Soil Health: A Roadmap for April Joy Farm

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Introduction

Why Develop a Soil Health Roadmap?

Farmers intuitively understand soil health is the fundamental basis of farm health. Yet there is no prescriptive path which will achieve the goal of improving soil health for all agricultural operations. By developing a Soil Health Roadmap, practical questions can be explored:

- How can farmers skillfully evaluate the specific health of the living, changing soil system under their care?
- What does the term "good soil health" mean in the context of the goals of a diversified farm?
- What decision making framework can farmers use to evaluate management practices in terms of supporting the restorative capacity of the soil?
- Can necessary adjustments to management practices be implemented while maintaining the economic viability of the farm?
- Can management approaches that directly contribute to improved soil health concurrently reduce reliance on external inputs, and/or buffer threats such as development pressure and climate change?

Diversified farms are complex systems which require multifaceted approaches to address the needs of the many stakeholders. Because of the intrinsic challenges, too often the goal of improving soil health is deferred or addressed in a piecemeal approach. A soil health roadmap is intended to provide the farmer a comprehensive view of her/his farm operations from the perspective of its co-creator: the living soil. It is the intent of this project team that by doing so, farmers will pursue their work with increased confidence and feel empowered to make operational changes that create long-term resilience and improved health for themselves, their families, and the farms they steward.

The Soil Health Roadmap

A Soil Health Roadmap is comprised of four sections:

1. A **comprehensive soil health assessment** establishes a baseline measurement of soil health for the farm.

2. A **systems nutrient budget** provides an overview of how nitrogen and phosphorous are cycling through the farm.

3. A **nutrient management plan** outlines the comprehensive historic and current practices which affect soil health. The nutrient management plan identifies specific, actionable recommendations in four categories: crop rotations, cover crops, organic material & fertility management, and machinery/equipment.

4. A **carbon footprint analysis** evaluates baseline farm management practices and proposed recommendations which impact greenhouse gas emissions and sequestration.

Figure 1: *Crimson clover roots with nodules support nitrogen-fixing* Rhizobia *bacteria, September 2017*

April Joy Farm: An Overview

April Joy Farm is a diversified crop and livestock farm located in southwest Washington state (see Table 1 for a farm profile). The certified organic, Animal Welfare Approved operation was started by April Jones Thatcher in 2006 and has developed strong partnerships with grocers, restaurants, and hundreds of area families. The April Joy Farm 50-member CSA program has a 93% retention rate.

April Joy Farm is a Limited Liability Company with two active managers (Brad and April Thatcher). The farm is April and Brad's (the farmers') sole livelihood. The 24-acre parcel is owned by the farmers (50%) and immediate family (50%) who live adjacent to the farm. In addition to two full-time farmers, several family members/volunteers have historically provided all the labor for farm operations. In 2017, the farm was certified by the Washington State Department of Labor and Industry as Clark County's first Agricultural Internship program. In 2018, the farm will host two part-time interns.

Initially, the farm established four market channels: grocers, restaurants, a CSA program, and direct sales of heritage pork. In 2013, the farm ceased sales to grocers due to the lower profitability of this market sector. In 2017, the heritage pork program was suspended due to limited pasture acreage and to allow the establishment of a 1.5-acre orchard. To support this transition, the CSA program has grown and the restaurant crop plan expanded to increase spring and late fall season sales. Farm livestock currently supporting the market produce operation include 50 layer hens, two donkeys, and two sows. The limited, yet highly diverse (forest, pasture, cropland, and riparian) acreage of April Joy Farm presents challenges and opportunities (Figure 2).

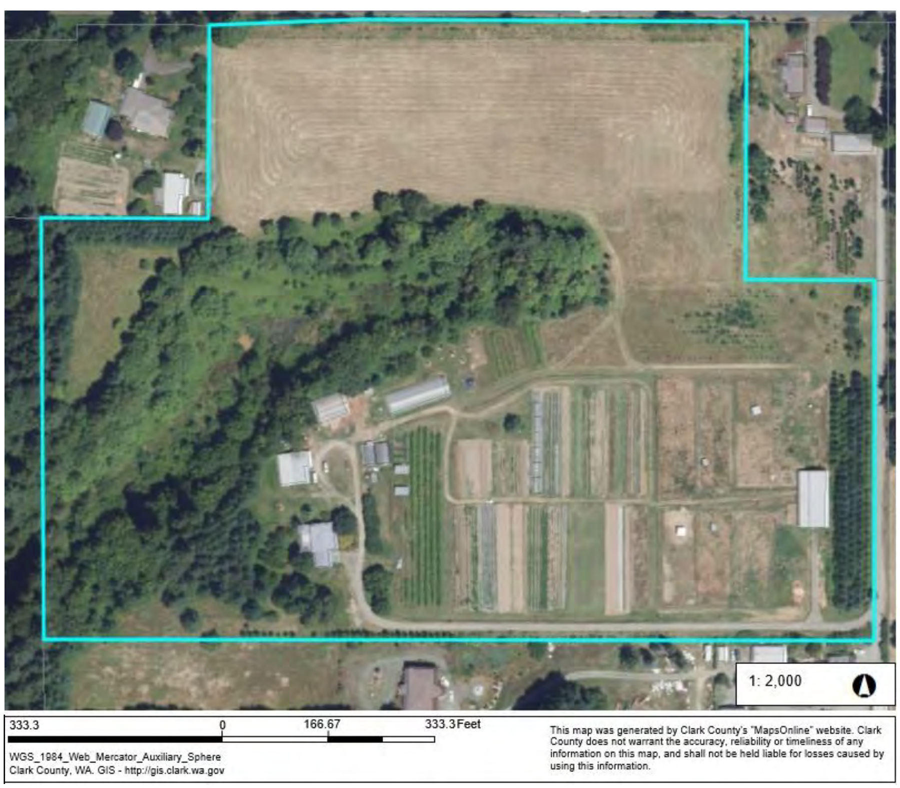

Figure 2: *Aerial photo of April Joy Farm, 24 acres*

Table 1: Farm Profile

Name	April Joy Farm
Location	Southwest Washington State, Clark County
Biome	Temperate Forest
Land Base of Operation	24 acres total, including: 2 acres annual crops, 5 acres hay, 1.5 acres grazing/orchard, 1 acre vineyard/orchard
Soil Types	Hillsboro Silt Loam, Gee Silt Loam
Annual Rainfall	40 inches, 85% occurring October – April
Markets	Direct (CSA) & wholesale (Restaurants) entirely within county of operation
Enterprises	Primary: Mixed Vegetables, Herbs, Fruit Secondary: Wine and Table Grapes Tertiary: Egg Sales
Land Ownership	Farmer Owned
Farm Ownership & Legal Structure	Brad and April Thatcher, Limited Liability Company
Age of Farm	Established in 2006
Labor Structure	Owner/Operators, with 2.5 FTE
Weather Patterns	Short, warm, dry, clear summers and moderately cold, wet, overcast winters. Mean daily temperature varies from 35°F to 84°F and is occasionally below 25°F or above 95°F.[1]
Population density of County	718 people per square mile
Per capita personal income of County	$43,153 in 2014[2]
No. of plant varieties to be sown in 2018:	248 plant varieties
No. of seed varieties produced and saved on-farm:	30
% certified organic seed:	92%
% open pollinated seed:	93%
2017 on-farm energy production (solar electricity):	11,200 kWh, 48% of all farm usage

[1] https://weatherspark.com.

[2] https://fortress.wa.gov/esd/employmentdata/reports-publications/regional-reports/county-profiles/clark-county-profile.

Farm Goals

The farmers seek to grow April Joy Farm into a diversified, resilient enterprise that provides a comfortable livelihood while protecting the regenerative ability of the natural ecosystem. Their goal is to establish April Joy Farm as a community asset which provides area residents access to healthy, high quality food. The farm is located on the outskirts of Ridgefield, which is currently the fastest growing community in the State of Washington. New housing developments and urban pressures are eliminating the viability of area agricultural operations. The farmers have been proactive in pursing multiple measures in an effort to safeguard the farm's long-term health.

Measure 1, Transforming Waste: Annually, the farmers complete a process improvement and operations review. The goal of this evaluation is to identify and transform or mitigate waste in three categories: materials (resources), time (labor), and finances (expenses).[3] The results of this review inform enterprise and market selection, staffing requirements and capital improvement projects. One such example is the pending (2018) construction of a static aerated composting structure capable of generating all the required compost necessary to meet the needs of the farm while reducing labor associated with management of the composting process. Through energy conservation, elimination of redundant labor, and reduction of food waste, the farmers continue to incrementally refine their farm model and improve their resiliency. Partnerships with the Natural Resources Conservation Service (NRCS) and the Clark Conservation District (CCD) have provided essential assistance to implement many of the farmers' waste reduction goals (Figure 3).

[3] The farmers have received Holistic Financial Management training, which has formed the basis for their annual review process. More information can be found at: https://www.savory.global/.

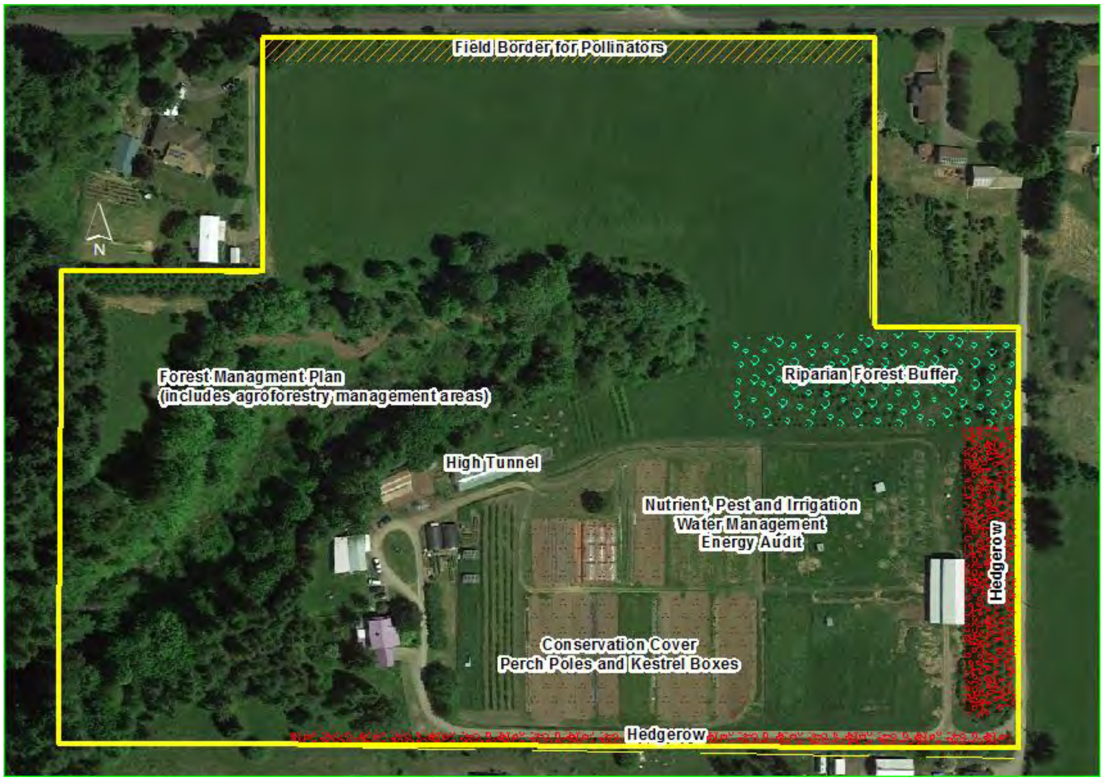

Figure 3: *NRCS and CCD Projects Completed at April Joy Farm 2009-2016*

Measure 2 Adapting to and Mitigating Climate Change: In 2017, the farmers developed a Climate Change Adaptation & Mitigation Plan (CCAMP) through Cornell University's inaugural Climate Smart Farming Class.[4] The CCAMP identified protecting and improving soil health as the most crucial link to ensuring long-term farm viability. See Appendix A for details.

Measure 3 Reduction of Carbon Footprint: In 2011, the farmers began a multi-year collaboration with Washington State University (WSU) Organic Farming Footprints (OFoot) Project.[5] The OFoot Project developed a scientific tool to estimate the carbon footprint of organic farms. April Joy Farm was one of five OFoot focus farms for the project. The OFoot carbon footprint analysis of April Joy Farm provides an important justification for focusing on soil health.

OFoot research identified that electricity use, tillage, and amendments/fertilizers represent a combined total of 75% of April Joy Farm's carbon footprint. To address the first of these "big three," the farm received a 2014 USDA grant to install an 8.64 kW photovoltaic system. This system annually provides over 45% of the entire farm's energy usage. By developing this Soil Health Roadmap, the farmers believe they can reduce greenhouse gas emissions associated with the second and third "big three": tillage and soil amendment usage.

[4] For more information about the project, visit: http://climateinstitute.cals.cornell.edu/climate-smart-farming-2/. To find the carbon footprint of your farm visit: https://ofoot.wsu.edu/.

[5] http://csanr.wsu.edu/organic-farming-footprints/.

Comprehensive Soil Health Assessment

Due to the wide variation of soil types and climatic environments, as well as diverse management styles and production methods utilized by farmers, one size does not fit all when it comes to caring for agricultural soils. A key objective of this soil health assessment is to identify assessment criteria and evaluation methods that are accessible and meaningful for farmers to undertake, given their location, existing resources and production methods. It is the intent of the project team that the framework utilized in this roadmap be of use for diversified farmers across Washington state.

While laboratory analysis provides necessary information, the farmers know a healthy soil ecosystem begins with knowledgeable, astute land stewardship. Thus, where feasible, on-farm assessment techniques were identified, with the hope that over time, evaluation of soil health can become more of an ongoing, real-time process and less of a once a year "review-the-soil-test" event.

The project team began by identifying the physical, chemical and biological assessment criteria of regionally appropriate and/or widely available soil health assessment resources (Table 2).[6] From this side-by-side comparison, a list of criteria appropriate to the farmer's management practices and the site characteristics of April Joy Farm were agreed upon, with input from project advisor Dr. Lynne Carpenter-Boggs of WSU.

Table 3 lists the selected soil health indicators selected specifically for April Joy Farm. Some common indicators were not included for evaluation or monitoring at April Joy Farm. Erosion for example, was excluded based on the lack of historical occurrence at the farm, the slopes of the field location, the existence of extensive perennial field buffers, the usage of cover crops and the timing of tillage relative to significant rain events. A neighboring farmer with extensive winter field operations and/or more steeply sloped fields would want to include erosion as part of their soil health evaluation.

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[6] A spreadsheet was developed for this project which organizes all soil health indicators by assessment source. This spreadsheet could be the basis for the development of a tool which helps farmers identify soil health indicators most critical to their operation. By entering information about their farm and management practices, a customized soil health assessment indicator list could be provided. There are so many ways to evaluate soil health; how does a diversified farmer choose what to focus on? Many simply choose the easiest to evaluate or the simplest to understand. This selection method does not necessarily encourage the farmer to make investments in long-term soil health. By providing a tool as described above, farmers may be able to better understand lowest/limiting factors in the health of their soil system.

Table 2: Soil Health Assessment Criteria

Assessment Method Letter Codes are referenced in Table 5

Letter Code	Source
(A)	Palouse and Nez Perce Prairies Soil Quality Card http://www.nezperceswcd.org/Projects/SoilQuality/SoilQualityIndicator.aspx
(B)	Willamette Valley Soil Quality Card (Oregon State University) http://smallfarms.oregonstate.edu/sites/default/files/small-farms-conference/2016Handouts/sfc2016_3soil_willamette_valley_soil_quality_cardem8711.pdf
(C)	Cornell University Comprehensive Assessment of Soil Health https://soilhealth.cals.cornell.edu/
(D)	NRCS Soil Quality Test Kit https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/health/assessment/?cid=nrcs142p2_053873
(E)	The Soil of Soil: A Soil-Building Guide for Master Gardeners and Farmers. Gershuny & Smillie
(F)	Building Soils for Better Crops. Magdoff & Van Es
(G)	Dr. Lynne Carpenter-Boggs, Washington State University
(H)	Know Soil Know Life. Lindbo, Kozlowski, Robinson

Table 3: List of April Joy Farm Soil Health Indicators[7]

Criteria that could feasibly be evaluated on-farm are indicated in bold.[8]

Physical	Chemical	Biological
P1: **Texture**	C1: pH and buffer pH	B1: Organic Matter
P2: **Structure & Soil Tilth**	C2: Plant Nutrients (See Table 4)	B2: **Macrobiotic Soil Life**
P3: **Compacted Layers** 0-12", 12-24"	C3: Initial Baseline: Soluble Salts	B3: **Plant Growth**
P4: Infiltration		B4: **Weed Evaluation**
P5: Water Holding Capacity		B5: Active Carbon
P6: **Depth of A and B Horizons**		B6: **Legume nodules**
		B7: **Mycorrhizae**

[7] Four biological soil health indicators, Macrobiotic Soil Life, Plant Growth, Weed Inventory, and Mycorrhizae could not be assessed in 2017 due to the timing of the grant. It is important these indicators are evaluated during the warm/active growing season.

[8] While organic matter and pH can be evaluated on farm, they are commonly included in laboratory analysis with base chemical analysis.

The laboratory tests undertaken using samples collected in October 2017 are listed in Table 4. All soil samples submitted to A&L Western Agriculture Laboratories as well as Cornell were a composite mix of individual soil samples taken from all ten annual field blocks (see Figure 7) at each respective depth range. Due to cost, only one sample was submitted to Cornell.

Table 4: April Joy Farm Off-Farm Soil Health Evaluation, October 2017

Laboratory	Test Name	Test Details
A&L Western Agriculture Laboratories (503) 968-9225 http://www.al-labs-west.com	S3CG (Complete Soil Package) Three samples submitted: 0-6" depth 6-12" depth 12-24" depth	Organic Matter, Estimated Nitrogen Release, Phosphorus (Weak Bray and Sodium Bicarbonate-P), Extractable Cations (Potassium. Magnesium, Calcium, Sodium), Hydrogen, Sulfate-S, pH, Cation Exchange Capacity and percent cation saturation (computed), Soluble Salts, Excess Lime, Nitrate-Nitrogen, Zinc, Manganese, Iron, Copper and Boron
Cornell Soil Health Laboratory (607) 255-1672 http://soilhealth.cals.cornell.edu	Standard Soil Health Analysis Package with Soluble Salts and Hot Water-soluble Boron One sample submitted: 0-6" depth	Soil pH, Organic Matter, Phosphorous (Modified Morgan Extractable), Potassium (Modified Morgan Extractable), Calcium, Magnesium, Sulfur, Iron, Manganese, Zinc, Copper, Boron, Molybdenum, Wet Aggregate Stability, Soil Respiration, Available Water Capacity, Surface and Subsurface hardness interpretation (based on on-farm penetrometer readings), Active Carbon, Soil Protein

The results of all tests are shown in Table 5, which is a snapshot of the spreadsheet to be used to track soil health indicators on an annual basis. This will provide the farmers an opportunity to collect all test results each year in an easy to use format and thus analyze changes over time. Appendix B and C provide detailed information and laboratory test results. Appendix D provides on-farm data collected for evaluation. Soil respiration and soil protein analysis are also listed in Table 5 because they were included as part of the standard soil health analysis package provide by Cornell Soil Health Laboratory.

Table 5: April Joy Farm 2017 Soil Health Assessment Results

	2017	Assessment Date	Estimated Soil Moisture (% Available) per NRCS Soils Assessment Method	Assessment Method
Physical				
P1: Texture	**Silt Loam** Sand 18%, Silt 69%, Clay 11%	1-Oct	25-50%	(H) pg 20, Cornell Soil
P2: Structure & Soil Tilth (Aggregate Stability)	Rating Indicator = 5 43.9%	11-Oct	25-50%	(A) Basic Test, Cornell
P3.1: Compacted Layers 0-12"	131 psi	24-Oct	Field Capacity	(C)Pentrometer & Cornell
P3.2: Compacted Layers 12-24"	200 psi	24-Oct	Field Capacity	(C)Pentrometer & Cornell
P4: Infiltration	**Good rating.** No ponding or runoff.	1-Oct	25-50%	(F) pg. 259
P5: Water Holding Capacity	0.29 g/g	11-Oct	25-50%	Cornell
P6.1: Depth of Horizon A	0-7 inches	1-Oct	25-50%	(D) On-Farm
P6.2: Depth of Horizon B	7-55 inches			Clark County Soil Survey
Chemical				
C1: pH (0-6" depth)	6.1, 6.3	20-Oct	25-50% at time of sampling	A&L Lab, Cornell
C2.1: Macronutrients (N-P-K-Ca-Mg-S, ppm)	22-131-224-1349-237-14	20-Oct	25-50% at time of sampling	A&L Lab
C2.2: Micronutrients Fe-Mn-B-Cu-Zn, ppm	60-4-0.2-0.5-1	20-Oct	25-50% at time of sampling	A&L Lab
C2.3: Soluble Boron (mg/Kg)	Medium-Low 0.36 mg/Kg	12-Dec	25-50% at time of sampling	Cornell
C3: Soluble Salts & Sodium	0.14 mmho/cm Na = 27 ppm	6-Dec	25-50% at time of sampling	Cornell, A&L Lab
Biological				
B1: Organic Matter (0-6" depth)	3.6, 3.7	20-Oct	25-50% at time of sampling	A&L Lab, Cornell
B2: Macrobiotic Soil Life (Earthworms)				(F) On-farm 2018
B3: Plant Growth				(B) On-farm 2018
B4: Weed Evaluation				(E) On-farm 2018
B5: Active Carbon	495 ppm	20-Oct	25-50% at time of sampling	Cornell
B6: Legume Nodules (% nodules dark/bright pink)	50% of sampled nodules dark pink, 10% bright pink	9-Sep	50-75%	(G) On-farm, Oct. 2017
B7: Mycorrhizae				(G) Lab, on-farm 2018 2018
Soil Respiration	0.5 mg	20-Oct	25-50% at time of sampling	Cornell
Soil Protein Index	7.1	20-Oct	25-50% at time of sampling	Cornell

Assessing Soil Health at April Joy Farm

Figure 4: *Soil Sampling to a depth of 24" depth newly seeded winter cover crop, October 2017*

Physical Characteristics

Overall, the inherent physical characteristics of April Joy Farm soil are highly desirable for specialty crop production. The Cornell Soil Health assessment indicates "excellent" or "near-optimal" functioning of soil processes with respect to available water capacity, hardness, and aggregate stability.

What the Farmers Learned:

- **Profile Analysis.** Soil samples at three depths had not been analyzed in the history of the farm (Figure 4). This is valuable information the farmers can begin to leverage. Considering the soil horizons can provide key insights, including the ability to assess leaching of nitrogen, and the identification of available nutrients in the lower soil horizons (i.e., "B" horizon), such as iron (Fe) and phosphorous (P). When identifying the nutrient status of the top 6" layer of soil, samples 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", deep-rooted or cover crops which tend to mine the deeper soil horizons could make this nutrient potentially available to the crop in the top 6" of the soil.

- **Soil Formation Cycle.** Understanding the three primary factors of soil formation: parent material[9], climate, and organisms, as well the two modifying factors: topography and time, provides farmers a critical contextual perspective. It is valuable to recognize that aside from utilizing climate-controlled structures and drastically regrading slopes and/or water channels, there is only one of the five factors which farmers can influence. At April Joy Farm, the basalt rock, damp, moderate climate, topography of fields and time horizon are a fixed framework. When considering soil health and management practices, it is only through changes in micro and macro flora and fauna (i.e., organisms) that farmers impact the restorative capability of the soil.
- **Compaction.** Due to intensive rotovator usage, the farmers have been concerned about compaction. Based on penetrometer readings, compaction is not severe. The procurement of an AMS Soil Compaction Tester (model BCK-315-59040) for the farm represents an economical tool to monitor this key soil health indicator.[10] The farmers' efforts to avoid machinery usage at critical soil moisture levels has apparently been successful.
- **Evaluation is Relative.** Many physical soil health indicators are "scored against a distribution observed in regional soils with similar texture."[11] It is important to understand this evaluation is only a relative indicator of 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 on a regular basis. By tracking changes over time on a particular farm (not relative to other regional soils), physical soil health can be more accurately assessed as declining, stable or improving.

Chemical Indicators

The chemical soil health indicators evaluated by Cornell: pH, extractable phosphorous, extractable potassium and minor elements (Mg, Fe, Mn and Zn) were all interpreted as residing in the "optimal" range (Appendix L). This assessment differs from the recommendations provided by A&L Laboratories (which is assumed to have more regionally appropriate experience). A&L lab results

[9] The parent material of April Joy Farm soil is alluvial deposits from the Columbia River comprised mostly of basalt. A Geological Map of Washington State can be found at: https://ngmdb.usgs.gov/Info/dmt/docs/schuster07b.pdf.

