsoil. Visible salt accumulations (white surface deposit) and salinity-related yield or quality reductions can occur. Cover



crops can play an especially vital role in restoring soil health and reducing reliance on compost and other organic amendments. Although rotating high tunnel space out of production foregoes substantial income in the short run, cover cropping may help sustain soil health and crop yield in the long run.

ORGANIC TRANSITION

Farmers undertaking the transition to organic production often encounter greater risks than established organic producers working fields with a history of organic management because:

- Newly organic farmers face a steep learning curve, especially with regard to nutrient, weed, and pest management without synthetic agrochemicals.
- Organic certification and higher prices for certified organic products are not available for the first three years on land transitioning from conventional to organic production.
- Newly-transitioning fields often have soil health problems such as low SOM, depleted soil life, depleted or excess nutrients, surface or subsurface compaction, and erosion.
- Soil microbes tend to consume N during the early stages of soil rebuilding, leaving less plant-available for crop production.
- Weeds, pests, and plant diseases can be difficult to manage during transition, especially if the previous crop rotation maintained low aboveground and soil biodiversity.
- As a result, crop yields may be substantially lower during transition, recovering in later years as the soil ecosystem adapts and responds to organic practices (Rodale, 2015).

It can be especially challenging for a beginning organic farmer to simultaneously acquire needed skills, restore soil health and ecological balance on land with conventional management history, and remain financially solvent during the transition period (Menalled et al., 2012). Established organic producers who are transitioning additional acreage have the advantage of experience, yet still have to be prepared for higher labor and other costs, soil health issues, and lower yields and market prices from crops in the new fields.

Results of several studies indicate that rotating fields into a multispecies perennial sod during the three-year organic transition can be especially effective for restoring soil health and fertility, and reducing weed seed populations (Borrelli et al., 2011; Briar et al., 2011; Cardina et al., 2011; Eastman et al., 2008; Hulting et al., 2008; Rosa and Masiunas, 2008). Although taking the field out of production means foregoing income during the transition, management costs are also greatly reduced compared to battling weeds and "tired" soil to bring a demanding crop to market. This strategy may not be feasible for small-acreage operations unless producers have off-farm income or other financial resources to tide them over through the transition period.

HUMAN HEALTH, ENVIRONMENTAL, AND REGULATORY RISKS; USDA PROGRAMS AND RESOURCES.

Organic producers may face several risks related to human and environmental health:

- Unintended contamination of organic crops with NOP-prohibited substances, resulting in loss of certification for certain crops, fields, or the entire farm.
- Potential exposure of food crops to pathogens in manure (discussed earlier), leading to risks of liability for customer health consequences, or state or federal regulatory action.
- Nutrient or sediment pollution of ground or surface water leading to state or federal regulatory action (organic practices generally reduce but do not eliminate this risk).

On the upside, the importance of soil health and benefits of organic systems are gaining wider recognition, and USDA agencies are offering more assistance and resources for organic and conservation-minded farmers and ranchers (see Resources 1-13, 18a and 18b in the Information Resources section on pages 36-41). In addition to administering USDA organic certification, the National Organic Program (NOP) provides excellent resources for organic growers, including an Organic Certification Cost Share (Resource 11).

The USDA Risk Management Agency (RMA) now recognizes NRCS Conservation Practices for soil, water, air, plant, and animal resources as Good Farming Practices compatible with crop insurance eligibility, effective in 2017 and subsequent years (USDA RMA, 2016).

Note: The use of NRCS Conservation Practices MAY be recognized by agricultural experts for the area as good farming practices; however, the use of NRCS Conservation Practices is not necessarily compatible with all crop insurance policies and should be discussed carefully with your insurance agent. This is particularly true if you are making sudden changes in farming practices. You must demonstrate that the new practices do not negatively impact the ability of the insured crops to make normal progress toward maturity and produce at least the yield used to determine the production guarantee or amount of insurance and provided. The NRCS Conservation Practice is not an uninsurable practice under the terms and conditions of the individual crop insurance policy.

RMA has worked with NRCS and the Farm Services Agency (FSA) to develop regional cover crop management guidelines for crop insurance eligibility (USDA NRCS, 2013). However, these guidelines still limit the flexibility of management decisions and could deter cover crop use, especially in lower-rainfall regions (Jeff Schahczenski, National Center for Appropriate Technology, personal communication, 2018). On the other hand, the most recent cover crop survey indicated that most crop insurance professionals now understand and support cover cropping (USDA, SARE, 2017). In addition, RMA now offers a Whole Farm Revenue Program (WFRP, Resource 13) that supports crop diversification (Schahczenski, 2018b).

NRCS working lands conservation programs provide financial and technical assistance to farmers to implement conservation measures, including cover crops, crop rotation, nutrient management, and other soil health practices (Resources 4, 18a, 18b, 18c, and 42c). Conservation program payments can help defray the up-front costs of adopting new practices, and NRCS also provides extensive information resources online related to soil health and soil management.

Other valuable conservation practices include installation of windbreaks, hedgerows, riparian buffers, filter strips, and other conservation buffers. These buffers consist of woody or herbaceous perennial plantings strategically placed: to protect streams, other sensitive ecosystems, or cropland from runoff containing sediment, nutrients, or pesticides; to intercept pesticide drift and other airborne contaminants; to protect soil on highly erodible land; and/or to provide wildlife habitat. Buffer plantings can entail substantial capital investments in perennial stock that many farmers could not afford without NRCS cost share (Resources 4 and 18b). In addition to helping organic growers meet NOP standards regarding wildlife and biodiversity, buffer plantings can address several risks related to food safety and organic integrity as well as soil health:

- Soil losses from highly erodible lands.
- Nutrient or sediment pollution of on-farm or nearby water resources.
- Pesticide or genetically engineered (GMO) crop pollen drift into organic fields from neighboring non-organic farms.
- Pathogen-laden dust from on- or off-farm livestock and manure facilities.
- Fertilizer, pesticide, or manure runoff from neighboring farms.

PRACTICAL TIPS FOR REDUCING RISK THROUGH SOIL HEALTH MANAGEMENT IN ORGANIC SYSTEMS

The first steps toward reducing risk in organic crop production are:

- Get to know your soil resources. Look up your location on the NRCS Web Soil Survey and identify the soil type, inherent properties, and potential constraints (drainage, slope, root-restrictive layers, etc.) for each field and pasture (Resource 1 on page 36).
- Evaluate the current condition of the soil in each production area.
    - Obtain a soil test and compare with past season soil tests if available.
    - Observe and record the physical and biological condition of the soil (tilth, workability, earthworms, etc.).
    - Supplement with additional in-field or lab soil health measurements if desired.
- Review current practices and assess their potential impacts on soil health.
- Identify simple changes you can undertake to protect, restore, or improve soil organic matter, fertility, and soil health without incurring substantial costs or foregone income.

Use worksheets 1 and 2 on pages 20-21 to help you conduct this initial assessment. Make a copy for each field, production area, or “map unit” on the soil survey. Answer each question, filling in relevant detail.

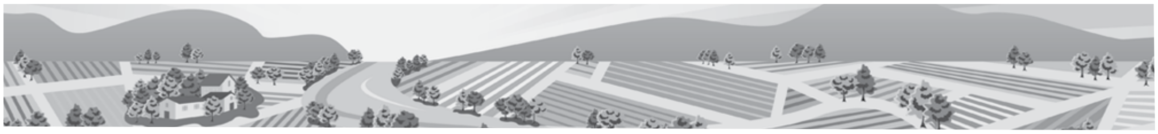
See the Resources section (pp 36-41) for more on the science and practice of soil health and soil management, especially Resources 1, 2, 3, 8, 14, 16, 17, 20, 23b, 29b, 31, and 42f.

