HOMER SOIL HEALTH STUDY
ADAPTIVE NUTRIENT MANAGEMENT

A feasibility study addressing the use of cover crops and reduced tillage on small scale vegetable production farms on the Southern Kenai Peninsula.

Homer Soil & Water Conservation District

USDA United States Department of Agriculture
Natural Resources Conservation Service

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Homer Soil Health Study Objectives

The Southern Kenai Peninsula supports a growing number of small-scale vegetable producers using high tunnels and outdoor vegetable production space. These producers have a wide range of knowledge and experience, but most share a strong interest in learning new techniques and practices to improve the soil used for vegetable production. Many vegetable producers are raising two to three successions of crops in one season, using intensive management practices. If sustained for a long period, these practices often degrade soil conditions, resulting in poor soil health and reduced productivity.

In conjunction with the USDA Natural Resources Conservation Service (NRCS), the Homer Soil & Water Conservation District (HSWCD) Board decided to evaluate intensive vegetable production practices by initiating trials of selected NRCS management practices that promote soil health and production sustainability. The four practices selected were; Cover Crop (340); Residue and Tillage Management, Reduced Till (345); Nutrient Management (590); and Conservation Crop Rotation (328). Adaptive Nutrient Management (described below) provided a mechanism for offering an incentive to farmers willing to try selected practices on a small portion of their growing operation and record results.

Four farmers agreed to work with Homer SWCD and NRCS on the trials. Each allocated 300 square feet of growing space inside a high tunnel and 300 square feet in an outdoor growing space on which to apply the NRCS soil health practices. Trials were designed to assess practice feasibility, methods of application, and impact on soil and plant health. Each farm operation was characterized by different management approaches, climatic conditions, and production styles, helping illustrate a variety of situations for implementing practices.

NRCS and HSWCD recognized the importance of incentivizing and providing outreach to farmers as part of the soil health study in order to increase farmer commitment to adopting the four conservation practices. Continued outreach and networking within the farming community have helped disseminate information through local demonstrations, classes, and group discussions.

Project Design

Each of the four farms involved in the soil health study replicated a Split-Plot system, where one plot was used to study the treatments in a high tunnel and the second plot was used to study the same treatments in an outdoor field. Each plot contained three treatments, described below. Each year fertility amendments were applied to maintain the same soil fertility and pH levels for each treatment. Treatments were located adjacent to each other in the plots, and the plots produced the same vegetables each season. Vegetable crops were rotated each year for 3-years. Each plot, indoor and outdoor, was 100 square feet including walking space.

- Treatment 1: an early-season vegetable crop, followed by a late-season legume cover crop mix of field pea, oats, buckwheat, and tillage radish, both crops with reduced tillage.
- Treatment 2: an early-season vegetable crop, followed by a late-season legume cover crop mix of field pea, oats, buckwheat, and tillage radish, both crops with conventional tillage.
- Treatment 3: (Control) an early and a late-season vegetable crop, both grown using conventional tillage.

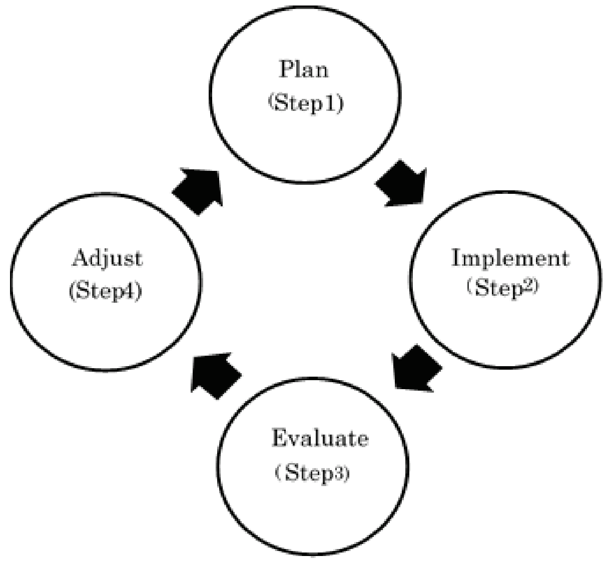
Main Plot	Treatment	Early Season	Late Season
Main Plot 1 in High Tunnel	Cover Crop & Reduced Tillage	Veg / Reduced Tillage	Cover Crop Mix / Reduced Tillage
	Cover Crop	Veg / Conventional Tillage	Cover Crop Mix / Conventional Tillage
	Control	Veg / Conventional Tillage	Veg / Conventional Tillage
Main Plot 2 in Outdoor Field	Cover Crop & Reduced Tillage	Veg / Reduced Tillage	Cover Crop Mix / Reduced Tillage
	Cover Crop	Veg / Conventional Tillage	Cover Crop Mix / Conventional Tillage
	Control	Veg / Conventional Tillage	Veg / Conventional Tillage