[10] A quality penetrometer can be purchased for ~$250. https://www.certifiedmtp.com/ams-soil-compaction-tester/.

[11] Cornell Soil Health Assessment Report for April Joy Farm, pg. 4.

identify pH, buffer pH, sulfur, boron and nitrogen as limiting and recommend amendments to improve the fertility of the soil (Appendix B).

What the Farmers Learned:

- **Plant Available versus Total Nutrient Values.** It is crucial growers are able to identify the forms of plant available nutrients, i.e., nitrate, ammonium, phosphates and potassium ion (NO_3^-, NH_4^+, $H_2PO_4^-$ and K^+) and how these values relate to reported soil test results and total nutrient values. Soil fertility testing tends to report the values of available nutrients, but does not indicate quantities of mineralizable nutrients. 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).
- **Utilization ratios are important.** Some resource materials aimed at assisting farmers with nutrient management indicate that nitrogen and phosphorous are utilized by plants in a 6:1 ratio.[12] Evaluating ratios of planned organic material and fertilizer applications is critical to avoid causing or exacerbating imbalances.
- **The interpretation of the results can be expected to vary.** It is important farmers develop their own insights to identify what is appropriate and necessary with respect to test result recommendations. Understanding what specific values are truly measuring 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, but this method is an indirect test, and not as reliable as a test which directly measures soil carbon.[13] Likewise, test results will often vary by laboratory, so consistency is important.
- **pH and some micronutrients (Zn, B, Cu)** are low according to A&L, but in the "excellent" category according to Cornell Soil Health Testing. Dr. Carpenter-Boggs also believes these values are relatively low and based on the 12-24" soil report, these nutrients are not available and thus will need to be imported to the farm. An application of lime will be important to raising the pH. The buffer pH test is used to guide lime applications. Soils with the same pH can have different lime requirements based on reserve acidity. Further investigation will be necessary to address potential micronutrient deficiencies.
- **Phosphorous Indigestion.** Levels of phosphorous are very high, (131 ppm in the 0-6" depth), but are also very high lower in the soil profile (54 ppm at 12-24" depth). Such levels are not necessarily indicative of over-fertilization by the grower, but could be from of naturally occurring deposits or prior land usage. The previous land renter grew conventionally fertilized raspberries and prior to perennial fruit production the land was a cattle pasture. It will be important to address this imbalance because mycorrhizae fungi and soil microorganisms do not function as effectively in soils saturated with phosphorus.

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[12] Grubinger, Vern. *Nutrient Management on Organic Vegetable Farms*.

[13] Sullivan, D.M., Peachey, E., Heinrich, A.L., and L. J. Brewer. *Nutrient Management for Sustainable Vegetable Cropping Systems in Western Oregon*, Oregon State University Extension Service Publication EM9165. https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/em9165_0.pdf.

Further research into a market crop that could export significant quantities is suggested. (Potatoes, onions, and cabbage can export 50-60 pounds of phosphate per acre.)[14] Use of alternative market crops could also provide significant phosphorous removal. University of Idaho Extension publication indicates crops such as wheat grain, mint hay, alfalfa hay[15] and corn silage[16] may remove 28, 30, 44 and 51 pounds of phosphorous[17] respectively per acre.[18]

- **The Cation Exchange Capacity (CEC)** is most affected by the clay content and type as well as the quantity and quality of organic matter present in the soil. The former is difficult for farmers to influence or change. Improvements to the CEC then, are primarily achieved through additions of organic matter.

Biological Function

Organic matter levels are in the "excellent" range as rated by Cornell Soil Health Report, however the farmers believe there is significant room for improvement. Measured active carbon was scored as "medium" at 495 ppm, with indications that "management practices should be geared toward improving this condition as it currently indicates suboptimal functioning." Nitrogen fixation appears to be functioning as evidenced by results of the legume nodules sampling. (See Appendix D.) Soil Respiration appears low, (0.5mg C02-g $soil^{-1}$-4 $days^{-1}$), but this may be a result of the delay between soil sampling and actual assessment due to the shipping distance between the farm and the Cornell Laboratory.

What the Farmers Learned:

- **Biological soil health monitoring is in its infancy.** Biological indicators of soil health have traditionally been very qualitative. Aside from organic matter, only recently have quantitative tools been accessible for evaluating biological soil health, and the validity of such tests are not widely agreed upon. Complicating matters, such measurements are variable throughout the seasons.

[14] Sullivan, D.M., Peachey, E., Heinrich, A.L., and L. J. Brewer. *Nutrient Management for Sustainable Vegetable Cropping Systems in Western Oregon*, Oregon State University Extension Service Publication EM9165. https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/em9165_0.pdf (see Table 3).

[15] Cornell University research indicates clover hay may provide a similar benefit. http://nmsp.cals.cornell.edu/publications/factsheets/factsheet28.pdf.

[16] Silage is not feasible to be produced at April Joy Farm, but as long as the aerial portion of the corn crop is removed, it is assumed the same quantity of phosphorous would be exported from the farm. Stalks and leaves could be utilized as swine fodder.

[17] To convert from P to P_2O_5, divide by 0.44.

[18] Sheffield, R., Brown, B., Chahine, M., de Haro Marti, M., and C. Falen. *Mitigating High-Phosphorous Soils*. University of Idaho Extension, Bulletin 851. https://www.cals.uidaho.edu/edcomm/pdf/BUL/BUL0851.pdf (see Table 10). To convert from P_2O_5 to P, multiply by 0.44.

- **The data is only as good as the sampling procedure. Farmers need to be consistent with the test method, tools used and time of year**. Appendix E is the first soil test report the farmers had assessed by A&L Labs in 2009. OM is indicated at 2.9%. However, over the years, the test results have fluctuated significantly: in 2010 OM was 3.8%, in 2011: 3.9%. 2012, 5.7%; 2013, 4.2%; 2014, 3.7%; 2016, 4.1%. A&L Laboratory was consistently used for all these tests, but some surface debris was included in early samples due to the inexperience of the farmer. Teaching farmers good soil sampling procedures, with an emphasis on proper procedures, consistency and timing, is important.
- **Time of year** and/or stage of plant growth is crucial when assessing most on-farm biological measures of soil health. Evaluating earthworms, plant growth, weeds and mycorrhizae in the spring/summer (active) season is necessary. Setting aside time to evaluate these indicators during the active growing season will be important for the success of monitoring change in biological soil health (Figure 5).

Figure 5: *Earthworms mating in early spring on sparsely vegetated drive aisles along the produce field are a common sight at April Joy Farm. March 2017.*

- **Biological soil health is an essential element of healthy soil.** The complex ecosystem of living soil provides a number of critical soil functions. By committing to learn more about supporting biological soil health, it is clear the farmers will be most capable of supporting the long-term health of their farm. Significant biological indicators are best assessed on-farm, in-situ. Developing such a practice will be a focus area for the farmers.
- **Soil is and must always be considered as a living system, not simply a stale medium or a material input.** While scientists do not yet fully understand the complex biological

workings of soil function, this does not mean we cannot take steps to protect and encourage the soil's natural processes including: air exchange, nutrient mixing, decomposition, reorganization, maintaining (structural integrity), growing (nitrogen fixation) and reproduction (humus formation) (Figure 6).

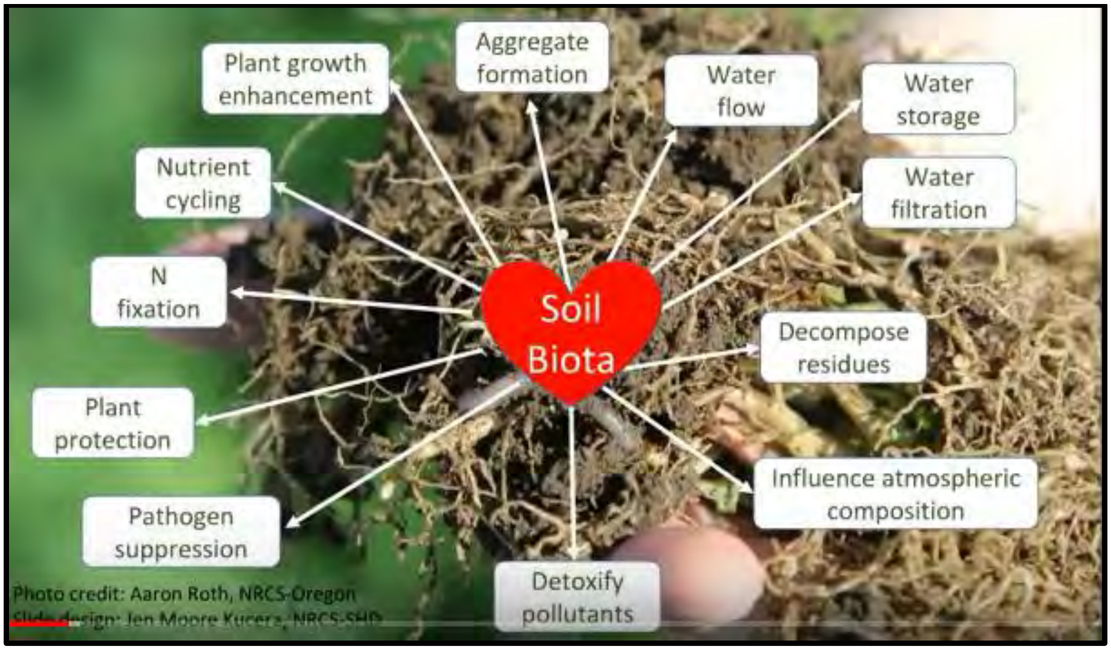

Figure 6: *Understanding soil biology to a key to understanding soil health. Photo credit: Aaron Roth, NRCS-Oregon, Slide design: Jen Moore Kucera, NRCS-SHD*

Systems Nutrient Budget

The following systems nutrient budget (SNB) was prepared for the 1.98-acre annual crop field at April Joy Farm. While the SNB was focused on the nitrogen and phosphorous, where possible, data for potassium and sulfur are also provided. The field is divided into ten blocks (Figure 7). Blocks 1-5 and 13-15 are each comprised of twelve, 5 feet wide by 160 feet long beds for a total block area of 60 feet by 160 feet (0.22 acres). Blocks 11 & 12 are each comprised of twelve 5 feet wide by 80 feet long beds for a total area of 60 feet by 80 feet in length (0.11 acres).

Figure 7: *Annual Crop Field Blocks*

The SNB budget was prepared using 2016 (winter) cover crop records and 2017 market crop data. Because manure imports were not uniformly applied to the two-acre field, and because the manure represents a significant nutrient source, the nutrient budget was calculated in two ways: for the blocks that did not receive any application of manure in 2017 and for those blocks (3, 14, and 15) that did, at a rate of 2000 pounds of manure per block.

Nutrient imports utilized on the 1.98-acre crop field from October 2016 through September 2017 are categorized in Table 6, with actual values calculated in Table 7.

Nutrients exported off the crop field included the categories outlined in Table 8, with calculated results shown in Table 9. See Table 11 for the completed system nutrient budget. Appendix F includes calculations for nutrient imports. Appendix G provides nutrient values from 2017 lab tests for donkey manure, maple leaves, and wheat straw. Appendix H includes 2017 crop yield data and nutrient export values for all harvested crops. The export data represents only that portion of the crop that was sold off the farm, i.e., the broccoli heads and tomatoes, not the broccoli leaves or tomato vines.

Table 6: Nutrient Import Categories

Import Category	Materials and Notes
Soil Blocking/Potting Mix used for the production of transplants	Peat Moss, Lime, Pumice, Perlite, Soil from the farm, Vermicompost, Crustacean Meal, Blood Meal, Colloidal Phosphate, Kelp Meal.
Transplant & Direct Seeding Amendments and Fertilizers	Bone Meal, Blood Meal, Sulfate of Potash, All-purpose fertilizer 9-3-7, Fish emulsion liquid fertilizer
Broadcast/Non-Crop specific amendments	Donkey manure was applied to three blocks B14, B15, and B3. No gypsum, lime, or dolomite was applied in 2017.
Leguminous Cover Crops	Crimson Clover, Red Clover, Field Peas
Plant Residues	Grain stalks (straw), grass hay (aisle mulch) were not included in the SNB due to sporadic use*, but are included in this table because they should be recognized as a potential source of nutrients. (See Appendices G and L.) *Minor applications of nutrients (3 beds/block or less) examples: maple leaf mulch on 1 bed of rhubarb, straw mulch on 1 bed garlic, 1 bed pole beans.
Other	Other sources of imported nutrients, including soil and mineral solubilization, biological weathering, atmospheric deposition and/or precipitation are outside the scope of this systems nutrient budget.

** Most material applications were applied to the standard four-foot-wide bed top.*

Table 7: 2017 Nutrient Imports by Category for 1.98-acre field

	Soil Blocks (lbs)	Transplants (lbs)	Broadcast: Manure in B14, 15, & 3 (lbs)	Leguminous Cover Crops (lbs)	Total (lbs)	Totals Non-Manure (lbs)
Nitrogen	4	44	63	26	137	74
Phosphorous	2	16	17	0	35	18
Potassium	1	39	64	0	104	41
Sulfur	1	12	8	0	20	13

Table 8: Nutrient Export Categories

Export Category	Notes
Harvested Crops and plant residues removed from the field	Twenty-eight crops are included in the SNB. Nutrient content was calculated using N-P-K estimates from three sources: (1) Maynard, D. N., and G. J. Hochmuth. Knott's handbook for vegetable growers. 5th ed. (2) http://articles.extension.org/pages/18794/nutrient-budget-basics-for-organic-farming-systems. (3) https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/em9165_0.pdf. The top five crops (by weight) exported were: tomatoes (2,917 lbs), lettuces (2,433 lbs), squash (1,720 lbs), peppers (1,539 lbs), and onions (1,253 lbs).
Leaching	Analysis of estimated nitrogen leaching at April Joy Farm was done by Cornelius Adewale, Ph. D. in 2012 as part of the OFoot project. Interestingly, if winter cover crops were not used, Dr. Adewale estimated a net loss of N through leaching of 145 lbs. for the 1.98-acre field. It is assumed that P, K and S are not leaching from the soil.
Soil Erosion	Erosion is not a significant issue at April Joy Farm and thus was not included in this system nutrient budget.
Other	Other sources of exported nutrients, including denitrification and ammonification are outside the scope of this systems nutrient budget.

Table 9: 2017 Nutrient Exports by Category for the 1.98-acre field

	Crop Sale (lbs)	Leaching (lbs)	Total (lbs)
Nitrogen	38	85	123
Phosphorous	11	0	11
Potassium	57	0	57
Sulfur	*	0	?

**Values for sulfur loss via crop sales were not available at the time this budget was prepared.*

The systems nutrient budget is shown in Table 10.

Table 10: 2017 Systems Nutrient Budget for 1.98-acre field

	Non-Manure IMPORTS (lbs)	Manure IMPORTS Blocks 14, 15, 3 (lbs)	EXPORTS (lbs)	NET VALUE Non-Manured Blocks 1, 2, 4, 5, 11-13 (lbs)	NET VALUE Manured Blocks 3, 14, 15 (lbs)
Nitrogen	74	63	123	-49	14
Phosphorous	18	17	11	7	24
Potassium	41	64	57	-16	48
Sulfur	13	8	*		

**Values for sulfur loss via crop sales were not available at the time this budget was prepared.*

What the Farmers Learned:

- **Nitrogen loss from leaching is more than double that of losses due to crop exports.** Annual rainfall averages 40 inches per year, the majority of which occurs between October and April. This means the use of winter cover crops is absolutely essential to limiting costs associated with importing nitrogen fertilizers. The use of legume cover crops could offset losses from leaching without adding phosphorous to the soil. However, a grain cover crop is necessary to better prevent nitrogen leaching.

Nutrient imports from soil blocking/potting activities are negligible, and do not contribute significant nutrient additions to the field. However, these imports do constitute a significant addition of organic matter for the field, including 1.4 tons of vermicompost and 0.5 tons of peat moss.

- **Transplant nutrient imports were time-consuming to calculate** because of the extensive number of fertilizer mixes that were used, as well as the inconsistent methods of application. Reducing the variety of amendments would greatly simplify field management practices, labor needs, and record keeping.
- **Deciding on specific nutrient inputs and application rates is challenging** because of the extensive number of crops being grown. Typically, the farmers have amended individual transplant holes, which is precise, but very labor intensive. The alternative is to

broadcast or band amendments in a generalized fashion over the entire area of the bed top. This approach is expensive and may lead to higher than necessary nutrient loads. A split application of fertilizer with side dressing is another approach. Generalized amendment recommendations can also be detrimental to specific crop families, but attempting to fine tune nutrient levels for the various crops is not always practical.

- **The contribution of cover crop nutrient imports needs to be validated in 2018.** The cover crop values used in the 2017 nutrient budget were estimated using Oregon State University guidelines. A field estimate of plant available nitrogen would be very helpful in validating the system nutrient budget results. [19]
- **Sporadic applications of manure not uniformly applied over the field have hindered efforts**. This approach is not ideal considering the soil tests used for this report were not block specific but rather a composite sampling of all blocks.[20] When manure is spot applied in certain blocks, it skews the reported nutrient values considerably. Manure applications are providing a significant source of nitrogen and potassium, but are increasing already high phosphorus loads.
- **The right resource can greatly simplify SNB calculations for diversified farmers**. Once such example is the NRCS Plants Database Nutrient Content of Crops website which estimates the nitrogen, phosphorous and potassium of harvested crops: https://plants.usda.gov/npk/main.

[19] https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/pnw636.pdf.

[20] See Collins, 2012. Soil Testing: A guide for Diversified Vegetable Farmers for more information.

Nutrient Management: Historical Practices and Action Plan

Crop Rotation

Historical Practices

The farmers have practiced some form of crop rotation since the inception of their farm (Table 11, Figure 8). The original rotation grouped crops by plant family without any main season fallow (non-marketable crop) periods. Each crop family occupied a given block during the spring/summer/fall season. A few crops are overwintered, including brassicas, leaf celery, chard and garlic. The rotation was originally designed as nine years in length between crop families, except for Solanaceae. Due to the proportionally high growing area required, a 4-year rotation has been attempted, e.g.: tomatoes and peppers in Year 1 are followed by potatoes in Year 4. Appendix I provides an overview map of 2017 crop families by location and total area of the field.

Table 11: Percentage Area by Crop Family Over A 5-Year Period in the 1.98-acre field

	2013	2014	2015	2016	2017	5 YR AVG.
SOLANACEAE	24%	19%	18%	17%	15.2%	19%
BRASSICACEAE	14%	13%	10%	11%	10.5%	12%
CUCURBITACEAE	15%	10%	7%	8%	9.0%	10%
AMARYLLICACEAE	5%	5%	5%	7%	5.4%	5%
COMPOSITAE	3%	9%	5%	5%	4.1%	5%
CHENOPODIACEAE	8%	4%	1%	4%	3.1%	4%
UMBELLIFERAE	5%	7%	6%	5%	2.8%	5%
LEGUMINOSAE	8%	3%	2%	1%	1.4%	3%
PERENNIAL[1]	0%	0%	2%	2%	1.4%	1%
POACEAE[2]	0%	0%	3%	4%	11.8%	4%
FALLOW[2]	15%	29%	39%	35%	34.4%	30%
OTHER[3]	5%	2%	3%	2%	0.9%	2%

[1] *Perennial crops include rhubarb and strawberries.*

[2]*Grain crops including rye, wheat, and barley are planted as cover crops and to produce straw that is returned to the field as mulch for garlic. Total acreage of fallow land available for cover cropping is the sum of these two categories, i.e., for 2017, total available fallow land is 11.8% + 34.4% = 46.2%*

[3] *Sweet potatoes, basil, shiso.*

Figure 8: *Swine at April Joy Farm have historically been pastured in paddocks and not rotated through market crop fields. In 2017 the heritage pork program was suspended in order to improve the soil health of the livestock paddocks and to plant a new mixed species orchard. (Pear saplings, shown above, are enclosed by deer fencing.) By multi-stacking functions, the farmers hope to provide an enriched environment for grazing livestock, expand perennial crop production, and reduce imports of livestock feed. March 2018.*

Challenges of the Current Crop Rotation

Crop Diversity & Required Acreage: Over the last five years, the rotation has been significantly altered to accommodate fluctuating market demands. These alterations have been exacerbated by a shift in markets the farm serves. For instance, in 2015 the farm ceased grocer sales which significantly decreased the cucurbit acreage. Table 12 highlights the difficulty of maintaining a consistent rotation, given the extensive number of market crops. See Appendix O for a timeline of significant farm management changes and milestones.

Table 12: Crop Family by Block Over a 5-Year Period

	2013	2014	2015	2016	2017
B1	CUCURBITACEAE	SOLANACEAE	UMBELLIFERAE	AMARYLLICACEAE & CUCURBITACEAE	COMPOSITAE
B2	FALLOW	FALLOW	SOLANACEAE	CHENOPODIACEAE & UMBELLIFERAE	AMARYLLICACEAE & CUCURBITACEAE
B3	BRASSICACEAE	FALLOW	FALLOW	SOLANACEAE	GRAIN FALLOW
B4	AMARYLLICACEAE & SWEET CORN	BRASSICACEAE	FALLOW	FALLOW	SOLANACEAE
B5	SOLANACEAE	AMARYLLICACEAE	BRASSICACEAE	BRASSICACEAE	CHENOPODIACEAE & UMBELLIFERAE
B11/12	SOLANACEAE	LEGUMINOSAE & COMPOSITAE	LEGUMINOSAE, COMPOSITAE	COMPOSITAE	FALLOW
B13	LEGUMINOSAE & COMPOSITAE	CHENOPODIACEAE & UMBELLIFERAE	AMARYLLICACEAE & CUCURBITACEAE	SOLANACEAE	FALLOW
B14	CHENOPODIACEAE & UMBELLIFERAE	CUCURBITACEAE	SOLANACEAE	FALLOW	BRASSICACEAE
B15	CUCURBITACEAE	SOLANACEAE	FALLOW	BRASSICACEAE/ FALLOW	SOLANACEAE

Physical Constraints: The rotation has not accounted for differences in the natural characteristics of the blocks. For instance, the south blocks (1-5) are much less well drained, which has consistently delayed spring planting activities. The rotation has been compromised in order to ensure the health of the transplants.

Compartmentalization: The rotation has not been set up to enhance logistical aspects of plant care. For instance, early and late season crops are frequently located in adjacent beds, leading to a very fragmented rotation that does not lend itself to cover cropping or larger "block" sized amendments/soil improvement practices. This has necessitated an increase in tillage and cultivate practices.

Recommendations:

1. Consider a rotation that groups market crops primarily by planting season (April – June, July – October) and secondarily by crop family. Subdivide the field to accommodate physical characteristics. Cycle the early season crops through the most well drained blocks and utilize the lower blocks for later season crops.
2. Modify the current practice of taking blocks out of vegetable production every fifth year. Instead, introduce an entire year-long soil building period between all market crops every three to four years. This recommendation would require additional land or a reduction of current crop production acreage to achieve a 40% soil building land base. The farmers have existing land available to the east of the current field that could be utilized for this purpose.

3. Following a fallow year, the cash crop rotation would begin with the crops which have the highest nutrient (nitrogen) requirements, followed in succession by medium, then light feeders in subsequent years.

Table 13: Nitrogen requirements for vegetable crops[21]

Low: 3 lbs/1000 ft^2	Medium: 4 lbs/1000 ft^2	High: 5 lbs/1000 ft^2
Baby Greens	Carrot	Broccoli
Bean	Corn, sweet	Cabbage
Cucumber	Garlic	Cauliflower
Radish	Lettuce	Celery
Spinach	Melon	Potato
Squash	Onion	
	Pepper	
	Tomato	
Multiply values by 44 to approximate the conversion of lbs/1000 ft^2 to lbs/acre.		

4. Spatial and temporal diversity within the crop rotation is encouraged to provide beneficial results with respect to weed and pest management. [22] Specific elements to consider are listed below.
   a. Cash crops: plant family, nitrogen needs (heavy, medium and light feeders)
   b. Cover crops: grain and legume combinations, for example: oats and peas, rye and vetch, wheat and clover
   c. Type of tillage: shallow, deep, none
   d. Timing of cash crop plant/harvest: early season, late season, overwintering
   e. Timing of cover crop plant/harvest: winter, summer, full year
   f. Type and source of nutrient amendments: compost, nitrogen fixation via leguminous cover crop, organic mulches, raw manure/animal grazing.[23]

A proposed rotation for early and late season crops is shown in Tables 15 and 16. This rotation will require one additional block (160 ft x 60 ft) to be added to the current field, to allow the heavy feeding Solanaceae crops (potatoes and tomatoes) to both be preceded by a fallow year in which leguminous crop could be grown to provide a substantial portion of the nitrogen requirements of the crop.

