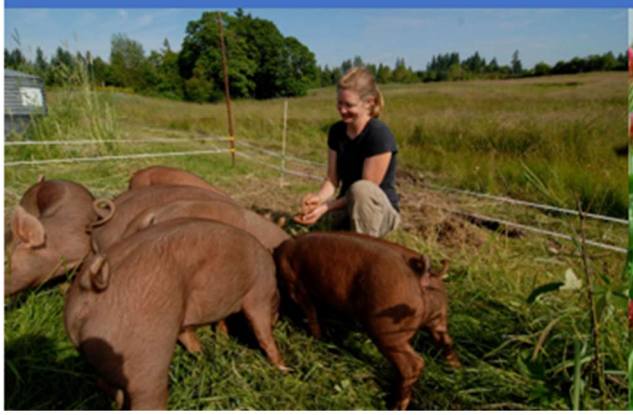
Creating A Soil Health Roadmap For Your Diversified Farm

CASE STUDY



Acknowledgements

This project was made possible by a Washington State Soil Health Committee grant in partnership with Clark Conservation District.

Technical assistance provided by Dr. Lynne Carpenter-Boggs, Dr. Cornelius Adewale, and Dr. Doug Collins of Washington State University; and by Anitra Gorham of the Natural Resources Conservation Service.

Prepared by Lauren Snyder, Ph.D., Ricardo Perez-Alvarez Ph.D., and April Thatcher, Farmer, April Joy Farm, Ridgefield, Washington.

INTRODUCTION

Farmers intuitively understand soil health is the fundamental basis of farm health. Healthy soils are characterized by good structure and tilth, properties that promote aeration, water infiltration, and strong root growth. Healthy soils also have a sufficient and renewing source of soil organic matter—which provides plant-available nutrients—and supports a thriving community of macro and microbiota. Building soil health is one of the best forms of crop insurance because healthy, living soils provide a number of valuable services that support crop production. Not only do healthy soils increase crop vigor, they can also enhance crop resilience to abiotic (e.g., drought and extreme fluctuations in temperature) and biotic stresses (e.g., pests and pathogens).

Despite the many benefits associated with healthy soils, building soil health is not straightforward. This is particularly true for farmers managing diversified operations that require multifaceted approaches to address the needs of the many stakeholders involved in the process. Moreover, there is no one prescriptive path that will improve soil health for all agricultural operations. Due to these intrinsic challenges, the goal of improving soil health is too often deferred or addressed in a piecemeal way. One strategy for overcoming these challenges is to build a soil health roadmap that is tailored to your specific operation.

A soil health roadmap is intended to provide you with a comprehensive view of your farm operations from the perspective of its creator: the living soil. In this soil health roadmap case study, we break down the elements of a soil health roadmap using examples from the roadmap created for April Joy Farm in Ridgefield, Washington. As you move through this case study, keep in mind that the overall goal of the soil health roadmap is to increase your confidence and empower you to make strategic operational changes that create long-term resilience and improved health for yourself, your family, and the farm you steward.

Access the full soil health roadmap for April Joy Farm at:
http://www.soilhealthwa.org/grants-projects/project-soil-health-roadmap-and-toolkit/

WHAT IS A SOIL HEALTH ROADMAP?

A soil health roadmap (SHR) represents a systems approach to planning for soil health. Just as agricultural practitioners routinely create crop, marketing, and financial plans, the SHR is a framework which provides a multifaceted approach to creating a soil health plan. There are five elements to the SHR (Figure 1).

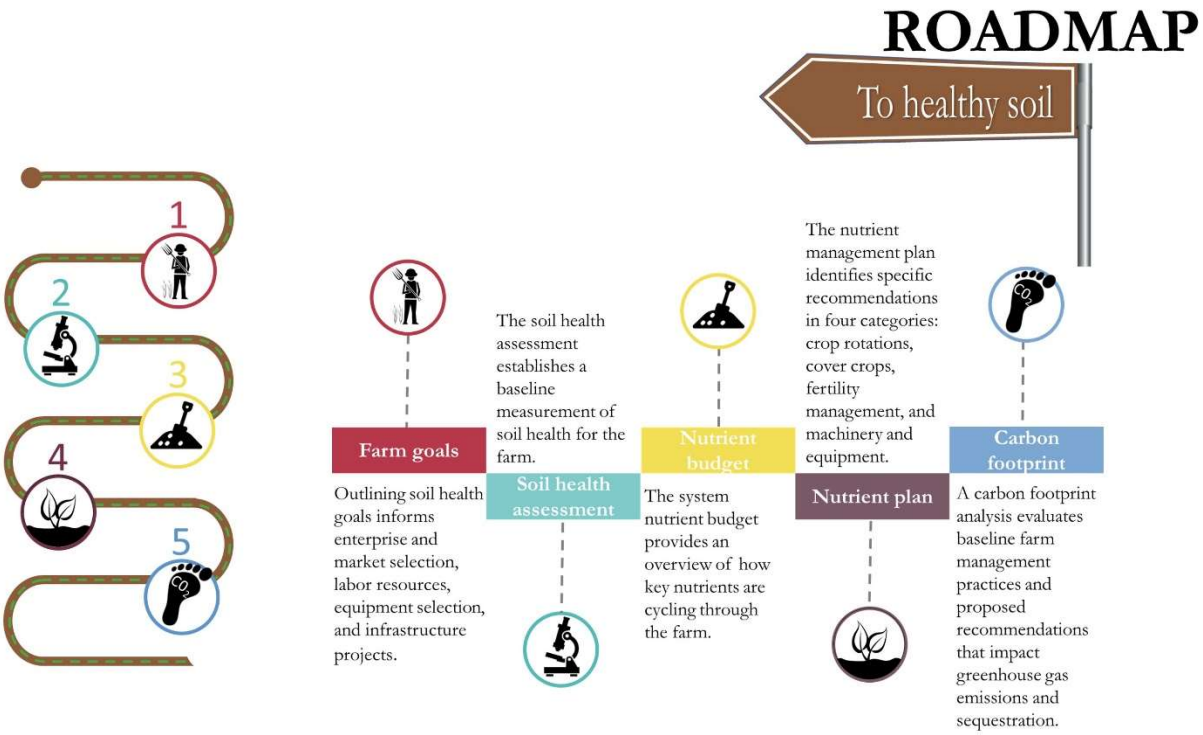


Figure 1: The Elements of The Soil Health Roadmap

Farm Goals

An important first step in creating a soil health roadmap is to clearly articulate the goals of your operation. For example, the farmers at April Joy Farm (AJF) want to manage a diversified enterprise that provides a financially comfortable livelihood while protecting the health and integrity of their farm ecosystem. They aim to establish the farm as a community asset that affords area residents access to healthy, high quality food. They want to steward their land to create optimal soil health to support resilience in the face of a changing climate.

There are many reasons for working in the field of sustainable agriculture. What are your objectives? Make sure to consider your financial needs, business and/or family partnerships. Specific goals you may want to consider include: creating a business plan that supports the long-term viability of the operation in the face of development pressure, restoring depleted pasture or cropland, limiting the quantity and expense of off-farm inputs, or protecting a particular cultural or natural resource.

As you solidify the goals of your operation, keep the following in mind:

1. Goal setting is not a one time activity, but rather an iterative process. It is important to set aside time on an annual basis to review what you have accomplished, assess your progress, and, given what you have learned, decide where you want to go. In other words, are your goals from last year still aligned with all the knowledge you have gained about yourself, your land, and your community? If not, how can you make adjustments to move closer to your vision?