WORKSHEET 1: EVALUATE YOURS SOIL RESOURCES.

Farm Location: **Date:**

Field No. and Description:

NRCS WEB SOIL SURVEY	
Soil series and map unit	
Land capability class	
Other production constraints	
SOIL HEALTH EVALUATION	
Are there visible signs of sheet, rill, or gully erosion?	
Is the topsoil soft, dark, crumbly, and easy to work, or hard and cloddy?	
Does the field drain well after rain, or does it remain wet, pond, or run off?	
Does the soil surface crust or seal readily after rainfall?	
Is there a subsurface hardpan that restricts rooting depth?	
Do you see evidence of abundant earthworms and other soil life?	
Do most crops thrive well with few pest, disease, or weed problems?	
Do crops stand well during dry spells, or do they soon become stressed?	
Do crops sustain yields and quality in dry, wet, and other difficult years?	
Do soil tests show an adequate and stable % SOM, or upward trend in SOM?	
Do soil test P and K reach optimum ("high") range, then level off?	
Do soil tests show buildup of excessive levels of P or other nutrients?	
Do soil tests indicate a drawdown of K or other nutrients below optimum?	
Have you conducted assessments, such as microbial respiration, active SOM, potentially mineralizable N, in-field soil health scorecards, or the Cornell Comprehensive Soil Health Assessment or other soil health evaluations? If so, summarize results here.	



WORKSHEET 2: REVIEW CURRENT PRODUCTION PRACTICES, THEIR SOIL HEALTH IMPACTS, AND NEXT STEPS TO IMPROVE SOIL CONDITION AND REDUCE RISK.

Consider your production system in the context of the soil assessment (Worksheet 1), note positive and negative impacts of current practices, and identify simple, low-risk modifications that can improve soil health or reduce risks, and can be implemented with current tools and resources at little additional cost. Examples include growing a cover crop during a long gap (fallow) in the rotation, leaving surface residues over winter in lieu of fall tillage, adjusting tillage implements to lessen soil impact, or adjusting nutrient inputs based on soil test results. More complex system changes will be considered in the following pages, including Worksheet 3 for crop rotation changes.

CURRENT PRACTICES	SOIL HEALTH IMPACTS, OTHER COSTS, RISKS, AND BENEFITS	POTENTIAL LOW-COST SOLUTIONS
Crop rotation, fallow periods:		
Cover cropping practices:		
Tillage tools, practices, and timing:		
Cultivation (tools, frequency) and other weed control tactics		
Organic amendments and nutrient (fertilizer) inputs		

The next steps toward effective co-management of soil health and production risks include adopting new or modified practices in three general areas:

- *Adding crops* – including cover crops, sod crops, and new cash crops or enterprises.
- *Reducing tillage* – frequency, intensity, depth, or percentage of field disturbed.
- *Adjusting inputs* – nutrients, organic matter, etc.

The long term goal is to build or refine an integrated, sustainable, and profitable organic production system suited to your site. The rewards can include greatly improved soil health and water quality, increased crop resilience and yield stability, and a less risky, more profitable operation. However, adopting new practices can require gaining new knowledge, learning new skills, acquiring new capital equipment, and purchasing new seeds, amendments, or other supplies. Selecting the right suite of crops and practices for your climate, soil, and production system requires careful and informed decision making.

TIPS:

- Take this process one step at a time. Adopting all the components of a new system at once can make for an impossibly steep learning curve, or capital investments in new tools that exceed the farm's financial capacity.
- Do a partial budget for each new practice you are considering. A partial budget estimates costs and benefits resulting from a specific practice or change in the operation. See Resources 5 and 21c for a partial budget for cover crops.
- Try a new crop, nutrient source, practice, or suite of practices on a small scale first.
- Do side-by-side trials to verify the crop yield or soil benefits of a new material or practice.
- Join a farmer network engaged in on-farm trials or information sharing. Some examples are listed in Resources 23a, 24, 29c, 30, and 31.
- Utilize USDA programs that can help defray costs, reduce risks, or provide information and technical support. See Resources 4, 11, 12 13, 18, 42a, 42b, 42c, 43, and 45.

ADDING CROPS

Adding a new crop to the rotation—whether annual or perennial, harvested for sale, grazed by on-farm livestock, or returned to the soil in its entirety—can address three of the four NRCS soil health principles: keep the soil covered, maintain living roots, and enhance biodiversity. A diversified rotation can confer long term benefits to soil health, yield stability in cash crops, and net economic returns.

The simplest way to build crop diversity is to add a cover crop to the existing rotation. Successful cover cropping requires careful selection of species, seeding rates, and planting and termination dates and methods, based on the farm's climate, soils, production system, and rotation niches. Avoid cover crop pitfalls (see Concept #6) and optimize outcomes with a few basic steps:

- Identify your cover cropping goals.
- Identify the niches in your crop rotation into which a cover crop might fit.
- Note any cover cropping risks or constraints associated with your production crop mix, growing season, hardiness zone, rainfall patterns, soil types, and current soil condition.
- Utilize cover crop information and decision tools designed for your locale or region.
- Develop a partial budget for the cover crop, considering costs of seed, planting, and termination; savings on fertilizer or weed control; and expected soil and yield benefits. Partial budgeting tools provide research-based estimates of dollar value of these benefits.

A few cover crop pitfalls to avoid and a few tips to reduce risks

A thin, low-biomass, weedy cover crop can result from:

- Cover crop species not suited to climate and season, soil type, or farming system. *Nearby farmers or Extension can help you identify best cover crops for your locale and season.*
- Late planting (especially fall/winter cover crops).
- Low seeding rates.
- Old or poor-quality seed. *Buy fresh seed yearly (grasses, buckwheat, oilseeds) or every two years (legumes, crucifers).*
- Inadequate planting method. *Broadcast seed usually must be shallowly incorporated.*

Cover crops can interfere with production in certain circumstances:

- In regions with short growing seasons, it can be difficult to fit a cash and cover crop into the season, which means a difficult choice between terminating the cover crop early (low biomass, little benefit) and delaying cash crop planting (lower yield). Interseeding or overseeding cover crops into standing cash crops can help address this constraint.
- In drier regions, cover crops terminated too late (just before cash crop planting) can leave the soil profile too dry for crop establishment, thereby reducing yields. Select cover crops, planting, and termination dates to conserve moisture – see Concept #3 on page 10.

Nutrient and weed management problems can arise when:

- Overmature cover crops self-seed. *Mow, roll, or till cover crops at late flowering.*
- Overmature or all-grass cover crops tie up soil N during subsequent cash crop.
- All-legume or crucifer cover crops release N too fast for the following crop to utilize, resulting in N leaching or denitrification. *Plant legume with cereal grain or other grass.*

Highly diversified cover crop mixes or cocktails have shown great promise in NRCS and on-farm trials from Pennsylvania to North Dakota, and elsewhere. However, cocktails can fall short of expectation when:

- Added costs of purchasing and blending seed of multiple crops exceed the added benefits compared to a single-species or two-species cover crop.
- Logistics of planting many different sizes and types of seed add to labor or equipment costs, or result in poor emergence of some species. *Build your cocktail gradually, add one new species at a time to the current cover crop on a trial basis.*
- One or two species in the mix dominate over the others, so that functions of the latter are lost. *Adjust seeding rates accordingly.*
- Different species mature at different times, which can make no-till termination (rolling or mowing) impossible, or lead to cover crop self-seeding.

Adding a perennial sod phase to your rotation can be an excellent long-term investment in soil health and yield stability when:

- Land resources are sufficient to make a living with some fields out of production.
- Sod provides grazing or hay for on-farm or nearby livestock operations.
- Yield improvements or cost savings from soil restoration compensate for the income foregone during the sod phase.

