Soil Health/Carbon Farm Plan
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Prepared by:

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Overview:

Ranch is a family-oriented diverse farm in ____, Washington. The ranch supports a diverse pasture-based livestock operation (beef, sheep, pigs, chickens), forested areas, lake and stream, gardens and orchard, and fish and wildlife. Ranch management is driven by the shared values of the owners and managers including:

- family
- land stewardship
- humane animal treatment
- rejuvenation and recreation
- experiences, especially for youth
- fun!

These values inform both long-term management objectives and annual/seasonal work plans. From our perspective as frequent visitors, Ranch is a great reflection of these values: It is a diverse operation that broadly embraces the practices of regenerative agriculture; soil health and land stewardship inform all management decisions; the pastures are improving year by year; care of and compassion toward the animals is exemplary; a committed group of young people are learning by doing; and a broad collection of family and friends are nourished around the dinner table regularly.

Prior to acquisition of the ranch in 2017, the property had been used primarily as a residence with a limited amount of livestock grazing. Since 2017, the ranch has benefitted from considerable investment in infrastructure, pasture renovation, timber stand improvement, and integration of livestock. These improvements include (but are not limited to):

- A new barn
- power and water service to various locations
- permanent fencing
- extensive brush clearing
- irrigation system improvements
- pasture fertilization and seed drilling
- timber thinning
- garden and orchard expansion
The farm team has clearly been busy over the past three years. The values and intent that underpin management of Ranch broadly reflect the practices of regenerative agriculture. Annual work plan reviews between owners and managers generally ensure that management of the farm and the guiding values are aligned and that the farm is progressing according to those values.

Ideally each of the guiding values would have a set of measures that provided a transparent and objective assessment of progress and trends. Such a monitoring framework would be an important tool to provide real data on effects of management actions and changes. Additionally, monitoring can provide validation for the messages about the farm, the benefits it provides, and the products coming from the farm. For example, a claim that the farm is helping address climate change would be backed by data on carbon storage in soils and emissions reductions from farm operations.

**Project goals and objectives**

The goals of this report are to provide recommendations to further establish Ranch as a future-focused regenerative farm actively working to build soil carbon and overall soil health, produce exceptional quality meats, and to reduce overall carbon emissions. This work will allow Ranch to test methods, measure change over time, effectively communicate the benefits of soil health to customers and other audiences, and serve as a positive, climate-friendly model for other farms.

The focus of this report is on soil health and carbon dynamics related to the pastures and livestock operation. A full monitoring framework would encompass the full range of values (e.g., is the farm providing positive experiences for youth?) and the full range of ecosystem benefits (e.g., wildlife and biodiversity, timber management, lake and stream health). These areas are outside of the scope of our current assessment.

Specifically, we have:

- Reviewed and collated past soil test and treatment information
- Developed recommendations for data management tools and adaptive management frameworks to use for soil and pasture management
• Recommended a monitoring framework for tracking soil health, pasture health, and nutrient density of meat produced on the farm

• Develop messaging for communicating goals of the farm to a variety of relevant audiences.

Below we provide our core recommendations along with supporting background information. In addition, we have summarized a larger body of information as background material to be used as reference information. This information is included in the Appendices sections of this report.

Recommendations

1. Establish a soil health baseline in 2020 as the starting point for regular monitoring. Samples should be taken after soils have dried out and pastures growth is in full swing (i.e., late June/early July) and repeated every three years at a minimum. The lab and field tests recommended below are an efficient means to cover the spectrum of soil health tests generally promoted by soil health experts (see Appendix 1, Table 1). Specifics include:

   Lab analysis of soil samples from both productive pastures and pasture restoration areas. Samples should be taken from representative areas and analysis repeated at least every 3 years. Minor training on sampling methods required. Time required is 2-4 hours/year for sampling and packaging/mailing. See Appendix 2 for soil sampling methods and tools. Cost = $75-100/sample. Minimum of two samples recommended (e.g., productive pastures plus pasture restoration areas).

   a. Field soil tests to determine bulk density, water infiltration rate, level of compaction, aggregate stability, visual observation of earthworms and legume root nodules. Initial minor investment in making equipment. Estimate 2-4 hours for training. Sampling = 4-6 hours/year. See Appendix 2 for soil sampling methods, tools and cost.

   b. Weed transects and invasive plant monitoring. Weed transects across pasture areas annually; invasive plant monitoring as part of normal property walks with special attention to disturbed areas (e.g., pig paddocks). Skill in plant ID required. Labor = 4-6 hours/year.

   c. Forage nutrient analysis [crude protein, brix] to monitor forage quality throughout the growing season. Brix levels in leaves can be regularly tested using an inexpensive refractometer (~$20) to track changes in forage quality throughout the season. Minor training involved.
d. Lake and stream water quality analysis for N and P levels. Inexpensive test strips can be used to see if nitrogen and phosphorus is leaching from pastures into surface water. Testing to be conducted monthly especially after rain events. Little training involved. Cost <$10 per monitoring event.

a. Pork, lamb and beef nutrient analysis to compare to commodity lamb and pork. Cost estimates pending from Cascade Analytic lab. Test once, possible repeating every three years. Labor estimate is one hour for sample preparation and packaging for sending to lab. No training involved. Cost being researched; not yet available.

2. Consider adopting a data management framework to integrate information on soil/pasture health and paddock use/management. Based on preliminary use (free 14-day trial) PastureMap appears to be a viable tool. Its strength is in planning and tracking herds and paddock moves, including the ability to subdivide pastures and track moves between subdivisions. Soil and forage quality data can be integrated, but it is a bit clunky, involving sending a spreadsheet to technical support at PastureMap who will integrate the data into the specific pasture location.