2. It is important to think about what you are doing, why, and for whom. A good framework is: self, land, and community.

Understanding your own strengths and interests, the resources and capacity of your land, and the needs of your community can help you figure out the sweet spot for your operation. In the Venn diagram above, your goal is to create a business model that lands in the center! For instance, if you do not enjoy interacting with customers, do not want to manage employees, have a depleted soil base, and the local markets are flooded with produce, trying to grow and direct market produce will prove to be very challenging. Instead, ask yourself, what unique gifts can I offer my community that support the inherent qualities of my land?

Figure 2: Goal Setting in the Context of Soil Health

Comprehensive Soil Health Assessment

The second step in creating a SHR is to conduct a comprehensive soil health assessment. First, you must identify appropriate assessment criteria that are accessible and meaningful for you to undertake given your location, existing resources, and production methods. When choosing criteria, it is important to consider the chemical, physical, and biological properties of your soil. The illustration below outlines the indicators selected at AJF (Figure 3). These are just some of the many indicators that can play a role in a soil health assessment—you will want to consider many others for your operation such as plant residues, tissue analysis, or erosion.

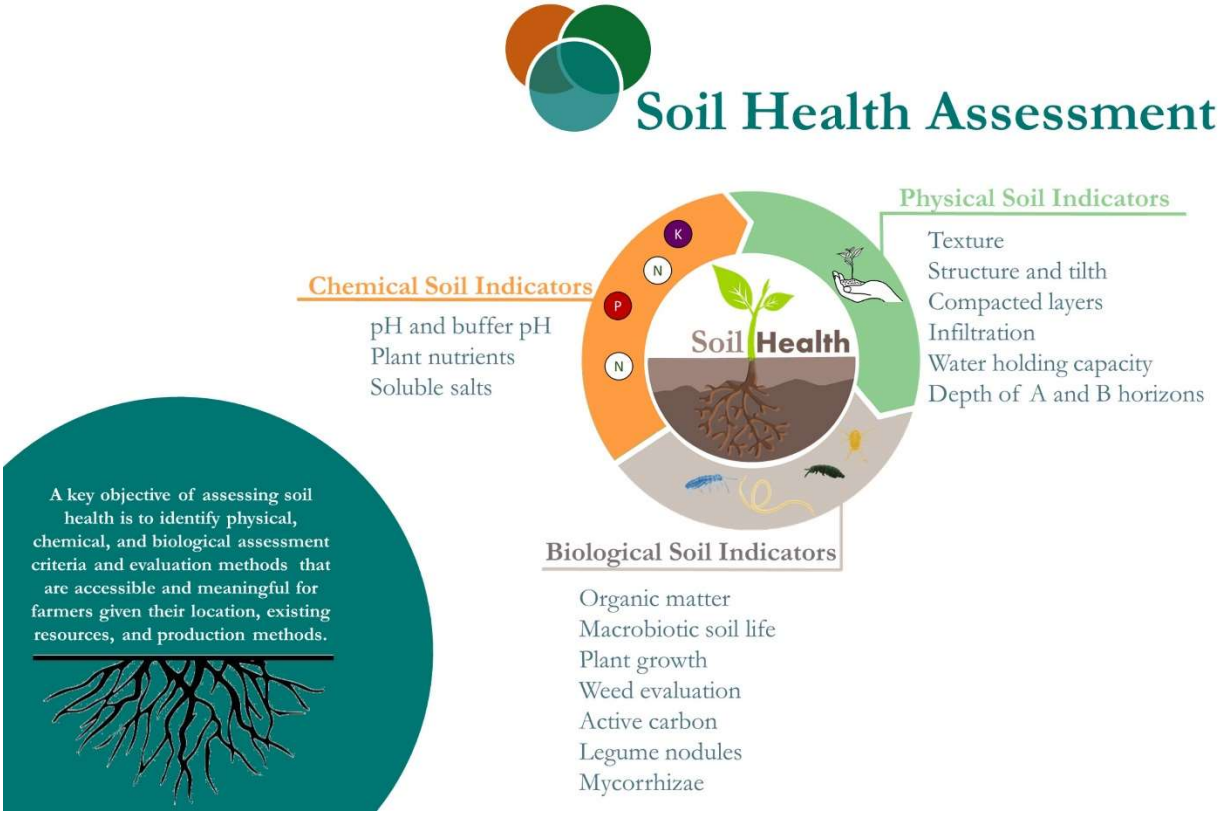


Figure 3: Components of a Soil Health Assessment Highlighting Indicators for AJF

There are many resources available to help you determine which indicators are appropriate for your farm. Table 1 lists the resources the farmers at AJF utilized to identify their indicators.

Physical characteristics

The physical characteristics of your soil include its color, texture, structure, consistency, and the horizons (layers). Although many of these characteristics are difficult to change, management practices can have a significant impact on the physical health of your soil. For example, a well-structured (uncompacted) soil can improve infiltration and nutrient exchange, and reduce erosion. The farmers at AJF learned a great deal about physical soil health through their soil health assessment, including:

- **Soil formation cycle:** Understanding the three primary factors of soil formation—parent material, climate, and organisms—as well the two modifying factors—topography and time—provide a critical contextual perspective. It is valuable to recognize that of the five factors, you can only influence one, organisms, unless you utilize climate-controlled structures and/or drastically regrade landforms. Thus, when considering soil health and management practices, it is only through changes in micro and macro flora and fauna (i.e. living plants), that you can impact the restorative capability of the soil.

- **Compaction:** Penetrometer readings can give you a sense of whether compaction is an issue on your farm. If you are using any kind of machinery in your fields, it is important to understand its impact on soil health. Assessing the level of soil compaction is one way to do so. The farmers at AJF purchased a quality penetrometer for $250[1]. This instrument has served as an economical tool to monitor this key soil health indicator. Check with your Conservation District, community college, or extension agency as they may have one available for you to use.

- **Evaluation is relative:** Many physical soil health indicators are scored against a distribution of indicators measured on other regional soils. It is important to understand this evaluation is only a *relative* indicator of soil health because the overall health of other regional soils is not known. A more accurate evaluation of soil health will be possible if these physical indicators are evaluated from the same location (i.e., your farm) on a regular basis. By tracking changes in soil health on your farm over time (not relative to other regional soils), your physical soil health can be more accurately assessed as declining, stable, or improving.

Chemical characteristics

It is crucial for you to be able to identify the forms of plant available nutrients, i.e., nitrate, ammonium, phosphates and potassium ions (NO_3^-, NH_4^+, $H_2PO_4^-$ and K^+), and how these values relate to reported soil test results and total nutrient values. It is also important to understand how the various plant-available nutrients are retained and removed from soils (i.e., the transport mechanism for all biologically available forms of nutrients). The information captured in the chemical portion of the soil assessment will inform management decisions about when to apply inputs such as compost to augment nutrient availability or lime to adjust soil pH. It may also influence how you manage the organic materials available to you, and possibly the crops you choose

[1] https://www.certifiedmtp.com/ams-soil-compaction-tester/

to grow. For example, in response to a soil test revealing very high levels of phosphorus, the farmers at AJF eliminated direct applications of manure to their fields and are working to reduce their reliance on purchased livestock feed (i.e., the importation of additional phosphorous) by growing their own grains.

Soil profile: Testing the soil physical properties at multiple depths can provide key insights, including the ability to assess nitrogen leaching, and the identification of available nutrients lower in the soil horizons (i.e., "B" horizon), such as iron and phosphorus. Identifying nutrient availability at three depths (0-6", 6-12", and 12-24") can help assess if it is necessary to import fertility. For example, if boron is low in the top profile, but in excess at 24", growing deep-rooted cover crops that mine the deeper soil horizons can make this nutrient potentially available to the crop in the top 6" of the soil.