See Concept #7 for a successful example of sod phase and crop-livestock integration.

Elmwood Stock Farm: A Crop-Livestock Integrated System

John Bell, Mac Stone, and Ann Bell Stone of Elmwood Stock Farm in Scott County, Kentucky (http://elmwoodstockfarm.com/) operate a 550 acre, diversified, certified-organic crop-livestock farm producing beef, pork, lamb, poultry, eggs, and mixed vegetables. Their rotations include:

- Corn-soybean-winter cereal (for their livestock); pasture seeded after grain in year 3 and managed for years 4-8 under multispecies, management-intensive rotational grazing.
- Three years of intensive vegetable production with tillage and cover crops, followed by five years pasture managed as above.
- Steeper areas are kept in permanent pasture.

Keys to the success of this operation:

- A long sod break allows the soil to recover fully. University of Kentucky found soil health in year 4 of the vegetable rotation, similar to the permanent pasture.
- Crop-livestock integration optimizes nutrient cycling and minimizes off farm inputs. The farmers bought only 200 lb organic fertilizers for the entire farm in 2016.
- Product diversity and quality, NOP certification, and best food safety practices ensure a loyal Community Supported Agriculture (CSA) membership and a profitable operation.

Based on a tour of Elmwood Stock Farm hosted by Ann and John Stone on January 26, 2017.

Another way to build the diversity of your rotation is to add one or more new production crops for sale, or to provide pasture, hay, or feed grains for an existing or new livestock enterprise. Enterprise diversification can reduce risk if the level of system complexity is manageable and practical. Farmers can "go under" as a result of trying to manage too many crops or enterprises at once, or launching a new enterprise or cropping system across the entire farm in one season. Suggested steps include:

- Evaluate your current enterprise mix, noting yields and net returns, risks, and soil health benefits and drawbacks for each crop or enterprise, and the overall farming system.
- Conduct a similar evaluation of the diversified enterprise mix under consideration
- Develop enterprise budgets for current and proposed new enterprises including:
    - Variable costs (seeds/starts, soil amendments, other inputs, labor, fuel, etc.).
    - Fixed costs (machinery and equipment, land use, etc.).
    - Gross income – historical data for current enterprises, best estimates for new ones.
- Try a new crop or livestock enterprise on a small area or small scale first, then expand it in future years if initial results are promising.
- Add one or two new components (cash crop, soil building crop, or livestock enterprise) at a time, and gradually build the functional diversity of your farming system.

Use Worksheet 3 (page 26) to evaluate your current rotation, identify opportunities to reduce risk and build soil health by adding crops, and record changes implemented or trialed, and document outcomes. See examples on page 26.

For more on Adding Crops, see Resources section (pages 36-41), including:

- *Crop diversification, designing crop rotations: Resources 10, 22, 25, 27, 29a, 34, and 37.*
- *Cover crops, general: Resources 6, 7, 9, 15, 16c, 21, 25, 26, 27, 31, 32, 34, 39, 40, and 41.*
- *Relay interplanting cover crops into standing production crops: Resources 26 and 34.*
- *Cover crop selection tools: Resources 5, 21b, 26a, and 29a.*
- *Cover crops for dryland rotations in semiarid regions: Resources 36, 37, and 38.*
- *Economics of cover cropping: Resources 5, 19d, 21c, 26b, 26c, 30, and 33.*
- *Enterprise budgets and marketing for new enterprises: Resources 42e and 44.*
- *Crop-livestock integrated systems: Resources 29a and 30.*

WORKSHEET 3 – ADDING CROPS FOR SOIL HEALTH, PROFIT, AND RISK REDUCTION.

Example 1: corn-soy rotation

CURRENT ROTATION		CONCERNS	NEW CROP	IMPLEMENTATION, OUTCOME, *NEXT STEPS*
May-Sept	Corn	Needs lot of N		
Oct-May	Fall till, fallow	Erosion, N leaching	Rye cover	Plant 10/5, till 5/15, good biomass *Plant again next year, larger scale*
June-Oct	Soybean			Some skips in stand, yield same, fewer weeds *Adjust planter for better seed soil contact.*
Nov-Apr	Fallow	Severe erosion	Vetch cover	Plant 11/2, poor biomass, weedy. *Interplant into soybean at 4-leaf stage.*

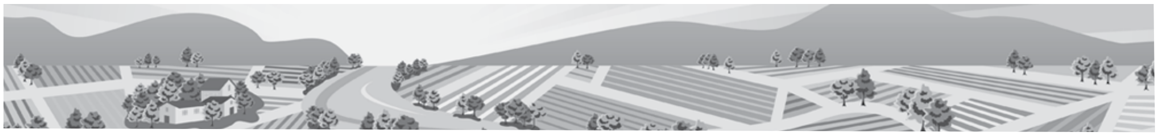
Example 2: intensive vegetable production

CURRENT ROTATION		CONCERNS	NEW CROP	IMPLEMENTATION, OUTCOME, *NEXT STEPS*
Apr-Oct	Greens triple crop	Low residue, crusting	2 greens crops, then oats + peas	Plant cover 8/15 after summer greens harvest. Less erosion, better tilth, but significant income foregone. *Harvest pea tips for market.*
Nov-Mar	Fallow	Erosion		
Apr-Aug	Potato	Needs lot of N to yield		Higher yield, less response to added N. *Reduce feather meal rate.*
Sept-Apr	Oats + vetch cover	Thin stand, vetch hard seed, weedy	Rye + crimson clover	Seeded cover crop 9/1 Satisfactory cover crop stand and bio-mass
May-Sept	Summer vegies			Less weeding labor *Continue rye+clover before summer veg.*
Oct-Feb	Fall till, fallow	Erosion, N leaching	Rye + red clover thru year	Plant cover 10/1. Established well, but rotation now less profitable. *Try specialty grain for harvest (needs market research); expand rotation to 4 years with brassica after grain/red clover.*
Mar-July	Head brassicas	Low yield, soil de-pleted		

WORKSHEET 3: ADDING CROPS FOR SOIL HEALTH, PROFIT, AND RISK REDUCTION

CURRENT ROTATION*		**CONCERNS**	**NEW CROPS**	**IMPLEMENTATION, OUTCOMES, *NEXT STEPS***
APPROX. DATES	CROPS OR FALLOW			

* *Include all cash crops, cover crops, and fallow periods; note whether tilled or residue left on surface during fallows.*



REDUCING TILLAGE

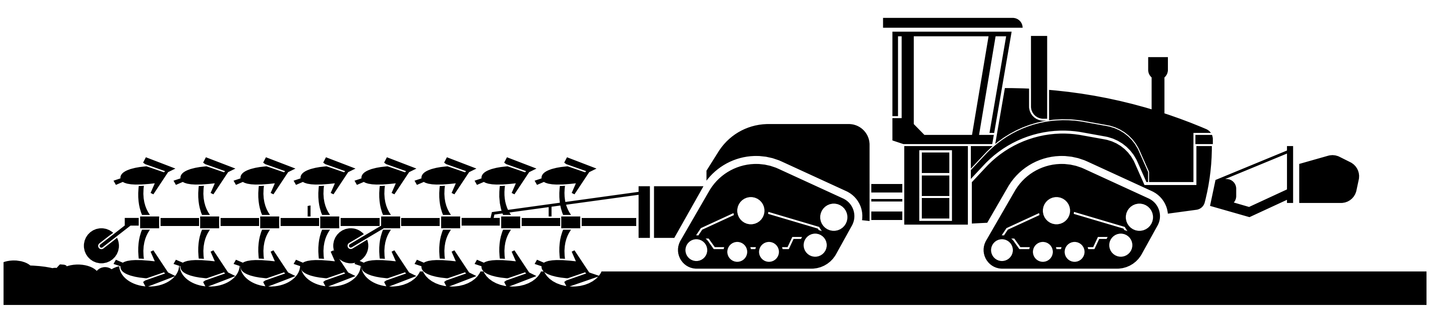
Look for opportunities to reduce tillage frequency and intensity in the cropping system. However, remember that it is not necessary to eliminate tillage. Strip tillage, in which a 4-12-inch wide swath of soil is worked up to create a seedbed for each crop row, leaving alleys untilled, concentrates preplant soil disturbance in the crop row to promote soil warming, microbial activity and nutrient mineralization, and better seed-soil contact for prompt crop establishment. A large and growing number of tools for effective strip tillage, planting, and mechanical weed management have been developed that make strip tillage a viable option for many organic producers, especially when weed pressure is low to moderate.