Adaptive Nutrient Management Process

Adaptive nutrient management is a process used to evaluate and adjust nutrient application and utilization strategies over multiple seasons. The process allows for continued adjustments of the NRCS-assisted practice Nutrient Management (590) to achieve better nutrient use efficiency. Adaptive nutrient management promotes the coordination of amount (rate), source, timing, and placement (method of application) of plant nutrients to minimize nutrient losses. Utilizing on-farm field trials enables growers to make well informed and documented decisions on how to adjust their management to be more profitable and sustainable. This protocol helps the grower establish and test out new practices while studying the effect it is making on their soil and plants.
(see https://efotg.sc.egov.usda.gov/references/public/SC/AG_TechNote_6_Adaptive_Nutrient_Management_2011.pdf on March 7, 2020.)

Adaptive nutrient management can be used to:

- Improve nutrient use efficiency.
- Decrease loss of nutrients to the environment while maintaining or increasing yields.
- Evaluate effectiveness of new nutrient management technologies.
- Test and evaluate performance of new tools or techniques for nutrient management.
- Evaluate postseason site-specific data that can be used to establish future optimal nutrient applications.
- Establish groups of farmers who cooperate with nutrient management specialists to learn from results of evaluations on their farms.



The goal of the adaptive management approach is to test and evaluate how a practice can best be applied on a given farming operation or site condition. New or alternative approaches to nutrient management often have a variety of application options, so it is important to perform test plots before applying the practice to a large area. Assessing the new management approach in test plots allows the grower to field test new methods, make annual adjustments, and use alternative management strategies without sacrificing a major part of their production space. Growers collect data, interpret results, and make adaptive changes to nutrient management as a result. These same on-farm field trial techniques can also be used to evaluate other management practices, such as seeding rates, tillage systems, cover crops, weed and pest control, etc.

The most critical review of a nutrient management plan takes place between seasons, when farmers meet as groups or one-on-one with an advisor to discuss the results of their adaptive nutrient management trials. Growers are then able to review results and adjust their nutrient management approach to try different amendments, tools, or techniques. Each year farmers can use the quantitative and qualitative data from the growing season to build on their experience and make more educated management decisions in the future.

Including multiple growers interested in new nutrient management approaches or technology greatly improves the likelihood of farmers adopting new practices. Growers may apply the new technologies in a variety of tillage systems, timing, rates, etc. Growers are able to converse and network with other growers to learn what may be best suited for their situation. In this manner adaptive nutrient management can be a strategy for incorporating alternative nutrient management techniques and tools to a regional growing community.

Overview of Farms

The lower Kenai Peninsula is characterized by a wide variety of microclimates, soils, and moisture regimes. In this region, small-scale vegetable producers have a range of approaches and needs; they use an assortment of growing practices, produce different vegetables, target different markets, and utilize many labor strategies. In order to capture some of this diversity, we worked with four farmers whose operations are at different altitudes, encompass different soil types, and who use different growing practices.

Anchor Point Greenhouse

Located right in Anchor Point and less than a mile from Cook Inlet this farm and garden center sits at about 140 ft elevation on a nearly level bench that was once dominated by spruce. Soils in production are mapped primarily as Whitsol silt loam, 0 to 4 percent slopes, with some areas on the east edge of the operation in Qutal silt loam, 4 to 8 percent slopes. These are both deep silt soils with a shallow layer of organic matter at the surface and are moderately well drained to somewhat poorly drained. The water table is well below the root zone except on the shoulder seasons when a water table often exists near the surface.

Vegetable production is centered on crops like cabbage, broccoli, and root crops in the outdoor field plot. Greenhouse crops like tomatoes, cucumber, and zucchini are grown in the indoor plots. Standard tillage practices are used fall and spring to manage weeds, incorporate amendments, and prepare ground for planting. In the indoor plots, weed barrier fabric is used, as well as drip irrigation and fertigation, and season extension is maximized with the use of oil heaters. Outdoor plots are primarily managed by tractor and manual weeding.

Will Grow Farms

Situated over 5 miles inland from Cook Inlet, within an area of spruce forest mixed with peatlands, this farm is located at 410 ft elevation on a west-facing slope. Soils in production are mapped as Qutal silt loam, 0 to 4 percent slopes, which is a deep silt soil with a shallow layer of organic matter at the surface. These soils are classified as somewhat poorly drained. Due to the proximity of a wetland, a shallow water table exists year-round, and as a result, in some seasons no irrigation is required.