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[21] See Table 1: "Nitrogen requirement for vegetable crops based on seasonal nitrogen uptake (adapted from Gaskell et al. 2007) in Pacific Northwest Extension Publication PWP646. *Soil Fertility in Organic Systems: A Guide for Gardeners and Small Acreage Farmers.*

[22] One useful framework is: The Bio-extensive Market Garden approach developed by Anne and Eric Nordell, who utilized a 50% fallow crop rotation. Nordell, Anne & Eric. Weed the Soil, Not the Crop. A Whole Farm Approach to Weed Management Jan. 21, 2007. See chart page 8.

[23] Until phosphorous levels are reduced, direct applications of manure and/or grazing of livestock on crop land is not recommended.

Table 14: Proposed Rotations for Early Season Crops [April – June Seeded/Transplanted]

EARLY SEASON CROP ROTATION

Year	Crop	Nitrogen Requirement	Primary Fertility Source	Tillage Practices	Row Feet	No. of Beds	Total Beds/Year
1	Fallow: Nitrogen Cover Crop	--		None		10	
	Pollinator Species, Medicinal Herbs, Perennials	Low	Amendments	Shallow/None	varies	2	12.00
2	Potatoes	High	Cover Crop	Deep/Frequent	1600	10	
	Pollinator Species, Medicinal Herbs, Perennials	Low		Shallow/None	varies	2	12.00
3	Fallow Nitrogen Cover Crop	--		None		10	
	Pollinator Plants, Medicinal Herbs, Perennials	Low	Amendments	Shallow/None	varies	2	12.00
4	Tomatillos		Cover Crop	Shallow & Frequent	100	0.25	
	Eggplant				160	0.5	
	Tomatoes	Medium			240	4	
	Peppers - Sweet	Medium			960	3	
	Tomatoes - Sauce	Medium			160	1	
	Tomatoes - Cherry	Medium			160	1	
	Pollinator Species, Medicinal Herbs, Perennials	Low	Amendments	Shallow/None	varies	2	11.75
5	Onions	Medium	Amendments, Compost	Shallow & Frequent	1440	3	
	Peppers - Hot	Medium			510	1.5	
	Lettuce - Salad Mix Spring	Medium		Shallow & Infrequent	1600	2	
	Lettuce - Butterhead Spring	Medium			800	1	
	Lettuce - Romaine Spring	Medium			800	1	
	Pollinator Plants, Medicinal Herbs, Perennials	Low		Shallow/None	varies	2	10.50
6	Chard		Amendments, Compost	Shallow & Infrequent	80	0.25	
	Parsley				160	0.50	
	Celery	High			40	0.125	
	Cabbage	High			640	2	
	Kohlrabi				480	1.00	
	Radishes - Spring	Low			160	0.3	
	Turnips - Spring				160	0.30	
	Greens - Asian Spring	Low			720	1.5	
	Beans - Pole	Low			80	0.5	
	Beans - dry	Low			40	0.25	
	Peas - Soup/Flour	Low			40	0.25	
	Squash - Summer	Low		None, Mulched	320	2	
	Melons	Medium			80	0.5	
	Cucumbers	Low			80	0.5	
	Pollinator Plants, Medicinal Herbs, Perennials	Low		Shallow/None	varies	2	11.98

Crops are color coded by Plant Family.

Table 15: Proposed Rotations for Late Season Crops [July – October Seeded/Transplanted]

LATE SEASON CROP ROTATION

Year	Crop	Nitrogen Requirement	Primary Fertility Source	Tillage Practices	Row Feet	No. of Beds	Total Beds/ Year
1	Fallow: Nitrogen Cover Crop	--		None		10	
	Pollinator Species, Medicinal Herbs, Perennials	Low	Compost	Shallow/ None	varies	2	12.00
2	Broccoli	High	Cover Crop	Shallow & Infrequent	640	3	
	Cauliflower	High			640	2	
	Kale				640	2	
	Cabbage	High			480	1.5	
	Flower Sprouts	High			320	0.5	
	Collards				160	0.5	
	Radishes	Low			320	0.5	
	Pollinator Species, Medicinal Herbs, Perennials	Low	Amendments	Shallow/ None	varies	2	12.00
3	Lettuce - Salad Mix	Medium	Amendments, Compost	Shallow & Infrequent	1600	2	
	Lettuce - Romaine	Medium			800	1	
	Lettuce - Butterhead	Medium			800	1	
	Garlic - Hardneck			None, Mulched	800	1	
	Beets - Fall			Shallow & Frequent	960	2	
	Carrots - Fall	Medium			960	2	
	Fallow	--		Shallow/ None	160	1	
	Pollinator Species, Medicinal Herbs, Perennials	Low			varies	2	12.00
4	Squash - Winter	Low	Amendments, Compost	Shallow & Frequent	1600	10	
	Pollinator Species, Medicinal Herbs, Perennials	Low		Shallow/ None	varies	2	12.00

Crops are color coded by Plant Family

Cover Crops

History and Current Practices: An Overview

Figure 9: *Winter cover cropping at April Joy Farm has required a mixed approach. A rye/pea mix on the right borders pepper plants intercropped with marigolds on the left. At the transition between the two, chickweed fills in all gaps. Peppers and other main season crops are often harvested into mid-October and sometimes planted on weed barrier. Neither practice allows for the establishment of robust winter cover crops.*

Both winter and summer cover cropping have been a practice at April Joy Farm since inception. Winter cover cropping has required multiple tactics, because fall harvest periods often vary both between crops but also between years for the same crop (Figure 9.) For example, sweet pepper harvests can end mid-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, (cabbage, kales, cauliflower, collards, broccoli) 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 (Figure 10.) Appendix J details the 2017 spring/summer crop map as well as the fall/winter crop map, which includes overwintered crops and sown cover crops by block and bed.

Over the years, the most consistent winter cover cropping practice 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 (Figure 11). Commonly utilized cover crops are identified in Table 16 and Figure 12.

Figure 10: *A common volunteer winter cover crop cocktail at AJF includes Persian speedwell, Henbit, (Lamium amplexicaule) and grasses. Chickweed and Purple dead-nettle are common at areas of increased fertility. Feb 2018.*

Figure 11: *A second flush of spring sown buckwheat will soon winterkill, allowing the chickweed growing in the foreground to take over the bed. October 2014.*

Table 16: Cover Crops at April Joy Farm

Winter Cover Crops sown by the Farmers	Volunteer Winter Cover Crops (Weeds)	Spring/Summer Cover Crops Sown by the Farmers	Volunteer Summer Cover Crops (Weeds)
Rye grain	Chickweed	Buckwheat	Pigweed
Hairy vetch	Persian speedwell	Phacelia	Lambsquarter
Oats	Purple dead-nettle	Crimson Clover	Crab grass
Winter peas	Quack grass	Calendula[2]	Dandelion
Crimson Clover	Radish & mustards	Borage[2]	
Medium Red Clover	Dock		
Winter Wheat	Dandelion		
Tillage radishes[1]	Henbit		

[1] *Overwintering brassica crops are limited where possible. Their termination is carefully coordinated in the spring to reduce both habitat and available forage for resident aphid populations. This strategy ensures tender spring transplants are not decimated by pest pressure.*

[2] *Borage and Calendula are companion planted in buffer zones adjacent to cucurbits but act effectively as drought tolerant summer cover crops. Like buckwheat, they are not typically terminated. While they do re-seed themselves, no long-term significant weed pressure has resulted.*

Figure 12: *The two most common winter crop mixes utilized at AJF include oats/peas (25%/75%) on the left and rye/vetch (78%/22%) on the right. Note the Persian speedwell in the foreground, which is a common understory winter plant. Also note the deer have heavily cropped the oats, while leaving the rye mostly untouched. The peas and vetch are just beginning to become established. Vetch has proven to be the more reliable legume. February 2018.*

Challenges of the Current Cover-Cropping Strategy

Multi-cropping: Relay planting or overseeding market crops (in-row and aisles) with cover crop seed is in theory an excellent practice, but it has not gained widespread use at AJF. Two challenges to adopting this practice are (1) the frequent foot traffic in aisleways that compacts the soil and damages the newly germinating cover crop, and (2) the cover crop does not grow fast enough to adequately compete with weed pressure, which then requires cultivation.

Connecting Cover Crops with Nutrient Management: Managing leguminous cover crops to provide nitrogen has long been a goal, but has proven challenging to consistently achieve. Winter peas have not reliably germinated or overwintered, ostensibly due to the late sowings and soil acidity. Hairy vetch has been an excellent legume winter cover crop, but it has proven challenging to allow adequate time in the spring for the vetch to achieve significant top growth. (See *Coordinating Crop Rotations with Winter Cover Crop Usage* for more details.) Because of these hurdles, the farmers have not properly accounted for the fertility provided by this practice and thus still apply fertilizers each year in rates suggested by soil lab test results.

Coordinating Crop Rotations with Winter Cover Crop Usage: Due to the quantity and intensity of winter precipitation, healthy stands of overwintering cover crops are crucial for preventing nutrient leaching and protecting soil health. However, the current production practices coupled with the existing crop rotation too often pit winter cover crop establishment against extended sales of high value main season crops (Figure 13).

In the spring, additional challenges arise from the premature termination of cover crops in order to meet planting dates for market crops. Block 11 will be transplanted into spring greens by mid-April 2018, at which time the peas will not have put on sufficient growth. Another common scenario which occurs is one in which an excellent stand of rye/vetch is established in the fall, but must be terminated very early in the spring to meet planting dates. Due to the fibrous root system, this requires additional cultivation. The farmers believe the practice damages the soil unnecessarily at a time of year it is particularly vulnerable.

Figure 13: *A poor stand of winter peas and oats provided little protection from winter rains. This cover crop was not sown until mid-October, which was dictated by an extended fall tomato harvest. February 9, 2018.*

Limited summer cover crops: The approach to summer cover crops has been very ad-hoc. There is little strategy utilized, other than to spring till beds that have significant perennial weed pressure, then sow to buckwheat in order to expedite fall planting of those beds. Too often, the fallow blocks that are not needed for vegetable production in a given year are not effectively managed to reduce weed pressure and establish nutrient building cover crops (Figure 14). The farmers would like to expand the use of summer cover crops for weed management and nutrient building, however they also face restrictions with respect to irrigation usage. State regulations limit the quantity of water which can be used daily for agricultural purposes without water-rights. In addition, the farmers do not have adequately sized irrigation equipment or pumps to overhead irrigate larger acreage. The drip irrigation system in place for market crops is only suitable for row crops. Thus, a lack of precipitation during the summer months requires excellent soil moisture management practices and nearly-perfect timing for healthy crop establishment.

Figure 14: *Sporadic Crimson Clover and Dock with an understory of Persian Speedwell is one example of poor cover crop management. At this point in the year, the ground was too dry to attempt renovation. The block was not mowed until the following spring. May 2015.*

Because of these various challenges, cover crops have not been successfully integrated into the farm production practices.

Recommendations:

1. Establish a rotation specific to cover crop usage which aligns with the market crop rotation. Three main goals for this cover crop rotation are: (1) supply a majority of the nitrogen requirement for the heaviest feeding market crops, (2) replenish organic matter, and (3) reduce weed pressure.

   A cover crop program would not aim to increase the complexity of field management practices, but rather simplify the fallow block management by treating cover crops as cultivated market crops that simply are not exported off the farm. Extensive use of cover crops will provide nitrogen without increasing phosphorous loads[24]. Following a fallow year of nitrogen building cover crop mix, the cash crop rotation would begin with the heaviest feeding crop, followed by 2-3 years of crops requiring successively lower quantities of nitrogen. Mowing the nitrogen building cover crop (clover or other legume) during the

[24] It should be noted that while cover crops will not increase the quantity of phosphorous in the soil, cover crops may act as nutrient accumulators, i.e., reallocate phosphorous from lower soil horizon.

fallow year will provide additional biomass and potentially increase nitrogen fixation. Tables 17 and 18 provide the details for this recommendation.

2. A biomass sample of crimson clover should be taken in the summer, prior to leaf drop, in order to validate plant available nitrogen estimates from cover crop contributions.[25] For the 2018 SNB, an assumed N value of 44.5 lbs/acre, (88 lbs/1.98 ac field), might be of relevance based on WSU research. *"A laboratory incubation estimating N release from a mixture of 75% rye biomass, and 25% hairy vetch biomass, indicated that about 50% of the cover crop N was released over the equivalent of a growing season, or about 50 kg ha^{-1} for the mixtures planted in September and terminated in April in this study."*[26]

3. Strive for a fall cover crop sowing no later than September 15th. For blocks where an earlier sowing is not possible, consider over seeding a rye-vetch cover crop. Reduce or eliminate synthetic weed barriers to make this possible. Early crops will require cover crop termination by mid-March to allow for early April transplants. In these instances, it is more important to establish an early sowing date the prior fall, mid-August if possible. Adjusting cover crop sowing and termination dates will greatly improve contributions to organic matter. *"Monoculture rye and rye-hairy vetch mixtures produced greater biomass than monoculture hairy vetch averaged over all planting and termination dates and years. Delaying planting from mid-September to early October reduced average biomass by half, and moving termination from late April to late March reduced average biomass by 60%."*[27]

4. Carefully manage dates of cover crop termination. In general, terminate grain cover crops at stem-elongation/early boot stage, and legumes at vegetative/pre-bloom stage. Assuming warm soil conditions and adequate moisture, nitrogen building cover crops need to be terminated approximately two weeks prior to transplanting in order to minimize the need for off farm nitrogen fertilizers. If time allows in the spring, the rye-vetch can be repeatedly mowed while still in vegetative state to increase biomass and lower C:N ratio prior to incorporation.

5. Replace poor performing winter field peas with crimson clover or vetch, which can contribute between 70-150 lbs of N/acre.[28] Experiment with a nitrogen building and scavenging cover crop mix comprised of oats, crimson clover, and tillage radishes, sown as early as September 1st. Crimson clover has proven to be a reliable winter cover crop for the farmers, even in the least well-drained blocks.

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25 One resource is Pacific Northwest Publication PNP 646. http://cru.cahe.wsu.edu/CEPublications/PNW646/PNW646.pdf.

26 Lawson, A., Fortuna, AM., Cogger, C., Bary, A., and Stubbs, T. Nitrogen contribution of rye–hairy vetch cover crop mixtures to organically grown sweet corn. 2013.

27 Lawson, A., Cogger, C., Bary, A. & Fortuna, AM. Influence of Seeding Ratio, Planting Date, and Termination Date on Rye-Hairy Vetch Cover Crop Mixture Performance under Organic Management 2015. https://doi.org/10.1371/journal.pone.0129597.

28 https://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition/Text-Version/Legume-Cover-Crops/Crimson-Clover.

6. Consider including a 3-year perennial in the crop rotation. Alfalfa is commonly utilized to fill this niche- both to break the weed cycle and to provide sufficient nitrogen to subsequent crops. However, at April Joy Farm, soil acidity and wet winter soils may not make it a feasible choice. A test plot could be sowed in 2018 to evaluate alfalfa's suitability, along with other potential legume perennials such as Birdsfoot trefoil.

Table 17: Cover Crop Rotation for Apr.-June Early Planted Market Crops

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
	Nitrogen Building Fallow	**Heavy Feeding Market Crops**	**Nitrogen Building Fallow**	**Heavy Feeding Market Crops**	**Medium Feeding Market Crops**	**Low Feeding Market Crops**
Spring	Oats & Crimson Clover	Oats & Crimson Clover → Potatoes	Oats & Crimson Clover	Oats & Crimson Clover→ Tomatoes	Rye & Vetch → Onions, Lettuces	Rye & Vetch → Spring Greens, Legumes, Cucurbits
Summer	Oats & Crimson Clover	Potatoes	Oats & Crimson Clover	Tomatoes	Onions, Lettuces	Spring Greens, Legumes, Cucurbits
Fall	Oats & Crimson Clover	Potatoes → Oats & Crimson Clover	Oats & Crimson Clover	Tomatoes → Over seed with Rye & Vetch	Lettuces →Rye & Vetch	Spring Greens, Legumes, Cucurbits →Oats & Crimson Clover
Winter	Oats & Crimson Clover	Oats & Crimson Clover	Oats & Crimson Clover	Rye & Vetch	Rye & Vetch	Oats & Crimson Clover

In fallow years, add tillage radishes to cover crop mix if possible.

Table 18: Cover Crop Rotation for July-Oct. Late Planted Market Crops

	Year 1	Year 2	Year 3	Year 4
	Nitrogen Building Fallow	**Heavy Feeding Crops**	**Medium Feeding Crops**	**Light Feeding Crops**
Spring	Oats, Crimson Clover	Oats & Crimson Clover	Brassicas, Rye & Vetch	Over seeded Rye & Vetch
Summer	Oats & Crimson Clover	Brassicas	Fall Lettuces, Beets & Carrots	Winter Squash
Fall	Oats & Crimson Clover	Brassicas, Over seed Rye & Vetch	Lettuces, Beets & Carrots, Over seed Rye & Vetch	Winter Squash → Oats & Crimson Clover
Winter	Oats & Crimson Clover	Brassicas, Rye & Vetch	Over seeded Rye & Vetch	Oats & Crimson Clover

In fallow years, add tillage radishes to cover crop mix if possible.

Organic Materials Usage

History and Current Practices: An Overview

Fertility

To provide fertility for market crops, the farmers have historically relied on purchased amendments. Organic matter has been maintained through long-term use of winter cover crops, and by consistently keeping as much plant residue as possible in the fields at harvest. Because 100% of annual transplants are grown on the farm and on average 70% percent of all crops are transplanted (vs. direct sown), substantial inputs of peat moss, (0.5 tons) and vermicompost, (1.4 tons) are applied on an annual basis. See Appendix L for nutrient test results of the purchased vermicompost. Annual fertilizer purchases (blood meal, bone meal, etc.) range from $1,000-$3,000. See Appendix M for the farm's WSDA organic certification materials inventory list.

Packing operations from cleaning and processing market crops generates a significant amount of vegetable waste (20 cubic feet per week) for up to 35 weeks per year. Currently these wastes are dumped into a passive compost pile in the chicken yard that is not managed or turned (Figure 15). The pile is anaerobic at most times. Each fall, tomato vine plants are removed from the field and added to this pile. Hay bales are used to cap the pile at the end of the season. The compost generated has not been used in production operations, due to assumed pathogens present and the continuous additions of fresh chicken manure.

Fertility Timing

Manure is typically applied in late October to only the blocks that will be fallow the following year. In the winter of 2017, no manure was applied to the field, as all of it was applied as topdressing to newly planted orchard trees. 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.

Weed, Pest and Disease Management

The farmers have not traditionally relied on the use of chemical sprays or other material applications to manage weed, pest or disease pressures. Weed pressure is most often managed through cultivation and organic or synthetic weed barrier, the latter of which is only used seasonally.

Pest concerns are addressed most often through physical exclusion. The use of polyspun row covers is standard practice for all early season transplants vulnerable to insect, rabbit and deer damage. Deer fencing has been in place for eight years and is nearing the end of its useful life. Bird netting has not been used in the orchards. Farm dogs, proximity to human traffic patterns, and timely harvest practices have sufficed as avian deterrents in the table grape vineyard.

The only pest material applied to crops is Surround KP kaolin clay. This practice is used sporadically to deter flea beetles at brassica crops and cucumber beetles at cucurbits. No kaolin clay was used in 2017. Physical exclusion combined with timely cultivation and management of overwintering host plants has proven to be more effective than spraying kaolin clay. Beneficial host plants such as marigolds are now intercropped with summer squash as standard practice.

No disease management materials are applied to any crops at April Joy Farm. Instead, great attention is given to seed selection, plant spacing, field layouts, row orientation (to take advantage of prevailing winds). In addition, the elimination of overhead irrigation and good cultural practices such as removal of diseased plant material from the fields and careful, clean harvest practices have been relied upon to ensure the health of the market crops.

Figure 15: *Passive, anaerobic composting of packing shed scraps in the chicken yard produces a compost potentially harmful to germinating seeds; therefore, it is not utilized in production operations.*

Nutrient Management

In 2009 an EQIP Nutrient Management plan (Practice 590) was completed for the farm. Since that time, multiple changes to production practices have occurred. Most notably with respect to fertility is the addition of donkeys to the operation, whose feed source is hay produced at the farm.

In 2017, the farmers received funding to build a covered composting structure for improved manure management. Additional funding through the Clark Conservation District was secured in early 2018. Combined, these grants will be used to construct a 32' x 8' four bay aerated static composting structure in 2018. In addition, these funds will also help in the purchase of a continuous flow vermicomposting unit[29] to provide year-round production of finely screened, non-manure compost

[29] *See Sustainable Agriculture Technologies, Inc. Unit 5x4:* http://www.wormwigwam.com/specifications/.

for transplant seedling production. This unit will be purchased and operational by early 2019. Table 19 identifies sources of organic matter currently produced/available on the farm.

Table 19: Raw Organic Materials Inventory for April Joy Farm

Source	Annual Quantity (CYDS)[1]	Availability and Rate of Production	Estimated C:N Ratio[4]	Notes
Donkey Manure & Hay Bedding (2 miniature)	23	Weekly, 0.44 cyd/week	25-30:1	See Appendix G for nutrient test results of manure and Appendix L for test results of hay.
Chicken Manure & Hay Bedding (65 head flock)	24	Quarterly, 10 cyd/ 3 months	13-30:1	Chicken manure was not tested in 2017 for nutrient values. Appendix L shows test results for hay bedding.
Swine Manure & Hay/wood chip bedding (2 sows)	32	Winter, Annually		C:N for raw swine manure is 5-7:1. C:N with wood chip bedding is unavailable. Manure was not tested for nutrient values in 2017.
Packing Shed Green Wastes	39	May-Nov: bi-weekly, 0.4 cyd/(2x/wk). Dec-April: n/a	12:1	
Plant Residues (tomato vines, etc.)	20-60	October, Annually	12:1	Residues removed from the field for disease management purposes
Grain Straw[2]	0.25	August, Annually	80:1	See Appendix G for nutrient test results.
Maple Leaves	2	November, Annually	40:1	Significantly larger quantities could be collected. See Appendix G for nutrient test results.
Wood Chips[3]	230-262	32 cyds on hand most times of year	600:1	Delivery schedule is unpredictable
Grass Clippings		Weekly, March - October	12-25:1	Currently uncollected due to lack of equipment but available in significant quantities at the farm. (Over 0.5 acre)
Grass Hay	335 bales	Annually	40:1	AJF hay field is cut once per year by a neighbor, in exchange for 50% (~168 bales/year). Bales are roughly 40 lbs each. Hay is used for donkey fodder, animal bedding, and occasionally as mulch in the vegetable field aisles for fall mud and weed control. See Appendix L for nutrient test results.
Total	370-442			

[1] *See Appendix K for Calculations.*

[2] *Wheat straw is typically stored and used as mulch for garlic, excess is returned to the block it was harvested from.*

[3] *Wood chips are provided free of charge by a local tree trimming business and vary in quantity. So far, they have not been used in the annual market crop field, but are used as barnyard bedding and for mud management. These numbers do not include AJF orchard and vineyard prunings that are flail mowed/chipped and returned to the perennial cropland.*

[4] *Field Guide to On-Farm Composting NRAES publication 114.*

Figure 16: *Materials management at April Joy Farm. Wood chips (in the foreground) and the tarped donkey manure pile are shown. Note that manure has just been spread at the base of fruit trees in the distance, then top-dressed with wood chips to reduce annual weeds.*

Organic Material Usage Challenges

Organic materials (OM) 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. In addition, determining the most beneficial use for these materials has been a perennial question for the farmers. Balancing the benefits of simply applying manure to the fields with the drawbacks of restricted timing due to field conditions, market crop schedules and National Organic Program (NOP) regulations has proven difficult. In addition, lack of appropriately sized equipment for spreading manure and adequate storage areas have contributed to an ad-hoc approach (Figure 16).

High quality, pathogen-free compost in sufficient quantities has also, to date, not been feasible for the farmers to produce. 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.

Recommendations:

1. The planned aerated static composting structure with bays for material storage represents a significant step forward to reducing off farm amendments. With this facility in place, the

primary goal for 2018 for the farmers could be to gain experience and expertise with this method of composting.

2. A long-range goal should be to supply half the required nitrogen from farm generated compost. Per PWN Publication 646: *"One cubic yard of compost covers about 600 square feet of area to a depth of 1/2 inch. Assuming 1.5% total nitrogen, a C:N of 20:1, and a density of 1000 lb per cubic yard, this amount of compost would provide about 2.5 pounds of N per 1000 ft2 over the first season."* [30]
3. Over the next five years, steps to improve the fertility of the existing 4.8-acre hay field could be taken. Liming to increase pH is recommended based on the 2017 soil test results (see Appendix N). Dolomite at a rate of 4.5 tons/acre will be sufficient, and should be applied over a 2 year period. Ruts and deep wallows in the south east corner of the field have deterred haying operations and could be remedied to allow increased bales to be cut annually. Introducing grazing ruminants to this field on a rotation basis could still allow hay production while adding manure for fertility.
4. Consider reducing or eliminating off farm feed purchases for swine and poultry. 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.