The cost of a PastureMap subscription is $42/month ($504/year) for the basic package or $62/month ($744/year) for the pro package. As with any software package, there will be a time investment required for learning the software (~10 hours), initial entering of pasture and herd information (~5-10 hours), and keeping data entry up-to-date (~1-2 hours/week).

3. Adopt the Five Freedoms of Animal Welfare - the globally recognized gold standard for humane livestock raising - and adhere to the practices that define the five freedoms. The five freedoms include:

- Freedom from hunger and thirst
- Freedom from discomfort
- Freedom from pain, injury, and disease
- Freedom to express normal and natural behavior
- Freedom from fear and distress.

The five freedoms were first articulated in the U.K. in 1965 and formalized by the Farm Animal Welfare Council in 1979. A number of non-profit organizations such as the American Humane Society provide auditing services and
certification around the five freedoms and the five freedoms are incorporated in the Regenerative Organic Alliance certification.

_______ Ranch is already managing the animals under its care in alignment with the five freedoms so adhering to the practices would not impose additional management burden or costs. Pursuing certification would involve additional documentation (e.g., written policies, record keeping) and hard costs paid to a certifying body. We are inquiring with certification bodies to provide an estimate of costs involved should the certification avenue be desired. The Regenerative Organic Alliance uses detailed criteria for determining the level of adherence to the five freedoms of animal welfare found here: https://regenorganic.org/pdf/ROC-Framework.pdf.

4. **Become an early adopter of the Soil Carbon Initiative standard.** The Soil Carbon Initiative (SCI) is a scientific standard designed to help farmers and supply chains measure improvements in soil health and soil carbon (see https://www.soilcarboninitiative.org/executive-summary). The SCI framework does not dictate practices and is focused on measuring outcomes. Producers can adopt the standard in any production system – conventional, Non-GMO, Organic, and Biodynamic. In addition, the outcomes focus allows supply chains to use SCI to measure the results of customized soil health programs. SCI is launching a certification program that appears likely to be widely accepted by interested producers.

The foundation of the SCI standard is tests of four performance areas: soil organic carbon, soil water dynamics, aggregate stability and microbial biomass. Participants in the SCI standard progress through stages of involvement:

1. **Enrollment**

2. **Demonstration of commitments to store carbon in the soil, steward water resources, enhance on-farm biodiversity, and advance knowledge of soil health**

3. **Outcomes-based testing of soil conditions (within one year of enrollment and then every three years)**

Farms can achieve SCI-verification by demonstrating either a high level of current soil health or measured progress in soil health. Importantly, _______ Ranch, once enrolled, would immediately meet the criteria for demonstrating commitments and, assuming baseline soil testing is conducted in summer 2020, would likely meet the SCI verification standards. Enrollment appears to have little downside and participation could both distinguish _______ Ranch products and contribute to an important national effort to improve soil health and soil carbon sequestration.
5. **Evaluate pig paddock impacts and recovery.** The pig paddocks present an interesting challenge (for management, assessment, and messaging). These paddocks are intensively used and disturbed given the pigs’ natural inclination to root. We recommend that a specific study be conducted to understand soil and vegetation impacts and recovery. The study can be designed with an adaptive management approach by trying different approaches (e.g., one year of rest vs two; seeding following use or not; efficacy of biochar application for nutrient retention; etc.) and measuring for differences. Areas of concern to be evaluated include: soil carbon, compaction, infiltration, leaching of excess phosphorus and nitrogen, invasive plant colonization. The primary costs would be for additional soil tests ($150-200/year) and time to design the studies, collect data, and interpret results.

6. **Consider conducting a greenhouse gas emissions assessment** for the overall _______ Ranch enterprise. The overall carbon footprint of an operation depends on the balance of carbon storage (e.g., in soils from regenerative practices) and emissions (e.g., from fossil fuel use). White Oak Pastures provides an excellent example of a whole-farm carbon accounting that has been integrated into their farm management and marketing ([https://blog.whiteoakpastures.com/hubfs/WOP-LCA-Quantis-2019.pdf](https://blog.whiteoakpastures.com/hubfs/WOP-LCA-Quantis-2019.pdf)).

   COMET-Energy is an open-source tool from Colorado State (see Appendix 4) that models overall farm emissions based on inputs related to type and number of animals, feeds used, fuel used on farm, etc. The software tool is free, though using it requires input of an extensive amount of information derived from farm records (utility bills, feed bills, livestock and cropping practices). NRCS may be able to provide technical support as the COMET suite of software tools are the official carbon accounting tools used by NRCS. There is no cost involved for use of the COMET software. There will be a time investment (~10-15 hours?) to compile and enter information on livestock numbers, feed types, duration on pasture, fuel use etc.

**Summary:**

We are impressed with the current practices on the farm and don’t perceive any practices that contradict what we understand about soil health and regenerative farming. Pasture conditions appear to have improved significantly since 2017 due to a regime of brush clearing and mowing, managed grazing, seeding and fertilization, and irrigation. Our impressions are subjective of course given the limited baseline and monitoring data. A solid baseline of soil, pasture, animal condition, and meat nutritional content needs to be established if an adaptive management approach is to guide management actions in the future.
References/Resources
The following includes references we used for in this draft plan plus additional resources that might prove useful going forward.