The outdoor field plot was located within a row of potatoes, and the indoor plot was focused on production of greens and alliums. Standard tillage practices are used to manage weeds, incorporate amendments, and prepare ground for planting. Indoor and outdoor plots are primarily managed by tractor, manual weeding, and hand watering if needed.

Homer Hilltop Farm

As the name suggests, this farm is located on a ridgetop north of Homer on ground recently converted from native grass and wildflower meadows intermixed with spruce forest. The cropping area is slightly north facing at about 1,080 ft elevation, creating a shorter growing season than at the other farms. Soils in production are mapped as Kachemak silt loam, 4 to 8 percent slopes, which is a well-drained, deep silt soil with a shallow layer of organic matter at the surface.

Outdoor plots were in rows with beets, peas, and cabbage, and the indoor plots were in a high tunnel growing greens and alliums primarily. Low intensity tillage, including broadforks, rakes, and occasional shallow tillage with a walk behind tractor was used to manage weeds, incorporate amendments, and prepare ground for planting. Weed barriers were sometimes used indoors, and drip irrigation was used in all plots.

Oceanside Farms

Situated less than a mile north of Kachemak Bay within a converted hay field, this farm is located at 260 ft elevation on a south-facing slope of about 10 percent slope. Low elevation and southern aspect create a warm microclimate for ag production. Soils in production are mapped as Beluga Smokey-Bay Complex 4 to 8 percent slopes, which is a silt loam and silty clay loam series creating a poorly drained soil.

Squash, kale, and carrots were grown in the outdoor plots, and the indoor crops consisted of brussel sprouts, carrots, and squash. Limited tillage was practiced with the help of weed barrier fabric both indoors and outdoors, as well as many permanent beds worked only to incorporate new compost and amendments. All plots utilized drip irrigation and hand weeding.

Application and Feasibility of Soil Health Study Practices:

Cover Cropping

Cover cropping within a vegetable production system is not a common practice on the Kenai Peninsula. The average commercial vegetable plot is 0.7 acres for the lower Kenai peninsula according to a recent producer study. With these small plots, most farmers are trying to maximize the output of profitable crops during the short growing season. Finding a time for cover cropping within this high intensity growing system is difficult. Following discussions with farmers and Homer Soil and Water, study designers decided the most feasible option was to follow up the short season vegetable crop with cover cropping in the fall.

The plan in the beginning of the first season was to plant a vegetable crop that would be harvested by the end of July, and then prepare the ground for a cover crop in the beginning of August. This timeline allowed for harvest of a range of vegetables, such as carrots, turnips, beets, or greens, with 6-8 weeks left in the growing season for cover crop establishment. As it turned out, during the first trial season, three of the four producers did not establish cover crops until the first week of September. Outdoor cover crop plantings struggled to establish a substantial stand, and some indoor plots lacked irrigation. Alaskans tend to overschedule activities during the short summer growing season so getting summer crops harvested completely and trial plots ready for cover crops was not a high priority.

Different approaches were trialed the second growing season, including intercropping, planting earlier maturing crop varieties, and drawing up cropping schedules for the season. Some farms were better prepared to get a good cover crop established, but a harsh early fall hindered success in most of the outdoor plots. Indoor plots were successfully established but were also affected by cold temperatures and lack of sunlight. Intercropping in some greenhouse plots produced a substantial head start, resulting in a thick cover crop by late fall. Also, notable, a well-established cover crop plot was able to survive a frost event with greater resilience than less established cover crops. Working with earlier maturing vegetables and scheduling crop harvest timelines did not seem to have a major impact, partly because of the cold springtime conditions and early fall frosts. The window for establishing both a successful vegetable crop and cover crop in a single season was limited this season.

By year three there was a noticeable difference in farmers' adoption of the practice. Cover cropping had become less of a mystery, and the thought of putting in a cover crop mid-to-late season was easier for the producers to entertain this time around. The practice was still challenging to execute, and its benefits and feasibility were still unknown to the producers due to limited success in the previous 2 years. The same challenges existed, which resulted in 2 plots not getting planted until September, but most indoor and outdoor plots produced well. Intercropping was used on two farms this year, and different techniques were used for crop termination in order to leave the soil undisturbed and allow a greens crop to become green manure within the cover crop. At this point each farmer had developed their own strategies on how to incorporate cover cropping into their system.