In the event that high weed pressure, close row spacing for production crops, or other circumstances necessitate full-width tillage, several tools exist that do much less damage to soil structure than "conventional tillage" with moldboard plow, disk and/or rototiller. Examples include the rotary or reciprocating spader, power harrows that work the soil more shallowly and gently than the rototiller, and older, simpler tools such as chisel plow and field cultivator. These tillage methods reduce pulverization of soil aggregates, lessen damage to soil life, avoid inverting the soil profile, reduce risks of compaction and erosion, and thereby help maintain the soil health and resilience gained through cover cropping and other organic practices.

Cover crop-based rotational no-till is the most "advanced" conservation tillage option for annual crop rotations, and is both most promising for soil health and most risky for cash crop yields.

Rotational no-till is most likely to succeed and be economically viable:

- In warm climates with long growing seasons, in which slower N mineralization can be beneficial, and the cover crop has plenty of time to mature and attain high biomass.
- In sandy soils that drain and warm up quickly.
- Where weed pressure is light and dominated by annual species.
- On farms that already have the needed equipment, and farmers have past experience with no-till.
- When a strong N fixer like soybean or southern pea is sown into roll-crimped winter cereal grain cover, whose N tie-up slows weeds but not the legume production crop.
- In small-scale operations, in which opaque tarps or landscape fabric can be laid for 2-4 weeks over mowed or rolled cover before planting vegetable crops, to ensure full termination and weed control (Brust, 2014; Rangarajan, et al., 2016)



Changes in tillage practices often require a significant capital investment in new tillage and cultivation equipment and tools. Opportunities for reducing tillage with less up front cost include:

- Adjusting current tools to work the soil more gently or shallowly, e.g., slowing the PTO speed when operating rototiller or rotary harrow.
- Implementing or improving weed IPM to reduce need for cultivation.
- Cooperative purchase and sharing of a new tool.

For more on Reducing Tillage, see Resources section (pages 36-41), including:

- Organic conservation tillage, general: Resources 7, 16d, 16e, 19, and 41
- Roller-crimper and other no-till equipment: 19b, 39, and 40.
- Strip till equipment: 19a (demo video), 39, and 40.
- Economic analysis of organic no-till: 19d.
- Cover crop interseeding: 34.

ADJUSTING INPUTS

As noted earlier, organic growers can face risks related to either deficient or excessive plant-available nutrients, especially N and P. The historical lack of research data on crop responses to nutrients in organically managed soils has left organic producers with insufficient guidance to minimize these risks. Fortunately, with the growing understanding of the central role of soil health in crop nutrition, this is beginning to change. For example, Oregon State Extension recently updated its nutrient management guidelines for vegetable crops, taking a more conservative approach. N recommendations account for N from all sources (SOM, cover crops, compost and other amendments, irrigation water), and low or zero P and K recommendations are given when soil test levels are optimal (Sullivan et al., 2017).

Once the soil is healthy and soil test levels of P, K, and other nutrients test within optimum ("high") ranges, try to adjust inputs to maintain nutrient levels without building them any higher. Using compost or manure to meet crop N requirements will build soil P and possibly K, while legumes add N and organic matter without P or K. In addition, N from legumes costs $2-3/lb, compared to $5 -6/lb N from organic fertilizers (Sullivan and Andrews, 2012). As noted earlier, N can be especially challenging to manage in a manner that both optimizes net returns and protects water quality and soil health.

Some nutrient related risk reduction tips include:

- Build overall soil health to reduce input needs for all nutrients.
    - Use living plants (cover, sod, and high residue cash crops) as the primary source of microbial food and soil fertility.
    - Use compost or manure sparingly as a supplement. These materials complement living plants in building soil health, and a little goes a long way.

- Use legume cover crops to provide N at a fraction of the cost of organic fertilizers.
- Ensure that any fertilizers or amendments are NOP-allowed before using them.
- Conduct side-by-side comparison trials to fine-tune N or other inputs.
    - Grow a crop with and without added N, or with different N rates.
    - Conduct trials for other nutrients and amendments.
    - Test microbial products, humates, biochar, and other products marketed for soil health in this way before investing in treating whole fields.
    - Conduct a partial budget analysis to estimate return on investment on for inputs.
- Provide plant-available N near crop roots to maximize utilization and minimize leaching.
    - Band-apply organic N fertilizer, or use in-row drip fertigation.
    - Use ridge or strip till to promote N mineralization near crop rows.
    - Plant legume or crucifer cover crop in future crop rows, and grass or grass-legume mix in alleys.
- Avoid over-irrigation in irrigated crops, which can leach N and reduce N use efficiency.
- For rice production, use the non-flooded System of Rice Intensification to improve crop and soil health, nutrient cycling, and yields (Thakur et al., 2016).
- Recycle nutrients within the farm to the greatest extent practical.
    - Crop-livestock integration can greatly reduce the need for NPK imports.
- Use crop foliar analysis to help identify actual needs for NPK and other nutrients.
- Test soil every 1-3 years to track nutrient trends and adjust inputs accordingly.
    - Use the same lab and take samples to the same depth and at the same season in successive sampling years.
- Adjust compost and manure rates according to current soil test P levels.
    - If soil P is low, apply these materials to meet crop N needs.
    - If soil P is high (optimal) apply at ~10 – 15 lb P/ac (= 22 – 35 lb P_2O_5/ac).
    - If soil P is very high (surplus) apply little or no compost or manure
- In high tunnel production, avoid or manage crop-limiting salt accumulations and nutrient excesses or imbalances.
    - Test soil once or twice a year, including soluble salts and nitrate-N.
    - Foliar analysis can be especially important in high tunnel nutrient management.

- Use manure-based compost or fertilizer in moderation, based on soil test P levels.
- Maintain SOM with plant-based compost or other low-nutrient organic materials.
- Integrate legume cover or cash crops into high tunnel rotation to help meet N requirements, or use low-P organic N fertilizers.
- To leach excess salts out of the topsoil, remove cover for a few months every few years to admit natural rainfall, or apply a heavy (4-6 inches) overhead irrigation.

For more on Adjusting Inputs, see Resources section (pages 36-41), including:

- Organic nutrient management, general: Resources 8, 14, 16b, 17, and 25.
- Estimating plant-available N in over crops and organic fertilizers: Resource 33.
- Nutrient management for organic dryland grains: Resources 35 and 36.
- Nutrient management in high tunnels: Resources 17e and 42d.

MANAGING RISK DURING ORGANIC TRANSITION

As noted before, the organic transition period can be especially risky. A few tips for mitigating this risk include:

- Transition one or a few fields at a time, keeping the majority of your acreage under its current management system to sustain farm income. In future years, transition more acreage as feasible until the entire farm is organic.
- Be sure to keep organic and non-organic production separate during harvest, post-harvest handling, and marketing.
- Consider rotating transition fields into perennial sod for one, two, or all three years if practical.