References & resources for soil health metrics


Soil Carbon Initiative’s soil health Performance Areas
https://www.soilcarboninitiative.org/executive-summary

Soil Health Institute Tier 1 soil health indicators and measurements
https://soilhealthinstitute.org/2017-tier-measurements/


NRCS: https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/ (Many soil health resources here...)


Measuring Soil Carbon and Soil Carbon Change

Metrics to Make it Work, presentation by J. Chiartas & A. McLauchlan, https://doc-0o-48-apps-viewer.googleusercontent.com/viewer/secure/pdf/v3vbgraacqao8cjokqfrm92tvns pf1nr/nntlt5ojrbtojinno9g1vqh8o65goju/1580426475000/drive/0786174222054036865/ACFrOgCzoSIf4XkLMnjED3VHdcHZ_QzuSJX8r0VE27ym196LdGR7TFmC

8
USDA/NRCS Kellogg Soil Survey Laboratory Methods Manual (2014) (good reference for standard procedures for soil health related measurements such as texture (particle size), clay mineralogy, bulk density, macro- and micronutrients, salt and exchangeable sodium contents, and several others.)


Weed analysis

*When Weeds Talk* by Jay L. McCaman (available from Acres USA).  (Includes weed charts and the associated soil issues. Then use Charles Walter's *Weed Control Without Poisons* to develop a plan to fix the soil issues.)

Dr. Elaine Ingham at Soil Foodweb Institute https://www.soilfoodweb.com (for which microbial communities interact with different types of plants and how best to manage for intended outcomes.)

Masters, Nicole. Integrity Soils (https://www.integritysoils.co.nz and her book *For the Love of Soil* (2019))

Utah State http://www.behave.net (on training animals to eat weeds)

Labs

Biological testing
  - www.earthfort.com  (direct count)
  - www.wardlabs.com  (Haney and PLFA)

Mineral
  - Ward labs www.wardlabs.com
  - www.ag-labs.com

Plant Tissue testing
  - https://agrilifeextension.tamu.edu/solutions
• Ward labs www.wardlabs.com
• Most soil labs do plant testing

Food Testing
• www.Eurofins.com

Tools
PastureMap – app for managing rotational grazing: https://pasturemap.com
Story about it: https://civileats.com/2018/06/08/pasturemap-brings-a-high-tech-approach-to-sustainable-grazing/

Cool Farm Tool: https://coolfarmtool.org/coolfarmtool/ Free, worth trying

OpenTEAM:
• OpenTEAM, or OpenTechnology Ecosystem for Agricultural Management, is a farmer-driven, interoperable platform to provide farmers around the world with the best possible knowledge to improve soil health. This work is nascent, but promises to offer field-level carbon measurement, digital management records, remote sensing, predictive analytics, and input and economic management decision support in a connected platform that reduces the need for farmer data entry while improving access to a wide array of tools.
• https://www.wolfesneck.org/openteam/ Worth tracking, and if/when bandwidth allows, it may be worth become a testing node farm?

Certification

Regenerative Organic Certification (https://regenorganic.org) (Restricted to certified organic growers, but excellent platform with useful information.)

Carbon Farm Planning & Assessing GHG Emissions On-Farm
Carbon Farm Planning (CFP) https://www.carboncycle.org/carbon-farming/carbon-farm-planning/
This is a whole farm approach to optimizing carbon capture on working landscapes developed by the Marin Carbon Project/Carbon Cycle Institute. It uses a subset of
the Natural Resource Conservation Service (NRCS) Conservation Planning process, but with carbon and carbon capture as the organizing principle. The CFP process uses COMET-farm to quantify GHG benefits.

COMET-Energy (http://comet-farm.com) COMET-Energy is a stand-alone tool that allows you to calculate reductions in greenhouse gas emissions based on anticipated fuel savings. You can use COMET-Energy by itself or in conjunction with your COMET-Farm user account.

Carbon Trust (https://www.carbontrust.com/resources/) has various tools and guides, including Carbon Footprinting and Energy Efficiency in Agriculture Guides,
Appendix 1 – A Soil Health and Soil Carbon Primer

The USDA/NRCS defines soil health as “the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans.” This definition reflects significant advances in our understanding of soil ecology in the past 10-20 years, and is a huge departure from the definition most prevalent since the mid-19th century, which was based primarily on maximum yields and application of fertilizer to drive productivity.

Healthy soil is a living, dynamic ecosystem that functions holistically. Healthy soil contains billions of bacteria, fungi, and other microbes that when provided the basic necessities of life - food, shelter, and water – interact to create a mutually beneficial, symbiotic environment. Healthy soil:

- Has the full complement of nutrients and micronutrients to promote vigorous plant growth and support healthy animals
- Is full of life, including soil microbes, mycorrhizal fungi, soil invertebrates
- Stores and cycles nutrients (including carbon, nitrogen and phosphorus)
- Is not compacted, instead has abundant spaces between soil particles
- Has stable soil aggregates that maintain soil structure and inhibit erosion and soil loss
- Absorbs excess water to prevent flooding
- Holds rainwater for use during dryer periods
- Filters and buffers potential pollutants from leaving fields
- Ultimately supports farm productivity and profitability, nutrient-dense food, and human health

Many soil properties impact soil health, but soil carbon, especially that contained in soil organic matter (SOM) deserves special attention because it enables many of the critical soil functions listed above, acting as a keystone element (i.e., without sufficient SOM the rest of the attributes of healthy soil begin to collapse). Soil organic matter is rich in nitrogen, phosphorus, sulfur, and micronutrients. It is comprised of about 50% carbon. Increasing soil organic matter can reduce atmospheric CO2 levels that contribute to climate change by capturing CO2 through photosynthesis, thus it’s the driving force behind “carbon farming” (see https://en.wikipedia.org/wiki/Carbon_farming). The number one recommendation of the USDA-NRCS Soil Quality Team is to increase soil organic matter (http://soils.usda.gov/sqi/).