Cover crop mix consisted of buckwheat, oats, tillage radish, and field peas. Depending on temperature, water input, and seeding technique, some seeds fared better than others in the late planting schedule. Buckwheat and oats got started quickly, but buckwheat would not establish if warm temperatures were not present. Oats and field peas handled frost best, particularly when they were strongly established. Tillage radish was a minor component in the mix and was not very noticeable. Seeding rates were adjusted based on time of season planted. The cover crop mix was heavily planted—at 1.2 pounds per 100 square feet—when a short timeline followed planting, and to prevent overcrowding the plots, lower rates—at 0.8 pounds per 100 square feet–were used when an adequate growing period followed planting.

Cover crop establishment was highly variable based on a wide range of factors. Timing in relation to seasonality of daylight and temperatures was the number one factor. Ground preparation and embedment of seed into the soil impacted germination whether the area was tilled, raked, left bare, or covered with soil, compost, or row cover. The cover crop mix struggled to establish if left on the surface and watered in or lightly raked in. Oats were the only seed in the mix that could successfully handle that kind of establishment. Row cover, such a Remay, significantly improved cover crop establishment late in the season by providing greater warmth and moisture retention. Intercropping had the added benefits of moisture retention within a crop canopy, greater seasonal warmth, and being able to start earlier in the season. Intercropping did make it difficult to work the ground at all to embed cover crop seed, so the solution was to lightly bury the seed with either soil or compost additions.

Application and Feasibility of Soil Health Study Practices:

Reduced Tillage

A variety of tillage practices have been trialed among vegetable growers on the Lower Peninsula as a result of the wide range of management styles used by producers. Many factors contribute to the desire to till including seedbed preparation, weed management, incorporation of organic debris or fertilizer amendments, disrupting pest cycles, or simply "fluffing up" the soil. Rather than eliminating tillage altogether, reduced tillage promotes consideration of appropriate timing and other factors to accomplish multiple tillage purposes in a single event. For this reason, each farm in the soil health study incorporated reduced tillage in a different manner.

Several common types of tillage are used on Lower Kenai Peninsula vegetable farms such as rototill, disk, or power-harrow tillage, use of horse drawn implements and handheld tools. Deep rototilling is the most disruptive to soil structure and biota. As a part of the soil health study, Homer Soil and Water made available some alternative tillage options: the tilther (a miniature rototiller), a flame-weeder, and broadforks (hand implement for deep soil aerating). These implements replaced standard tillage events with minimally invasive tools and techniques.

The tilther is a small handheld rototiller that works the top two inches of soil to a fine consistency, primarily for seedbed preparation. This implement is driven by a battery powered drill, so it is limited to loose, well-textured soil conditions. It has enough power to turn in light plant and root debris, like a greens crop or young vegetative growth. These limitations made it difficult to implement on plots with compacted soil or dense plant debris. The tilther had mixed success with participants, but one farmer adopted the tool and now uses it as their primary tillage tool for indoor production. It can produce an extremely smooth seedbed ideal for precision seeders or crops with delicate root systems. The shallow tillage also disrupts pest eggs and larvae at or near the soil surface. If only shallow tillage is accomplished, the lower soil profile can develop compaction and root restriction depending on soil type and conditions. Due to this, the broadfork is commonly used in conjunction with the tilther.

Commonly used in hobby farms and gardens, the broadfork has been gaining popularity in production-style vegetable farms. The broadfork is a simple hand tool with long, heavy-duty tines and two handles. It is used to loosen and aerate soils up to 12 inches deep without disrupting soil structure or biota. Manual tillage appears daunting to work more than an acre, but the broadfork's ease of use makes it possible. Several of the producers already utilized broadforks in their systems, boasting of their ease of use and benefits to soil and plants. Its primary purpose is to aerate soils, but broadforks can also incorporate amendments and organic debris deeper in the soil. However, switching from tractor tillage to manual tillage is an intimidating increase in manual labor, so it is no small feat for a farmer to shift away from standard roto-tillage.

Finally, the flame weeder was made available to manage low growing weeds without mechanical cultivation. This tool has a relatively specific timing in production where it is effective. After the soil has been prepared for seeding, and in some cases after seeding has occurred but before germination, the flame weeder can dramatically reduce weed populations by scorching young weeds and creating a "sterile" soil bed for the crop. The tool was sparsely utilized by the producers due to its niche use. Since the flame weeder is only successful in killing young seedlings, it cannot be used to manage weeds during the growing season or post-harvest, when tillage or soil surface cultivation are commonly used.