For more on managing risk during organic transition, see Resources section (pages 36-41), especially Resources 25, 37, 42b, and 43.

RECENT RESEARCH ON SELECTED TOPICS IN SOIL HEALTH AND RISK MANAGEMENT

Crop diversification, soil health, organic crop yields, and production risks

The National Center for Appropriate Technology has conducted a nationwide farmer survey to compare production and market risks in diversified organic production systems versus conventional systems (Schahczenski, 2017). Preliminary findings indicate that organic producers spread their risk through crop diversification, reduce input costs by not using expensive GMO seeds and synthetic agro-chemicals, and having markets for productions with generally higher and perhaps more stable prices. They may reduce risk through cover cropping and other soil health management practices. A final report will be issued after survey analysis is completed.

Other research indicates that crop diversification can also reduce risk by building soil health directly (Kane, 2015). While organic and conventional rotations in the Rodale Institute long term farming systems trials generated similar aboveground plant biomass, the more diverse organic rotations accrued higher active and total SOM and soil microbial activity (Wander et al., 1994). In addition, the average "yield gap" between organic and conventional crop production has been estimated at about 19%, but this figure diminishes to 8% when organic crops produced within a diversified crop rotation are compared to conventional crops in monoculture or low-diversity rotation (Ponisio et al., 2014).

FARMER PERCEPTIONS OF BENEFITS AND RISKS ASSOCIATED WITH COVER CROPPING

Annual farmer surveys conducted by the SARE program since the 2012 growing season have documented a steady increase in the use of the practice, based on widespread perception of benefits to soil health, weed management, and crop yield stability. Survey respondents who use cover crops, planted an average of 217 acres per farm in cover crops in 2012, increasing to more than 400 acres in 2017 (USDA, SARE), citing soil health, weed management, and crop yield stability as their top three reasons for adopting or expanding the practice. Eighty-five percent reported observable improvements in soil health, 69% saw weed control benefits, two-thirds noted greater yield stability, and one-third realized greater net profits from cover cropping. While survey respondents who reported not using cover crops indicated that financial incentives (such as EQIP cost share under the Cover Crop conservation practice code 340) would increase the likelihood that they would adopt the practice in the future; those currently using cover crops consider financial incentives only a minor factor in their cover cropping decisions.

Average yield gains from cover cropping have been modest but consistent over the five years of the survey, and tend to increase with number of years of cover crop use. For example, cover cropping improved 2015 corn yields by an average of 3.4 bu/ac (1.9%), but farmers who had been cover cropping for four or more years saw a corn yield benefit of 8 bu/ac (4.5%). In the severe drought year of 2012, cover cropping conferred greater yield benefits to soybean (11.6%) and corn (9.6%) than in the more favorable seasons since then. This illustrates the yield stability benefits of this practice, an important risk management consideration.

In a survey of 182 farmers in New York State, respondents cited poor drainage (60%), soil compaction (60%) and soil erosion (40%) as leading constraints on production (Mason and Wolfe, 2018). Half of those who planted cover crops and/or reduced tillage reported yield improvements from these practices, while only 3% and 10% reported yield costs from cover crops and reduced tillage, respectively. Over 60% of farmers reported that both practices reduced soil erosion and flooding, and enhanced crop drought resilience. Some 83% of respondents who planted cover crops or reduced tillage saved erosion repair costs; 74% of those who reduced tillage reported savings on labor, fuel, and machinery; 47% of those who use cover crops have been able to reduce fertilizer inputs, and crop-livestock integrated farms used cover crops as forage.

COVER CROPS IN MOISTURE LIMITED REGIONS

Dryland grain producers in semiarid regions face a paradox, in that the traditional wheat-fallow rotation degrades soil quality, even under no-till management, while growing a cover crop or a production crop (lentil, pea, dry bean, sunflower, or cereal grain) in lieu of fallow maintains or enhances health (Engel et al., 2017; Halvorson et al., 2002; Miller et al., 2008). However, the short-term effects of a cover crop (in lieu of tilled or herbicide fallow) on the yield of the following grain crop depends on how the cover crop affects available soil moisture.

For example, two studies in south-central Nebraska gave contrasting results with dryland corn grown in rotation with winter wheat. In trials at two sites (Franklin and Clay Counties), planting a diverse cocktail of non-winter-hardy grasses, legumes, and crucifers into wheat stubble in August reduced soil moisture reserves by 1.5 inches compared to leaving the field fallow after wheat harvest; as a result, non-irrigated corn grown the following year showed a 5-10 bu/ac yield loss after the cover crop (Thompson et al., 2016). On the other hand, a SARE-funded on-farm trial in Webster County documented 10% higher corn yields after diverse cover crop mixtures were planted in July of the preceding year after wheat harvest (Berns and Berns., 2012). The mixtures left soil moisture levels similar to wheat stubble alone, while single-species cover crops of soybean, sunflower, or radish significantly reduced soil moisture and did not affect corn yield.

A Western SARE funded on-farm project showed significant decreases in dryland wheat yields after cover crops in the northern Great Plains, resulting from water consumption and sometimes N consumption by the cover crop (Miller, 2016). Winter pea generally supports higher subsequent wheat yields than spring planted legumes, and terminating legume covers at bloom rather than pod stage reduces water consumption and improves wheat yield (Olson-Rutz et al., 2010). While only a minority of farmers in a Montana survey reported planting cover crops in dryland grain rotations, most who do plan to continue or expand cover crop use, cited long term soil health as the main benefit (Jones et al., 2015). Survey respondents also noted the N contributions, forage value, and long-term net economic benefits of cover crops, and most often cited seed cost and water consumption as reasons to consider not planting cover crops.

In a series of on-farm trials (20 farms X 4 years) in interior Washington State, cover crop impacts on wheat yield varied from severe (65%) reductions to significant (10-22%) increases (Michel, 2018). The depth to available soil moisture (DtM) at the time of wheat planting appeared critical: when the cover crop had little effect on DtM, wheat yields were unaffected or improved; when the cover crop dried the top several inches of the soil profile, wheat crop establishment and yield suffered. Field pea planted with cereal grains in spring or summer gave better cover crop biomass and weed control than covers planted in fall after harvest of the preceding wheat crop, again because of moisture limitation in the latter scenario. In addition to total annual precipitation (9-13 inches for the farms in this study), the seasonal distribution of moisture (mostly winter in Eastern Washington vs. mostly in summer in the Northern Great Plains) plays a key role in determining best cover crops, planting, and termination dates (Michel, 2018).

PLANT BREEDING AND GENETICS

Perhaps one of the greatest sources of risk in organic production is the relative lack of regionally adapted crop cultivars that are well suited to organic farming systems. Key traits for successful organic production include the capacity to emerge vigorously without chemical seed treatments, to utilize organic sources effectively, to outcompete weeds, and to withstand pests and pathogens (Lyon, 2018). A 2015 survey of 210 organic vegetable farmers in the Northeastern region, identified resilience to diseases, pests, heat, cold, and other stresses as top priorities for plant breeders (Hultengren et al., 2016). In addition, the project's working group of farmers, breeders, Extension personnel, and other stake holders noted:

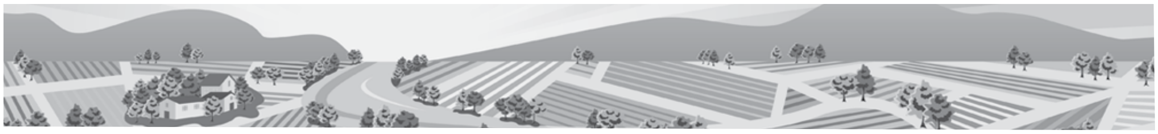
"Cultivars are most productive under the conditions for which they were bred. This central concept of plant breeding points to the need for Northeast growers to have regionally-adapted varieties that were bred to thrive in the Northeast, with the climate and pests unique to our region. Furthermore, cultivars bred under conventional management— aided by synthetic fertilizer, herbicides and pesticides—will likely not be as productive under organic management." (Hultengren et al., 2016, page 26).