Machinery & Equipment

History and Current Practices: An Overview

The following machinery and equipment has been utilized at April Joy Farm for the last five years. Plowing has never been practiced, and in the early years of the farm, the rotovator was utilized for primary and secondary tillage due to the limited finances of the farmer. Table 20 provides an overview of all equipment currently used that impact soil health.

[30] http://cru.cahe.wsu.edu/CEPublications/PNW646/PNW646.pdf.

Table 20: Machinery and Equipment Utilized that Impact Soil Health

Machinery	Mowing & Swathing	Primary Tillage	Secondary & Finishing Tillage	Cultivation	Harvest	Seeding	Organic Material Handling	Irrigation
35 hp tractor	Flail Mower	Disc, Single Shank Ripper, Furrow	60" rotovator, bed shaper, s-tine harrow		Potato Digger	Culti-packer	Front End Loader, Manure Spreader, Seeder Spreader	
Farmall A	Rotary Mower							
Allis Chalmers G				Basket weeder, Tine Weeder				
Non-mechanized				All other cultivation is by hand.	All other crops harvested by hand.	All seeding is done by hand using a bike seeder or broadcast seeder / spreader.	Most soil amendments and mulch are applied by hand.	Drip irrigation or dry farming is utilized for all crops.

Machinery and Equipment Challenges

Machinery and equipment choices have a substantial impact on the health of the agricultural soils and not surprisingly, have an equally significant impact on a farmer's budget. Purchasing equipment that is both affordable and effective continues to be a challenge. Accessing right-sized equipment that is not unnecessarily harmful to soil life is difficult, and it is exacerbated by the diversity of crops grown at the farm. Efficiency, cost, and impact on soil health are variables that are difficult to reconcile.

Two categories of equipment especially challenging from a soil health perspective are: primary tillage and small grain harvesting equipment.

Acquiring a primary tillage implement that is significantly less damaging to soil health than the rotovator has long been a goal of the farmers. Spading machines, for instance, can be used for primary and secondary tillage in silt loam soils to incorporate material and prepare seedbeds, without inverting the profile or creating a hardpan. Accessing no-till organic machinery is equally challenging, and without assurances that such expensive purchase will be appropriate and effective, the farmers are not inclined to risk such outlays of cash. Due to cost, the farmers have not had any experience with no-till equipment such as roller/crimpers and no-till planters/transplanters.

The farmers have experimented with low-cost no-till practices such as solarization using silage tarps. This highly touted technique has proven to create several challenges at April Joy Farm. Primarily, this is due to winter climate conditions. Silage tarps must be left in place for multiple weeks to adequately terminate cover crops and/or weeds. Extensive late winter/spring rains actually cause significant compaction because of the force and constancy with which the rain hits the flat tarps.

This compacted soil then dries out quickly because in this climate there is negligible summer rain. This technique creates difficult conditions to transplant into, and impossible conditions to direct seed. In addition, such tarps encourage vole activity due to the sheltered, heated environment. Kestrels and other raptors have difficulty hunting this small game when so much area is covered. In 2017, these voles did not noticeably damage any market crops, however their extensive tunnel systems caused untenable yield reductions in multiple crops due to pockets of air which stunted roots and channeled irrigation water and nutrients away from the growing plants.

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.[31] 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. This too, would be an excellent opportunity to export significant amounts of phosphorous off the farm. 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.

Recommendations:

1. Reduce the frequency of rotovator use where possible and be mindful of the depth of tillage necessary to create adequate seeding/transplanting conditions.
2. Consider replacing the rotovator with an articulating spading (non-rotary) machine, chisel plow and/or power harrow.
3. Consider purchasing lower impact, bed-scaled tillage equipment such as walk-behind tractor which could eliminate the need for heavy tractor cultivation in the high tunnel and reduce compaction and emissions in the field when only a few beds require preparation at any given time. Additional implements such a hay rake and sickle bar mower could further assist with organic material management.
4. Pursue a grant for purchase of a small-scale grain harvester / plot combine.
5. Consider additional research into the feasibility of reduced/no till solutions for rainy winter climates. Gain experience / trial equipment with roller-crimpers and no-till transplanting equipment.

[31] Feed corn, in which all stalks are removed from the field, represents an opportunity to reduce phosphorous loads from the crop fields. Stalks could be fed to swine, and corn cracked for poultry and swine feed.

Carbon Footprint Analysis

Table 21 provides a baseline of the carbon footprint of the farm for 2014. An updated analysis will be completed in 2018 and will include the impact of all implemented recommendations from this report.

Table 21: Estimated Carbon Footprint of April Joy Farm, 2014

April Joy Farm

Summary of the Estimated Carbon footprint (kg CO_2 e ha^{-1} yr^{-1}) of the farm based on 2014 operation data	
Activities	
Weeding equipment	125.13
Tillage Equipment	100.92
Tractors	275.62
Mowing	46.95
Vehicles	175.96
Electricity	711.64
Gasoline	1686.67
Diesel	1710.04
Soil Amendments	504.60
Green House materials	808.18
Net Soil emissions	737.41
Infrastructure	259.69
Total Farm CF	**7142.80**

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Summary of Recommendations

Table 22: Summary of Key Next Steps

Crop Rotation	• Group crops by planting season, then group by crop family and nitrogen requirements, (<120 lbs N/acre, 120-200 lbs N/acre, or <200 lbs N/acre). • Divide the field blocks by physical characteristics to align the planting schedule with field drainage. • Introduce an entire year fallow period between all market crops every three to four years. Devote the fallow area to growing nitrogen fixing cover crops. • Arrange the rotation so the heaviest feeding crops follow the fallow year. See Tables 15 and 16.
Cover Crops	• Establish a cover crop rotation that aligns with the market crop plan. See Tables 17 and 18 for details. • In fall 2018, perform field analysis to quantify PAN contributions from crimson clover. • Sow winter cover crops no later than September 15th. Reduce/eliminate use of synthetic weed barrier so over seeding of fall cover crops is possible. • Terminate cover crops at proper growth stage and time market crop establishment to maximize nutrient contributions from nitrogen fixing legumes.
Organic Materials	• Complete construction of static aerated composting structure and gain experience in larger scale compost production. Test completed compost for nutrient values. The long-range goal is to provide 50% of nitrogen requirements from applications of compost, while limiting phosphorous additions. • Over two years, apply dolomite to the hay field at a rate of 4.5 tons/acre to adjust pH above 6.1 and supplement levels of calcium. • Consider reducing or eliminating off farm purchases of swine and poultry feed to help manage soil phosphorous levels. Field corn represents a viable feedstock.
Equipment	• Reduce frequency of use of rotovator where possible. • Consider replacing the rototiller with less damaging secondary tillage tool such as a spading machine, power harrow or chisel plow. (Estimated cost $10,000.) • Consider purchase of a walk-behind tractor with tillage and organic material management implements. (Estimated cost $8,000.) • Pursue grant funding for the purchase of a combine harvester to allow efficient production of small grains. • Research possible reduced/no till solutions for rainy winter climates. Gain experience / trial equipment with roller-crimpers and no-till transplanting equipment.

For additional recommendations, refer to the table in Appendix C titled: *Management Suggestions for Physical and Biological Constraints*.

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Appendix A: April Joy Farm Climate Change Plan Summary

NAME: **April Thatcher** **FARM NAME:** **April Joy Farm**

Management Unit	REVISED Management Objectives (from Step #1) REVISED	Challenges To Meeting Management Objective With Climate Change	Opportunities for Meeting Management Objective With Climate Change	Feasibility of Objectives Under Current Management	Other Considerations
Entire Farm	Adaptation & Mitigation: Maintain and improve soil health by focusing on closed loop nutrient cycling, increasing OM and reducing off farm inputs (contaminant risk). Develop Compost program. Reduce tillage, consider no-till. Better manage timing, quantity and location of nutrient inputs. Use more green manures and cover crops.	Extreme weather events can cause erosion and soil loss. Drought (5% less rain in summer) can cause wind loss and decrease in soil health.	Longer GDD (16 day increase) might allow for later planting of winter cover cropping or expanded cover cropping scenarios. Might also provide higher residues for on farm composting generation to improve OM. Also may allow for longer grazing season for livestock, which could improve soil health through low impact additional fertility inputs. Increased rainfall could lead to higher groundwater recharge?	On farm nutrient cycling program & composting: HIGH, need additional support. Reduced Tillage: Difficult, potentially feasible. Nutrient Management: feasible, uncertain how to document/measure. Increase green manures/cover crops: HIGH.	Apply for grants & CSP/EQIP to help evaluation and implement soil health improvements
	Adaptation: Develop and maintain seed stock with diverse genetic capabilities that is regionally adapted and resilient.	Extreme weather events and drought make seed production more risky, difficult. Drought potential may require expensive irrigation inputs.	Longer GDD may help seed production.	Difficult- we have no seed production expertise or mentors. However, OSA is based out of WA state and could be an excellent partner.	We grow so many crops what should we even start with? How many different seed types can we realistically save on our limited acreage? Contact OSA for guidance and recommendations which may support regional & national Organic seed saving efforts.
	Adaptation: Maintain or increase crop yields. Major focus will be soil health improvement, however, added on farm fertility generation will be important. Consider adding livestock to provide steady stream of manure and compost.	For Plants: Drought a significant detriment to crop yields. Extreme weather events very difficult to manage/plan for. Longer GDD may cause increased pest and disease issues. For Livestock: Pasture management will be critical support nutritional needs of ruminents (cows.) Drought potential could cause significant livestock stress. Additional on-farm water supply may be necessary.	Longer GDD may assist summer crops yields. Shifts to planting zone may allow for greater diversification which will reduce tillage/detrimental soil activities.	Moderately difficult due to infrastructure (fencing, water, structure) costs associated with adding livestock. Also challenging due to limited size of acreage and need for constant rotational grazing strategy.	EQIP/CSP may help with fencing costs and water for livestock.
	Adaptation & Mitigation: Increase the diversity of crop and livestock offerings to include: perennial fruits and nuts, medicinal herbs, bees, cows and perennial vegetables. Transition to a perennial based multi-level (stacked) crop and livestock system. Agro-forestry and alley-cropping.	Difficult to select perennial plants that will do well in future climate zone but may not be frost tolerant enough in existing climate zone. Difficult establishing young new plantings during extreme weather events, drought.	Longer growing season may provide for wider diversification of market ready crops. Ability to select heat stress/cold stress tolerant livestock breeds since we are starting with new herds.	High. Multi-staged approach allows for small finanical impacts.	
	Adaptation: Grow more crops in the shoulder seasons. Transition to early CSA start in April - Sept.	Extreme weather events could cause crop failure.	Longer growing season would be a positive impact on our ability to field plant crops. (Currently it is only feasible due to heavy rains to plant shoulder crops under poly houses.	HIGH.	Consider perennial crops and non-tillage crops like shitake mushrooms and willow cuttings for basketry which make use of non-crop land.

Management Unit	REVISED Management Objectives (from Step #1) REVISED	Challenges To Meeting Management Objective With Climate Change	Opportunities for Meeting Management Objective With Climate Change	Feasibility of Objectives Under Current Management	Other Considerations
	Adaptation: Add a processing facility at the farm (licensed commercial kitchen) to increase value added and self reliance.	n/a	n/a	Possible, but financial cost is the limiting factor. (New septic system needed plus build out costs expensive and not easily spread over a long period of time.)	Although expensive, this represents a tremendous opportunity for minimizing risk associated with crop loss. The ability to quickly process crops that have been damaged by pest/insect/weather and still have a marketable product is a great advantage in terms of finanical stability and self-reliance.
	Mitigation: Eliminate the farm's GHG emissions entirely (have a "negative carbon footprint"). Reduce off farm inputs and work towards energy independence. (Phase II: Double the size of our current solar array to produce 90-100% of our electricity needs and/or reduce energy consumption. Phase III - Provide on farm storage of electricity (non grid tied). Reduce tillage, consider draft oxen power for some field operations, increase agroforestry/tree planting. Focus on nitrogen management.	n/a	n/a	Totally feasible - but need accurate estimate of current GHG emissions, which includes accounting of forest land.	
	Adaptation: Pay off outstanding debt (mortgage).	Erratic weather patterns may cause increased risk of crop failures, loss, and infrastructure damage.	Increased resiliency of our farm may support good yields (along with 16+GDD) may provide market advantage to increase revenue.	At current payment schedule: HIGH. Increased (quicker) payment schedule: Difficult but acheivable. Consider FSA refinance loan.	Risk management and diversification of markets and enterprises especially important.

Appendix B: 2017 A&L Soil Tests

Crop Field Soil Sample 0-6 Inch Depth

A & L WESTERN AGRICULTURAL LABORATORIES

10220 SW NIMBUS AVE Bldg K-9 | PORTLAND OREGON 97223 | (503) 968-9225 | FAX (503) 598-7702

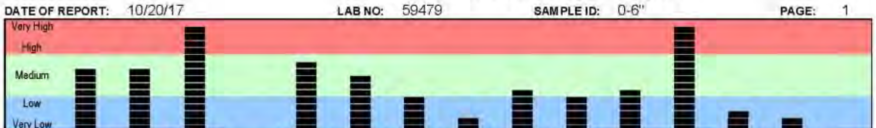
REPORT NUMBER: 17-286-083 CLIENT NO: 99999

SEND TO: APRIL THATCHER SUBMITTED BY:

GROWER:

Graphical Soil Analysis Report

DATE OF REPORT: 10/20/17 LAB NO: 59479 SAMPLE ID: 0-6" PAGE: 1



Percent Cation Saturation (computed)

Analyte	Organic Matter %	Nitrogen NO_3-N ppm	Phosphorus Weak Bray ppm	Phosphorus $NaHCO_3$-P ppm	Potassium K ppm	Magnesium Mg ppm	Calcium Ca ppm	Sodium Na ppm	Sulfur SO_4-S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Chloride Cl ppm
Results	3.6	22	131	62	224	237	1349	27	14	1.0	4	60	0.5	0.2	

Potassium K %	Magnesium Mg %	Calcium Ca %	Sodium Na %
5.3	17.9	61.8	1.1

ECe dS/m: 0.6 (LOW / AVERAGE / HIGH — INCREASING SALINITY →)

CEC meq/100g: 10.9

Ex. Lime: L

pH: 6.1 (ACIDIC / BASIC — ← INCREASING NEED FOR LIME)

Buffer pH: 6.7

NaHCO3-P unreliable at this soil pH

Soil Fertility Guidelines

CROP: MIXED VEG RATE: lb/1000 sq ft NOTES:

Dolomite 100 score	Lime 100 score	Gypsum	Elemental Sulfur	Nitrogen N	Phosphate P_2O_5	Potash K_2O	Magnesium Mg	Sulfur SO_4-S	Zinc Zn	Manganese Mn	Iron Fe	Copper Cu	Boron B	
	50			2.4				0.5	*				*	

COMMENTS

PRIOR TO PLANTING: Spread the above requirements per 1000 sq ft and mix into the top 6 inches of soil. Initially, limit nitrogen to 25-30 ppm NO3-N or 1.5 lb N/1000 sq ft, to avoid salt damage.
SPLIT any extra nitrogen evenly over the active growing season. Adjust rate according to local conditions and requirements. Allow for adequate establishment first (up to 30 days).
* ZINC: Where levels are low, apply according to label instructions. Consider fertilizer brands that also contain zinc, although they may not be sufficient to correct a severe deficiency.
MICRONUTRIENTS: Where levels appear to be high, avoid any further applications for the time being. Very high (VH) levels may not necessarily be toxic, but avoid. Maintain correct soil pH.

Rogell Rogers, CCA, PCA
A & L WESTERN LABORATORIES, INC

Crop Field Soil Sample 6-12 Inch Depth

A & L WESTERN AGRICULTURAL LABORATORIES

10220 SW NIMBUS AVE Bldg K-9 I PORTLAND OREGON 97223 I (503) 968-9225 I FAX (503) 598-7702

REPORT NUMBER: 17-286-084 CLIENT NO: 99999

SEND TO: APRIL THATCHER SUBMITTED BY:

GROWER:

Graphical Soil Analysis Report

DATE OF REPORT: 10/20/17 LAB NO: 59480 SAMPLE ID: 6-12" PAGE: 1

Percent Cation Saturation (computed)

Analyte	Organic Matter %	Nitrogen NO_3-N ppm	Phosphorus Weak Bray ppm	Phosphorus $NaHCO_3$-P ppm	Potassium K ppm	Magnesium Mg ppm	Calcium Ca ppm	Sodium Na ppm	Sulfur SO_4-S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Chloride Cl ppm
Results	2.8	11	96	50	144	177	1013	23	10	0.6	2	57	0.4	0.2	

Potassium K %	Magnesium Mg %	Calcium Ca %	Sodium Na %
4.3	16.9	58.7	1.2

ECe dS/m	Salinity (LOW / AVERAGE / HIGH)	CEC meq/100g	Ex. Lime	pH	Buffer pH
0.3	INCREASING SALINITY →	8.6	L	5.8	6.5

ACIDIC BASIC ← INCREASING NEED FOR LIME

NaHCO3-P unreliable at this soil pH

Soil Fertility Guidelines

CROP: RATE: NOTES:

Dolomite 100 score	Lime 100 score	Gypsum	Elemental Sulfur	Nitrogen N	Phosphate P_2O_5	Potash K_2O	Magnesium Mg	Sulfur SO_4-S	Zinc Zn	Manganese Mn	Iron Fe	Copper Cu	Boron B	

COMMENTS

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Crop Field Soil Sample 12-24 Inch Depth

A & L WESTERN AGRICULTURAL LABORATORIES

10220 SW NIMBUS AVE Bldg K-9 I PORTLAND OREGON 97223 I (503) 968-9225 I FAX (503) 598-7702

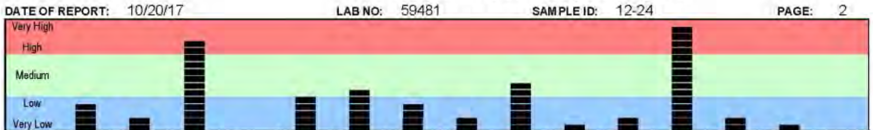
REPORT NUMBER: 17-286-084 **CLIENT NO:** 99999

SEND TO: APRIL THATCHER **SUBMITTED BY:**

GROWER:

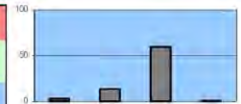
Graphical Soil Analysis Report

DATE OF REPORT: 10/20/17 **LAB NO:** 59481 **SAMPLE ID:** 12-24 **PAGE:** 2



Analyte	Organic Matter %	Nitrogen NO_3-N ppm	Phosphorus Weak Bray ppm	Phosphorus $NaHCO_3$-P ppm	Potassium K ppm	Magnesium Mg ppm	Calcium Ca ppm	Sodium Na ppm	Sulfur SO_4-S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Chloride Cl ppm
Results	1.8	5	54	49	96	158	1154	20	17	0.2	1	38	0.2	0.1	

Percent Cation Saturation (computed)



Potassium K %	Magnesium Mg %	Calcium Ca %	Sodium Na %
2.5	13.4	59.6	0.9

ECe dS/m: 0.2 — LOW / AVERAGE / HIGH — INCREASING SALINITY →

CEC meq/100g: 9.7

Ex. Lime: L

pH: 5.6 — ACIDIC / BASIC — ← INCREASING NEED FOR LIME

Buffer pH: 6.7

NaHCO3-P unreliable at this soil pH

Soil Fertility Guidelines

CROP: **RATE:** **NOTES:**

Dolomite 100 score	Lime 100 score	Gypsum	Elemental Sulfur	Nitrogen N	Phosphate P_2O_5	Potash K_2O	Magnesium Mg	Sulfur SO_4-S	Zinc Zn	Manganese Mn	Iron Fe	Copper Cu	Boron B	

COMMENTS

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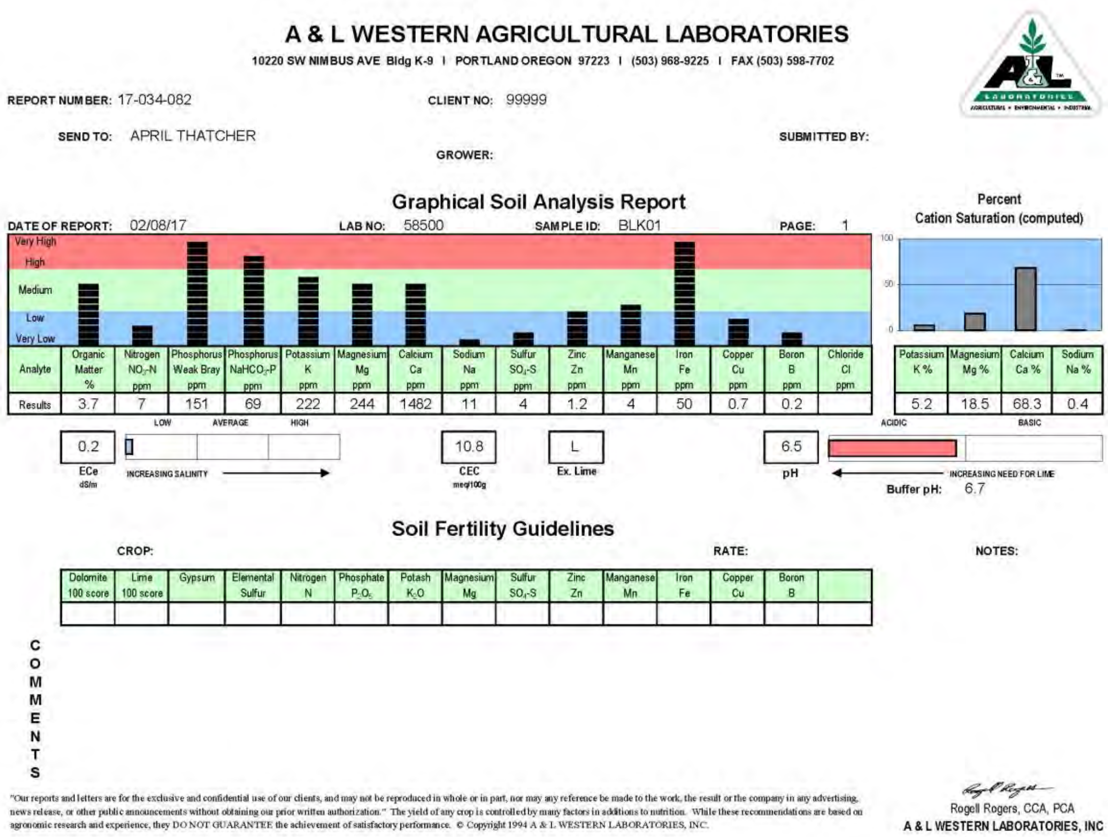
Appendix B1: February 2017 Soil Test Results by Block

These test results are included as a reference only. This is the traditional method of soil testing done by the farmers each year.