Why measure soil health and soil carbon?
The saying goes “without measurement there is no management”. Reasons to implement a system for monitoring in any type of endeavor include:

- Benchmark – understand starting point and changes over time
- Adaptive management – take action in response to indicators
- Evaluate – when to change management strategy to better meet objectives
- Record – of conditions, events and management practices
- Inform – information to guide management effectiveness
- Warn – early warning for damaging practices changing conditions
- Track – changes over time & provide a record
- Proof – management intentions are effective
- Communication and transparency - assure customers and stakeholders

**Indicators for measuring soil health and soil carbon**

A soil health assessment is a measure of how well soil performs all of its functions now and how those functions are being preserved for future use. Measuring soil health and soil carbon are emerging practices based primarily on evaluating a suite of indicators. No one test provides a full measure of soil health, but several recently developed test suites combine sets of indicators to produce an important component of a soil health assessment.

The decision about what to measure should be based on management objectives (what are you managing for, and what do you need to know to determine if your actions are having the intended results?). Decisions about monitoring may also be based on or modified for enrollment in a specific program (e.g., NRCS 9-step conservation planning process) or a soil health/soil carbon certification system such as the Soil Carbon Initiative (SCI) (see Certification below).

**Recommended Soil Health Measures**

The following table of soil health measures is a synthesis and distillation of several recognized approaches based primarily around the Soil Carbon Initiative (SCI) recommendations with additions from other sources (see References/Resources).

Soil Carbon Initiative has four “performance areas”: Soil organic carbon, water holding capacity, aggregate stability, and microbial biomass along with three levels of assessment for each (subjective, field test, lab test). We have added other soil and plant indicators to the SCI matrix based on recommendations from NRCS, Nicole Masters, the Soil Health
Institute, and The Soil Carbon Coalition. Note there is considerable overlap in recommendations from all sources, and almost all of the SCI recommendations are also recommended by the other entities (exceptions noted).
Table 1: Summary of recommended soil tests- organized around SCI (red), with additions from NRCS (black), Masters (blue), SHI (green). Note there is considerable overlap of recommendations from all sources and almost all of the SCI recommendations are also recommended by the other entities (exceptions noted). (* indicates included in Haney Test)

<table>
<thead>
<tr>
<th>Subjective Assessment</th>
<th>Soil Color</th>
<th>Water holding capacity</th>
<th>Aggregate stability</th>
<th>Microbial biomass</th>
<th>Additional Soil indicators</th>
<th>Plant indicators</th>
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<tr>
<td></td>
<td>Soil Organic Carbon</td>
<td>Ponding assessment</td>
<td>Soil Compaction</td>
<td>Slake Test</td>
<td>Penetration Resistance test</td>
<td>Insect / Arthropod Assessment</td>
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<tr>
<td>In Field</td>
<td>TBD</td>
<td>NRCS Infiltration Test</td>
<td>Soil Compaction</td>
<td>Slake Test</td>
<td>Penetration Resistance test</td>
<td>Solvita CO2 Burst</td>
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<td></td>
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<td>Dual Head Infiltrometer</td>
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<tr>
<td>In Lab</td>
<td>*Dry Combustion Test</td>
<td>Soil Moisture Content</td>
<td>*Solvita Volumetric Aggregate Test (VAST)</td>
<td>*Solvita O2 Burst</td>
<td>Mycorrhizal colonization</td>
<td></td>
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<td></td>
<td>*SOM % Carbon</td>
<td>Pressure Plate</td>
<td>ARS Aggregate Stability Test</td>
<td>(NRCS recommends 4-day soil incubation</td>
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* indicates included in Haney Test.
* Brix

Brix is a measure of % dissolved solids (amino acids, proteins, minerals, vitamins) and the sugars produced during photosynthesis. Measuring plant sap Brix with a refractometer across several samples in a crop or pasture on a regular basis (Nicole Masters recommends daily testing) is an easy way to monitor overall crop or forage health. Brix levels change throughout the day as the sun rises and sets. It’s therefore important to take readings consistently at the same time of day from the same part of the plant to insure comparable results over time. Generally, optimal health and quality for grasses is indicated by Brix reading above 12, and for most legumes above 14. Monitoring for Brix can help directly and immediately inform management (e.g., graze when Brix is highest; if low skip the rotation).
Soil Carbon Overview

(Primary source https://soilcarboncoalition.org/files/MeasuringSoilCarbonChange.pdf )

Carbon arrives in soil through photosynthesis, when plants growing in healthy soils capture carbon from the air and through their root system transfer it to microbes in the soil. Increasing the amount of photosynthetically captured carbon held, or “sequestered,” in long-term carbon pools on the farm, including soil organic matter, perennial plant roots and standing woody biomass, directly reduces the amount of carbon dioxide in the atmosphere. Carbon can be beneficially stored long-term (decades to centuries or more) in soils and vegetation through biological carbon sequestration.

Carbon exists in the soil in many forms but for the purposes of measurement and analysis there are three main forms: organic soil carbon, charcoal and inorganic soil carbon. All three forms can be important to soil health and fertility but it is soil organic carbon (SOC) that is often used as a gauge or indicator of healthy, productive soils.