Analyzing Recommendations: It is important to develop your own insights to identify what is appropriate and necessary with respect to test recommendations. Understanding what specific values are truly being measured is the first step. Recognizing the reliability of the test results is also important. For instance, organic matter is frequently tested by laboratories using the loss on ignition method. This method indirectly tests for organic matter, and it is quite different from a test which directly measures soil carbon. Learning about the different testing methods will help you decide which is more meaningful for your operation. Know too, that test results will often vary by laboratory. Consistency in both lab and method of assessment is crucial to attaining valid data.

Conducting a comprehensive soil health analysis identifies the strengths and weaknesses of your farm's soil. This information plays a crucial role when it comes time to select management practices that address the needs of your unique system. As an example, the illustration below highlights the areas for AJF soil health improvement, as identified through comprehensive soil health analysis.

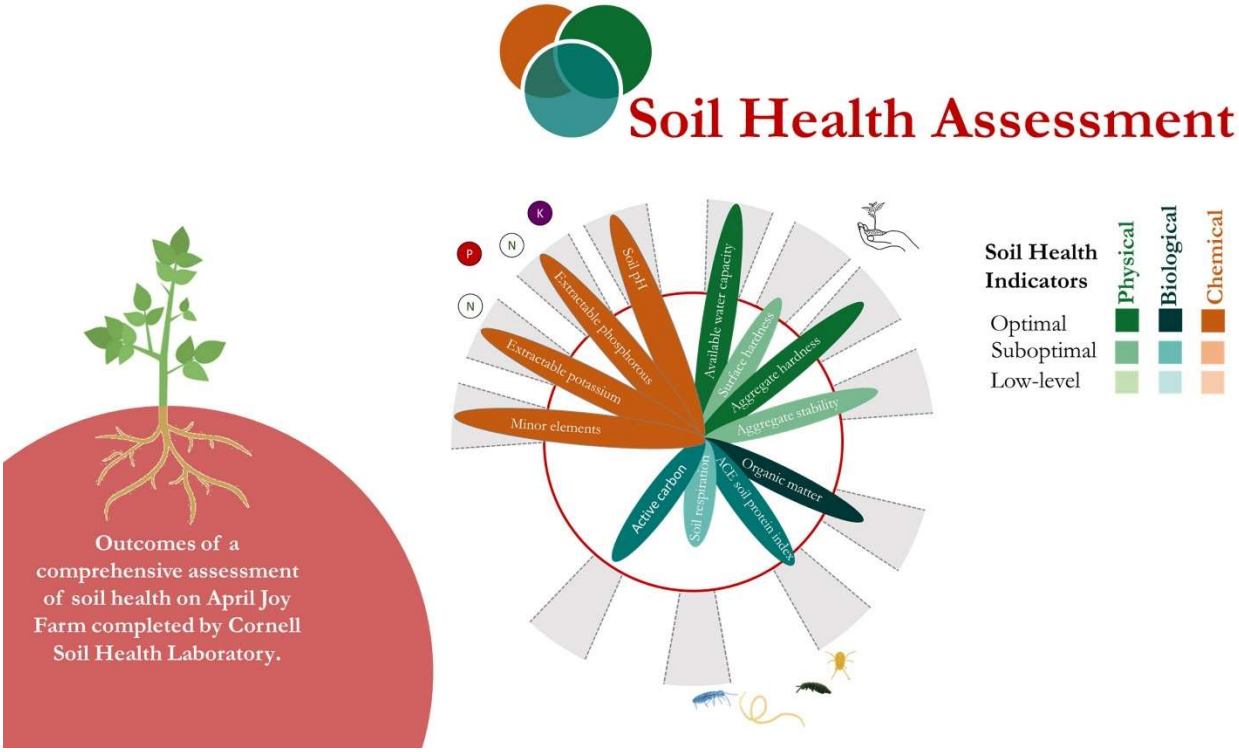


Figure 4: Results of a Comprehensive Soil Health Assessment for AJF

Photo 1: Soil Biology is Critical to Soil Health

<u>Biological characteristics</u>

The complex ecosystem of living soil provides a number of critical soil functions. Significant biological indicators are best assessed on-farm, in-situ. While biological soil health is crucial to overall soil health, biological soil monitoring is in its technical infancy. Biological indicators of soil health have traditionally been very qualitative. Aside from organic matter, only recently have quantitative tools been accessible for evaluating soil biological health, and the validity of such tests are not widely agreed upon. Therefore, it's important to rely on your intuition and commit to learning more about supporting and assessing biological health. Setting aside time to evaluate earthworm abundance, plant growth, weed species, and mycorrhizae populations may be important for the success of monitoring change in biological soil health on your operation. While scientists do not yet fully understand the complex biological workings of soil function, you can still take steps to protect and encourage the soil's natural processes such as air exchange, nutrient mixing, decomposition, and humus formation. In addition, reaching out to regional soil scientists for help evaluating the biological health of your soils can help you establish a network and

keep you up–to-date on biological soil health advances. In evaluating their soil health, the AJF farmers relied on the expertise and support of both Washington State University soil and extension scientists, as well as a comprehensive soil health assessment provided by Cornell University.

One final indicator you may wish to consider including in your soil health assessment is the average yield(s) of common crops or products produced at your farm in recent years. Such yields can serve as an indicator when compared to historic yields and by analyzing trends. Healthy soil will support consistent or improving yields (not-withstanding erratic weather or other such factors).

Identifying Indicators

You can identify a number of different indicators, but you need to select the ones most relevant to your farm and the ones realistic for you to assess on a routine basis. Safeguard time to integrate these assessments into your annual farm schedule. **Keep in mind, the data you collect at this phase is only as good as the sampling procedure. It is important to be consistent with the test method, tools, and times of year each portion of your assessment is completed.** Below are some of the resources the farmers at April Joy Farm used to identify the soil health indicators relevant to their farm. The full list of resources they used can be found in Table 2 of the April Joy Farm Soil Health Roadmap.

Resources

http://www.nezperceswcd.org/Projects/SoilQuality/SoilQualityIndicator.aspx

https://extension.oregonstate.edu/news/soil-quality-test-available-gardeners-farmers-willamette-valley

https://soilhealth.cals.cornell.edu/

https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/health/assessment/?cid=nrcs142p2_053873

Systems Nutrient Budget

The next step in creating a SHR is to develop a systems nutrient budget, which will allow you to track how nutrients are cycling through your farm. Results from your soil health assessment will inform which macro and/or micronutrients you will want to focus on in this step. For instance, the soil health assessment for AJF revealed a deficiency of nitrogen and an excess of phosphorus. Therefore, the farmers focused on capturing the dynamics of these nutrients in their systems nutrient budget. You may choose to track different nutrients based on the goals of your production plan and the crop rotations you currently employ. For instance, if one of your farm goals is to grow high-protein feed grain, then your systems nutrient budget will need to focus on the relatively high nitrogen demand of such crops. Alternatively, if your farm goals is to grow alfalfa hay, replacing exported phosphorous will be a key focus. Consulting with trusted technical advisors and farm mentors is highly encouraged.

The goal of the systems nutrient budget is to identify the origin of deficits and/or surpluses of key nutrients on your farm so you can make better decisions about fertility management. Figure 5 shows the nutrient imports and exports considered in the nutrient budget for a 2 acre crop field at AJF. Keep in mind that while the categories of imports and exports shown below are those used at AJF, the specific elements that make up those categories and their relative importance may be different for your farm. For example, at AJF, soil amendments included blood meal and manure, but you may not use either of these materials on your farm. Likewise, leaching is a very significant factor at AJF, while erosion is non-existent. This may not be true for your operation. Certain categories, such as plant residues, could be either a nutrient import or export depending on how you are using them; if you remove plant residues from the field they would represent nutrient exports, but plant residues like straw, hay or leaf mulches that you apply to the field would be considered nutrient imports. Likewise, a systems nutrient budget for a livestock operation will include different elements, for instance feedstocks.