Application and Feasibility of Soil Health Study Practices:

Reduced Tillage

Implementing reduced tillage in soil health study plots was accomplished through a variety of management techniques, including use of the tillage implements mentioned above. The primary goal was to reduce the number of deep, disruptive tillage events. Farms that generally rototill in spring and fall reduced tillage to a single event or eliminated rototilling altogether. For instance, fall tillage to reduce weeds and incorporate litter was eliminated, and cover crops were planted instead. In this management approach, the soil surface was disturbed only when seeding the cover crop, killing off weed seedlings while establishing living roots, and growing plant debris to be turned into the soil in the spring. Labor is increased slightly for prepping and establishing a cover crop vs tilling in weeds, but the benefit of living plant roots late into the fall is substantial. In this scenario, reduced till and cover cropping work together to make a functional alternative management system for controlling weeds, improving soil structure, and incorporating organic matter.

Another reduced tillage technique trialed was intercropping a cover crop under the canopy of a summer vegetable. As mentioned previously, the canopy of the summer crop created an ideal environment for cover crop establishment: warm and moist. Instead of pulling out all the root and plant debris of the summer crop and preparing the ground for a cover crop, the summer crop was harvested and the cover crop below was left to continue into the fall. In instances where tomatoes or cucumbers were grown, the plant can easily be removed once harvest is complete, leaving the roots to decompose while the cover crop takes over for the fall. Once again, reduced tillage relied on cover cropping to make the practice feasible.

A different set of challenges arose when inter-seeding greens and root crops. Cover crops were established in a “cut and come again” greens mix where several cuttings of the greens can take place before the crop is not productive and needs to be replanted. Cover crops grew up within the dense greens patch and became overcrowded, developing a thick mat of vegetation that created a pest and disease issue. Slugs thrived in the thick vegetation, having greens to feed on and cover for overwintering their eggs. Also, as colder days arrived and the greens died back, they turned into a sludge that made an ideal habitat for molds and plant disease to overwinter. Root crops, such as beets, had similar overcrowding issues except that beets were able to withstand moderate frost.

When tillage was eliminated entirely at farms that had previously employed heavy tillage practices, a multitude of issues developed. First off, soil structure collapsed after the first year of no till. When soil has been artificially loosened and aerated by tillage, it has no inherent structure. As a result, no-till dramatically reduced plant productivity the first year because roots suffocated in compacted soil. Also, when planting a fall cover crop without tilling in the spring, some species in the cover crop mix either overwintered or volunteers came up. This created an additional need for weeding, as well as competition with the main summer crop. In some cases, the volunteer cover crop outcompeted the summer field crop.

Farms that already practiced minimal tillage were more easily transitioned to a no-till system. Instead of preparing garden beds with broadforks and a tilther, plant residue was left in place, and planting was done directly into the residue if possible. This shift in management made it more difficult to plant into beds, reduced germination rates, and increased pest issues. The expected benefit of reduced labor was not realized because mechanical planters failed in the undisturbed beds. In addition, weed seedlings proliferated in the absence of cultivation. One farm has permanent raised beds, and soils are disturbed only to mix in compost and nutrients where plants will be grown next planting season. Tools introduced through the soil health study were adopted by farms and resulted in reduced labor for bed prep, amendment incorporation, and weed control.

Soil Health Study Results:

Parameters Measured

To study effects of cover cropping and reduced tillage on soils, field tests were conducted, and lab samples were collected each year including baseline sampling. Soil tests S001AN and S019 were performed at Brookside Laboratories, Inc. These tests provide a complete analysis of soil macro and micronutrients, organic matter, pH, C/N ratio, and total exchange capacity. Field tests included measurements of bulk density, infiltration rate, aggregate stability, soil structure, and cover crop biomass. All field tests were performed during the end of the summer season, in August or September, and soil samples for lab analysis were collected in spring.

Data collected from indoor and outdoor study plots were insufficient to support statistical analysis. Instead, data were used to identify trends within treatment areas and to compare results among farms. Some data showed a clear trend at one farm but no notable effect at another. Trends are discussed here only if they were observed on two or more participating farms. Trends were considered insignificant when the same results were observed in control plots as in treatment plots.