**Soil organic carbon** is the carbon component (50–58 percent carbon by dry weight) of soil organic matter (SOM), material derived from living tissue: plant leaves and roots, sap and exudates, microbes, fungi, and animals. SOC holds many times its weight in water. Its critical sticky components (such as glomalin) play a critical role in the formation of soil aggregates, which give soil its stability against weathering and erosion, and its ability to hold water and air for plants and microbes.

Soil organic matter may be the most valuable form of soil carbon, but is generally the least stable, though some forms may persist for a thousand years or so. Many forms of SOM are readily oxidized (turned into carbon dioxide) by common bacteria in the presence of oxygen. But it is also the form of soil carbon that can readily increase as a result of plant growth, the root shedding of perennial grasses, the incorporation of manure or compost, the liquid carbohydrate exudates of plant roots, all processed by microbial metabolisms. Soil organic matter is the most abundant form of soil carbon.

**Charcoal** also derives from living tissue, so it is considered organic. It is often called biochar. It can range from 50 to 95 percent carbon by weight. It is more stable and more resistant to bacterial oxidation than most other forms of organic carbon, which is one reason why there is considerable interest in incorporating biochar into soil as a carbon sequestration strategy.

**Inorganic soil carbon** is mineralized forms of soil carbon such as calcium carbonate (CaCO3) or caliche. It is more stable than most organic carbon because it is not food or fuel for microorganisms. Because acid dissolves calcium carbonate, it is not usually abundant in soils of pH 7 or lower, or in humid regions. Carbonates are common in more arid regions and alkali soils, and are a significant soil carbon pool worldwide, derived mostly from organic carbon fixed by photosynthesis.
Inorganic carbon, while it does not possess the water-holding and soil-enhancing properties of organic carbon, is nevertheless a significant sink for atmospheric carbon, though it typically changes at a slower rate.

There are two commonly measured attributes of soil carbon:

1. **Trend**, or percentage change in soil carbon, to a given depth (e.g., in three years soil carbon percentage in the top 30 cm has changed from 1.9% to 2.7%, a relative gain of 42%). Conclusions about trend in soil carbon require measurement of only one parameter: carbon percentage in soil.

2. **Mass**, quantity, or tonnage of soil carbon, per hectare or per acre, to a given depth (e.g., in three years this area, plot, or field has added 4.2 tons C (equivalent to 15.4 tons CO2) per hectare per year. Conclusions about mass or quantity of soil carbon require measurement of two parameters: 1) carbon percentage of soil, multiplied by 2) bulk density of soil (dry mass per unit volume). This multiplication converts percentage carbon to mass.

Because of variability combined with relatively small sample sizes, both types of measurements result in statistical estimates, qualified by standard error (± error) and probability or confidence (for example, p ≤ .05 or 95% confidence).

For purposes of feedback to management, or establishing that management is storing more soil carbon, or for progress in soil quality, trend may be all you need. See soilcarboncoalition.org/changemap.htm for some examples.

The policy and “offset” market discussions have focused on mass, quantity, or tonnage of carbon or carbon dioxide. Detecting change in soil carbon mass, since it requires measurement of three parameters (carbon percentage, volume sampled, and bulk density) is more complicated.

**Measuring carbon**

Carbon exists in the soil in many forms but for the purposes of measurement and analysis there are three main forms: organic soil carbon, charcoal (biochar) and inorganic soil carbon (mineralized forms). All three forms can be important to soil health and fertility but it is soil organic carbon (SOC) that is often used as a gauge or indicator of healthy, productive soils. Most research indicates that change in soil carbon occurs most readily in the soil organic matter fraction, so that if you detect change, it is likely to be in the organic carbon.

Soil carbon cannot be measured directly, however there are several common indirect measures. Some remote sensing and high-tech field methods of assessing soil carbon are now being used, including COMET farm, and others are in development.
The Soil Carbon Coalition (Peter Donovan et al) has developed a methodology for measuring soil carbon aimed at detecting change over time (see the field procedures here: [https://soilcarboncoalition.org/challenge-procedures/](https://soilcarboncoalition.org/challenge-procedures/) and the more comprehensive manual here: [https://soilcarboncoalition.org/files/MeasuringSoilCarbonChange.pdf](https://soilcarboncoalition.org/files/MeasuringSoilCarbonChange.pdf). They believe the most reliable method is careful, repeated field sampling followed by laboratory analysis. Their method establishes one or more benchmarks or fixed plots from which a time series of multiple samples can be taken and analyzed, in order to detect and measure change over relatively long periods of time (3-10 years). They believe the most accurate standard laboratory test for soil carbon is the dry combustion method, often called elemental analysis.

To measure different forms of soil carbon they recommend the following tests:

<table>
<thead>
<tr>
<th>Form or aspect of soil Carbon</th>
<th>Tests</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic C</td>
<td>Dry combustion (prior acidification of sample will remove inorganic carbon), loss on ignition, Walkley-Black, soil respiration, active carbon tests</td>
<td>The largest and most important soil carbon pool</td>
</tr>
<tr>
<td>Inorganic C (carbonates)</td>
<td>Dry combustion (with organic carbon subtracted)</td>
<td>An important soil carbon pool, but slower to change</td>
</tr>
<tr>
<td>Charcoal</td>
<td>Dry combustion, Walkley-Black (partial)</td>
<td>Recalcitrant form of organic matter</td>
</tr>
<tr>
<td>Total carbon</td>
<td>Dry combustion</td>
<td>For most purposes, dry combustion is the best and most accurate test</td>
</tr>
<tr>
<td>Bulk density</td>
<td>Oven-drying and then weighing a sample of known volume</td>
<td>Essential to be able to quantify mass or tonnage of carbon in soil</td>
</tr>
</tbody>
</table>
Appendix 2 – Soil Health Tests

Standardized soil tests have been conducted for decades that look at a narrow subset of soil characteristics including soil pH, organic matter, major nutrients (e.g., N-P-K) and minerals. These tests are typically used to make recommendations about fertilizer applications to support various crops and do not measure broader soil health parameters.