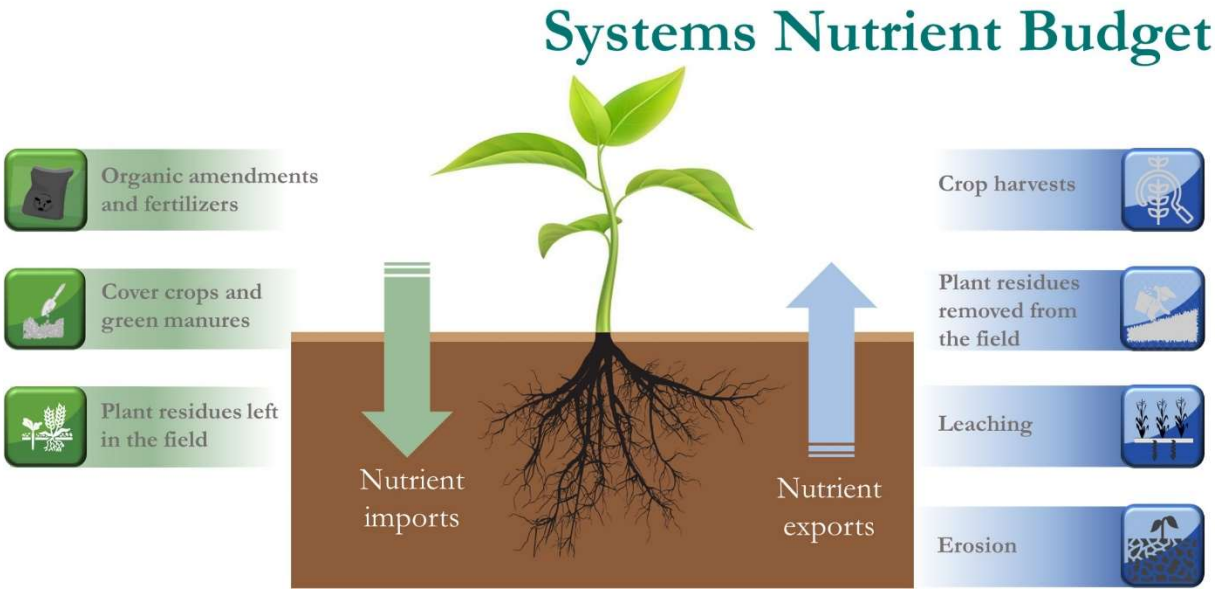


Figure 5: Nutrient Imports and Exports Considered in a Systems Nutrient Budget for an AJF Vegetable Field

Understanding how nutrients are added and removed from your fields will help you develop targeted management practices to stabilize nutrients that are currently out of balance. For example, the AJF nutrient budget revealed the farm was losing almost twice as much nitrogen from leaching as from crop exports. Therefore, to limit costs associated with importing nitrogen fertilizers, it will be essential for the farmers to grow winter cover crops that can capture these nutrients before they leave the field. A grain cover crop such as rye is a good option as it can effectively scavenge for nitrogen in the soil and prevent it from leaching. In addition, the use of legume cover crop could offset losses from leaching through nitrogen fixation, providing fertility to the field without adding phosphorus to the soil.

Resources to Help You Develop Your Own Systems Nutrient Budget

This eOrganic article on Nutrient Budget Basics for Organic Farming Systems is a good place to start as you begin creating your own systems nutrient budget:
https://eorganic.org/node/3060

Nutrient budgets for livestock operations will be different and include imported livestock feed. Here is one resource: **http://orgprints.org/8387/1/cuttle_Nutrient_budgets_tool.pdf**

For a more detailed example, the farmers at April Joy Farm provide an in-depth description of their methodology and the resources they used on pages 17-20 of their Soil Health Roadmap:
http://www.soilhealthwa.org/grants-projects/project-soil-health-roadmap-and-toolkit/

Selecting the appropriate resource to estimate the nutrient profiles of your crops will greatly simplify the calculations needed in a systems nutrient budget for a diversified farm. One such example is the Natural Resources Conservation Service (NRCS) Plants Database Nutrient Content of Crops website, which calculates the approximate amount of nitrogen, phosphorus, and potassium removed by the harvest of crops: **https://plants.usda.gov/npk/main**

Nutrient and Field Management Plan

Developing a nutrient and field management plan is your opportunity to:

- review your historic and current practices,
- identify challenges and opportunities,
- make recommendations to improve your management practices.

You will want to evaluate the following four categories outlined in Figure 6: rotations, cover crops, organic materials, and machinery/equipment. As we move through these four categories, we will provide useful questions for you to consider followed by real life examples from AJF.

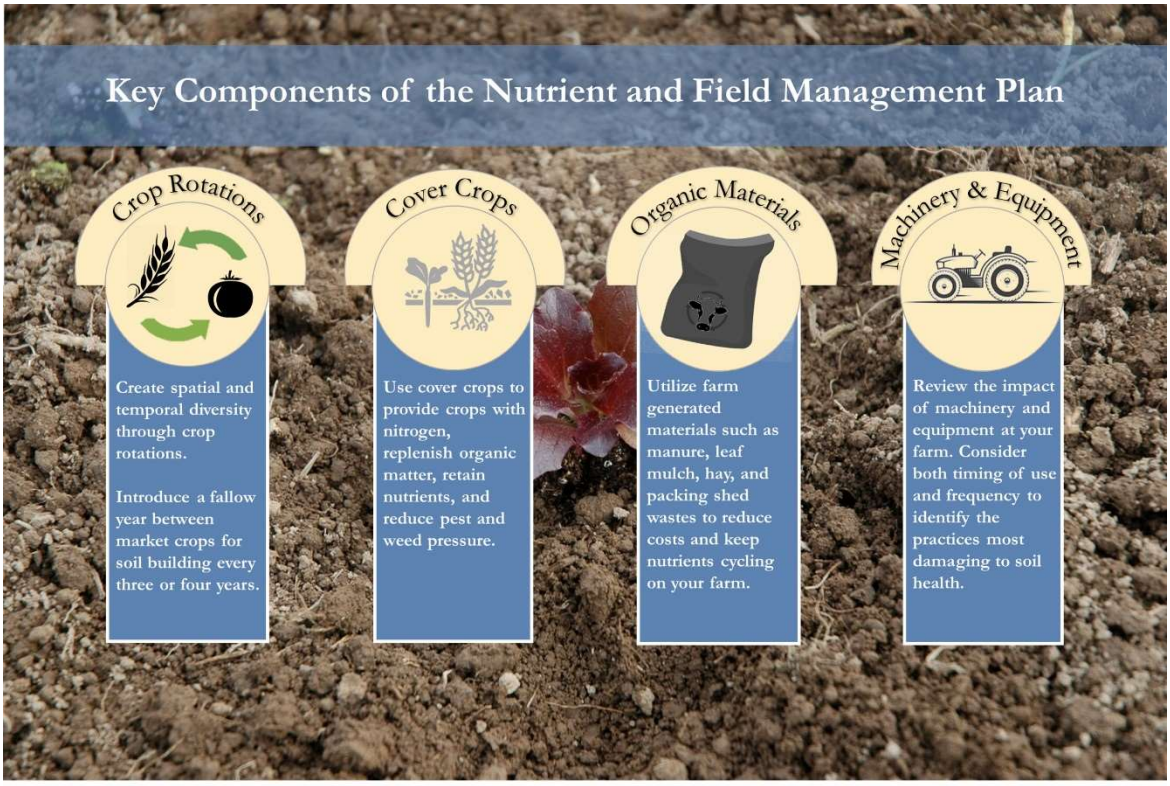


Figure 6: Management Categories to Consider in a Nutrient and Field Management Plan

Crop and Grazing Rotations

1) Review Current and Historical Practices

As you create your nutrient and field management plan, the first step is to document your historical and current practices. Take some time to write down your rotational practices. Often seeing things visually can help you gain new perspectives. Consider the following questions:

1. How are animals and/or plants moving across your land both spatially and temporally?

2. How do you currently group your crops, perhaps by plant family or date of sowing?
3. What is the typical length of your rotation?
4. Do you incorporate a fallow or soil-building break between market crops?