A meta-analysis of 115 studies comparing crop yields in organic versus conventional farming systems showed the greatest "yield gaps" in wheat, barley, rice, and corn—crops for which "Green Revolution" cultivars were developed to give maximal yields in high-input conventional systems (Ponisio et al., 2014). The authors recommended breeding crops "under organic conditions" to narrow the yield gap and reduce environmental costs of high yield agriculture.

Over the past 15 years, several farmer-scientist participatory plant breeding teams funded through the USDA Organic Research and Extension Initiative (OREI) and Organic Transitions Program (ORG) began to address the need for new crop cultivars better suited to organic systems. Some promising developments include:

- Highly N-efficient and N-fixing corn with enhanced drought tolerance, giving competitive grain yields of superior protein content and quality. Seeds are now available to farmers and scientists through licensing agreements (Goldstein, 2015, 2018).
- The Northern Organic Vegetable Improvement Collaborative (NOVIC) has released cultivars of snap pea, snow pea, and sweet corn ('Who Gets Kissed?') with excellent emergence from cold soil (Myers et al., 2014).
- Heritable traits related to crop vigor, canopy closure, and habit of growth in wheat and soybean correlate with weed competitiveness; one new food-grade soybean cultivar has been released (Orf et al, 2016; Place et al., 2011; Worthington et al., 2015).
- Tomato advanced breeding lines that combine excellent flavor with resistance to several major fungal diseases. The team is also exploring tomato genetics and soil management practices that enhance crop interaction with soil microbes that induce systemic resistance (ISR) to foliar pathogens (Hoagland, 2016; Myers et al., 2018).
- Carrot advanced breeding lines that combine weed competitive traits (seedling vigor, large tops, early canopy closure) with resistance to Alternaria leaf blight, a leading carrot disease (Simon et al., 2016a, 2016b, Turner, 2015).
- Cover crop (Austrian winter pea, crimson clover, hairy vetch) breeding trials in IA, MD, NC, ND, NY, WA, and WI addressing farmer-identified priorities: N fixation, early emergence, biomass, winter hardiness, and regional adaptation (Ackroyd et al., 2016, Mirsky, 2017).
- Extensive research confirms genetic regulation of plant root depth and architecture, and great potential to breed crops for larger, deeper root systems that build SOM, improve nutrient and moisture use efficiency, and potentially enhance yields (Kell, 2011).

Each of these plant breeding developments can contribute to soil health and risk reduction by facilitating profitable organic production, reducing nutrient and water input needs, enhancing organic matter inputs to the soil, or promoting beneficial plant-soil-microbe interactions.



Conclusion

The past two or three decades of research have validated what experienced farmers have known for centuries: healthy, living soils support resilient farming systems with greater yield stability in the face of unpredictable weather extremes and other stresses. In other words, managing for soil health reduces production and financial risks, and therefore constitutes good business management as well as environmental stewardship. Research further validates the NRCS four principles of soil health: keep the soil covered, maintain living roots, increase diversity, and minimize disturbance.

While healthy soil in itself almost always reduces production risks, practices undertaken to build soil health can entail new challenges, costs, and sometimes risks. For example, efforts to maximize cover crop biomass and eliminate tillage in a rotation of annual crops can lead to yield tradeoffs, especially for organic producers who cannot resort to herbicides and soluble fertilizers to address weed pressure and nutrient limitations. However, a growing body of research outcomes, producer experience, and innovation by farmers, scientists, and agricultural engineers has built—and continues to build—a substantial toolbox for organic growers seeking to optimize soil health while reducing their production and financial risks.

This guide aims to provide the organic producer with an outline of the principles of soil health-based risk management, and a set of information resources and tools to help put these principles into practice. Because of the highly site-specific nature of best crop rotation, cover crops, tillage methods, and nutrient management in organic production, this guide cannot, and does not aspire to prescribe a formula for best soil-based risk management practices. Its goal is to equip farmers with the knowledge and tools needed to identify and implement the best suite of crops and practices to build healthy soils, reduce risks, and optimize net financial returns from their farming operations.

Information Resources and Decision Support Tools for Risk Reduction through Soil Health Management in Organic Farming

NATIONWIDE RESOURCES

1. **NRCS Web Soil Survey.** Click "Start WSS," enter your postal address, select the appropriate area on the aerial map, click on Soil Map, and use Soil Data Explorer to learn more about each of the Map Units within your farming operation. Once you have identified your soil types (series), you can review the Official Soil Series Descriptions (see menu on survey home page). https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

2. **Explore the Science of Soil Health.** NRCS video series. Dr. Robin Kloot interviews farmers and scientists explaining the science and practice of soil health practices. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/health/?cid=stelprdb1245890

3. **NRCS Webinar Archive. Science and Technology Training Library.** Includes cover cropping, nutrient management, and other practices that reduce risk through soil health improvement. http://www.conservationwebinars.net/listArchivedWebinars

4. **NRCS working lands programs – Environmental Quality Incentives Program (EQIP) and Conservation Stewardship Program (CSP).** Provide financial assistance to farmers to implement conservation, including cover crops, rotations, and other soil health practices. EQIP offers an Organic Initiative to help organic and transitioning producers meet NOP conservation requirements. See full listing of NRCS programs at https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/.

5. **Cover Crop Economic Decision Support Tool.** A spreadsheet-based online partial budgeting tool for cover crops, available through NRCS Missouri Soil Health http://www.nrcs.usda.gov/wps/portal/nrcs/main/mo/soils/health; or NRCS Illinois Soil Health, http://www.nrcs.usda.gov/wps/portal/nrcs/main/il/soils/health/.

6. **USDA Cover Crop Chart.** Provides succinct information on cover crop life cycle, habit of growth, and water use intensity for 58 cover crop species. Updated Feb 2018. https://www.ars.usda.gov/plains-area/mandan-nd/ngprl/docs/cover-crop-chart/

7. **SARE Learning Center, Cover Crops Topic Room**. https://www.sare.org/Learning-Center/Topic-Rooms/Cover-Crops

8. **Building Soils for Better Crops, 3rd ed., by Fred Magdoff and Harold van Es. 2009. Sustainable Agriculture research and Education (SARE).** http://www.sare.org/Learning-Center/Books/Building-Soils-for-Better-Crops-3rd-Edition

9. **Managing Cover Crop Profitably, 3rd edition, USDA Sustainable Agriculture Research and Education (SARE).** http://www.sare.org/Learning-Center/Books

10. **Crop Rotation on Organic Farms: a Planning Manual.** Charles L. Mohler and Sue Ellen Johnson, editors. Developed by a panel of 12 experienced organic vegetable farmers in the Northeastern region, this manual illustrates their crop rotations and discusses principles and practices for developing rotations that are applicable anywhere. Published by SARE. http://www.sare.org/Learning-Center/Books

11. **National Organic Program.** Provides detailed information about organic certification https://www.ams.usda.gov/about-ams/programs-offices/national-organic-program, and **National Organic Certification Cost Share Program** offers 75% cost share for certification expenses up to a payment of $750, https://www.fsa.usda.gov/programs-and-services/occsp/index

12. **Food Safety Outreach Program (FSOP).** Offered by USDA, funds non-profit organizations to provide education and training to help small, diversified, and organic producers meet FDA produce safety requirements. https://nifa.usda.gov/food-safety-outreach-program. For more information on farmer resources developed with FSOP funds, visit http://sustainableagriculture.net/publications/grassrootsguide/food-safety/food-safety-training-program/.