Soil Health Study Treatment Data Trends

		Cover Crop		Cover Crop & Reduced Till	
		Indoor	**Outdoor**	**Indoor**	**Outdoor**
Soil Nutrients	Nitrogen	Increase		Increase	
	Phosphorus		Increase		Increase
	Potassium	Decrease			
	Calcium	Increase		Increase	Increase
	Magnesium				Increase
	Sulfur		Increase		
	Sodium	Increase	Increase		
	Boron	Increase		Increase	
Additional Tests	Total Exchange Capacity		Increase		
	Bulk Density	Decrease		Decrease	Decrease
	Infiltration Rate			Increase	Decrease
	Aggregate Stability				Increase

As shown in Table 1, levels of measured soil nutrients (other than K) increased in indoor and/or outdoor fields that incorporated cover cropping and reduced tillage. This increase is most likely due to the ability of cover crops to take up nutrients from the soil and make them available to subsequent crops as cover crop biomass breaks down. Legumes, such as peas in our mix, fix nitrogen in their root nodules. Buckwheat is touted for its ability to extract phosphorus from soil particles by secreting an acid to help release soil nutrients. Grains and grasses, like oats, are known for their deep fibrous roots, which can pull in minerals such as potassium, calcium, and magnesium. Having a diverse cover crop blend helps provide an array of nutrients to following crops.

An increase in soil nitrogen occurred in part because peas are N-fixing legumes, but all cover crops incorporate nitrogen into their tissues, which then break down in the soil, making N available. Nitrogen is easily leached from root zones, which may explain why increased N was found only in indoor plots. All outdoor plots showed increased phosphorus, but changes in P in indoor plots were considered insignificant because control plots also showed an increase. Calcium increased with all treatments except outdoor cover crop plots which could be a significant benefit for vegetable producers growing fruiting crops, such as tomatoes or squash. Boron, another commonly deficient nutrient in Homer soils, also showed increased levels in indoor plots. Boron is also easily leached out, which may be why improvements were seen only in indoor plots. Potassium and magnesium could be expected to increase at a rate like that of calcium, but we saw only moderate improvements or decreases.

Variables associated with each plot and season played major roles in what we observed, affecting the degree to which plants could develop biomass or deep roots. In some cases, only 10 grams of cover crop biomass per square foot were produced, an amount that likely had an insignificant impact on soil nutrition.

Other nutrient trends observed, such as increased sulfur and sodium, are not discussed in cover crop research, but these elements may play a small role in the ability of cover crops to transport and make nutrients available. When soil has increased amounts of living roots and organic debris, it provides a suitable environment for micro-organisms to thrive. These micro-organisms in combination with root exudates can increase micro and macro nutrients available to plants.

Soil Health Study Results:

Field Test Trends

Data from field tests showed bulk density changed most significantly with treatments. Bulk density is defined as the dry weight of soil per unit volume of soil; it reflects both soil solids and pore spaces (air) within the soil. Cover crops play a role in reducing bulk density by opening root channels, incorporating organic matter, and promoting micro-organism activity that aerates soil. When a cover crop is grown on a plot that would usually be tilled, planted into vegetables, or left fallow, it provides nutrition to micro-organisms and adds new roots and organic matter to the soil. Within cover crop plots, a beneficial decrease in bulk density was observed within all indoor plots, but not in the outdoor plots. When cover cropping and reduced tillage were combined, bulk density increased in both indoor and outdoor plots.

A main purpose of tillage is to loosen dense soil by increasing aeration, yet high bulk density is commonly associated with heavy tillage. This was true in our study: farms regularly applying heavy tillage had dense soils with poor aeration. When reduced tillage in combination with cover cropping was initially applied on these fields, the immediate effect was poorer soil conditions and reduced plant productivity. The photo to the left shows the effect of compacted soils on a cucumber crop in year 1 of reduced tillage. Reduced tillage was a difficult transition for a grower who relied on spring tillage, and was particularly challenging when the farmer attempted to plant sensitive transplants into a cold compacted spring soil. In year 2 and 3 of the study, improvements started to become apparent, and the reduced till plots became looser and eventually developed lower bulk density than the adjacent tilled plots. Once organic matter from cover crops and other debris is incorporated, soil structure improves after a year or 2 and supports natural tillage of micro-organisms and plant debris. Cover cropping and reduced tillage led to significant decreases in bulk density at all farms, which translates to more space for air, roots, micro-organisms, and water.

Reduced tillage also had an impact on infiltration rate, the rate at which water is absorbed into the soil. Repetitive tillage creates fine soil particles that easily compact and restrict roots, air, and water movement. Higher infiltration rates were anticipated with reduced tillage, but this trend was not consistent, and in the case of outdoor cover crops and reduced till plots, the rate decreased. Field measurements were usually taken late summer to early fall, and sometimes it was difficult to avoid moist or wet soils, which may cause some of this inconsistency. It may also be due to the time it takes for infiltration rates to respond during the transition from standard tillage to reduced tillage.