At AJF, the farmers have practiced rotations since the inception of the farm and group their rotations by plant family. Their rotation is nine years in length (with a few exceptions) and historically they have incorporated a soil building period.

2) Identifying challenges and opportunities

Now that you have described your past and current rotational practices, focus on identifying the challenges you are facing. Here, you may want to ask yourself the following:

1. Is the timing or diversity of your rotations constrained by space, poor field conditions (i.e. compaction, flooding, weed pressure) or a lack of accessible markets?
2. Are there logistical challenges that are hindering production?
3. What portions of your rotation are most successful and why? Can you leverage that success in other ways?

While completing their nutrient and field management plan, the farmers at AJF noted that they have had to significantly alter their crop rotations each year in response to fluctuating market demands. This is a challenge and requires a lot of extra effort. They also recognized that their current rotation plan did not account for differences in the natural characteristics of their fields. For instance, their south fields are much less well-drained, which has consistently delayed spring planting activities. As a result, the rotation (and in some cases, soil health) has been compromised in order to ensure the health of the transplants.

Finally, they identified an opportunity to improve the logistics of their rotations. Historically, they often planted early and late season crops in adjacent beds, leading to a very fragmented rotation that did not lend itself to cover cropping or larger "block" sized amendments/soil improvement practices. This necessitated increased tillage and cultivation.

3) Make Recommendations

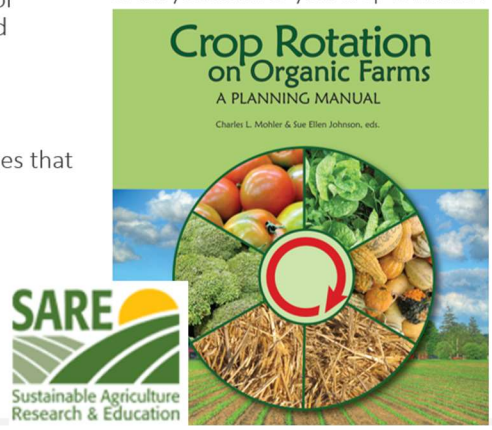
Given the challenges you outlined above, what improvements could you make to your crop rotations? Perhaps you will want to consider grouping your rotations in a different way or adjusting the length of your rotations to accommodate market demands or soil fertility needs. Brainstorm specific strategies and changes you could make that would improve this aspect of your operation. Make sure to review technical resources that can help identify potential strategies. One resource for crop producers is: Crop Rotations on Organic Farms, A Planning Manual, published by Sustainable Agriculture Research and Education (https://www.sare.org/Learning-Center/Books/Crop-Rotation-on-Organic-Farms).

To address the logistical issues caused by planting early and late season crops adjacent to one another at AJF, the farmers divided their rotation into two sub-rotations that group market crops primarily by planting season and secondarily by crop family. Their "early" rotation crops will be planted in the most well-drained portions of their field. Their summer and fall crops will be planted in the lower sections of the field that are not workable until June. The farmers have also introduced

a two year-long soil building fallow every three to four years and plan to immediately follow this fallow with crops that have the highest nutrient (nitrogen) requirements, followed in succession by medium, then light feeders in subsequent years. This will maximize the usage of nitrogen accumulated through cover cropping.

Crop & Grazing Rotations

Historical & Current Practices	Challenges & Opportunities	Recommendations
How are animals and/or plants moving across your land both spatially and temporally? How do you currently group your rotation, perhaps by plant family, time of sowing, or age of livestock? What is the typical length of your rotation? Do you incorporate a fallow or soil-building 'break' between market crops?	Is the timing or diversity of your rotation(s) constrained by space, field conditions (saturated or compacted soil, heavy weed pressure, etc.), or a lack of accessible markets? Are there logistical challenges that are hindering production?	Given the challenges and opportunities you outlined, what improvements could you make to your crop rotations?



SARE
Sustainable Agriculture
Research & Education

Table 1: A Framework for Identifying Strategies to Improving Rotations

Cover Crops

1) Review Current and Historic Practices

The following questions are good to keep in mind as you begin describing your current cover cropping practices:

1. What cover crop(s) or cover crop mixture(s) do you currently grow and why?
2. When do you typically plant and terminate your cover crops?
3. Do you directly incorporate cover crops with any of your market crops?

Both winter and summer cover crops have been used consistently on AJF. Winter cover cropping has required multiple tactics because fall harvest periods often vary both between crops, but also between years for the same crop. For example, sweet pepper harvests can end mid to late September in some years, and in others extend well into late October. Other crops require an overwinter growing season to be harvested (garlic and flower sprouts). In addition, most fall brassicas as well as some herbs including parsley and celery are purposely overwintered in order to harvest rapini (flower buds) or resume leaf/stalk harvests in early spring. In these instances, volunteer weeds germinate and cover the exposed soil.

Over the years, the most consistent winter cover cropping practice on AJF has been a rye-vetch mix sown in mid-October and terminated mid-March. Summer cover-cropping practices have been both sporadic and inconsistent. Buckwheat and phacelia have been used in strip plantings (1-6 bed widths), but are not terminated prior to seed set. This allows two rounds of buckwheat to grow over the course of the summer, without replanting.

2) Identify Challenges

Remember, the next step is to identify challenges associated with your current cover crop practices. You may want to consider the following:

1. Review your Soil Health Assessment and System Nutrient Budget. Are your current cover cropping practices exacerbating the retention or loss of key nutrients?
2. Have you observed poor germination in your cover crops?
3. Do you have any issues related to terminating your cover crops?
4. Has it been logistically challenging to incorporate cover crops?
5. Have weeds, insect pests, or diseases been an issue as a result of your cover crop practices?

The farmers at AJF have experienced a number of challenges related to cover cropping. It has taken them multiple years to successfully integrate cover crops into their production practices. For instance, while they always wanted to relay plant (overseed) market crops with cover crops, they faced three major hurdles: 1) the frequent foot traffic in aisleways compacts the soil and damages the newly germinating cover crop, 2) the cover crop does not grow fast enough to adequately compete with weed pressure, which then requires cultivation, and 3) the use of synthetic weed barrier for some crops eliminates the opportunity for overseeding.

Planting leguminous cover crops like winter field peas has also been a challenge due to poor germination or an inability for the cover crop to overwinter, potentially due to late sowing dates and soil acidity. There is often insufficient time for certain spring cover crops such as hairy vetch to achieve significant top growth. The farmers would also like to expand the use of summer cover crops for weed management and nutrient building, but they face restrictions with respect to irrigation usage. In addition, the farmers do not have adequately sized irrigation equipment or pumps to overhead irrigate larger acreage.

3) Make Recommendations

Having identified your challenges, you have the opportunity to revise your current cover cropping practices. For example, perhaps you want to adjust the dates you sow and terminate your cover crops, or experiment with a different cover crop species. Remember to utilize the information you've gained from your comprehensive soil health assessment and system nutrient budget to identify the primary goals for using cover crops. One additional resource to consider is Soil Health and Organic Farming, Cover Crops: Selection and Management. This guide was published by the Organic Farming Research Foundation and can be downloaded for free (https://ofrf.org/soil-health-and-organic-farming-ecological-approach-0).