13. **Whole Farm Revenue Protection.** A risk management product offered by USDA Risk Management Agency, "tailored for any farm with up to $8.5M in insured revenue, including farms with specialty or organic commodities (both crops and livestock), or those marketing to local, regional, farm-identity preserved, specialty, or direct markets." https://www.rma.usda.gov/policies/wfrp.html. Farm enterprise diversification is rewarded with premium discounts. For more on WFRP, see an updated (2018) primer published by ATTRA at https://attra.ncat.org/attra-pub/download.php?id=595.

14. **Soil and Fertility Management in Organic Farming Systems.** Extension website, Organic Resource Area. Articles and video clips cover sustainable organic nutrient budgeting and management including improved N efficiency and avoiding / managing P and K excesses. Several articles on role of soil organisms and soil health in enhancing nutrient efficiency and reducing crop disease risks. http://articles.extension.org/pages/59460/soil-and-fertility-management-in-organic-farming-systems

15. **Cover Cropping in Organic Farming Systems.** Extension website, Organic Resource Area. Articles and video clips on cover crop selection and management for organic systems and during organic transition, including several on reduced till management. http://articles.extension.org/pages/59454/cover-cropping-in-organic-farming-systems

16. **Soil Health and Organic Farming: a series of practical guides published by the Organic Farming Research Foundation** (OFRF, http://ofrf.org/), and webinars archived at https://articles.extension.org/pages/25242/webinars-by-eorganic. Topics include:

    a. Building Organic Matter for Healthy Soils: An Overview.

    b. Nutrient Management for Crops, Soil, and the Environment

    c. Cover crops: Selection and Management

    d. Practical Conservation Tillage

    e. Weed Management: An Ecological Approach

    f. Water Management and Water Quality

    g. Plant Genetics, Plant Breeding, and Variety Selection

17. **National Sustainable Agriculture Information Service** (aka ATTRA). Offers one-on-one consulting by phone or online ("Ask an Ag Expert" on home page), as well as many information resources available free or for nominal charge. https://attra.ncat.org/

a. *Soils and Compost.* Info sheets and videos at https://attra.ncat.org/soils.html

b. *Tipsheet: Assessing the Soil Resource for Beginning Organic Farmers*, https://attra.ncat.org/attra-pub/summaries/summary.php?pub=529

c. *Marketing, Business, and Risk Management*. Info sheet and videos at https://attra.ncat.org/marketing.html

d. *Water Quality, Conservation, Drought, and Irrigation*. Info sheets and videos, including role of soil health in drought resilience and water quality. https://attra.ncat.org/water_quality.html

e. *High Tunnels in Urban Agriculture*. Includes nutrient and salt management tips. https://attra.ncat.org/attra-pub/summaries/summary.php?pub=552

18. **National Sustainable Agriculture Coalition** (NSAC), http://sustainableagriculture.net/, is the lead policy advocacy organization for sustainable agriculture and food systems at the national level. In addition to giving farmers a voice on Capitol Hill during Farm Bill negotiations and within USDA in program implementation, NSAC offers producers information resources at http://sustainableagriculture.net/publications/, including:

a. *Growing Opportunity: A Guide to USDA Sustainable Farming Programs*. 2017. Summary information on USDA programs including loans and microloans, crop insurance, conservation, food safety, organic certification cost-share, and more.

b. *Grassroots Guide to Federal Farm and Food Programs*. Updated after each new Farm Bill reauthorization (approximately every five years).

c. *Farmers' Guide to the Conservation Stewardship Program*. Last updated 2016.

d. *Organic Farmers' Guide to the Conservation Reserve Program Field Border Buffer Initiative*. May, 2016.

e. *Food safety information, including special reports on Understanding FDA's Rules for Produce Farms and Food Facilities (August, 2016), and Am I affected?* (updated July, 2018). A flow chart to help the producer determine what the FDA rules require for their operation based on products sold and total annual sales.

NORTHEAST REGION RESOURCES

19. **Reduced Tillage in Organic Systems Field Day Program Handbook.** Cornell University Cooperative Extension, July 31, 2018 at Cornell University Willsboro Research Farm, Willsboro NY. https://rvpadmin.cce.cornell.edu/uploads/doc_699.pdf

a. Excellent information resources on strip tillage, pp 11-15.

b. Roller-crimper to terminate cover crops – pros, cons, trouble shooting, pp 19-40.

c. Roles of soil life in nutrient cycling, soil structure, and effects of tillage pp 41-59.

d. Cover crop-based organic rotational no-till, including economic analysis from Rodale Farming Systems Trials, pp 61-107.

20. **New York Soil Health.** A joint program of New York Department of Agriculture, Cornell University, and NRCS has conducted a farmer survey on benefits and costs of soil health practices. Ongoing activities include innovative organic cropping systems, soil amendments, and developing a Soil Health Roadmap. http://newyorksoilhealth.org

21. **Northeast Cover Crops Council**. http://northeastcovercrops.com/

   a. Information by state and cover crop type (grass, legume, broadleaf, mix).
   b. Decision support tool to be released in the near future.
   c. *Cover Cropping Costs and Benefits*. Jeffrey Sanders, U. Vermont, 2014, 2 pp. Partial budget for several cover crop species and management scenarios in New England. http://northeastcovercrops.com/wp-content/uploads/2018/02/Cover-Cropping-Costs-and-Benefits.pdf

22. **Rodale Institute Farming Systems Trial.** Reports and summaries of soil health and fertility, crop yield and net economic returns in long term (since 1981) comparison of organic crop-livestock, organic crop, and conventional cash grain systems. https://rodaleinstitute.org/our-work/farming-systems-trial/

23. **Northeast Organic Farming Association** (NOFA, https://nofa.org/), with state chapters in CT, MA, NJ, NY, RI, and VT, offers research-based, practical information on soil health management practices.

24. **Pennsylvania Association for Sustainable Agriculture** (PASA). Conducts farmer-driven research and farmer-farmer exchange on soil health practices and farm economic viability through its Soil Institute, https://pasafarming.org/soil-institute/. PASA received a 2018 Conservation Innovation Grant to continue and expand its Soil health Benchmark Study. https://pasafarming.org/

NORTH CENTRAL REGION RESOURCES

25. **Risk Management Guide for Organic Producers** (K. Moncada and C. Sheaffer, 2010, U. Minnesota, 300 pp). Chapters on soil health, soil fertility, crop rotation, and cover cropping for organic corn-soy-forage production in the North Central region. http://organicriskmanagement.umn.edu/

26. **Midwest Cover Crop Council**. Treasure-trove of information on selecting, planting, and terminating cover crops, including species descriptions, state-specific information, organic no-till, and interplanting. http://mccc.msu.edu/

   a. *Cover crop selector tools for vegetable and field crops*. http://mccc.msu.edu/selector-tool/.
   b. *Economics of Cover Crops*, James J. Hoorman, Ohio State U., 2015, 54 pp. http://mccc.msu.edu/economics-cover-crops/
   c. Other economic analyses. http://mccc.msu.edu/?s=economics

27. **Integrated Weed Management: Fine-tuning the System**. Michigan State University Extension, 2008. (131 pp). Excellent manual developed in collaboration with organic farmers, with farm case studies. http://www.msuweeds.com/publications/extension-publications/iwm-fine-tuningthe-system-e-3065/.

28. **Reduced Tillage in Organic Systems Field Day Program Handbook.** Cornell (see item 3 in Northeast Region). Includes information for the North Central region.