Recently developed soil tests are aimed at helping producers measure and monitor the impact of their efforts to improve soil health. These tests integrate chemical and biological soil test data to quantify soil health. They have been developed to help overcome some of the limitations of conventional soil test procedures and add to the understanding of management effects and nutrient cycling in soils.

Currently, a coalition of organizations is undertaking an effort to identify and adopt a suite of standardized soil health indicators for North America. To date, the coalition has proposed 19 “Tier 1” widely-accepted indicators and 12 “Tier 2” indicators that need additional research. The effort will also evaluate three soil health frameworks: the Soil Health Management Assessment Framework (Andrews et al., 2004), Cornell’s Comprehensive Assessment of Soil Health (Moebius-Clune et al., 2016), and the “Haney test” (Haney et al., 2010). Once finalized and adopted, these measures may become the new standard and be available from soil test labs throughout the country.

Solvita Soil Respiration

The Solvita low-CO2 probe is used to assess soil health. Carbon dioxide (CO2) emissions from soil are primarily due to microbial respiration. The level of microbial activity is indicative of the amount of active organic matter that is being broken down and nutrients being released. Both a Basal Respiration field method and a CO2-Burst lab method provide a quantitative level soil health.

Field or Basal Respiration is based on using minimally disturbed or unaltered soil taken directly from the field with no lab processing or drying. This test is most appropriate to observe native respiration and carbon emissions from unaltered soil. “CO2-Burst” is a lab protocol based on pre-drying and sieving soil and then subjecting it to a rapid rewetting to capture the pulse of “flush” of CO2 that results. This test is best for tilled or other disturbed soils.

The Solvita CO2-Burst test can be used alone but is also an important component of the Haney Soil Health Test. The Cornell CASH test uses a similar CO2 release test, but measures release over four days rather than one day.
Haney Soil Health Test

The Haney soil health test, developed by Rick Haney of United States Department of Agriculture-Ag Research Service, is designed to mimic nature’s approach to soil nutrient availability.

The Haney test uses unique soil extracts in the lab to determine what quantity of soil nutrients are available to soil microbes. This test also evaluates soil health indicators such as soil respiration, water-soluble organic carbon, organic nitrogen and their ratio. These results indicate the amount of food that is readily available to soil microbes and is sensitive to measuring root exudates and decomposed organic material. The test results should be used as a comparison over time to determine progress in improving soil health in a given location.

Haney Soil Health Test results include:

- **N-P-K**
  
The results for these represent the amount of nitrogen, phosphate, and potash in the soil in lbs. per acre. The results include the inorganics nitrate, ammonia, and phosphate from an H3A extract and the nitrogen and phosphorus the soil microbes can provide through microbial activity. The inorganic nitrogen (ammonia and nitrate) can easily be lost through plant uptake or erosion/leaching.

- **Soil respiration (Solvita CO2-Burst Test):**
  
  This test is one of the most important numbers in the soil health report. The result (in ppm) is the amount of CO2-C released in a 24-hr. period from soil microbes after the soil has been dried and re-wetted and is an indication of the microbial activity of the soil. The microbial activity is an excellent indicator of soil fertility. As soil microbes grow and reproduce, they take in nutrients and give off carbon dioxide as a by-product and the greater the amount of carbon dioxide, the greater the microbial activity.

- **Water-extractable organic Carbon:**
  
The result has units of ppm and is a measurement of the amount of organic carbon extracted from the soil with just water. This carbon source is what is used by the soil microbes and reflects the quality of the soil.

- **Water extractable organic Nitrogen:**
  
  This result is a measurement of the amount of nitrogen that can be extracted by water but does not include inorganic nitrogen sources such as ammonia or nitrate. Like extractable organic carbon, the organic nitrogen is easily broken down by microbes to inorganic nitrogen forms that can be used by plants.
- **Organic Carbon: Organic Nitrogen ratio:**

  This is a unit-less result comparing the amount of water extractable carbon to water extractable organic nitrogen (C: N ratio). The ratio is important in microbial activity in the mineralization of nitrogen and phosphorus. The optimal ratio is between 8:1 and 15:1.

- **Soil health score:**

  A soil health score is calculated based on soil respiration and water extractable carbon and nitrogen (determined as 1-day CO2-C divided by the organic C: N ratio plus the water extractable organic carbon/100 + water extractable organic nitrogen/10). The calculation combines 5 independent soil measurements and varies from 0 to over 50. The goal is to see an increase in the number over time as a result of using soil-building practices. Due to the inherent differences in climatic regions and soil types Haney test scores are regionally relative and cannot be compared across widely different areas.

  Calibration of test results is ongoing to establish the extent to which biological tests can predict fertilizer needs on a range of soils since they use different extracts compared to traditional soil test labs.

  The value of the Haney test is to determine a baseline of soil health for that location. It is important to standardize the time of year and crop rotation when comparing over time.