Block 01



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10220 SW NIMBUS AVE Bldg K-9 | PORTLAND OREGON 97223 | (503) 968-9225 | FAX (503) 598-7702

REPORT NUMBER: 17-034-082 CLIENT NO: 99999

SEND TO: APRIL THATCHER SUBMITTED BY:

GROWER:

Graphical Soil Analysis Report

DATE OF REPORT: 02/08/17 LAB NO: 58500 SAMPLE ID: BLK01 PAGE: 1

Analyte	Organic Matter %	Nitrogen NO_3-N ppm	Phosphorus Weak Bray ppm	Phosphorus $NaHCO_3$-P ppm	Potassium K ppm	Magnesium Mg ppm	Calcium Ca ppm	Sodium Na ppm	Sulfur SO_4-S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Chloride Cl ppm
Results	3.7	7	151	69	222	244	1482	11	4	1.2	4	50	0.7	0.2	

Percent Cation Saturation (computed)

Potassium K %	Magnesium Mg %	Calcium Ca %	Sodium Na %
5.2	18.5	68.3	0.4

ECe dS/m: 0.2 (LOW / AVERAGE / HIGH — INCREASING SALINITY)

CEC meq/100g: 10.8

Ex. Lime: L

pH: 6.5 (ACIDIC / BASIC — INCREASING NEED FOR LIME)

Buffer pH: 6.7

Soil Fertility Guidelines

CROP: RATE: NOTES:

Dolomite 100 score	Lime 100 score	Gypsum	Elemental Sulfur	Nitrogen N	Phosphate P_2O_5	Potash K_2O	Magnesium Mg	Sulfur SO_4-S	Zinc Zn	Manganese Mn	Iron Fe	Copper Cu	Boron B	

COMMENTS

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Block 02

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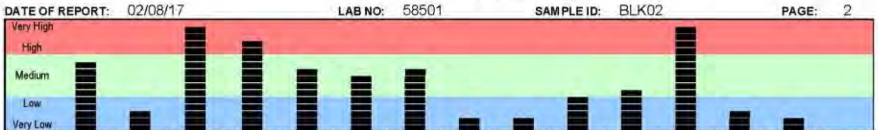
REPORT NUMBER: 17-034-082 CLIENT NO: 99999

SEND TO: APRIL THATCHER SUBMITTED BY:

GROWER:

Graphical Soil Analysis Report

DATE OF REPORT: 02/08/17 LAB NO: 58501 SAMPLE ID: BLK02 PAGE: 2



Analyte	Organic Matter %	Nitrogen NO_3-N ppm	Phosphorus Weak Bray ppm	Phosphorus $NaHCO_3$-P ppm	Potassium K ppm	Magnesium Mg ppm	Calcium Ca ppm	Sodium Na ppm	Sulfur SO_4-S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Chloride Cl ppm
Results	3.8	7	175	88	177	195	1381	11	4	1.2	5	67	0.6	0.2	

Percent Cation Saturation (computed)

Potassium K %	Magnesium Mg %	Calcium Ca %	Sodium Na %
4.6	16.2	69.7	0.5

ECe dS/m: 0.2 — LOW / AVERAGE / HIGH — INCREASING SALINITY →

CEC meq/100g: 9.9

Ex. Lime: L

pH: 6.4 — ACIDIC / BASIC — ← INCREASING NEED FOR LIME

Buffer pH: 6.8

Soil Fertility Guidelines

CROP: RATE: NOTES:

Dolomite 100 score	Lime 100 score	Gypsum	Elemental Sulfur	Nitrogen N	Phosphate P_2O_5	Potash K_2O	Magnesium Mg	Sulfur SO_4-S	Zinc Zn	Manganese Mn	Iron Fe	Copper Cu	Boron B	

COMMENTS

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Block 04

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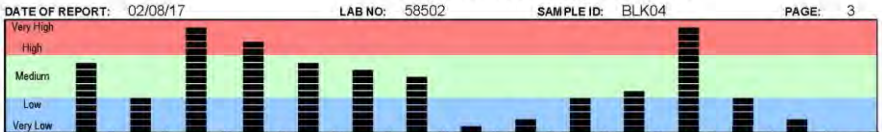
REPORT NUMBER: 17-034-082 CLIENT NO: 99999

SEND TO: APRIL THATCHER SUBMITTED BY:

GROWER:

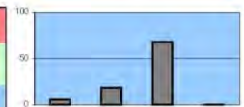
Graphical Soil Analysis Report

DATE OF REPORT: 02/08/17 LAB NO: 58502 SAMPLE ID: BLK04 PAGE: 3



Analyte	Organic Matter %	Nitrogen NO_3-N ppm	Phosphorus Weak Bray ppm	Phosphorus $NaHCO_3$-P ppm	Potassium K ppm	Magnesium Mg ppm	Calcium Ca ppm	Sodium Na ppm	Sulfur SO_4-S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Chloride Cl ppm
Results	4.1	12	154	77	224	218	1321	10	3	1.2	5	68	0.8	0.3	

Percent Cation Saturation (computed)



Potassium K %	Magnesium Mg %	Calcium Ca %	Sodium Na %
5.9	18.4	67.8	0.4

ECe dS/m	CEC meq/100g	Ex. Lime	pH	Buffer pH
0.1	9.7	L	6.5	6.8

LOW AVERAGE HIGH — INCREASING SALINITY →

ACIDIC BASIC — ← INCREASING NEED FOR LIME

Soil Fertility Guidelines

CROP: RATE: NOTES:

Dolomite 100 score	Lime 100 score	Gypsum	Elemental Sulfur	Nitrogen N	Phosphate P_2O_5	Potash K_2O	Magnesium Mg	Sulfur SO_4-S	Zinc Zn	Manganese Mn	Iron Fe	Copper Cu	Boron B	

COMMENTS

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Block 05

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REPORT NUMBER: 17-034-082 **CLIENT NO:** 99999

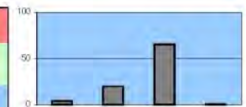
SEND TO: APRIL THATCHER **SUBMITTED BY:**

GROWER:

Graphical Soil Analysis Report

DATE OF REPORT: 02/08/17 **LAB NO:** 58503 **SAMPLE ID:** BLK05 **PAGE:** 4

Percent Cation Saturation (computed)



Analyte	Organic Matter %	Nitrogen NO_3-N ppm	Phosphorus Weak Bray ppm	Phosphorus $NaHCO_3$-P ppm	Potassium K ppm	Magnesium Mg ppm	Calcium Ca ppm	Sodium Na ppm	Sulfur SO_4-S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Chloride Cl ppm
Results	3.2	10	141	71	132	210	1145	15	4	0.8	3	49	0.5	0.2	

Potassium K %	Magnesium Mg %	Calcium Ca %	Sodium Na %
3.9	19.7	65.2	0.7

ECe dS/m	CEC meq/100g	Ex. Lime	pH	Buffer pH
0.2	8.8	L	6.3	6.7

LOW AVERAGE HIGH — INCREASING SALINITY →

ACIDIC BASIC — ← INCREASING NEED FOR LIME

Soil Fertility Guidelines

CROP: **RATE:** **NOTES:**

Dolomite 100 score	Lime 100 score	Gypsum	Elemental Sulfur	Nitrogen N	Phosphate P_2O_5	Potash K_2O	Magnesium Mg	Sulfur SO_4-S	Zinc Zn	Manganese Mn	Iron Fe	Copper Cu	Boron B	

COMMENTS

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Block 11/12

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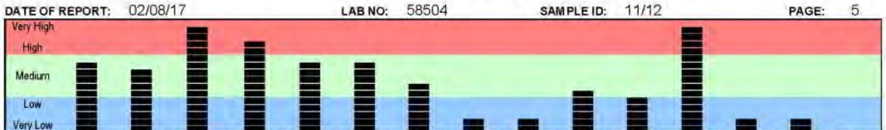
REPORT NUMBER: 17-034-082 **CLIENT NO:** 99999

SEND TO: APRIL THATCHER **SUBMITTED BY:**

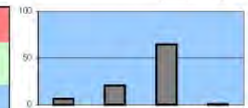
GROWER:

Graphical Soil Analysis Report

DATE OF REPORT: 02/08/17 **LAB NO:** 58504 **SAMPLE ID:** 11/12 **PAGE:** 5



Percent Cation Saturation (computed)



Analyte	Organic Matter %	Nitrogen NO_3-N ppm	Phosphorus Weak Bray ppm	Phosphorus $NaHCO_3$-P ppm	Potassium K ppm	Magnesium Mg ppm	Calcium Ca ppm	Sodium Na ppm	Sulfur SO_4-S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Chloride Cl ppm
Results	3.9	25	157	78	251	258	1323	13	3	1.4	3	53	0.4	0.2	

Potassium K %	Magnesium Mg %	Calcium Ca %	Sodium Na %
6.3	20.8	64.8	0.6

ECe dS/m: 0.2 — LOW AVERAGE HIGH — INCREASING SALINITY →

CEC meq/100g: 10.2

Ex. Lime: L

pH: 6.5 — ACIDIC BASIC — ← INCREASING NEED FOR LIME

Buffer pH: 6.8

Soil Fertility Guidelines

CROP: **RATE:** **NOTES:**

Dolomite 100 score	Lime 100 score	Gypsum	Elemental Sulfur	Nitrogen N	Phosphate P_2O_5	Potash K_2O	Magnesium Mg	Sulfur SO_4-S	Zinc Zn	Manganese Mn	Iron Fe	Copper Cu	Boron B	

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Block 13/14

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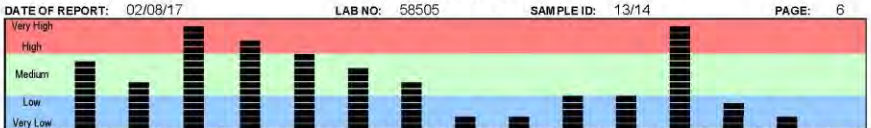
REPORT NUMBER: 17-034-082 **CLIENT NO:** 99999

SEND TO: APRIL THATCHER **SUBMITTED BY:**

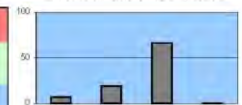
GROWER:

Graphical Soil Analysis Report

DATE OF REPORT: 02/08/17 **LAB NO:** 58505 **SAMPLE ID:** 13/14 **PAGE:** 6



Percent Cation Saturation (computed)



Analyte	Organic Matter %	Nitrogen NO_3-N ppm	Phosphorus Weak Bray ppm	Phosphorus $NaHCO_3$-P ppm	Potassium K ppm	Magnesium Mg ppm	Calcium Ca ppm	Sodium Na ppm	Sulfur SO_4-S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Chloride Cl ppm
Results	4.1	17	152	71	282	244	1378	11	4	1.3	4	50	0.7	0.3	

Potassium K %	Magnesium Mg %	Calcium Ca %	Sodium Na %
6.9	19.2	65.9	0.5

ECe dS/m: 0.3 — LOW / AVERAGE / HIGH — INCREASING SALINITY →

CEC meq/100g: 10.4

Ex. Lime: L

pH: 6.5 — ACIDIC / BASIC — ← INCREASING NEED FOR LIME

Buffer pH: 6.8

Soil Fertility Guidelines

CROP: **RATE:** **NOTES:**

Dolomite 100 score	Lime 100 score	Gypsum	Elemental Sulfur	Nitrogen N	Phosphate P_2O_5	Potash K_2O	Magnesium Mg	Sulfur SO_4-S	Zinc Zn	Manganese Mn	Iron Fe	Copper Cu	Boron B	

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High Tunnel (30' x 96')

For Comparison Only. This growing area was not evaluated or included in the SNB.

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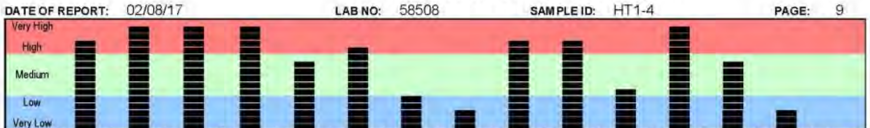
REPORT NUMBER: 17-034-082 CLIENT NO: 99999

SEND TO: APRIL THATCHER SUBMITTED BY:

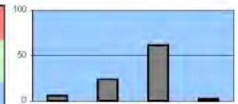
GROWER:

Graphical Soil Analysis Report

DATE OF REPORT: 02/08/17 LAB NO: 58508 SAMPLE ID: HT1-4 PAGE: 9



Percent Cation Saturation (computed)



Analyte	Organic Matter %	Nitrogen NO_3-N ppm	Phosphorus Weak Bray ppm	Phosphorus $NaHCO_3$-P ppm	Potassium K ppm	Magnesium Mg ppm	Calcium Ca ppm	Sodium Na ppm	Sulfur SO_4-S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Chloride Cl ppm
Results	5.8	80	204	138	311	409	1759	68	56	7.8	5	69	1.6	0.4	

Potassium K %	Magnesium Mg %	Calcium Ca %	Sodium Na %
5.6	23.5	61.4	2.1

LOW AVERAGE HIGH

1.4 ECe dS/m — INCREASING SALINITY →

14.3 CEC meq/100g

L Ex. Lime

6.5 pH — ACIDIC BASIC ← INCREASING NEED FOR LIME

Buffer pH: 7.0

Soil Fertility Guidelines

CROP: RATE: NOTES:

Dolomite 100 score	Lime 100 score	Gypsum	Elemental Sulfur	Nitrogen N	Phosphate P_2O_5	Potash K_2O	Magnesium Mg	Sulfur SO_4-S	Zinc Zn	Manganese Mn	Iron Fe	Copper Cu	Boron B	

COMMENTS

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Appendix C: 2017 Cornell Soil Health Assessment

Comprehensive Assessment of Soil Health

From the Cornell Soil Health Laboratory, Department of Soil and Crop Sciences, School of Integrative Plant Science, Cornell University, Ithaca, NY 14853. http://soilhealth.cals.cornell.edu

Grower:
April Thatcher
PO Box 973
Ridgefield, WA 98642
april@apriljoyfarm.com

Sample ID: RR599
Field ID: Block1-5, 11-15
Date Sampled: 10/11/2017
Given Soil Type: HoA (hillsboro silt loam)
Crops Grown: MIX/MIX/MIX
Tillage: more than 9 inches
Coordinates: Latitude: 45.763046000000
Longitude: -122.718701000000

Measured Soil Textural Class: **silt loam**

Sand: **18%** - Silt: **69%** - Clay: **11%**

Group	Indicator	Value	Rating	Constraints
physical	Available Water Capacity	0.29	97	
physical	Surface Hardness	131	64	
physical	Subsurface Hardness	200	81	
physical	Aggregate Stability	43.9	76	
biological	Organic Matter	3.7	78	
biological	ACE Soil Protein Index	7.1	57	
biological	Soil Respiration	0.5	37	
biological	Active Carbon	495	49	
chemical	Soil pH	6.3	100	
chemical	Extractable Phosphorus	14.2	100	
chemical	Extractable Potassium	202.2	100	
chemical	Minor Elements Mg: 262.3 / Fe: 6.4 / Mn: 11.0 / Zn: 0.7		100	

Overall Quality Score: **78** / Excellent

Measured Soil Health Indicators

The Cornell Soil Health Test measures several indicators of soil physical, biological and chemical health. These are listed on the left side of the report summary, on the first page. The "value" column shows each result as a value, measured in the laboratory or in the field, in units of measure as described in the indicator summaries below. The "rating" column interprets that measured value on a scale of 0 to 100, where higher scores are better. Ratings in red are particularly important to take note of, but any in yellow, particularly those that are close to a rating of 30 are also important in addressing soil health problems.

- **A rating below 20 indicates a *Constraint* and is color-coded red.** This indicates a problem that is likely limiting yields, crop quality, and long-term sustainability of the agroecosystem. In several cases this indicates risks of environmental loss as well. The "constraint" column provides a short list of soil processes that are not functioning optimally when an indicator rating is red. It is particularly important to take advantage of any opportunities to improve management that will address these constraints.
- **A rating between 20 and 40 indicates *Low-level* functioning and is color-coded orange.** This indicates that a soil process is functioning somewhat poorly and addressing this should be considered in the field management plan. The Management Suggestions Table at the end of the Soil Health Assessment Report provides linkages to field management practices that are useful in addressing each soil indicator process.
- **A rating between 40 and 60 indicates *Suboptimal* functioning and is color-coded yellow.** This indicates that soil health could be better, and yield and sustainability could decrease over time if this is not addressed. This is especially so if the condition is being caused, or not being alleviated, by current management. Pay attention particularly to those indicators rated in yellow and close to 40.
- **A rating between 60 and 80 indicates *Excellent* functioning and is color-coded light green.** This indicates that this soil process is functioning at a non-limiting level. Field soil management approaches should be maintained at the current intensity or improved.
- **A rating of 80 or greater indicates *Optimal or near-optimal* functioning and is color-coded dark green.** Past management has been effective at maintaining soil health. It can be useful to note which particular aspects of management have likely maintained soil health, so that such management can be continued. Note that soil health is often high, when first converting from a permanent sod or forest. In these situations, intensive management quickly damages soil health when it includes intensive tillage, low organic matter inputs, bare soils for significant parts of the year, or excessive traffic, especially during wet times.
- **The Overall Quality Score** at the bottom of the report is an average of all ratings, and provides an indication of the soil's overall health status. However, the important part is to know which particular soil processes are constrained or suboptimal so that these issues can be addressed through appropriate management. Therefore the ratings for each indicator are more important information.

The Indicators measured in the Cornell Soil Health Assessment are important soil properties and characteristics in themselves, but also are representative of key soil processes, necessary for the proper functioning of the soil. The following is a summary of the indicators measured, what each of these indicates about your soil's health status, and what may influence the relevant properties and processes described.

A Management Suggestions Table follows, at the end of the report, with short and long term suggestions for addressing constraints or maintaining a well-functioning system. This table will indicate constraints identified in this assessment for your soil sample by the same yellow and red color coding described above. Please also find further useful information by following the links to relevant publications and web resources that follow this section.

Texture is an inherent property of soil, meaning that it is rarely changed by management. It is thus not a soil health indicator per se, but is helpful both in interpreting the measured values of indicators (see the Cornell Soil Health Assessment Training Manual), and for deciding on appropriate management strategies that will work for that soil.

Your soil's measured textural class and composition: silt loam

Sand: 18% Silt: 69% Clay: 11%

Available Water Capacity is a measure of the porosity of the soil, within a pore size range important for water retention. Measured by the amount of water held by the soil sample between field capacity and wilting point by applying different levels of air pressure, the value is presented in grams of water per gram of soil. This value is scored against an observed distribution in regional soils with similar texture. A physical soil characteristic, AWC is an indicator of the amount of plant-available water the soil can store, and therefore how crops will fare in droughty conditions. Soils with lower storage capacity will cause greater risk of drought stress. AWC is generally lower when total organic matter and/or aggregation is low. It can be improved by reducing tillage, long-term cover cropping, and adding large amounts of well-decomposed organic matter such as compost. Coarse textured (sandy) soils inherently store less water than finer textured soils, so that managing for relatively high water storage capacity is particularly important in coarse textured soils. While the textural effect cannot be influenced by management, management decisions can be in part based on an understanding of inherent soil characteristics.

Your measured Available Water Capacity value is **0.29 g/g**, corresponding with a score of **97**. This score is in the **Optimal** range, relative to regional soils with similar texture. **This suggests that management practices should be geared toward maintaining this condition, as it currently indicates ideal soil functioning.** Please refer to the management suggestions table at the end of this document.

Surface Hardness is a measure of compaction that develops when large pores are lost in the surface soil (0-6 inches). Compaction is measured in the field using a penetrometer, and the resultant value is expressed in pounds per square inch (p.s.i.), representing the localized pressure necessary to break forward through soil. It is scored by comparison with a distribution observed in regional soils, with lower hardness values rating higher scores. A strongly physical characteristic of soils, surface hardness is an indicator of both physical and biological health of the soil, as growing roots and fungal hyphae must be able to grow through soil, and may be severely restricted by excessively hard soil. Compaction also influences water movement through soil. When surface soils are compacted, runoff, erosion, and slow infiltration can result. Soil compaction is influenced by management, particularly in timing and degree of traffic and plowing disturbance, being worst when the soil is worked wet.

Your measured Surface Hardness value is **131 p.s.i.**, corresponding with a score of **64**. This score is in the **Excellent** range, relative to regional soils with similar texture. **This suggests that this soil process is enhancing overall soil resilience. Soil management should aim at maintaining this functionality while addressing any other measured soil constraints as identified in the Soil Health Assessment**

Report. Please refer to the management suggestions table at the end of this document.

Subsurface Hardness is a measure of compaction that develops when large pores are lost in the subsurface soil (6-18 inches). Subsurface hardness is measured and scored similarly to surface hardness, but deeper in the profile, and scored against an observed distribution in regional soils with similar texture. Large pores are necessary for water and air movement and to allow roots to explorethe soil. Subsurface hardness prevents deep rooting and thus deep water and nutrient uptake by plants, and can increase disease pressure by stressing plants. It also causes poor drainage and poor deep water storage. After heavy rain events, water can build up over a hard pan causing poor aeration both at depth and at the surface, as well as ponding, poor infiltration, runoff and erosion. Impaired water movement and storage create greater risk during heavy rainfall events, as well as greater risk of drought stress. Compaction occurs very rapidly when the soil is worked or trafficked while it is too wet, and compaction can be transferred deep into the soil even from surface pressure. Subsoil compaction in the form of a plow pan is usually found beneath the plow layer, and is caused by smearing and pressure exerted on the undisturbed soil just beneath the deepest tillage operation, especially when wet.

Your measured Subsurface Hardness value is **200 p.s.i.**, corresponding with a score of **81**. This score is in the **Optimal** range, relative to regional soils with similar texture. **This suggests that management practices should be geared toward maintaining this condition, as it currently indicates ideal soil functioning.** Please refer to the management suggestions table at the end of this document.

Aggregate Stability is a measure of how well soil aggregates or crumbs hold together under rainfall or other rapid wetting stresses. Measured by the fraction of dried aggregates that disintegrate under a controlled, simulated rainfall event similar in energy delivery to a hard spring rain, the value is presented as a percent, and scored against a distribution observed in regional soils with similar textural characteristics. A physical characteristic of soil, Aggregate Stability is a good indicator of soil biological and physical health. Good aggregate stability helps prevent crusting, runoff, and erosion, and facilitates aeration, infiltration, and water storage, along with improving seed germination and root and microbial health. Aggregate stability is influenced by microbial activity, as aggregates are largely held together by microbial colonies and exudates, and is impacted by management practices, particularly tillage, cover cropping, and fresh organic matter additions.

Your measured Aggregate Stability value is **43.9 %**, corresponding with a score of **76**. This score is in the **Excellent** range, relative to regional soils with similar texture. **This suggests that this soil process is enhancing overall soil resilience. Soil management should aim at maintaining this functionality while addressing any other measured soil constraints as identified in the Soil Health Assessment Report.** Please refer to the management suggestions table at the end of this document.

Organic Matter (OM) is a measure of the carbonaceous material in the soil that is biomass or biomass-derived. Measured by the mass lost on combustion of oven-dried soil, the value is presented as a percent of the total soil mass. This is scored against an observed distribution of OM in regional soils with similar texture. A soil characteristic that measures a physical substance of biological origin, OM is a key or central indicator of the physical, biological, and chemical health of the soil. OM content is an important influence on soil aggregate stabilization, water retention, nutrient cycling, and ion exchange capacity. OM acts as a long-term slow-release pool for nutrients. Soils with low organic matter tend to require higher inputs, and be less resilient to drought and extreme rainfall. OM is directly derived from biomass of microbial communities in the soil (bacterial, fungal, and protozoan), as well as from plant roots and detritus, and biomass-containing amendments like manure, green manures, mulches, composts, and crop residues. The retention and accumulation of OM is influenced by management practices such as tillage and cover cropping, as well as by microbial community growth. Intensive tillage and lack of organic matter additions from various sources (amendments, residues, active crop or cover crop growth) will decrease organic matter content and overall soil health with time.

> **Your measured Organic Matter value** is **3.7 %**, corresponding with a score of **78**. This score is in the **Excellent** range, relative to regional soils with similar texture. **This suggests that this soil process is enhancing overall soil resilience. Soil management should aim at maintaining this functionality while addressing any other measured soil constraints as identified in the Soil Health Assessment Report.** Please refer to the management suggestions table at the end of this document.

Soil Proteins are the fraction of the soil organic matter that are present as proteins or protein-like substances. This represents the large pool of organically bound N in the SOM, which microbial activity can mineralize, and make available for plant uptake. Measured by extraction with a citrate buffer under high temperature and pressure (hence Autoclave Citrate Extractable, or ACE proteins), the value given is expressed in mg extracted per gram of soil. As the method used extracts only a readily extractable fraction of the total amount of soil proteins in the SOM, we present this value as an index rather than as an absolute quantity. A measure of a physical substance, protein content is an indicator of the biological and chemical health of the soil, and is very well associated with overall soil health status. Protein content, as organically bound N, influences the ability of the soil to make N available by mineralization, and has been associated with soil aggregation and water movement. Protein content can be influenced by biomass additions, the presence of roots and soil microbes, and tends to decrease with increasing soil disturbance such as tillage.

> **Your measured ACE Soil Protein Index value** is **7.1** , corresponding with a score of **57**. This score is in the **Medium** range, relative to regional soils with similar texture. **This suggests that, while ACE Soil Protein Index is functioning at an average level, management practices should be geared toward improving this condition, as it currently indicates suboptimal functioning. Soil management should aim at improving this functionality while addressing any other measured soil constraints as identified in the Soil Health Assessment Report.** Please refer to the management suggestions table at the end of this document.

Soil Respiration is a measure of the metabolic activity of the soil microbial community. Measuredby capturing and quantifying carbon dioxide (CO_2) produced by this activity, the value is expressed as total CO_2 released (in mg) per gram of soil over a 4 day incubation period. Respiration is scored against an observed distribution in regional soils, taking texture into account. A direct biological activity measurement, respiration is an indicator of the biological status of the soil community, integrating abundance and activity of microbial life. Soil biological activity accomplishes numerous important functions, such as cycling of nutrients into and out of soil OM pools, transformations of N between its several forms, and decomposition of incorporated residues. Soil biological activity influences key physical characteristics like OM accumulation, and aggregate formation and stabilization. Microbial activity is influenced by management practices such as tillage, cover cropping, manure or green manure incorporation, and biocide (pesticide, fungicide, herbicide) use.