Aggregate stability increased only in outdoor plots managed with a cover crop and reduced till plots. We would expect positive soil structure development following reduced tillage in all plots, but that was not the case. Also, soil structure and macropores were tested annually, but did not show significant changes throughout the 3 years. These measurements are a common measurement of building a healthy soil structure. Development of soil structure takes time, and in this 3-year study incorporating reduced tillage practices and cover cropping did not lead to significant improvements in soils structure.

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Discussion of Soil Health Study and Practices:

Cover cropping and reduced tillage are currently popular topics in many areas of the US. Great benefits have been touted from these practices, including reduced fertilizer costs, less soil erosion, and better control of pests. We took these practices and applied them to small-scale, diversified vegetable farm operations. These operations represent intensive agriculture, getting the most out of a small area, as opposed to extensive agriculture that relies on production from huge acreage to turn a profit. We had the unique opportunity to work with a variety of farms, soils, climates, and growing practices. This provided a template for exploring ways to implement these practices effectively and efficiently in different settings.

Cover Cropping

The biggest challenge to applying cover cropping was finding time in the growing season to produce a substantial cover crop. Intercropping the cover crop into the summer crop 2-3 weeks prior to expected harvest produced by far the most substantial cover crop plots come late fall. Warm moist conditions under the canopy of a summer crop in late July provide an ideal environment for establishing most cover crops.

Cover crops seeded at the end of August or later showed only sparse germination and did not exceed 4-5 inches in height. Biomass produced in these situations was insignificant, but cover crops nonetheless helped soil absorb late fall moisture while protecting soil from erosion. Additionally, even though there were several plots that produced “insignificant” cover crop biomass, data still showed improving trends in nutrients and other conditions, as mentioned in results. This suggests that even late planting of a cover crop can benefit farmers by improving their soil.

Cover crop seed establishment was an issue common to participating farms, and several discoveries were made during the study. To get good germination rates, seed needed to be lightly embedded in the soil and heavily watered in. Row covers, such as Remay, dramatically improved emergence and establishment rates. Outdoor plots in the Homer area usually do not need additional water after seeds are established, but indoor cover crops will die back after establishment if regular watering is not supplied.

Different challenges to feasibility occurred at different farms depending on their management systems. If the planted cover crop species can overwinter and no tillage takes place before the next crop is planted, expect cover crop volunteers, both from seeds and roots. When a cover crop develops a dense vegetative mat, farmers should be aware that they are creating environments beneficial to slugs, including potential overwintering areas for slug eggs.

At the same time, cover cropping also provides a variety of benefits such as breaking up cropping and pest cycles, while also providing an environment for beneficial insects. Cover cropping helped reduce weed pressure at the end of the season, along with labor normally required to manage those weeds. If cover crops had more time to develop, they would provide increased amounts of organic matter and potentially create a pollinator magnet, although in our late planting schedules we did not see these results.

Discussion of Soil Health Study and Practices:

Reduced Tillage

Reduced tillage often accompanies cover cropping because cover crop roots break up soil and improve soil structure, reducing the need for mechanical tillage. Although this practice is being adopted in large grain farm operations, few examples are found in vegetable production. In the Homer soil health study, reduced tillage was used to combine multiple tillage events into one while simultaneously using less destructive tillage processes.

Success transitioning from deep, regular rototill events to tillage with tools such as the tilther depends on available farm implements, soil structure, and practices used. Soils formed with regular reliance on intensive mechanical tillage often becomes dense and compacted and therefore difficult to till with low power implements, such as the tilther. The first step is to reduce the number of tillage events occurring each season while still using the same tillage implement. The next step is to start applying different growing techniques, management practices, and tools to replace tillage. Finally, it becomes possible to use implements that promote reduced tillage, such as broadforks or other lightweight, shallow tillage implements.

Outlining to the farmer the transition process to reduced till is essential, otherwise the negative effects seen within the first 2 years, such as compaction, poor crop development, and potential weed issues, will discourage adoption of reduced tillage. Some actions can make the transition more manageable, such as applying reduced till on only a portion of the operation in order to work out how best to achieve benefits. Adjusting planting schedules to accommodate crops like brassicas that can withstand compaction can address such issues. Also, new forms of weed control can be applied, such as using ground covers or cover crops to create weed barriers while also maintaining soil moisture and thus promoting improved soil structure. Cover cropping and incorporating organic matter seem to speed up the timeline for improving soil structure.

Data on bulk density showed clear benefits from reduced tillage, but farmers noticed several benefits independent of collected data. When plots were left vegetated in the fall instead of tilling in the cover crop, the soil was drier and warmer in spring, making it easier to start working the ground. Providing any sort of season extension is a major benefit for farmers in the area, especially those that deal with cold saturated soils in the spring. Also, regular tillage to manage weeds in a fallow field required significant labor and equipment usage, but if cover crops were used as weed management, the need for tillage was eliminated.