More information:

- Ward laboratory  [https://www.wardlab.com/](https://www.wardlab.com/)
- Brookside Laboratory  [https://www.blinc.com/](https://www.blinc.com/)
- Midwest Laboratory  [https://midwestlabs.com/](https://midwestlabs.com/)
- Woods End Laboratory/Solvita  [https://solvita.com/soil/](https://solvita.com/soil/)

**Cornell Comprehensive Assessment of Soil Health (CASH)**

The Cornell CASH ([https://soilhealth.cals.cornell.edu](https://soilhealth.cals.cornell.edu)) was the first commercially-available lab test to add important biological and physical parameters to the nutrient analysis typical of most soil tests. The CASH is similar to the Haney test in intent and many parameters. This is the test recommended by the Regenerative Organic Alliance for their certification.

The measurements include:

- soil texture (to help interpret other measured indicators)
- available water capacity
- field penetrometer resistance
• wet aggregate stability
• organic matter content
• soil proteins
• respiration
• active carbon
• macro- and micro-nutrient content assessment
• Add-on tests include root pathogen pressure, salinity and sodicity, heavy metals, boron and potentially mineralizable nitrogen.
Appendix 3 – Soil and Vegetation Sampling Tools and Guides

Every soil testing lab will provide specific guidance on how they want soil samples taken, processed, and sent. These instructions are important to follow carefully.

For general guidance, the Regenerative Organic Alliance provides an excellent guide: https://regenorganic.org/pdf/ROC-Soil-Sampling-Guidelines.pdf

In addition, NRCS has instructions on assembling and using a field soil test kit: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_050937.pdf

Many of the tests included in the NRCS kit/guide can be done more efficiently and accurately by either the Haney or Cornell CASH tests in a lab. Other tests, including bulk density, resistance to penetration, and infiltration rate, must be done in the field and some tools are required (in addition to those commonly found in a farm shop):

1. 3” diameter pipe, 5” long for bulk density sampling  shop made
2. 6” diameter pipe, 5” long for infiltration measurement  shop made
3. Spade for digging soil (loing, straight blade)  $25-$50
4. Soil sampling probe  $50-$100
5. Penetrometer (buy or borrow from NRCS or Cons. District)  $180-$300
6. Brix refractometer  $18
7. Nitrite/nitrate and ortho-phosphate test strips  $50
Appendix 4 – Weed indicators

Plant community health and composition, including weed species, help reveal underlying soil conditions. For example Dock (*Rumex spp.*), Canadian thistle (*Cirsium arvense*), and Buttercup (*Ranunculus repens*) are indicators of compacted soils, while woodland species like such as Blackberry, wild rose, Foxglove (*Digitalis*), Hollyhock (*Alcea rosea*) indicate a microbial imbalance favoring fungal species. The first step is to monitor and understand what factors are driving germination of specific weeds.

There are 6 primary and related reasons why weeds germinate:

1. To colonize bare soil
2. In response to low OM
3. To open up compacted soils
4. In response to mineral availability
5. Microbial stimulation
6. As a safety valve for toxins

The following table summarizes some common weeds that indicate an underlying soil issue, and some examples of corrective actions.

<table>
<thead>
<tr>
<th>Weed</th>
<th>What it's indicating</th>
<th>What to do</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheatgrass (<em>Bromus tectorum</em>), Spotted knapweed (<em>Centaurea stoebe</em>), etc...</td>
<td>Low OM</td>
<td>Spread, feed &amp; add organic materials, manage for max ground cover, animal trampling, cover crops, etc.</td>
</tr>
<tr>
<td>Dock (<em>Rumex spp.</em>), Canadian thistle (<em>Cirsium arvense</em>), Buttercup (<em>Ranunculus repens</em>), etc...</td>
<td>Compacted soils or surface crusting</td>
<td>Multi-species cover crops w/ deep-rooted spp., rip/aerate &amp; drip w/ a carbon (humic acid, molasses, etc.)</td>
</tr>
<tr>
<td>High K/low P: Dandelion (<em>Taraxacum spp.</em>), Common plantain (<em>Plantago major</em>), Black nightshade (<em>Solanum nigrum</em>), etc.</td>
<td>Mineral availability</td>
<td>ID if functional or total deficiency -test weeds against crop &amp; soil tests; use sm amt mineral applied with carbon as catalyst to shift mineral availability.</td>
</tr>
<tr>
<td>Woodland species such as</td>
<td>Microbial imbalance:</td>
<td>Microbial soil test; check</td>
</tr>
<tr>
<td>Blackberry, wild rose, Foxglove (<em>Digitalis</em>), Hollyhock (<em>Alcea rosea</em>), Wormwood (<em>Artemisia spp</em>), etc.</td>
<td>Fungal dominated or 'sleepy' soils</td>
<td>Brix to see which plants happiest; optimize grazing management; biostimulants, compost extracts, carbon inputs to push succession backward or forward</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Early colonizers like Crab grass, Cheat grass &amp; Medusahead rye (add latin…)</td>
<td>Microbial imbalance: Bacterial dominated soil</td>
<td></td>
</tr>
<tr>
<td>Nettles (<em>Urtica dioica</em>), Lambsquarters (<em>Chenopodium album</em>), etc…</td>
<td>Removing high levels of toxins or nitrates from soil</td>
<td>Check Brix to see which plants happiest; Nitrates can be mopped up with humates, milk, fish hydrolysates and vermicast.</td>
</tr>
</tbody>
</table>

(Compiled from Nicole Masters *For the Love of Soil* and NRCS 2001 Suggested Management Solutions to Soil Quality Problems (p. 30)

**Recommendations for more in-depth weed analysis:**

*When Weeds Talk* by Jay L. McCaman (available from Acres USA). Includes weed charts and the associated soil issues. Then use Charles Walter's *Weed Control Without Poisons* to develop a plan to fix the soil issues.