The AJF farmers aim to establish a rotation specific to cover crop usage which aligns with the market crop rotation. The main goals for this cover crop rotation are to: 1) supply a majority of the nitrogen requirement for the heaviest feeding market crops, 2) replenish organic matter, 3) reduce nutrient leaching from winter precipitation, and 4) reduce weed pressure.

In response to the poor germination of winter pea, the farmers at AJF have transitioned to using crimson clover or vetch, which have proven to be more reliable cover crops. By using leguminous cover crops, they can add nitrogen to their soil without adding phosphorous. This is important because the AJF fields are currently quite high in phosphorous and continued applications could be detrimental. The farmers are also aiming for an earlier sowing date (September 1-15th) to give cover crops adequate time to establish prior to the onset of winter and thus reduce losses of nitrogen due to winter leaching. This will also result in greater biomass at incorporation. In addition, the farmers eliminated the use of synthetic weed barrier to allow fall cover crops to be overseeded and become well established by mid-October.

Cover Crops

Historical & Current Practices	Challenges & Opportunities	Recommendations
What cover crop(s) or cover crop mixture(s) do you currently grow and why? When do you typically plant and terminate your cover crops? Do you directly incorporate cover crops with any of your market crops? Do you irrigate your cover crops?	Review your Soil Health Assessment and System Nutrient Budget. Are your current cover cropping practices exacerbating the retention or loss of key nutrients? Have you observed consistently poor or robust germination or growth? Do you have any challenges related to termination, incorporation, or other management logistics related to your cover crops? Have weeds, insect pests, or diseases increased or been suppressed due to your cover cropping strategy?	Given the challenges and opportunities you outlined, what improvements could you make to your cover cropping strategy?

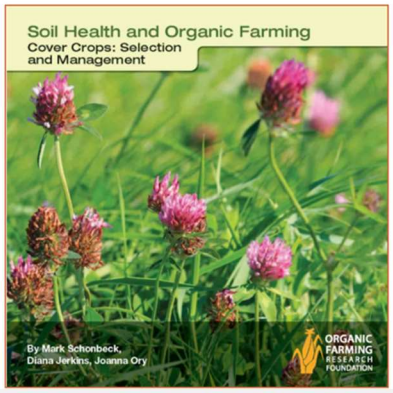


Table 2: A Framework for Identifying Strategies to Improve Cover Cropping Practices

Organic Materials

1) Review Current and Historic Practices

Consider the following as you review the usage of organic materials on your farm:

1. What existing materials, (leaves, wood chips, manure, grass clippings, hay) do you currently have on your farm? Estimate quantities and time of year they are available.
2. What do you use amendments for (e.g., fertility, pest and disease management, etc.)?
3. Do you typically purchase fertility amendments or produce them on your farm?
4. When do you typically apply amendments and do you use them routinely or inconsistently?

At AJF, organic amendments are used primarily for soil fertility and less for weed, insect pest, and disease management. Historically, most fertility amendments have been purchased rather than produced on the farm. While a passive compost pile has been used for vegetable waste and chicken manure, the compost generated has not been used for production operations, due to assumed pathogen presence.

Manure is typically applied in late October to only the blocks that will be fallow the following year. All purchased fertilizers are applied at the time of sowing or transplant. No secondary or mid-season fertilizers are used. Lime is typically applied every 2-3 years, in late winter or early spring. Two miniature donkeys provide an on-farm source of fertility.

2) Identify Challenges

As you identify challenges associated with your use of organic materials, ask yourself the following:

1. Review your Soil Health Assessment and System Nutrient Budget. What are the most limiting nutrients for your production? Are you making the best use of the materials already on your farm? If not, what are the barriers you face?
2. Do you feel the amendments you are using are effective?
3. Do you have concerns about the quality or potential contamination of any of the amendments you are using?
4. How does the use of these amendments affect labor and equipment requirements?

Organic materials have been underutilized at AJF due to both labor and the logistical hurdles of properly collecting, storing, and processing a diverse base of seasonally available materials. The farmers have also been unable to produce sufficient quantities of high quality, pathogen-free compost on the farm. Lack of equipment, time, proper storage facilities, and non-uniform quantities of feedstocks hamper efforts. Supplementing farm resources with off-farm raw manure inputs is not a feasible solution, as it subjects the farm to unnecessary risk of contamination from broadleaf aminopyralid herbicides which are prevalent in area hay production and do not break down in ruminant digestion. The Soil Health Assessment results at AJF indicate the soil is relatively low in nitrogen and very high in phosphorous. The farmer's System Nutrient Budget indicates the farmers are losing nitrogen and gaining phosphorous due to their current management practices.

3) Make Recommendations

Based on the challenges you outlined above, think about ways in which you can streamline your use of organic materials. For example, is it possible to reduce your reliance on off-farm inputs, perhaps by introducing livestock or adding a composting system to your operation? One resource that may assist you is WSU College of Agriculture, Human and Natural Resource Sciences publication # 646: *Soil Fertility in Organic Systems* (http://pubs.cahnrs.wsu.edu/publications/wp-content/uploads/sites/2/publications/PNW646.pdf).

At AJF, the farmers eliminated direct applications of manure to their fields to better manage phosphorous levels. They also shifted to sourcing amendments that only provide nitrogen, and not phosphorous (bloodmeal, for example). In order to more efficiently make use of the varied and seasonally available materials currently generated on-farm, the farmers decided to build a compost structure. They received cost share funds through their Conservation District to build a static aerated composting structure, and one of their long-range goals is to supply half the required

nitrogen from farm generated compost. They are considering reducing or eliminating off-farm feed purchases for livestock because these inputs contribute to increased phosphorous loads in the soil By migrating to farm-produced feedstuffs, existing phosphorous could be recycled through the farm system.

Organic Materials

Historical & Current Practices	Challenges & Opportunities	Recommendations
What existing organic materials do you currently have at your farm? Estimate quantities and time of year they are available. What do you use these amendments for (e.g., fertility, pest and disease management, etc.)? Do you typically purchase fertility amendments and/or produce them on your farm? When do you typically apply amendments and do you use them routinely or inconsistently?	Review your Soil Health Assessment and System Nutrient Budget. What are the most limiting nutrients for your production? Are your current practices exacerbating the retention or loss of key nutrients? Are you making the best use of the materials already existing on your farm? Do you feel the materials you are using are effective? If not, what are the barriers you face? Do you have concerns about the quality or potential contamination of any of the materials you are using? How does the use of these materials affect labor and equipment requirements? What is your annual cash outlay for purchased products?	Given the challenges and opportunities you outlined, what improvements could you make to better utilize existing resources, reduce costs and risk, and improve your use of organic materials?

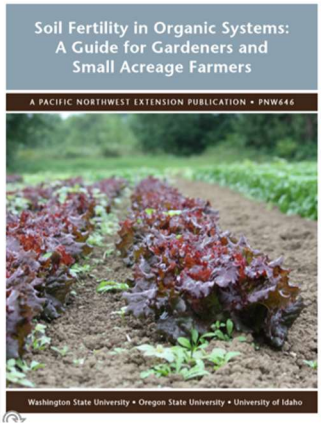


Table 3: A Framework for Identify Strategies to Improve Organic Materials Usage

Machinery and Equipment

1) Review Current and Historical Practices

Start by creating a table that summarizes all of the machinery and equipment you currently use. Then categorize this equipment by how it interacts with the soil (tillage, harvest, etc.)

2) Identify Challenges

Machinery and equipment choices have a substantial impact on the health of agricultural soils and, not surprisingly, have an equally significant impact on a farmer's budget. Therefore, it is important to think critically about how these resources are being used.

1. Did your soil health assessment indicate existing challenges such as heavy compaction, poor drainage, or signification erosion? If so, can you identify the specific equipment and associated management practices that are the root cause?
2. Are particular pieces of machinery or equipment inefficient or unpleasant to use?
3. Are you concerned certain pieces of machinery or equipment are negatively affecting soil health?