Your measured Soil Respiration value is **0.5 mg**, corresponding with a score of **37**. This score is in the **Low** range, relative to regional soils with similar texture. **This suggests that, while Soil Respiration does not currently register as a strong constraint, management practices should be geared toward improving this condition, as it currently indicates suboptimal functioning.** Please refer to the management suggestions table at the end of this document.

Active Carbon is a measure of the small portion of the organic matter that can serve as an easily available food source for soil microbes, thus helping maintain a healthy soil food web. Measured by potassium permanganate oxidation, the value is presented in parts per million (ppm), and scored against an observed distribution in regional soils with similar texture. While a measure of a class of physical substances, active carbon is a good leading indicator of biological soil health and tends to respond to changes in management earlier than total organic matter content, because when a large population of soil microbes is fed plentifully with enough organic matter over an extended period of time, well-decomposed organic matter builds up. A healthy and diverse microbial community is essential to maintain disease resistance, nutrient cycling, aggregation, and many other important functions. Intensive tillage and lack of organic matter additions from various sources (amendments, residues, active crop or cover crop growth) will decrease active carbon, and thus will over the longer term decrease total organic matter.

Your measured Active Carbon value is **495 ppm**, corresponding with a score of **49**. This score is in the **Medium** range, relative to regional soils with similar texture. **This suggests that, while Active Carbon is functioning at an average level, management practices should be geared toward improving this condition, as it currently indicates suboptimal functioning. Soil management should aim at improving this functionality while addressing any other measured soil constraints as identified in the Soil Health Assessment Report.** Please refer to the management suggestions table at the end of this document.

Soil pH is a measure of how acidic the soil is, which controls how available nutrients are to crops. A physico-chemical characteristic of soils, pH is an indicator of the chemical or nutrient status of the soil. Measured with an electrode in a 1:1 soil:water suspension, the value is presented in standard pH units, and scored using an optimality curve. Optimum pH is around 6.2-6.8 for most crops (exceptions include potatoes and blueberries, which grow best in more acidic soil – this is not accounted for in the report interpretation). If pH is too high, nutrients such as phosphorus, iron, manganese, copper and boron become unavailable to the crop. If pH is too low, calcium, magnesium, phosphorus, potassium and molybdenum become unavailable. Lack of nutrient availability will limit crop yields and quality. Aluminum toxicity can also be a concern in low pH soils, which can severely decrease root growth and yield, and in some cases lead to accumulation of aluminum and other metals in crop tissue. In general, as soil OM increases, crops can tolerate lower soil pH. Soil pH also influences the ability of certain pathogens to thrive, and of beneficial organisms to effectively colonize roots. Raising the pH through lime or wood ash applications, and organic matter additions, will help immobilize aluminum andheavy metals, and maintain proper nutrient availability.

Your measured Soil pH value is **6.3** , corresponding with a score of **100**. This score is in the **Optimal** range, relative to regional soils with similar texture. **This suggests that management practices should be geared toward maintaining this condition, as it currently indicates ideal soil functioning.** Please refer to the management suggestions table at the end of this document.

Extractable Phosphorus is a measure of phosphorus (P) availability to a crop. Measured on a modified Morgan's extractant, using a rapid-flow analyzer, the value is presented in parts per million (ppm), and scored against an optimality curve for sufficiency or excess. P is an essential plant macronutrient, and its availability varies with soil pH and mineral composition. Low P values indicate poor P availability to plants, and excessively high P values indicates a risk of adverse environmental impact through runoff and contamination of surface waters. Most soils in the Northeast store unavailable P from the soil's mineral make up or from previously applied fertilizer or manure. This becomes more available to plants as soils warm up. Therefore, incorporating or banding 10-25 lbs/acre of soluble 'starter' P fertilizer at planting can be useful even when soil levels are optimum. Some cover crops, such as buckwheat, are good at mining otherwise unavailable P so that it becomes more available to the following crop. When plants associate with mycorrhizal fungi, these can also help make P (and other nutrients and water) more available to the crop. P is an environmental contaminant and runoff of P into fresh surface water will cause damage through eutrophication, so over-application is strongly discouraged, especially close to surface water, on slopes, and on large scales.

Your measured Extractable Phosphorus value is **14.2 ppm**, corresponding with a score of **100**. This score is in the **Optimal** range, relative to regional soils with similar texture. **This suggests that management practices should be geared toward maintaining this condition, as it currently indicates ideal soil functioning.** Please refer to the management suggestions table at the end of this document.

Extractable Potassium is a measure of potassium (K) availability to the crop. Measured on a modified Morgan's extract using an ICP Spectrometer, the value is presented in parts per million (ppm), and scored against an optimality curve for sufficiency. K is an indicator of soil nutrient status, as it is an essential plant macronutrient. Plants with higher potassium tend to be more tolerant of frost and cold. Thus good potassium levels may help with season extension. While soil pH only marginally affects K availability, K is easily leached from sandy soils and is only weakly held by increased organic matter, so that applications of the amount removed by the specific crop being grown are generally necessary in such soils.

Your measured Extractable Potassium value is **202.2 ppm**, corresponding with a score of **100**. This score is in the **Optimal** range, relative to regional soils with similar texture. **This suggests that management practices should be geared toward maintaining this condition, as it currently indicates ideal soil functioning.** Please refer to the management suggestions table at the end of this document.

Minor Elements, also called secondary (calcium, magnesium and sulfur) and micro (iron, manganese, zinc, copper, boron, molybdenum, etc.) nutrients are essential plant nutrients taken up by plants in smaller quantities than the macro nutrients N, P and K. If any minor elements are deficient, this will decrease yield and crop quality, but toxicities can also occur when concentrationsare too high. This assessment's minor elements rating indicates whether four measured micronutrients (magnesium, iron, manganese, and zinc) are deficient or excessive. Micronutrient availability is strongly influenced by pH and organic matter. Low pH increases the availability of most micronutrients, whereas high pH increases the availability of molybdenum, magnesium and calcium. High OM and microbial activity tend to increase micronutrient availability. Note that this test does not measure all important micronutrients. Consider submitting a sample for a complete micronutrient analysis to find out the levels of the other micronutrients.

Your measured Minor Elements Rating is **100**. This score is in the **Optimal** range. Magnesium (262.3 ppm) is sufficient, Iron (6.4 ppm) is sufficient, Manganese (11.0 ppm) is sufficient, Zinc (0.7 ppm) is sufficient. **This suggests that management practices should be geared toward maintaining this condition, as it currently indicates ideal soil functioning.** Please refer to the management suggestions table at the end of this document.

Overall Quality Score: an overall quality score is computed from the individual indicator scores. This score is further rated as follows: less than 20% is regarded as very low, 20-40% is low, 40-60% is medium, 60-80% is excellent, and greater than 80% is optimal. The highest possible quality score is 100 and the least score is 0, thus it is a relative overall soil health status indicator. However, of greater importance than a single overall metric is identification of constrained or suboptimally functioning soil processes, so that these issues can be addressed through appropriate management. The overall soil quality score should be taken as a general summary rather than the main focus.

Your Overall Quality Score is **78**, which is in the **Excellent** range.

Management Suggestions for Physical and Biological Constraints

Constraint	Short Term Management Suggestions	Long Term Management Suggestions
Available Water Capacity Low	• Add stable organic materials, mulch • Add compost or biochar • Incorporate high biomass cover crop	• Reduce tillage • Rotate with sod crops • Incorporate high biomass cover crop
Surface Hardness High	• Perform some mechanical soil loosening (strip till, aerators, broadfork, spader) • Use shallow-rooted cover crops • Use a living mulch or interseed cover crop	• Shallow-rooted cover/rotation crops • Avoid traffic on wet soils, monitor • Avoid excessive traffic/tillage/loads • Use controlled traffic patterns/lanes
Subsurface Hardness High	• Use targeted deep tillage (subsoiler, yeomans plow, chisel plow, spader.) • Plant deep rooted cover crops/radish	• Avoid plows/disks that create pans • Avoid heavy loads • Reduce traffic when subsoil is wet
Aggregate Stability Low	• Incorporate fresh organic materials • Use shallow-rooted cover/rotation crops • Add manure, green manure, mulch	• Reduce tillage • Use a surface mulch • Rotate with sod crops and mycorrhizal hosts
Organic Matter Low	• Add stable organic materials, mulch • Add compost and biochar • Incorporate high biomass cover crop	• Reduce tillage/mechanical cultivation • Rotate with sod crop • Incorporate high biomass cover crop
ACE Soil Protein Index Low	• Add N-rich organic matter (low C:N source like manure, high N well-finished compost) • Incorporate young, green, cover crop biomass • Plant legumes and grass-legume mixtures • Inoculate legume seed with Rhizobia & check for nodulation	• Reduce tillage • Rotate with forage legume sod crop • Cover crop and add fresh manure • Keep pH at 6.2-6.5 (helps N fixation) • Monitor C:N ratio of inputs
Soil Respiration Low	• Maintain plant cover throughout season • Add fresh organic materials • Add manure, green manure • Consider reducing biocide usage	• Reduce tillage/mechanical cultivation • Increase rotational diversity • Maintain plant cover throughout season • Cover crop with symbiotic host plants
Active Carbon Low	• Add fresh organic materials • Use shallow-rooted cover/rotation crops • Add manure, green manure, mulch	• Reduce tillage/mechanical cultivation • Rotate with sod crop • Cover crop whenever possible

Management Suggestions for Chemical Constraints

Constraint	Short Term Management Suggestions	Long Term Management Suggestions
Soil pH Low	• Add lime or wood ash per soil test recommendations • Add calcium sulfate (gypsum) in addition to lime if aluminum is high • Use less ammonium or urea	• Test soil annually & add "maintenance" lime per soil test recommendations to keep pH in range • Raise organic matter to improve buffering capacity
Soil pH High	• Stop adding lime or wood ash • Add elemental sulfur per soil test recommendations	• Test soil annually • Use higher % ammonium or urea
Extractable Phosphorus Low	• Add P amendments per soil test recommendations • Use cover crops to recycle fixed P • Adjust pH to 6.2-6.5 to free up fixed P	• Promote mycorrhizal populations • Maintain a pH of 6.2-6.5 • Use cover crops to recycle fixed P
Extractable Phosphorus High	• Stop adding manure and compost • Choose low or no-P fertilizer blend • Apply only 20 lbs/ac starter P if needed • Apply P at or below crop removal rates	• Use cover crops that accumulate P and export to low P fields or offsite • Consider low P rations for livestock • Consider phytase for non-ruminants
Extractable Potassium Low	• Add wood ash, fertilizer, manure, or compost per soil test recommendations • Use cover crops to recycle K • Choose a high K fertilizer blend	• Use cover crops to recycle K • Add "maintenance" K per soil recommendations each year to keep K consistently available
Minor Elements Low	• Add chelated micros per soil test recommendations • Use cover crops to recycle micronutrients • Do not exceed pH 6.5 for most crops	• Promote mycorrhizal populations • Improve organic matter • Decrease soil P (binds micros)
Minor Elements High	• Raise pH to 6.2-6.5 (for all high micros except Molybdenum) • Do not use fertilizers with micronutrients	• Maintain a pH of 6.2-6.5 • Monitor irrigation/improve drainage • Improve soil calcium levels

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College of Agriculture and Life Sciences, Cornell University

Developed in partnership with Cornell Soil Health, Farmier, and GreenStart. Hosted by Farmier

Soluble Salts Results October 2017 Cornell Soil Health Assessment

Soluble Salts Data

Sample ID	mmho/cm	texture
RR599	0.14	silt loam

Typical crop response to soil soluble salts Electrical Conductivity (EC)		
EC (mmho/cm)	**Crop Response**	**Degree of Salinity**
0-2	Almost negligible effects	Non-saline
2-4	Yield of the most sensitive crops reduced	Slightly saline
4-8	Yield of most crops reduced	Moderately saline
8-16	Only tolerant crops yield well	Strongly saline
> 16	Only very tolerant crops yield well	Very strongly saline

Interpretation of 1 : 1 (volume soil : volume extract) Soluble Salts test
(taken from Dahnke and Whitney, 1988)

	Degree of Salinity				
Soil texture	**Non-saline**	**Slightly Saline**	**Moderately Saline**	**Strongly Saline**	**Very Strongly Saline**
	-------------------- *EC (mmhos cm $^{-1}$)* ------------------------				
Coarse sand to loamy sand	**0-1.1**	**1.2-2.4**	**2.5-4.4**	**4.5-8.9**	**9.0+**
Loamy fine sand to loam	**0-1.2**	**1.3-2.4**	**2.5-4.7**	**4.8-9.4**	**9.5+**
Silt loam to clay loam	**0-1.3**	**1.4-2.5**	**2.6-5.0**	**5.1-10.1**	**10.1+**
Silty clay loam to clay	**0-1.4**	**1.5-2.8**	**2.9-5.7**	**5.8-11.4**	**11.5+**

Boron Soil Level Results October 2017 Cornell Soil Health Assessment

Cornell Nutrient Analysis Laboratory
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Ithaca, New York 14853-4203
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fax.607-255-7656
soiltest@cornell.edu
web. http://cnal.cals.cornell.edu

1860 Hot water-soluble BORON	
Client:	Robert Schindelbeck
	rrs3@cornell.edu

Sample Name	Hot water soluble Boron mg/Kg (ppm)
RR599	0.36

Soil B levels (PPM) for most Vegetable crops

	High	Medium	Low
Boron	> 0.75	0.35-0.75	< 0.35

Multiply by 2 for lbs/A

Table adapted from:

http://www.fruit.cornell.edu/berry/production/pdfs/UnderstandingAgro1results.pdf

0.36 mg/kg (ppm) = 0.72 lbs/acre

Appendix D: On Farm Soil Health Analysis

Nodule Observations Procedure

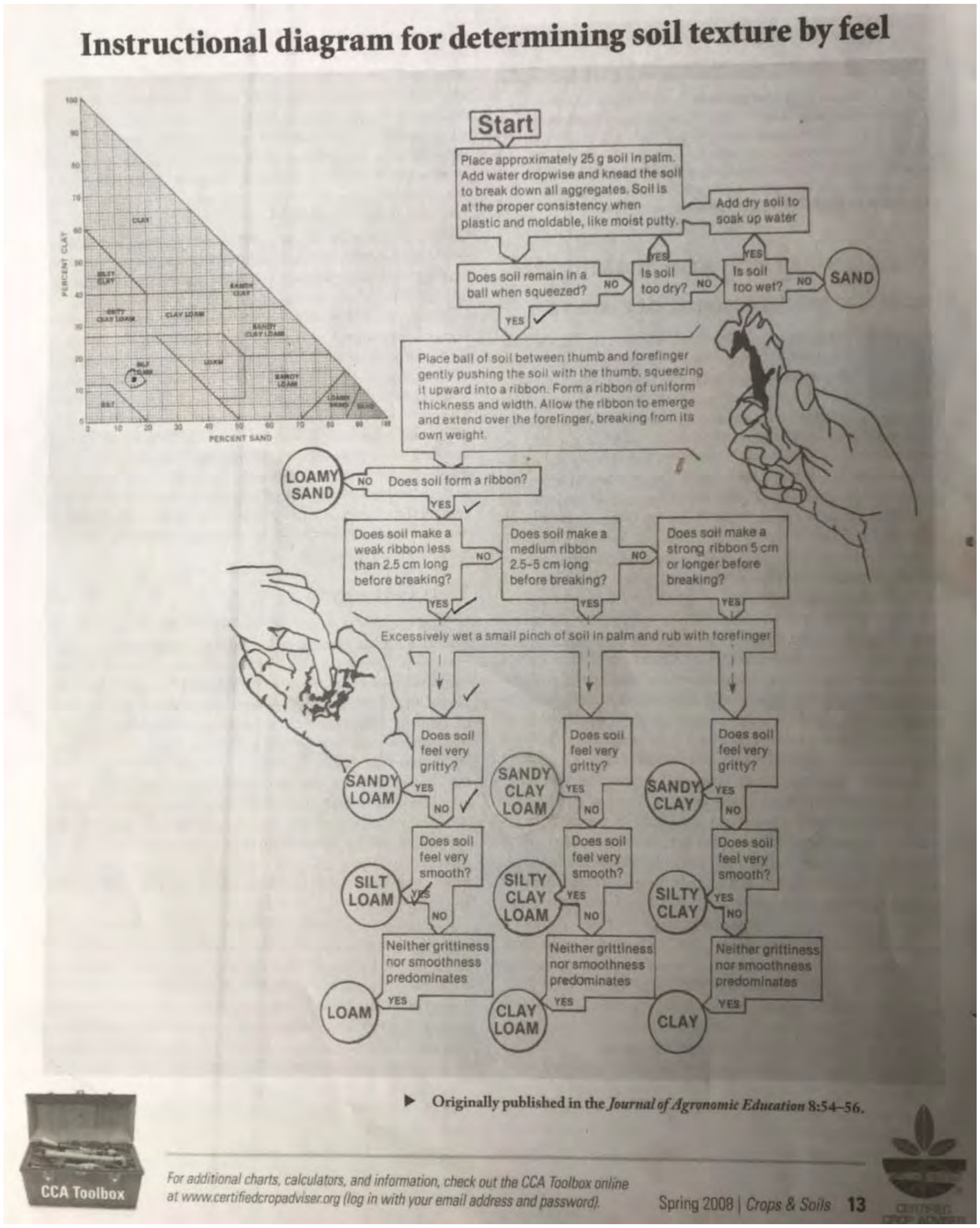
Observe 4 root systems from same species. Extract 2 Liters soil from 0-6" (0-15 cm) and 2 Liters from 6-12" (15-30 cm) under each legume.
Sort roots from soil. Count nodules in each sample; if over 20, estimate by 5's.
Select 10 firm, healthy nodules per sample (or all nodules if <10 available). Gently wash these. Slice with razor or very sharp knife.
Observe color: tan/pale, light pink, bright pink. Count number in each color group.
Ideal stage of growth: Any time from 1 month of growth to near senescence nodules should be visible. Ideal is at stage of rapid growth.

Date: 9/9/17
Performed BY: AJ, BT

Species: Crimson Clover
Location: Block 5

Sample #	Total Estimated Nodules	Nodule Color: Green/Tan/Pale	Green/Light Pink	Bright Pink	Dark Pink/Liver (Red/Brown)*	Totals:
1a. (0-6")	375	3	3	0	4	10
1b. (6-12")	7	2	0	0	2	Remaining nodules too small to slice.
2a. (0-6")	148	1	1	0	8	10
2b. (6-12")	76	2	0	0	8	10
3a. (0-6")	71	3	1	5	1	10
3b. (6-12")	33	2	3	2	3	10
4a. (0-6")	105	4	0	0	6	10
4b. (6-12")	8	2	0	0	2	Remaining nodules too small to slice.
Totals:		19	8	7	34	

Anaylsis: Any redness shows the leghemoglobin. It may be that the nodules are also in decline at this point in the season, at which point they will turn brown. So the really dark spots might be dying, but overall there is a lot of pink/red in this nodule.


Instructional diagram for determining soil texture by feel
Start
Place approximately 25 g soil in palm. Add water dropwise and knead the soil to break down all aggregates. Soil is at the proper consistency when plastic and moldable, like moist putty.
Add dry soil to soak up water
Does soil remain in a ball when squeezed?
NO
Is soil too dry?
YES
NO
Is soil too wet?
YES
NO
SAND
YES
Place ball of soil between thumb and forefinger gently pushing the soil with the thumb, squeezing it upward into a ribbon. Form a ribbon of uniform thickness and width. Allow the ribbon to emerge and extend over the forefinger, breaking from its own weight.
LOAMY SAND
NO
Does soil form a ribbon?
YES
Does soil make a weak ribbon less than 2.5 cm long before breaking?
NO
Does soil make a medium ribbon 2.5–5 cm long before breaking?
NO
Does soil make a strong ribbon 5 cm or longer before breaking?
YES
Excessively wet a small pinch of soil in palm and rub with forefinger
Does soil feel very gritty?
SANDY LOAM
SANDY CLAY LOAM
SANDY CLAY
NO
Does soil feel very smooth?
SILT LOAM
SILTY CLAY LOAM
SILTY CLAY
Neither grittiness nor smoothness predominates
LOAM
CLAY LOAM
CLAY
PERCENT CLAY
PERCENT SAND
Originally published in the Journal of Agronomic Education 8:54–56.
CCA Toolbox
For additional charts, calculators, and information, check out the CCA Toolbox online at www.certifiedcropadviser.org (log in with your email address and password).
Spring 2008 | Crops & Soils 13

10/24/17 Pentrometer Readings

	Depth							
Location #	3"	6"	9"	12"	15"	18"	21"	24"
Block 1	0	150	250	250	250	300	250	300
Block 2	0	0	100	100	200	250	250	180
Block 3	200	300	200	200	200	200	250	300
Block 4	0	100	100	200	200	100	100	250
Block 5	0	100	250	200	250	200	180	200
Block 11	0	200	180	200	250	250	250	250
Block 12	100	100	200	200	200	200	200	250
Block 13	0	100	200	180	200	100	100	100
Block 14	0	200	250	250	250	200	300	300+
Block 15	180	200	300	100	200	300	300+	300+

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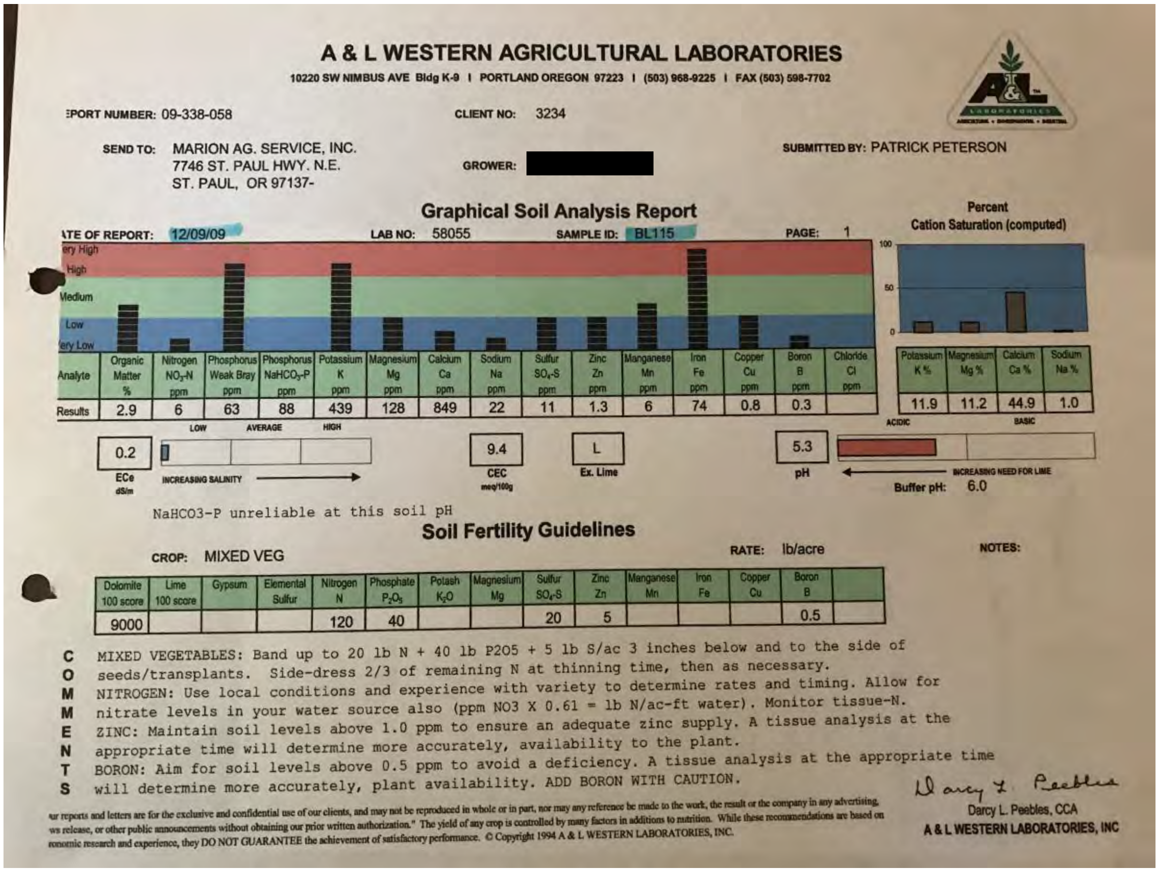
Appendix E: 2009 April Joy Farm Soil Test, Block 15

This is one of the first soil reports taken at April Joy Farm and is included for reference only. It is unclear why A&L recommended the addition of phosphorus given the high levels already in the soil.