Most of the benefits touted of reduced tillage are the long-term benefits of soil structure development. Like developing a good garden soil from raw ground, it takes years to build healthy nutrition, balanced pH, and a strong soil structure. When starting with heavily tilled soil it may take longer than three years to see a beneficial development of soil structure. Over time these shifts should provide healthy habitats for micro-organism, along with good drainage, air movement, and resilience to stresses. Many of these benefits can be seen in the permanent raised beds with minimal till in action at two of the soil health study participant farms. The baseline data for these raised beds were greatly improved in comparison to the other producers for bulk density, infiltration rate, and soil structure and macropores test.

Discussion of Soil Health Study and Practices:

Conclusion

Assessing multiple agricultural practices on four farming operations provides numerous variables to analyze. The benefit, however, is that a variety of ways to implement selected practices can be observed in a range of scenarios. Collected data show that incorporating cover crops and reduced till practices lead to different challenges and benefits depending on the management styles and production systems in place in an operation. Data also indicate that some beneficial results were observed across all farms, indicating that practices producing these positive results have the potential to benefit many different operations.

Intensive vegetable production can be destructive to the soil, particularly when every moment of the short growing season is used to produce nutrient-demanding crops. Practices like cover cropping and reduced till have the potential to replenish the soil with nutrients and organic matter and improve soil structure, all of which contribute to long-term soil health. We hope these practices can become more feasible for more farmers to implement based on shared knowledge about new tools, techniques, and the experiences of other growers. The study has indicated that there are multiple benefits associated with incorporating cover cropping and reduced tillage into vegetable production. These benefits can be expected to increase over time.

A big thanks to all our farmers for working with us to trial these practices and making valuable growing space available for the soil health study! Heroes to the local farming community are those that trial new ideas and practices for others to learn from so that we can build a healthy productive farming community.

Glossary

Conventional tillage: Tillage operations traditionally performed in preparing a seedbed for a given crop and grown in a given geographical area.

Cover Crop: A crop grown specifically for the use of manage soil erosion, help build and improve soil fertility and quality, suppress weeds, control diseases and pests, and promote biodiversity.

Crop Biomass: The total amount of organic material produced by living organisms in a particular area within a set period of time

Cultivation: A shallow tillage operation performed to promote growth of crop plants by creating a soil condition conducive to aeration, infiltration, and moisture conservation or to pest control.

Germination Rate: The percentage of seeds that actually germinate, based on growing out 100 seeds.

Harrowing: A secondary tillage operation commonly used before seeding which pulverizes, smoothes, and firms the soil.

Intercropping: Grow (a crop) among plants of a different kind, usually in the space between rows.

Organic Matter: Matter that has come from a living organism that is capable of decay, the product of decay, or is composed of organic compounds.

Minimum Tillage: The least soil manipulation necessary for crop production or for meeting tillage requirements under existing soil conditions.

Rotary Tillage: A tillage operation employing power-driven rotary action to cut, break up, and mix soil.

Shallow Tillage: A tillage practice that fully cuts through the whole working horizon at only 2-3cm working depth.

Soil Aggregate Stability: Aggregate stability refers to the ability of soil aggregates to resist disruption when outside forces are applied.

Soil Bulk Density: The dry weight of soil per unit volume of soil. Bulk density considers both the solids and the pore space;

Soil C/N ratio: A ratio of the mass of carbon to the mass of nitrogen in the soil. It measures residue decomposition and also nitrogen cycling in soil.

Soil Infiltration Rate: The speed at which water enters into the soil.

Soil Structure: The arrangement of soil particles in various aggregates differing in shape, size, stability, and degree of adhesion to one another.

Soil Macronutrients: Nitrogen (N), Potassium (K), Calcium (Ca), Magnesium (Mg), Phosphorus (P), Sulfur (S).

Soil Micronutrients: Boron (B), Chlorine (Cl), Copper (Cu), Iron. (Fe), Manganese (Mn), Molybdenum (Mo), and Zinc (Zn)

Soil pH: A measure of the acidity or alkalinity of the soil. It influences the availability of nutrients among other things.

Subsoiling: Deep tillage, below 350 mm for the purpose of loosening soil for root growth and/or water movement.

Tillage: The mechanical manipulation of soil for any desired purpose, but in agriculture the term is usually restricted to the changing of soil conditions for the enhancement of crop production.

Total Exchange Capacity: The total capacity of a soil to hold exchangeable cations. It influences the soil's ability to hold onto essential nutrients and provides a buffer against soil acidification.