At AJF, two categories of equipment have been especially challenging from a soil health perspective: primary tillage and small grain harvesting equipment. Acquiring a primary tillage implement that is significantly less damaging to soil health than the rotovator they currently use has long been a goal of the farmers. However, accessing such machinery is challenging, and without assurances that such an expensive purchase will be appropriate and effective, the farmers are not inclined to risk such outlays of cash. In addition, the farmers have experimented with the lower-cost practice of solarization using silage tarps, but, unfortunately, this technique has proven challenging to implement at AJF primarily due to the winter climate conditions and rodent pressure.

Small grains represent a significant opportunity to improve soil health if efficient equipment for harvest such as a right-sized combine were financially viable and available for diversified small farms. On-farm production of feed for all farm livestock would be feasible, thus contributing to the management of phosphorous levels. In addition, the farmers have a longstanding relationship with a local baker, who would purchase all the grain available and who also has the necessary seed cleaning and milling equipment. Finally, increased quantities of farm-produced, certified organic rye and wheat straw could be utilized for bed mulch and/or composting operations to further recycle nutrients within the farm in lieu of importing wood chips.

3) Make Recommendations

With these challenges and potential opportunities in mind, think about ways in which you may want to adjust your current use of machinery and equipment. Perhaps you will want to pursue financial assistance (e.g., a grant or loan) to purchase a new piece equipment or reduce the use of an existing piece of equipment you feel is particularly damaging to the soil.

In the case of AJF, the farmers continue to look for ways they can reduce the use of the rotovator, and are committed to purchasing lower-impact tillage equipment and a walk-behind tractor. They may also apply for a grant to purchase a small-grain harvester or plot combine to take advantage of the opportunities they identified with small grain production. Moving forward, they plan to conduct more research on the feasibility of no-till practices in rainy climates and want to gain experience with deep mulch practices that could mitigate tillage early in the season when soil structure is easily damaged due to heavy precipitation.

Machinery and Equipment

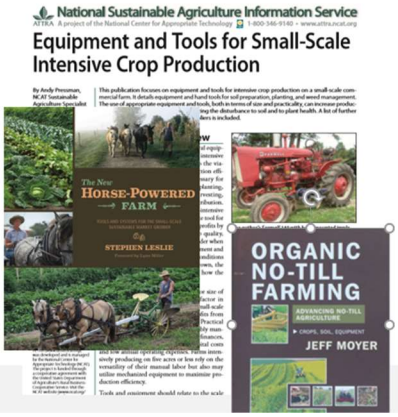
Historical & Current Practices	Challenges & Opportunities	Recommendations
Create a list of all your existing machinery and equipment. Categorize your list by how the equipment interacts with your soil: • Mowing & Swathing • Primary Tillage • Secondary Tillage / Tilthing • Seeding • Cultivation • Harvest • Organic Material Handling • Weed/Pest Management • Irrigation • Livestock Management	Did your physical soil health assessment indicate existing challenges such as heavy compaction, poor drainage, or signification erosion? If so, can you identify the specific equipment and associated management practices that are the root cause? Are you concerned certain pieces of machinery or equipment are negatively affecting soil health? Are particular pieces of machinery or equipment inefficient, unpleasant, or dangerous to use? How does your crop schedule work with or against the machinery and equipment you utilize? Think about the timing of your operations and the impact of your equipment from the perspective of the living soil. Review your goals statement. Are the machinery and equipment you are using the right fit? How much of your equipment is currently underutilized and/or competing with your philosophy of farming?	Given the challenges and opportunities you outlined, what improvements could you make to improve the health of your soil? What are the financial and operational impacts? What partnerships might you be required to develop? 

Table 4: A Framework for Identifying Strategies to Reduce the Impact of Machinery and Equipment on Soil Health

Strategies for Completing a Nutrient and Field Management Plan

Once you have generated a list of potential changes for each of the four categories of the Nutrient and Field Management Plan, prepare a one-page sheet that lists all your ideas. Pick one item that you are very interested in pursuing and/or that best aligns with your overall goals for soil health. Think about the impact of making this change with respect to the other three categories. For example, if the farmers at AJF want to increase the use of straw mulch to reduce tillage, they may choose to review the types of cover crops they grow to see if a certain grain will provide the best straw material. Likewise, they may need to review their crop rotations to make sure the timing of straw harvesting will not impact their market crop production. Finally, they will need to assess the machinery and equipment required to physically manage the production and harvest of the straw. If the farmers opt to purchase straw from off the farm, they will want to think about the machinery and equipment needed to move and distribute the straw. They will also need to identify how the straw mulch will be used. Will it, for example, be utilized to cover early spring planting beds to reduce tillage? Will this require an adjustment to their crop rotation and/or cover cropping strategy?

The examples described in this section highlight the value of completing a Nutrient and Field Management Plan as it allows you to identify a set of connected strategies that will help you achieve your soil health goals. That, in essence, is the power of a Soil Health Roadmap. By using a systems perspective, you identify which management changes will create the most impact.

Carbon Footprint Analysis

The final step of a soil health roadmap is to complete a carbon footprint analysis to identify sources of greenhouse gas emissions from your farm operation. Understanding the major sources of greenhouse gas emissions caused by your operation will help you focus your limited time and resources on developing management practices that will most effectively curb your environmental impact. The following webinar provides a good overview of the many ways organic agriculture can be both a source and sink for greenhouse gases (https://eorganic.org/node/5617).

To develop a carbon footprint analysis for your farm operation, you can use the Organic Farming Footprint (OFoot) tool developed by Washington State University. To access this tool, you will need to create a *free* account at **https://ofoot.wsu.edu/.** Once you set up your account, follow the prompts to provide a brief summary of your farm and describe a baseline scenario for your farm (i.e., your current management practices and equipment). After entering this information, you will see an option to "specify farm inventory." From here, you will enter information related to your farm inventory, land units and management practices, and operations. Once you have entered all of the relevant information, click "estimate my farm's carbon footprint" and in a matter of days you will receive your footprint analysis. Once you understand your current carbon footprint and are more comfortable with the OFoot tool, you can run different scenarios to see how different management practices could change your carbon footprint. For example, how would changing soil amendments, adding a new crop rotation or implementing a conservation tillage practices affect your greenhouse gas emissions?