29. **Land Stewardship Project.** Extensive practical information on soil health, sustainable farming, and risk management. https://landstewardshipproject.org/

   a. *Cropping Systems Calculator*. Helps producers in MN and IL evaluate economics of alternative crop rotations up to six years, including cash and cover crops with grazing (crop-livestock integrated) options. https://landstewardshipproject.org/stewardshipfood/chippewa10croppingsystemscalculator.

b. *Talking Smart Soil*. Podcasts of producers using soil health practices. https://landstewardshipproject.org/lspsoilbuilders/talkingsmartsoil

c. *Soil Builders Network*. Farmer stories on soil health, profits, and resiliency. https://landstewardshipproject.org/stewardship-food/soilquality.

30. Practical Farmers of Iowa. Conducts farmer-driven research into field crop production including cover crops. https://www.practicalfarmers.org/ Research findings at https://www.practicalfarmers.org/member-priorities/cover-crops/ include a Jan 4, 2018 report on Economic Impacts of Grazing Cover Crops in Cow-Calf Operations.

31. Midwest Organic and Sustainable Education Service (MOSES) maintains an extensive resource page with fact sheets, videos, etc. on Soils, Cover Crops, and Systems. https://mosesorganic.org/farming/farming-topics/soils-systems/

WESTERN REGION RESOURCES

32. Cover Crop (340) in Organic Systems Western States Implementation Guide. Rex Dufour (National Center for Appropriate Technology); Sarah Brown, Ben Bowell and Carrie Sendak (Oregon Tilth); Mace Vaughan and Eric Mader (Xerces Society), 2013. Excellent information on cover crop selection, innovative mixes, planting, and termination methods for organic production in the Pacific Northwest and California. https://attra.ncat.org/organic/

33. Cover Crop and Organic Fertilizer Calculator. Provides Excel calculators for maritime and inland regions to estimate costs and PAN for cover crops and amendments. Calculator for Hawaii in development. http://smallfarms.oregonstate.edu/calculator

34. Innovations Help Vegetable Growers Find that Cover Crop Niche. Nick Andrews, Oregon State University, 2016. https://extension.oregonstate.edu/crop-production/vegetables/innovations-help-vegetable-growers-find-cover-crop-niche. **Relay Seeding Cover Crops in Fall and Winter Harvested Vegetables.** Nick Andrews, 2014. https://extension.oregonstate.edu/crop-production/vegetables/relay-seeding-cover-crops-fall-winter-harvested-vegetables. Practical innovations for integrating cover crops into organic vegetable and strawberry production in the maritime Pacific region.

35. Nutrient Management for Sustainable Vegetable Cropping Systems in Western Oregon. Sullivan, D. M., E. Peachey, A.L. Heinrich, and L.J. Brewer. 2017. Oregon State Extension Bulletin EM 9165. More conservative (cost-effective) nutrient recommendations than past Extension bulletins, extensive section on N management, and careful consideration of both risks and benefits of fertilizers and organic amendments. https://catalog.extension.oregonstate.edu/topic/agriculture/soil-and-water

36. Soil nutrient management on organic grain farms in Montana. K. Olson-Rutz, C. Jones, and P. Miller. 2010. Montana State University Extension bulleting EB0200, 16 pp. Research findings on best cover crop species, and management for organic dryland wheat; analysis of costs, benefits, and net returns for various cover crop, intercrop, and crop-livestock integrated organic production systems. http://msuextension.org/publications/AgandNaturalResources/EB0200.pdf

37. From Conventional to Organic Cropping: what to Expect During the Transition Years. Menalled F., C. Jones, D. Buschena, and P. Miller. 2012. Montana State University Extension MontGuide MT200901AG Reviewed 3/12. Provides guidance for organic dryland grain growers in meeting economic, cropping system, nutrient, and weed management challenges during organic transition. https://store.msuextension.org/

38. **Meeting the Challenges of Soil Health in Dryland Wheat.** Leslie Michel, Okanogan Conservation District. On-farm research into cover crop choices (4 years, 20 farms) NRCS webinar October 9, 2018. Science and Technology Training Library, http://www.conservationwebinars.net/listArchivedWebinars

SOUTHERN REGION RESOURCES

39. **Southern Cover Crop Conference,** July 18-19, 2016. Includes fact sheets and videos on cover crop selection and mixes, soil health and soil life benefits, equipment for no-till and strip till systems, economics of cover cropping, and more. https://www.southernsare.org/Events/Southern-Cover-Crop-Conference

40. **Southern Cover Crop Council** is developing a regional information clearing house at https://southerncovercrops.org, which currently offers excellent practical information on cover crop planting and termination tools, and timing for the Southeast Coastal Plain. Additional information for other agro-ecoregions across the South is under development.

41. **Center for Environmental Farming Systems (CEFS)**, https://cefs.ncsu.edu/, in Goldsboro, NC includes an organic research unit including cover crops, conservation till, and organic grains. https://cefs.ncsu.edu/field-research/organic-research-unit/

42. **Carolina Farm Stewardship Association (CFSA).** Offers consulting, beginning farmer training and mentoring, and other services. https://www.carolinafarmstewards.org/

    a. Food safety – Good Agricultural Practices (GAP consulting. Manuals and videos. https://www.carolinafarmstewards.org/gaps-consulting/

    b. Organic Certification Consulting. Assistance with organic transition and NOP papaerwork. https://www.carolinafarmstewards.org/organic-certification-consulting-services/

    c. Conservation Activity Plan and enrollment in NRCS EQIP Organic Initiative. https://www.carolinafarmstewards.org/cap-consulting-services/

    d. Sustainable High Tunnel Management Consulting https://www.carolinafarmstewards.org/high-tunnel-consulting/.

    e. Organic enterprise budgets for ten leading vegetable crops. https://www.carolinafarmstewards.org/enterprise-budgets/

    f. Expert Tips monthly blog posts by CFSA staff. Topics include *soil health assessment* (Sept, 2018), *on-farm conservation and NRCS programs* (July, 2018) *organic weed management* (June, 2018), and more. Older posts available at link at bottom. https://www.carolinafarmstewards.org/forgrowers/experttips/

43. **Organic Transition and Production Handbook,** compiled by Eric Soderholm, Farm Organic Transitions Coordinator, CFSA. Extensive information on organic certification and soil fertility and soil health management practices for the Carolinas. https://www.carolinafarmstewards.org/organic-transition-handbook/

44. **Southern Sustainable Agriculture Working Group.** https://www.ssawg.org/. Offers on line courses that can help producers assess business management risks: *Growing Farm Profits*, https://www.ssawg.org/growing-farm-profits/, and *Choosing Your Markets*, https://www.ssawg.org/choosing-your-markets/.

45. **Florida Organic Growers (FOG)**, http://www.foginfo.org/, hosts Quality Certification Services for USDA organic, http://www.foginfo.org/our-programs/certification/.

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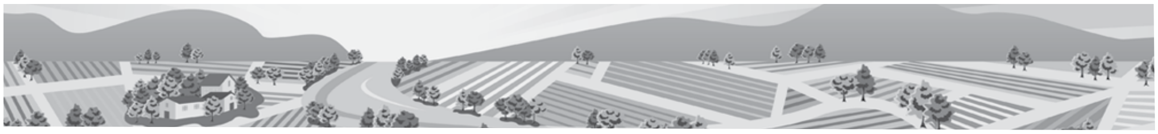
* For project proposal summaries, progress and final reports for USDA funded Organic Research and Exten¬sion Initiative (OREI) and Organic Transitions (ORG) projects, enter proposal number under "Grant No" and click "Search" on the CRIS Assisted Search Page at:

http://cris.nifa.usda.gov/cgi-bin/starfinder/0?path=crisassist.txt&id=anon&pass=&OK=OK.

Note that many of the final reports on the CRIS database include lists of publications in refereed journals that provide research findings in greater detail.

NOTES:



NOTES:

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