A & L WESTERN AGRICULTURAL LABORATORIES

10220 SW NIMBUS AVE Bldg K-9 | PORTLAND OREGON 97223 | (503) 968-9225 | FAX (503) 598-7702

EPORT NUMBER: 09-338-058 CLIENT NO: 3234

SEND TO: MARION AG. SERVICE, INC.
7746 ST. PAUL HWY. N.E.
ST. PAUL, OR 97137-

GROWER: [redacted]

SUBMITTED BY: PATRICK PETERSON

Graphical Soil Analysis Report

ATE OF REPORT: 12/09/09 LAB NO: 58055 SAMPLE ID: BL115 PAGE: 1

Analyte	Organic Matter %	Nitrogen NO_3-N ppm	Phosphorus Weak Bray ppm	Phosphorus $NaHCO_3$-P ppm	Potassium K ppm	Magnesium Mg ppm	Calcium Ca ppm	Sodium Na ppm	Sulfur SO_4-S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Chloride Cl ppm
Results	2.9	6	63	88	439	128	849	22	11	1.3	6	74	0.8	0.3	

Percent Cation Saturation (computed)

Potassium K %	Magnesium Mg %	Calcium Ca %	Sodium Na %
11.9	11.2	44.9	1.0

ECe dS/m	CEC meq/100g	Ex. Lime	pH	Buffer pH
0.2	9.4	L	5.3	6.0

NaHCO3-P unreliable at this soil pH

Soil Fertility Guidelines

CROP: MIXED VEG RATE: lb/acre NOTES:

Dolomite 100 score	Lime 100 score	Gypsum	Elemental Sulfur	Nitrogen N	Phosphate P_2O_5	Potash K_2O	Magnesium Mg	Sulfur SO_4-S	Zinc Zn	Manganese Mn	Iron Fe	Copper Cu	Boron B	
9000				120	40			20	5				0.5	

COMMENTS

MIXED VEGETABLES: Band up to 20 lb N + 40 lb P2O5 + 5 lb S/ac 3 inches below and to the side of seeds/transplants. Side-dress 2/3 of remaining N at thinning time, then as necessary.
NITROGEN: Use local conditions and experience with variety to determine rates and timing. Allow for nitrate levels in your water source also (ppm NO3 X 0.61 = lb N/ac-ft water). Monitor tissue-N.
ZINC: Maintain soil levels above 1.0 ppm to ensure an adequate zinc supply. A tissue analysis at the appropriate time will determine more accurately, availability to the plant.
BORON: Aim for soil levels above 0.5 ppm to avoid a deficiency. A tissue analysis at the appropriate time will determine more accurately, plant availability. ADD BORON WITH CAUTION.

Darcy L. Peebles, CCA
A & L WESTERN LABORATORIES, INC

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Appendix F: System Nutrient Budget Calculations

Cover Crop Imports

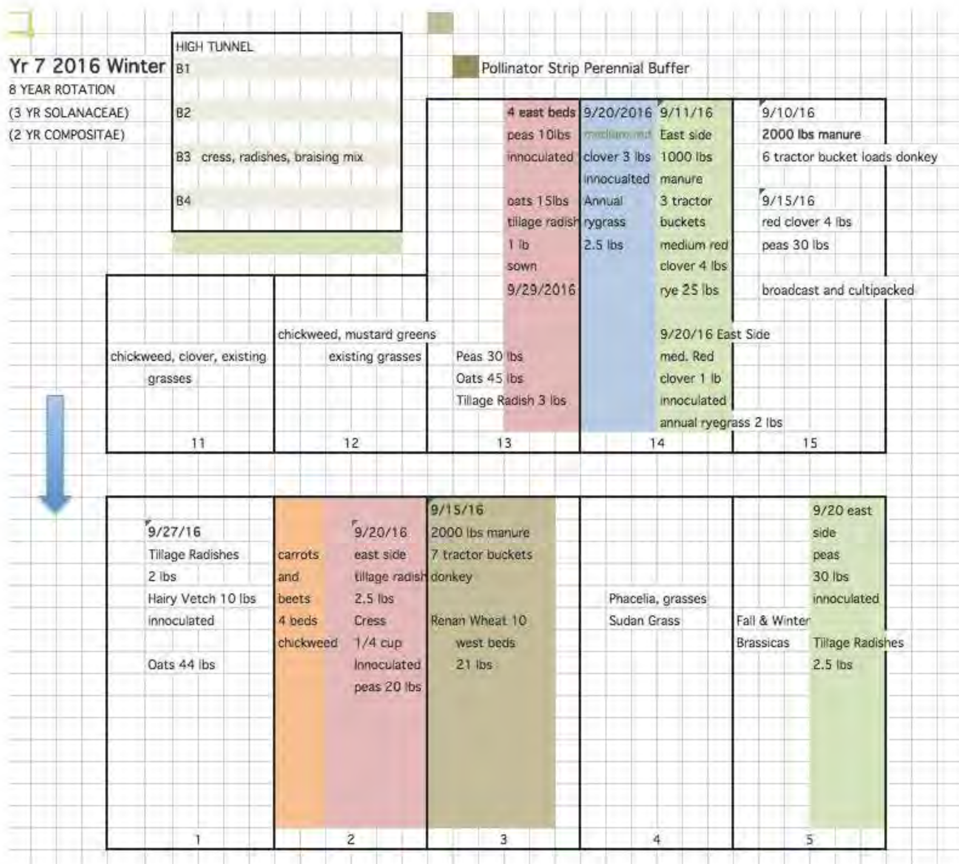
2016-2017 Winter Cover Crop

43,560 sf/ac

Legume Cover Crop	# of Beds	Block	Total Sq. Ft.	Date Seeded	LBS Seeded	Date Terminated	OSU: N uptake (lb/acre)*	Estimated PAN (lbs/acre) 15% of value	Total Acres	Estimated PAN (lbs)
Peas	12	13	9,600	Sept. 2016	30	Apr. 2017	120	36	0.22	8
Peas	12	15	9,600	Sept. 2016	30		120		0.22	
Peas	6	2	4,800	Sept. 2016	20	May 2017	120	36	0.11	4
Peas	6	5	4,800	Sept. 2016	30	May 2017	120	36	0.11	4
Med. Red Clover	12	14	9,600	Sept. 2016	8		100		0.22	
Med. Red Clover	12	15	9,600	Sept. 2016	4		100		0.22	
Hairy Vetch	12	1	9,600	Sept. 2016	10	May 2017	150	45	0.22	10
									Total N	26

Poor stands of cover crops due to winter kill and late so

* https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/pnw636.pdf



Soil Block Nutrient Values

2017 Application by Soil Blocks (Q: What % is used up in plant growth prior to being TS to the field?)	Annual Field Total (lbs)	Nitrogen (%)	Phosphorous (%)	Potassium (%)	Sulfur (%)	N (lbs)	P (lbs)	K (lbs)	S (lbs)
Peat Moss	905	0	0	0	0				
Microna Lime	19	0	0	0	0				
Pumice	1322	0	0	0	0				
Soil (Wet)	972	no net gain--	no net gain--	no net gain--	no net gain--				
Vermicompost	2788	0.0014	0.02	0.014	0.022	0.039	0.5576	0.3903	0.6133
Crustacean Meal	10	4	0	0		0.402			
Blood meal	21	13	0	0		2.7763			
Colloidal Phosphate	40	0	3	0			1.206		
Kelpmeal	24	2	0	4		0.4774		0.9548	
Water	2010	0	0	0					
Perlite	68	0	0	0					
	8180		Total Annual LBS Applied to Field by Soil Blocks:			3.7	1.8	1.3	0.6

Summary of Total Fertilizer Nutrient Imports

2017 Application by Transplant	Annual Field Total (lbs) or gallons where noted	Nitrogen (%)	Phosphorous (%)	Potassium (%)	Sulfur (%)	N (lbs)	P (lbs)	K (lbs)	S (lbs)
Bloodmeal	122	13	0	0	0	15.8	0	0	0
SoP	68	0	0	50	17	0	0	34.2	11.6
Feathermeal	141	12	0	0	0	17.0	0	0	0
Fishmeal	18	9.6	4.5	0	0	1.7	0.8	0.0	0.0
Gypsum	3	0	0	0	18	0	0	0	0.5
Fish Liquid Fertilizer 2-3-1 (gallons)	198	2	3	1	0	4.0	5.9	2.0	0.0
Fish Liquid Fertilizer 2-4-1 (gallons)	203	2	4	1	0	4.1	8.1	2.0	0.0
9-3-7 AP	17	9	3	7	0	1.5	0.5	1.2	0.0
Bonemeal	7	3	15	0	0	0.2	1.0	0.0	0.0
Donkey Manure B14, 15, 3	5000	1.26	0.34	1.28	0.15	63.0	17.0	64.0	7.5
			l LBS Applied to Field by Transplant or Broadcast:			107	33	103	20
			Applied to Field non-manure sources:			44	16	39	12

Appendix G: Fertilizer Values Maple Leaves, Wheat Straw, Donkey Manure

A & L WESTERN AGRICULTURAL LABORATORIES
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REPORT NUMBER: 17-289-057 **CLIENT NO:** 9999-D

SEND TO: APRIL THATCHER
PO BOX 973
RIDGEFIELD, WA 98642-

SUBMITTED BY:

CUSTOMER:

LAB NO: 23160 **DATE:** 10/19/2017 **PAGE:** 1

ORGANIC FERTILIZER REPORT

SAMPLE ID	REPORT OF ANALYSIS IN PERCENT									REPORT OF ANALYSIS IN PARTS PER MILLION					
	Nitrogen N	Phosphorus P	Phosphate P_2O_5	Potassium K	Potash K_2O	Sulfur S	Magnesium Mg	Calcium Ca	Sodium Na	Iron Fe	Aluminum Al	Manganese Mn	Copper Cu	Zinc Zn	B
MAPLE	1.38	0.33	0.76	1.280	1.542	0.190	0.240	2.780	0.180	382	207	295	6	69	14.0

SAMPLE ID	POUNDS OF NUTRIENTS / TON														
	Nitrogen N	Phosphorus P	Phosphate P_2O_5	Potassium K	Potash K_2O	Sulfur S	Magnesium Mg	Calcium Ca	Sodium Na	Iron Fe	Aluminum Al	Manganese Mn	Copper Cu	Zinc Zn	B
MAPLE	27.6	6.6	15.1	25.6	30.8	3.8	4.8	55.6	3.6	0.8	0.4	0.6	< 0.1	0.1	<0.1

☐ Reported on an as-received basis Moisture =

☒ Reported on a dry basis Moisture = 48.37%

Remarks: To convert to pounds of nutrients/ton as received, multiply pounds of nutrients/ton as reported by (100 - moisture %)/100.

This report applies only to the sample(s) tested. Samples are retained a maximum of thirty days after testing.

Robert Butterfield
A & L WESTERN LABORATORIES, INC.

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REPORT NUMBER: 17-289-057 **CLIENT NO:** 9999-D

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LAB NO: 23161 **DATE:** 10/19/2017 **PAGE:** 2

ORGANIC FERTILIZER REPORT

SAMPLE ID	REPORT OF ANALYSIS IN PERCENT									REPORT OF ANALYSIS IN PARTS PER MILLION					
	Nitrogen N	Phosphorus P	Phosphate P_2O_5	Potassium K	Potash K_2O	Sulfur S	Magnesium Mg	Calcium Ca	Sodium Na	Iron Fe	Aluminum Al	Manganese Mn	Copper Cu	Zinc Zn	B
WHEAT	0.37	0.09	0.21	0.930	1.120	0.300	0.080	0.420	0.060	428	134	201	3	3990	4.0

SAMPLE ID	POUNDS OF NUTRIENTS / TON														
	Nitrogen N	Phosphorus P	Phosphate P_2O_5	Potassium K	Potash K_2O	Sulfur S	Magnesium Mg	Calcium Ca	Sodium Na	Iron Fe	Aluminum Al	Manganese Mn	Copper Cu	Zinc Zn	B
WHEAT	7.4	1.8	4.1	18.6	22.4	6.0	1.6	8.4	1.2	0.9	0.3	0.4	< 0.1	8.0	<0.1

☐ Reported on an as-received basis Moisture =

☒ Reported on a dry basis Moisture = 15.34%

Remarks: To convert to pounds of nutrients/ton as received, multiply pounds of nutrients/ton as reported by (100 - moisture %)/100.

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This report applies only to the sample(s) tested. Samples are retained a maximum of thirty days after testing.

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CUSTOMER:

LAB NO: 23162 **DATE:** 10/19/2017

ORGANIC FERTILIZER REPORT

PAGE: 3

SAMPLE ID	REPORT OF ANALYSIS IN PERCENT									REPORT OF ANALYSIS IN PARTS PER MILLION						
	Nitrogen N	Phosphorus P	Phosphate P_2O_5	Potassium K	Potash K_2O	Sulfur S	Magnesium Mg	Calcium Ca	Sodium Na	Iron Fe	Aluminum Al	Manganese Mn	Copper Cu	Zinc Zn	B	
DONKE	1.26	0.34	0.78	1.280	1.542	0.150	0.190	0.640	0.080	3572	1555	622	19	391	6.0	

SAMPLE ID	POUNDS OF NUTRIENTS / TON															
	Nitrogen N	Phosphorus P	Phosphate P_2O_5	Potassium K	Potash K_2O	Sulfur S	Magnesium Mg	Calcium Ca	Sodium Na	Iron Fe	Aluminum Al	Manganese Mn	Copper Cu	Zinc Zn	B	
DONKE	25.2	6.8	15.6	25.6	30.8	3.0	3.8	12.8	1.6	7.1	3.1	1.2	< 0.1	0.8	<0.1	

☐ Reported on an as-received basis **Moisture =**

☒ Reported on a dry basis **Moisture =** 74.39%

Remarks: To convert to pounds of nutrients/ton as received, multiply pounds of nutrients/ton as reported by (100 - moisture %)/100.

This report applies only to the sample(s) tested. Samples are retained a maximum of thirty days after testing.

Robert Butterfield
A & L WESTERN LABORATORIES, INC.

Appendix H: SNB- Nutrient Export Calculations

2017 Field Acreage by Crop

2017 CROPS BY TOTAL OCCUPIED ACREAGE (BED SPACE)				
	Total RF	No. 160 Rows	No Rows/Bed	No. 160x5ft Beds
Potatoes	1920	12.0	1.0	12.0
Lettuce	7869	49.2	5.0	9.8
Squash	1440	9.0	1.0	9.0
Peppers	1600	10.0	2.0	5.0
Onions	2398	15.0	3.0	5.0
Tomatoes	660	4.1	1.0	4.1
Cauliflower	1280	8.0	2.0	4.0
Cabbage	1120	7.0	2.0	3.5
Carrots	1360	8.5	3.0	2.8
Beets	1200	7.5	3.0	2.5
Kale	800	5.0	2.0	2.5
Corn - Popcorn	640	4.0	2.0	2.0
Peas	240	1.5	1.0	1.5
Greens	1040	6.5	5.0	1.3
Beans	200	1.3	1.0	1.3
Kohlrabi - Early Summer	480	3.0	3.0	1.0
Broccoli	320	2.0	2.0	1.0
Flower Sprouts	320	2.0	2.0	1.0
Garlic - Hardneck	800	5.0	6.0	0.8
Turnips - Spring 4 year see	320	2.0	3.0	0.7
Cucumbers - White 10 yr se	100	0.6	1.0	0.6
Tomatillos	96	0.6	1.0	0.6
Basil	180	1.1	2.0	0.6
Chard	160	1.0	2.0	0.5
Collards 4 year seed life	160	1.0	2.0	0.5
Parsley	160	1.0	2.0	0.5
Eggplant - Black/Std	160	1.0	2.0	0.5
Leeks - Fall 3 year seed life	80	0.5	1.0	0.5
Arugula - Early Spring	360	2.3	5.0	0.5
Fennel Bulb	160	1.0	3.0	0.3
Celery	80	0.5	2.0	0.3

Nutrient Export Values for Harvested Crops

2017 CROPS BY TOTAL WEIGHT EXPORTED	Jan - Dec 17 Qty (lbs)	Nutrient content of crop (lbs/acre)*			Yield*, ^	lbs nutrient removed by crop		
		N	P	K	(cwt/acre)	N	P	K
Tomatoes	2,917	100	10	80	240	12.15	1.22	9.72
Lettuce	2,493	95	30	170	400	5.92	1.87	10.59
Squash, Summer	899	39	30	130	400	0.88	0.67	2.92
Squash, Winter	821	39	20	120	360	0.89	0.46	2.74
Peppers	1,539	45	30	110	400	1.73	1.15	4.23
Onions	1,253	145	50	160	680	2.67	0.92	2.95
Beets^1	883	53	9			2.22	0.67	3.36
Cabbage	861	0.12	55	230	600	0.00	0.79	3.30
Cucumbers	585		10	40	200	0.00	0.29	1.17
[illegible]	553	150	60	250	400	2.07	0.83	3.46
Carrots	530	80	25	110	160	2.65	0.83	3.64
Greens (Spinach values us	496	0.09	15	120	240	0.45	0.31	2.48
[illegible]	387					0.97	0.29	1.47
Beans	344	120	15	40	120	3.44	0.43	1.15
Kohlrabi	200					0.50	0.15	0.76
Eggplant	197	0.066	0.028	0.314		0.13	0.06	0.62
Parsley*****	171	170	35	380	1000	0.29	0.06	0.65
Rhubarb	151					0.00	0.00	0.00
Cauliflower	140	0.18	20	60	120	0.00	0.23	0.70
Fennel	138					0.00	0.00	0.00
Turnips	135					0.00	0.00	0.00
Tomatillos	126					0.00	0.00	0.00
Broccoli	119	20	2	45	100	0.24	0.02	0.53
Chard**	115	0.09	0.042	0.296		0.10	0.05	0.34
Garlic	68	0.384	0.153	0.401		0.26	0.10	0.27
Scallions***	61	145	25	155	400	0.22	0.04	0.24
Celery	28	170	35	380	1000	0.05	0.01	0.11
Collards	16					0.00	0.00	0.00
Basil	11					0.00	0.00	0
Sum lbs with available dat	**13,604.0**					**34.1**	**10.3**	**51.8**
Totals	16,236				Avg lb/crop	0.00251	0.00076	0.00380837
						38	11	57

^1 Nutrient content per crop N and P values from Drinkwater. OFRF Grant report entitled: On-farm nutrient budgets in organic cropping systems: A tool for soil fertility management

* Estimates of nutrient content are from Maynard and Hochmuth, 2007

Maynard, D. N., and G. J. Hochmuth. 2007. Knott's handbook for vegetable growers. 5th ed. John Wiley & Sons, Hoboken, NJ.
Values without cwt/acre are taken from http://articles.extension.org/pages/18794/nutrient-budget-basics-for-organic-farming-systems
Values listed in grey are taken from: https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/em9165_0.pdf

Appendix I: Spring/Summer Field Layout by Crop Family

YR: 2017 Spring/Summer Actual

	12	PERENNIAL
	11	FALLOW
	10	FALLOW
	9	BRASSICACEAE
	8	FALLOW
B1		CHENOPODIACEAE/UMBELLIFERAE
		CHENOPODIACEAE/UMBELLIFERAE
	5	COMPOSITAE
	4	LEGUMINOSAE
	3	COMPOSITAE
	2	COMPOSITAE
	1	COMPOSITAE
	12	AMARYLLIDACEAE
	11	AMARYLLIDACEAE
	10	AMARYLLIDACEAE
	9	AMARYLLIDACEAE
	8	AMARYLLIDACEAE
B2		CUCURBITACEAE
		CUCURBITACEAE
	5	CUCURBITACEAE
	4	CUCURBITACEAE
	3	CUCURBITACEAE
	2	CUCURBITACEAE
	1	CUCURBITACEAE
	12	POACEAE
	11	POACEAE
	10	POACEAE
	9	POACEAE
	8	POACEAE
B3		POACEAE
		POACEAE
	5	POACEAE
	4	POACEAE
	3	POACEAE
	2	POACEAE
	1	CUCURBITACEAE
	12	AMARYLLIDACEAE
	11	CUCURBITACEAE
	10	FALLOW
	9	POACEAE
	8	FALLOW
B4		SOLANACEAE
		SOLANACEAE
	5	SOLANACEAE
	4	SOLANACEAE
	3	SOLANACEAE
	2	SOLANACEAE
	1	SOLANACEAE
	12	FALLOW
	11	FALLOW
	10	FALLOW
	9	FALLOW
	8	FALLOW
B5		SOLANACEAE
		CUCURBITACEAE
	5	UMBELLIFERAE/CHENOPODIACEAE
	4	UMBELLIFERAE/CHENOPODIACEAE
	3	UMBELLIFERAE/CHENOPODIACEAE
	2	UMBELLIFERAE
	1	FALLOW

	1	PERENNIAL
	2	MINOR
	3	MINOR
	4	SOLANACEAE
	5	SOLANACEAE
B11		SOLANACEAE
		SOLANACEAE
	8	SOLANACEAE
	9	SOLANACEAE
	10	SOLANACEAE
	11	SOLANACEAE
	12	SOLANACEAE
	1	SOLANACEAE
	2	SOLANACEAE
	3	SOLANACEAE
	4	SOLANACEAE
	5	SOLANACEAE
B12		SOLANACEAE
		SOLANACEAE
	8	SOLANACEAE
	9	SOLANACEAE
	10	SOLANACEAE
	11	SOLANACEAE
	12	SOLANACEAE
	1	BRASSICACEAE
	2	BRASSICACEAE
	3	BRASSICACEAE
	4	BRASSICACEAE
	5	BRASSICACEAE
B13		BRASSICACEAE
		BRASSICACEAE
	8	BRASSICACEAE
	9	BRASSICACEAE
	10	BRASSICACEAE
	11	FALLOW
	12	FALLOW
	1	FALLOW
	2	FALLOW
	3	FALLOW
	4	FALLOW
	5	FALLOW
B14		FALLOW
		FALLOW
	8	FALLOW
	9	FALLOW
	10	FALLOW
	1	FALLOW
	12	FALLOW
	1	FALLOW
	2	FALLOW
	3	FALLOW
	4	FALLOW
	5	FALLOW
B15		FALLOW
		FALLOW
	8	FALLOW
	9	FALLOW
	10	FALLOW
	11	FALLOW
	12	FALLOW

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Appendix J: 2017 Field Maps

Spring/Summer Crop Map 2017

YR: 2017 Spring/Summer Actual

B1

12	Rhubarb
11	S/S; Bare Fallow
10	S/S; Bare Fallow
9	S/S; Bare Fallow
8	S/S; Bare Fallow
	S/S: Buckwheat 24', Poppies 67'+ 38', Chard 84', Celery 103'
	S/S/F/W: Chard 1r, Parsley 1r
5	S/S: Lettuces. Benkana F/W: Broc. 100', Collards 60', Kale 160'
4	S/S:Beans
3	S/S:Lettuces, F/W: Kale
2	S/S: Lettuces W: Oats and Peas
1	S/S: Lettuces. W: Oats and Peas

B2

12	S/S: Onions
11	S/S: Onions
10	S/S: Onions
9	S/S: Onions
8	S/S: Onions
	S/S: Winter Squash
	S/S: Winter Squash
5	S/S: Winter Squash
4	S/S: Winter Squash
3	S/S: Winter Squash
2	S/S: Winter Squash
1	S/S: Winter Squash

B3

12	S/S: Renan Wheat
11	S/S: Renan Wheat
10	S/S: Renan Wheat
9	S/S: Renan Wheat
8	S/S: Renan Wheat
	S/S: Renan Wheat
	S/S: Renan Wheat
5	S/S: Renan Wheat
4	S/S: Renan Wheat
3	S/S: Renan Wheat
2	S/S: Renan Wheat
1	S/S: Summer Squash

B4

12	2016 F/W: Garlic
11	S/S: Summer Squash
10	Buckwheat
9	S/S: Phacelia, Hulless Oats
8	Buckwheat
	S/S: Potatoes 12 total beds, 3' wide
	S/S: Potatoes 12 total beds, 3' wide
5	S/S: Potatoes 12 total beds, 3' wide
4	S/S: Potatoes 12 total beds, 3' wide
3	S/S: Potatoes 12 total beds, 3' wide
2	S/S: Potatoes 12 total beds, 3' wide
1	S/S: Potatoes 12 total beds, 3' wide

B5

12	S/S: Bare fallow/Phacelia
11	S/S: Bare Fallow/Phacelia
10	S/S: Bare Fallow/Phacelia
9	S/S: Bare Fallow/Phacelia
8	S/S: Bare Fallow/Phacelia
	S/S: Hot Peppers
	S/S: Cucumbers
5	S/F: Carrots Beets
4	S/F: Carrots Beets
3	S/F: Carrots Beets
2	S/F: Carrots
1	S/S: Bare Fallow/Crimson Clover

B11

1	Strawberries
2	Insectory Plants WGS Mix
3	Soy beans, Borage, Chamomile
4	Eggplant
5	Sweet Peppers
	Sweet Peppers
	Sweet Peppers
8	Sweet Peppers
9	Sweet Peppers
10	Sweet Peppers
11	Sauce Tomatoes
12	Sauce Tomatoes