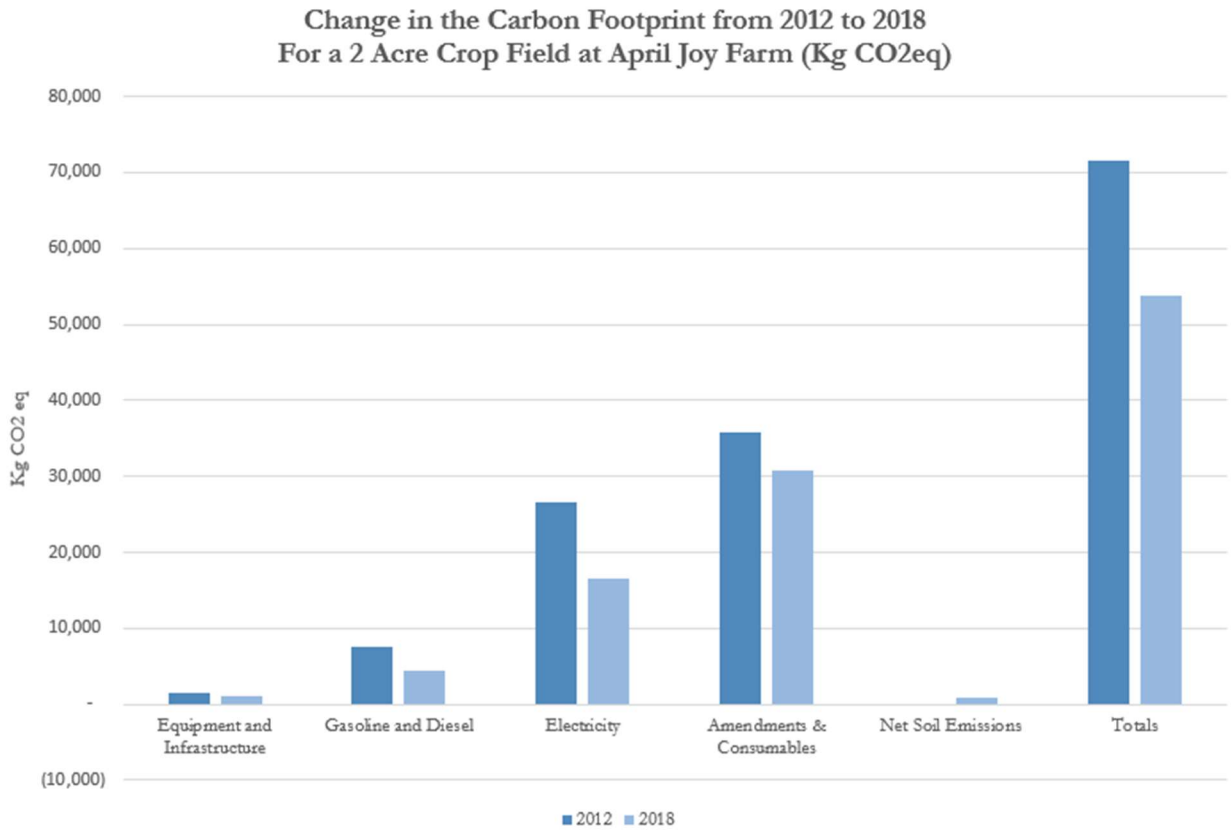


Figure 7: Cradle to Farmgate Carbon Footprint For A Two Acre Crop Field at AJF

In their original 2018 Soil Health Roadmap, the AJF farmers included a 2014 carbon footprint for their two acre crop field that had been completed by WSU researchers as part of the OFoot project. In 2019, the same WSU researchers completed a seven year longitudinal carbon footprint study at April Joy Farm (Figure 7). The 2019 calculations include not only field-applied amendments, but also propagation materials used to grow transplants, which the original 2014 carbon footprint did not include.

Figure 8 shows the 2018 carbon footprint for the two acre crop field at AJF. Over the past six years, the farmers reduced their greenhouse gas emissions by 25%, through many of the practices they identified in their Soil Health Roadmap. The farmers pursued a USDA grant to install a photovoltaic system that provides almost half of the entire farm's energy usage. Improving the implementation of cover crops that capture and store carbon is another way in which the farmers have mitigated their impact on climate change. Finally, by reworking their crop rotation program, they have successfully implemented more efficient tillage operations that save on fuel while reducing soil compaction.

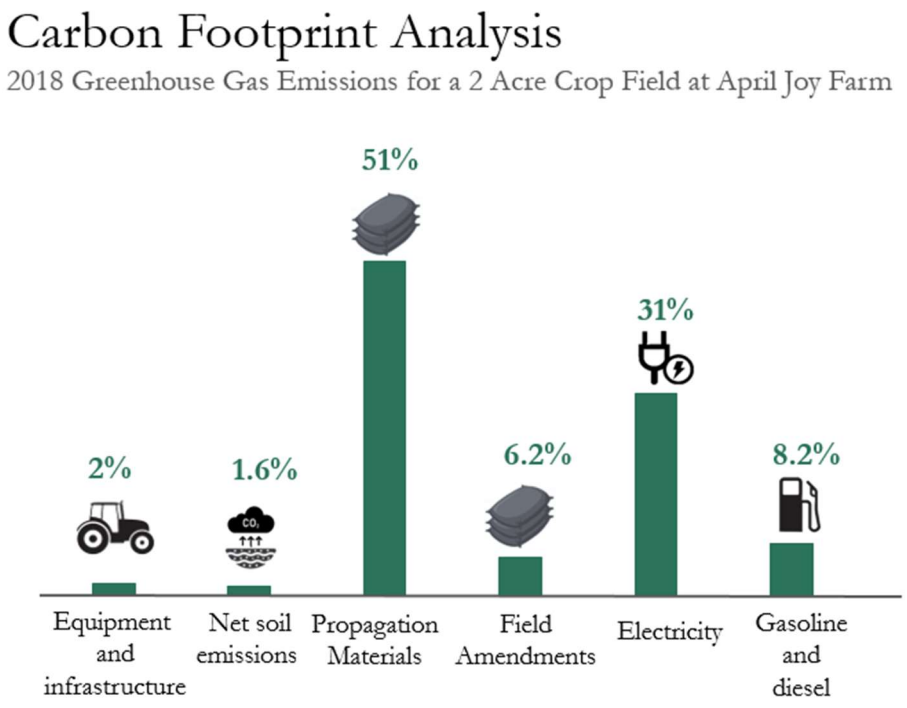


Figure 8: 2018 Carbon Footprint Analysis for AJF

Review the recommendations in your Nutrient and Field Management Plan in light of your carbon footprint analysis. Does your carbon footprint analysis give you additional justification to implement any of the strategies you identified in your Nutrient and Field Management Plan?

As the farmers at AJF plan their 2020 Soil Health Roadmap, a key focus will be to utilize their newly constructed static, aerated composting system to reduce the carbon emissions associated with off farm fertilizers and propagation materials. The farmers at AJF have set a goal of reducing the use of purchased propagation materials, most significantly peat moss[9], which accounts for the majority of the emissions associated with propagation materials. In addition, increasing the amount of solar electricity utilized by the farm and/or participating in their utility company's Green Lights Renewable Energy program, can help offset the carbon emissions associated with their electricity usage. Finally, by improving their usage of nitrogen fixing cover crops, and working to grow their own livestock feed, the farmers hope to improve the quality of farm generated compost while balancing nutrient loads to further reduce off farm purchases of fertilizers while improving their carbon footprint.

Summary

Creating a Soil Health Roadmap for your operation can be a significant undertaking, and once you have a baseline established, it will continue to be an iterative process. At AJF, the farmers spent a year compiling historical practices, performing their soil health assessment, calculating their systems nutrient budget and identifying primary challenges. Finding supportive and knowledgeable partners will be essential to your success. The farmers at AJF reached out to soil scientists and extension personnel at Washington State University, hosted graduate student researchers at their farm, utilized Natural Resource Conservation Service cost share programs, and partnered with the Conservation District to find and apply for grants. All these partners and resources helped the farmers learn about their soil, understand current soil health research, and brainstorm alternative management strategies.

In summary, a Soil Health Roadmap can:

- Instill confidence to make management changes
- Provide justification to pursue grants, alternative funding, potentially even carbon credits
- Improve the viability of your business through collaboration with like-minded partners
- Inform research that helps the larger community

A Soil Health Roadmap is a living document to support your stewardship efforts. Just as farmers create their annual production, marketing, and financial plans, farmers are encouraged to take a leadership role with respect to the health of their soil. By understanding how past practices have led to existing soil conditions, small changes in management practices can provide big impact.

Diversified farmers must make many decisions that impact the health of their soil. A Soil Health Roadmap is a comprehensive framework that utilizes a systems perspective to empower practitioners the ability to leverage many strategies to sustainably improve the viability and health of their operation.

This case study was made possible by the Washington State Soil Health Committee. If you would like assistance developing a Soil Health Roadmap for your operation, please contact April Thatcher at April Joy Farm (april@apriljoyfarm.com)