B12

1	Field Houses Wall
2	Heirlooms 30, Basil 30, Tomatillos 8
3	Heirlooms 30, Basil 30, Tomatillos 8
4	Field House Wall
5	Heirlooms 30, Basil 30, Tomatillos 8
	aisle
	Heirlooms 30, Basil 30, Tomatillos 8
8	Field House Wall
9	Cherry Toms, Basil, Tomatillos
10	aisle
11	Cherry Toms, Basil, Tomatillos
12	Field House Wall

B13

1	S/S: Asian Greens & Kohlrabi
2	S/S: Cabbage
3	Spring Lettuces
4	S/S: Cabbages 0.5b, Lettuces, Pac Choi, Fennel 0.5b
5	S/S: Lettuces, Asian Greens, Kohlrabi
	S/S: Jalapenos (20ft). F/W: Cabbages
	S/S: Jalapenos (20ft). F/W: Cabbages
8	S/S: Cauliflower
9	F/W: Broccoli
10	F/W: Cauliflower
11	S/S: Buckwheat
12	S/S: Buckwheat

B14

1	S/S: Buckwheat
2	S/S: Buckwheat
3	S/S: Buckwheat
4	S/S: Buckwheat
5	S/S: Buckwheat
	Existing grasses and clover
	Existing grasses and clover
8	Existing grasses and clover
9	Existing grasses and clover
10	Existing grasses and clover
1	Existing grasses and clover
12	Existing grasses and clover

B15

1	Existing grasses and clover
2	Existing grasses and clover
3	Existing grasses and clover
4	Existing grasses and clover
5	Existing grasses and clover
	Existing grasses and clover
	Existing grasses and clover
8	Existing grasses and clover
9	Existing grasses and clover
10	Existing grasses and clover
11	Existing grasses and clover
12	Existing grasses and clover

Winter Cover Crop Map 2017

YR: 2017 Winter Actual

	12	Rhubarb
	11	W: Oats 1# & Peas 3#
	10	W: Oats 1# & Peas 3#
	9	F/W: Broccoli 110', F Sprouts 230'
	8	F/W: Fallow - weeds
B1		S/S/F/W: Chard 84', Celery 103'
		S/S/F/W: Chard 1r, Parsley 1r
	5	F/W: Broc. 100', Collards 60', Kale 160'
	4	F/W: Kale
	3	F/W: Kale
	2	F/ W: Oats 1# and Peas 3#
	1	F/ W: Oats 1# and Peas 3#
	12	F/W: Rye 18.7#/block, Hairy Vetch innoculated 5# per block
	11	F/W: Rye 18.7#/block, Hairy Vetch innoculated 5# per block
	10	F/W: Rye 18.7#/block, Hairy Vetch innoculated 5# per block
	9	F/W: Rye 18.7#/block, Hairy Vetch innoculated 5# per block
	8	F/W: Rye 18.7#/block, Hairy Vetch innoculated 5# per block
B2		F/W: Rye 18.7#/block, Hairy Vetch innoculated 5# per block
		F/W: Rye 18.7#/block, Hairy Vetch innoculated 5# per block
	5	F/W: Rye 18.7#/block, Hairy Vetch innoculated 5# per block
	4	F/W: Rye 18.7#/block, Hairy Vetch innoculated 5# per block
	3	F/W: Rye 18.7#/block, Hairy Vetch innoculated 5# per block
	2	F/W: Rye 18.7#/block, Hairy Vetch innoculated 5# per block
	1	F/W: Rye 18.7#/block, Hairy Vetch innoculated 5# per block
	12	F/W: Rye 6.5#/4 beds, chickling vetch innoculated 1.7#/4 beds
	11	F/W: Rye 6.5#/4 beds, chickling vetch innoculated 1.7#/4 beds
	10	F/W: Rye 6.5#/4 beds, chickling vetch innoculated 1.7#/4 beds
	9	F/W: Rye 6.5#/4 beds, chickling vetch innoculated 1.7#/4 beds
	8	F/W: Peas 24# innculated per 8 beds, Oats 8# per 8 beds
B3		F/W: Peas 24# innculated per 8 beds, Oats 8# per 8 beds
		F/W: Peas 24# innculated per 8 beds, Oats 8# per 8 beds
	5	F/W: Peas 24# innculated per 8 beds, Oats 8# per 8 beds
	4	F/W: Peas 24# innculated per 8 beds, Oats 8# per 8 beds
	3	F/W: Peas 24# innculated per 8 beds, Oats 8# per 8 beds
	2	F/W: Peas 24# innculated per 8 beds, Oats 8# per 8 beds
	1	F/W: Summer Squash
	12	F/W: Rye 18#, Hair Vetch innoculated 4.6# per 12 beds
	11	F/W: Rye 18#, Hair Vetch innoculated 4.6# per 12 beds
	10	F/W: Rye 18#, Hair Vetch innoculated 4.6# per 12 beds
	9	F/W: Rye 18#, Hair Vetch innoculated 4.6# per 12 beds
	8	F/W: Rye 18#, Hair Vetch innoculated 4.6# per 12 beds
B4		F/W: Rye 18#, Hair Vetch innoculated 4.6# per 12 beds
		F/W: Rye 18#, Hair Vetch innoculated 4.6# per 12 beds
	5	F/W: Rye 18#, Hair Vetch innoculated 4.6# per 12 beds
	4	F/W: Rye 18#, Hair Vetch innoculated 4.6# per 12 beds
	3	F/W: Rye 18#, Hair Vetch innoculated 4.6# per 12 beds
	2	F/W: Rye 18#, Hair Vetch innoculated 4.6# per 12 beds
	1	F/W: Rye 18#, Hair Vetch innoculated 4.6# per 12 beds
	12	F/W: Peas 18# innoculated, Oats 6# per 6 beds
	11	F/W: Peas 18# innoculated, Oats 6# per 6 beds
	10	F/W: Peas 18# innoculated, Oats 6# per 6 beds
	9	F/W: Peas 18# innoculated, Oats 6# per 6 beds
	8	F/W: Peas 18# innoculated, Oats 6# per 6 beds
B5		F/W: Peas 18# innoculated, Oats 6# per 6 beds
		S/S: Cucumbers
	5	S/F: Carrots Beets
	4	S/F: Carrots Beets
	3	S/F: Carrots Beets
	2	S/F: Carrots
	1	F/W: Existing Weeds/Grasses

* Spread unthreshed stalks across bed and mowed, disced, tilled in

	1	Strawberries
	2	Insectory Plants WGS Mix
	3	Soy beans, Borage, Chamomile
	4	Eggplant
	5	Sweet Peppers
B11		Sweet Peppers
		Sweet Peppers
	8	Sweet Peppers
	9	Sweet Peppers
	10	Sweet Peppers
	11	Oats 1#, Peas 3#
	12	Oats 1# Peas 3#
	1	Field Houses
	2	Oats 6#/block 12. Peas 16#/block 12
	3	Oats 6#/block 12. Peas 16#/block 13
	4	Oats 6#/block 12. Peas 16#/block 14
	5	Oats 6#/block 12. Peas 16#/block 15
B12		Oats 6#/block 12. Peas 16#/block 16
		Oats 6#/block 12. Peas 16#/block 17
	8	Oats 6#/block 12. Peas 16#/block 18
	9	Oats 6#/block 12. Peas 16#/block 19
	10	Oats 6#/block 12. Peas 16#/block 20
	11	Oats 6#/block 12. Peas 16#/block 21
	12	Field House Wall
	1	Renan Wheat overseeded with Medium Red Clover 6.3# per 9 beds
	2	Renan Wheat* overseeded with Med. Red Clover 63# per 9 beds
	3	Renan Wheat* overseeded with Med. Red Clover 63# per 9 beds
	4	Renan Wheat* overseeded with Med. Red Clover 63# per 9 beds
	5	F/W: Cabbages
B13		F/W: Cabbages
		F/W: Cabbages
	8	F/W: 2017-2018 Garlic
	9	F/W: Broccoli
	10	F/W: Cauliflower
	11	F/W: Medium Red Clover 0.5#
	12	F/W: Medium Red Clover 0.5#
	1	F/W: Stephens Wheat 2.5# overseeded with Red Clover 6.3# per 9 beds
	2	F/W: Expresso Wheat 2.5# + Medium Red Clover 6.3# per 9 beds
	3	F/W: Expresso Wheat 2.5# + Medium Red Clover 6.3# per 9 beds
	4	F/W: Expresso Wheat 2.5# + Medium Red Clover 6.3# per 9 beds
	5	F/W: Rye Grain 2.75# + Medium Red Clover 6.3# per 9 beds
B14		F/W: Oats 1#, Peas 3#
		F/W: Oats 1#, Peas 3#
	8	Exising Grasses and clover
	9	Exising Grasses and clover
	10	Exising Grasses and clover
	1	Exising Grasses and clover
	12	Exising Grasses and clover
	1	Existing grasses and clover
	2	Existing grasses and clover
	3	Existing grasses and clover
	4	Existing grasses and clover
	5	Existing grasses and clover
B15		F/W: Oats 1#, Peas 3#
		F/W: Oats 1#, Peas 3#
	8	Existing grasses and clover
	9	Existing grasses and clover
	10	Existing grasses and clover
	11	Existing grasses and clover
	12	Existing grasses and clover

Appendix K: Organic Materials Inventory

April Joy Farm					
Organic Materials Handling and Storage Design					
10-Feb-18					
Source	**Quantity (CF)**	**Time Unit**	**CF/Week**	**Total Annual Cubic Yards**	**Current Storage**
Donkey Manure					
3 wheelbarrows (4 cf) per week	12	week	12.00	23	*Exterior Area - Tarp Covered 15 sq ft x 3 ft deep*
Chicken Manure					
Roost #1: 12 ft x 3 ft x 1 ft deep with hay bedding cleaned out 4 x per year	144	year	2.77	5	*Piled/Spread on orchard and vineyard plantings (non-managed compost)*
Roost #2: 12 ft x 7 ft x 1 ft deep with hay bedding cleaned out 4 x per year	336	year	6.46	12	*Piled/Spread on orchard and vineyard plantings (non-managed compost)*
Nesting House: 7 ft x 3 ft x 1 ft deep hay bedding cleaned out 2 x per year	42	year	0.81	2	*Piled/Spread on orchard and vineyard plantings (non-managed compost)*
Broiler House: 10 ft x 4 ft x 3 ft deep hay/wood shavings bedding cleaned out 1 x per year	114	year	2.19	4	*Piled/Spread on orchard and vineyard plantings (non-managed compost)*
Swine Manure				0	
12 ft x 12 ft x 2 ft deep stalls with hay bedding x 3 stalls 1x per year	864	year	16.62	32	12ft x 24 ft open stall x 5 ft
		Total CY Manure		79	
Packing Shed Green Wastes					
16 - 20 cf/week x 35 weeks	20	week	20.00	39	*Piled (non- managed compost)*
Field Reside (Tomato vines, etc) 8ft x 5ft x 10ft	400	year	7.69	15	*Piled (non- managed compost)*
Maple Leaves	45	year		2	Totes in barn
Wood Chips (Off Farm) 6-12 loads per year, 16 cyds/l	3456	year	66.46	128	
	Total Annual CY All Compostable Material			262	

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Appendix L: Organic Material Nutrient Analyses

This is the grass hay used as bedding for poultry, swine and feed for donkeys. It is also used as mulch occasionally in the crop field.

Grass Hay Nutrient Analysis

Analysis performed by: 5B

730 Warren Road
Ithaca, NY 14850
1-877-819-4110
www.equi-analytical.com

Lab Sample No: 20223590
Page 1 of 1

Analyzed for:

APRIL THATCHER
PO BOX 973
RIDGEFIELD, WA 98642

Lab Desc: 103
Date Sampled: 02/20/2014
Date Received: 02/24/2014
Date Printed: 02/25/2014
Description 1: FRONT FIELD 2013
Description 2:
Statement ID: MIXED GRASS

Visit our website **www.equi-analytical.com** for information on interpreting and using your results.

Results

% Moisture	8.1			
% Dry Matter	92.0			
	As Sampled		Dry Matter	
Digestible Energy (DE), Mcal/lb		.78		.85
	%	g/lb.	%	g/lb.
Crude Protein	5.1	23.1	5.6	25.2
Estimated Lysine	.18	.8	.19	.9
Lignin	6.3	28.8	6.9	31.3
Acid Detergent Fiber (ADF)	42.1	191.2	45.8	207.9
Neutral Detergent Fiber (NDF)	63.0	285.7	68.5	310.7
WSC (Water Sol. Carbs.)	10.8	48.9	11.7	53.2
ESC (Simple Sugars)	5.7	25.9	6.2	28.2
Starch	1.2	5.3	1.3	5.7
Non Fiber Carb. (NFC)	14.9	67.5	16.2	73.4
Crude Fat	1.6	7.0	1.7	7.7
Ash	7.4	33.7	8.1	36.7
	%	g/lb.	%	g/lb.
Calcium	.38	1.70	.41	1.85
Phosphorus	.18	.81	.19	.88
Magnesium	.09	.42	.10	.45
Potassium	1.58	7.16	1.72	7.79
Sodium	.008	.035	.009	.039
	ppm	mg/lb.	ppm	mg/lb.
Iron	351	159	382	173
Zinc	19	9	21	9
Copper	4	2	5	2
Manganese	250	114	272	124
Molybdenum	1.0	.5	1.1	.5
	As Fed		100% Dry	
RFV			72	

Vermicompost Bacteria and Fungi Test Results

Microbial Matrix Systems Inc.
P.O.Box 209 2300 Ferry St. SW #5
Tangent, OR 97389 Albany, OR 97322

Lab: 541-967-0554
Fax: 541-967-4025
Email: lrogers@microbialmatrix.com

Mathew Brown
22-May-14

Bacteria and Fungi

Sample #	Sample ID / Desired Range	GDW	Active Bacteria (100 - 200μg)	Active Fungi (2 -10μg)	Total Bacteria (50 - 300μg)	Total Fungi (150 - 200μg)	Fungal Dia
2017	May-14	0.41	59.53 *Low*	10.16 *Optimum*	1204.86 *High*	26.37 *Low*	2.5

Bacteria and Fungi Ratios and Percentages

	Desired Range	Percent Actvie Bacteria (10 - 20%)	Percent Active Fungi (10 - 20%)	Total Fungi:Total Bacteria (0.5 - 1.5)
2017	May-14	4.94% *Low*	38.5% *High*	0.022

While % Active Bacteria is low the %Active Fungi is high and does indicates worm castings may help to provide source of plant available nutrients. Total Bacteria populations is high and indicates a potential to provide a sustainable source of nutrients.

Total Fungi is low but maybe related to "age" of castings, variability found in feed, and basic fluctuations in microbial biomass. However, Total Bacteria populations are high which will help to provide nutrients lacking from fungi populations.

Pathogen Screening:
E. coli H0157 Negative

Vermicompost Bacteria and Fungi

Microbial Matrix Systems Inc.
P.O.Box 209 2300 Ferry St. SW #9
Tangent, OR 97389 Albany, OR 97322

Lab: 541-967-0554
Fax: 541-967-4025
Email: lrogers@microbialmatrix.com

Mathew Brown
Jan-15

Bacteria and Fungi

Sample #	Sample ID	GDW	Active Bacteria	Active Fungi	Total Bacteria	Total Fungi	Fungal Dia
	Desired Range		**(100 - 200µg)**	**(2 -10µg)**	**(50 - 300µg)**	**(150 - 200µg)**	
3000	Jan-15	0.49	66.14 *Low*	8.02 *High*	1014.63 *Very High*	9.40 *Low*	2.5

Bacteria and Fungi Ratios and Percentages

		Percent Actvie Bacteria	Percent Active Fungi
	Desired Range	**(10 - 20%)**	**(10 - 20%)**
3000	Jan-15	6.50% *Okay*	85.4% *High*

Pathogen Screening E.coli H0157 Negative

Comments:

Fungal percent activity is high and indicates a potential for high levels of soluble plant nutrients to be available.
Bacterial percent activity is okay and indicates a shift in activity being dominated by fungi at this point in time.

Changes in management of worms and/or food sources can affect the total and active populations. Populations can also be affected throughout the year while in storage. Monitor regularly.

Vermicompost Test Results

Date: 4/9/13
Report No 8024
Grower: Mathew Brown
Client: Mathew Brown
Sampler: Mathew Brown
Field: Castings 2013
Crop: Worm Castings

Microbial Matrix Systems Inc.
P.O. Box 209 Albany, OR 97389
2300 Ferry St. SW Unit#5
Tangent, OR 97389
Lab: 541-967-0554

SOIL ANALYSIS REPORT

Lab #	Depth ft	NO3 -N #/ac	NO3 -N ppm	NH4 -N #/ac	NH4 -N ppm	P Bray ppm	K Acet ppm	SO4 -S ppm	B ppm	O.M. %	pH	Zn ppm	Mn ppm	Cu ppm	Fe ppm
8024	1	32	13.8	1600	700.0	158	142	220	34.00	30.0	6.5	16.6	53	35.0	134

Very High in Nutrient Value.

Ideal for variety of uses such as in potting medium, compost tea productions mixed with thermocompost, as amending or side dressing plants.

1

Appendix M: April Joy Farm Materials Inventory

2018 Amendments/Materials Used in the Crop Field

0-3-0 Calphos 20% Ca. Canton Mills Inc.
Canadian Sphagnum Peat Moss, Aurora Peat Products
Sulfate of Potash 0-0-50 Solution Grade Ultra Fines, Diamond K Gypsum
Farmer Brown's Earthworm Vermicompost
Hay - AJF
Kelpmeal 1-0.15-2 Acadian Seaplants Limited
Maple Leaves AJF
Donkey Manure - AJF
Black Plastic Mulch
Nature's Intent Calpril Pacific Calcium
N-Dure A Premium Peat Inoculant for Peas, Vetch and Lentils INTX Microbials
Premium 97 Solution Grade Gypsum Diamond K Gypsum
Pro-Pell- IT! Bone Meal 3-15-0 Marion Ag
Pro Pell It! Crustacean Meal 4-0-0+12 Ca Marion Ag
Pro-Pell It! Feathermal Marion Ag 12-0-0
Pro-Pell It! Dolomite Marion Ag
Pro-Pell It! 13-0-0 Bloodmeal Marion Ag
Wheat Straw – AJF
Supreme Perlite Propagation Grade
Supreme Perlite Soil Mix Grade
Surround WP Tessenderlo Kerley Inc
Tidal Organics Kelp/Seaweed Meal Tidal Organics
Wood Chips
Fertilizer Mix (Calphos, Kelp, Bloodmeal 1-1-1)
Microna Ag H20 Solution Grade Lime Columbia River Carbonates
Par 4 Kelpmeal 1-0-2 Bridgewell Resources
Vermiculite Ultra Grade Premium Horticultural Fine
Vermiculite Ultra Grade Premium Horticultural Medium

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Appendix N: Soil Test Results for Supporting Lands

<u>Soil Test Results for Blocks East of Current Production Field.</u>

This land could be utilized to achieve the 50% annual fallow crop rotation recommendation.

A & L WESTERN AGRICULTURAL LABORATORIES

10220 SW NIMBUS AVE Bldg K-9 | PORTLAND OREGON 97223 | (503) 968-9225 | FAX (503) 598-7702

REPORT NUMBER: 17-034-082 CLIENT NO: 99999

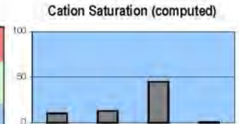
SEND TO: APRIL THATCHER SUBMITTED BY:

GROWER:

Graphical Soil Analysis Report

DATE OF REPORT: 02/08/17 LAB NO: 58506 SAMPLE ID: 16-18 PAGE: 7

Percent Cation Saturation (computed)



Analyte	Organic Matter %	Nitrogen NO_3-N ppm	Phosphorus Weak Bray ppm	Phosphorus $NaHCO_3$-P ppm	Potassium K ppm	Magnesium Mg ppm	Calcium Ca ppm	Sodium Na ppm	Sulfur SO_4-S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Chloride Cl ppm
Results	4.1	10	97	67	298	114	664	9	10	1.6	19	105	0.6	0.3	

Potassium K %	Magnesium Mg %	Calcium Ca %	Sodium Na %
10.4	12.8	45.2	0.6

LOW AVERAGE HIGH ACIDIC BASIC

ECe dS/m	CEC meq/100g	Ex. Lime	pH
0.2	7.3	L	5.3

INCREASING SALINITY → ← INCREASING NEED FOR LIME

Buffer pH: 6.2

NaHCO3-P unreliable at this soil pH

Soil Fertility Guidelines

CROP: RATE: NOTES:

Dolomite 100 score	Lime 100 score	Gypsum	Elemental Sulfur	Nitrogen N	Phosphate P_2O_5	Potash K_2O	Magnesium Mg	Sulfur SO_4-S	Zinc Zn	Manganese Mn	Iron Fe	Copper Cu	Boron B	

COMMENTS

Rogell Rogers, CCA, PCA
A & L WESTERN LABORATORIES, INC

Hay Field Soil Test Results

A & L WESTERN AGRICULTURAL LABORATORIES

10220 SW NIMBUS AVE Bldg K-9 I PORTLAND OREGON 97223 I (503) 968-9225 I FAX (503) 598-7702

REPORT NUMBER: 17-034-082 CLIENT NO: 99999

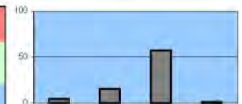
SEND TO: APRIL THATCHER SUBMITTED BY:

GROWER:

Graphical Soil Analysis Report

DATE OF REPORT: 02/08/17 LAB NO: 58507 SAMPLE ID: CNUTS PAGE: 8

Percent Cation Saturation (computed)



Analyte	Organic Matter %	Nitrogen NO_3-N ppm	Phosphorus Weak Bray ppm	Phosphorus $NaHCO_3$-P ppm	Potassium K ppm	Magnesium Mg ppm	Calcium Ca ppm	Sodium Na ppm	Sulfur SO_4-S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Chloride Cl ppm
Results	4.1	8	77	65	117	124	751	21	5	0.9	45	110	0.5	0.3	

Potassium K %	Magnesium Mg %	Calcium Ca %	Sodium Na %
4.6	15.6	57.4	1.4

ECe dS/m	CEC meq/100g	Ex. Lime	pH	Buffer pH
0.1	6.5	L	5.7	6.3

LOW AVERAGE HIGH — INCREASING SALINITY →

ACIDIC BASIC — ← INCREASING NEED FOR LIME

NaHCO3-P unreliable at this soil pH

Soil Fertility Guidelines

CROP: RATE: NOTES:

Dolomite 100 score	Lime 100 score	Gypsum	Elemental Sulfur	Nitrogen N	Phosphate P_2O_5	Potash K_2O	Magnesium Mg	Sulfur SO_4-S	Zinc Zn	Manganese Mn	Iron Fe	Copper Cu	Boron B	

COMMENTS

Rogell Rogers, CCA, PCA
A & L WESTERN LABORATORIES, INC

Appendix O: Farm Management Changes and Milestones

Year	Milestone/Event
2006	Farm established by April Jones
2006	Vineyard planted
2007	Certified Organic
2009	Certified Animal Welfare Approved (First AWA pork producer in the NorthWest Region)
2009	Well installed, current field blocks (60x160) laid out, drip irrigation purchased
2011	Six 20' x 15' portable field houses constructed for growing tomatoes
2011	Piggery built (84' x 42' barn)
2012	Brad joins farm as LLC Manager/Farmer
2012	32 x 96' high tunnel constructed
2013	Fruit tree orchard established at Piggery
2013	AJF ceases to hire employees
2013	Family/Volunteers assist at farm (2)
2014	Rescue donkeys (3) arrive at the farm for manure production
2014	8.64 KW solar photovoltaic system installed, 32 panel array, each panel 270 watts Annually offsets 75% of commercial (Farm business) electricity needs, 40%+ total farm electricity usage
2014	Two of 9 blocks taken out of vegetable production for fallow soil building efforts
2015	A third blocks taken out of vegetable production for fallow soil building efforts
2015	Concerted effort to shift toward perennial production model
2016	Five raised beds installed (15 ft x 40") to provide shoulder season greens and root crops
2017	Orchard at Piggery expanded by 28 fruit trees
2017	Three field houses replaced due to wind storm damage
2017	Pork program ceased
2017	Three additional raised beds 15 ft x 40" installed for carrot/shoulder season leaf production
2017	Five metal troughs 2x3x8ft installed for herb production
2017	Apprenticeship program started, first apprentice on the farm in August
2018	Two beds per block to be planted to medicinal herbs & pollinator species (0.33 acres of the 1.98-acre field)
2018	Six additional raised beds 15 ft x 40" installed for carrot/beet/leafy greens production
2018	Apprenticeship program increased to 3 part-time apprentices