See also Dr. Elaine Ingham at Soil Foodweb Institute for which microbial communities interact with different types of plants and how best to manage for intended outcomes. [https://www.soilfoodweb.com](https://www.soilfoodweb.com)

Utah State on training animals to eat weeds [http://www.behave.net](http://www.behave.net)
Appendix 5 – Planning Frameworks and Monitoring Tools

We evaluated several frameworks that could be used as tools for soil health monitoring including:

- NRCS Conservation Planning
- Holistic Resource Management (HRM)
- Open Standards for the Practice of Conservation
- PastureMap
- COMET-Farm and COMET-Planner
- LandPKS
- Open Technology Ecosystem for Agricultural Management (OpenTEAM)

The first three frameworks are really different implementations of an adaptive management framework and include common elements of setting goals and objectives; understanding the landscape context; designing management actions; monitoring progress; evaluating effectiveness relative to goals and objectives; and modifying management actions as needed.

PastureMap is an app-based tool to support grazing management and record and track data on pasture conditions.

The COMET-Farm and Planner tools are used to estimate or predict the potential carbon capture and emissions of various farm management actions. COMET is the carbon accounting system used by NRCS.

Similarly, LandPKS is currently a predictor of land capacity rather than an adaptive management tool. (LandPKS has farm management modules under development.)

Finally, OpenTEAM is a multi-sector effort to develop a suite of tools to assist in farm planning and management to improve soil health and carbon capture. The project is in early stages. While not ready for adoption at this time, OpenTEAM should clearly be on the radar as the suite of tools are developed and refined.

NRCS Conservation Planning has been developed specifically for farming and ranching applications. It is a comprehensive approach that integrates ecological, economic and regulatory needs and has considerable flexibility and a depth of supporting materials. Importantly, an NRCS compliant conservation plan is a prerequisite for receiving funding from NRCS from various conservation programs such as Environmental Quality Incentives Program (EQIP). As such, the NRCS approach is used extensively.

The NRCS approach makes extensive use of a variety of templates and checklists, and the recommended actions are often somewhat generic fact sheets that cover
issues such as ‘nutrient management’ or ‘watering facility’. As such, the plans wind up being a bit “plug-and-play” and formulaic.

In addition, the NRCS planning approach focuses on practices rather than specific outcomes. There is an underlying assumption that if the practices are implemented, then there will be a positive response in aspects of the farm. There appears to be no emphasis on monitoring to determine if there is in fact a benefit to the land or water.

The **HRM approach** grew out of a body of work around arid land grazing by Alan Savory and the approach is often misconstrued as applying only to intensive rotational grazing. In reality, it is a broadly applicable adaptive management approach that starts with an articulation of broad life goals. The strengths of the HRM approach include an explicit situation analysis of ecosystem processes (biological community, water cycle, mineral cycle, energy flow) and testing proposed management actions against a set of probing questions (root cause, weak links, comparing options, gross profit analysis, input analysis, vision analysis, and gut check).

**Open Standards for the Practice of Conservation** was developed by a consortium of conservation organizations as a standard method for designing and evaluating conservation actions. Although developed as a tool for strategic conservation, the tool is flexible enough to have broader applicability. One of the key strengths of the Open Standards approach is development of an explicit, usually graphic, ‘results chain’ that shows how proposed management actions are assumed to create a desired effect, either at improving ecosystem condition or reducing the stresses on an aspect of the ecosystem. Second, key ecological attributes are defined as the most important elements of the biological system in question. The ecological attributes form the basis for creating indicators of ecosystem health that can evaluated in terms of current and desired condition.

**PastureMap** is an app designed to manage and track information relevant to grass-based grazing operations. Management information is tied to pasture maps and stored in the cloud. PastureMap can store information on grass and soil health, weight and condition of livestock, grazing history and moves between paddocks, etc. It is subscription-based (Basic $42/month, Pro $62/month, or custom enterprise pricing).

The **COMET** suite of tools are used widely by NRCS and others as the primary carbon accounting tool for agricultural applications. COMET uses research-based biogeochemical models, IPCC models, and other published research to predict and/or estimate carbon dynamics under various cropping and pasture management scenarios. Soil and land cover data is pulled automatically from existing soil maps and remotely sensed data, with cropping and other management information provided by the farmer. As such, COMET provides a first level of approximation and a means to evaluate potential carbon dynamics of potential future management alternatives, rather than direct measure in the field. One module of COMET –
COMET-Energy – provides an accounting tool to estimate greenhouse gas emissions from a farm, incorporating data on fuel use, livestock type and management (including feed) and other inputs.

**LandPKS** has been developed by USDA with initial implementation in Africa. The primary intent has been to provide easy access to remote-sensing data on soil and landcover and subjective assessment of soil and vegetation characteristics (e.g., color, texture, landscape position, % cover) in the field to provide a first approximation of productive potential. The tool will include modules for land/farm management and soil health.

**OpenTEAM** is being developed by a consortium of government, farmers, researchers, and food companies as a platform to support adaptive management of soil health on farms and ranches at any scale across all geographies. The tools will support “…field-level carbon measurement, digital management records, remote sensing, predictive analytics, and input and economic management decision support in a connected platform that reduces the need for farmer data entry while improving access to a wide array of tools (source: https://www.wolfesneck.org/openteam/).” Both COMET and LandPKS are involved in tools development with OpenTEAM.

OpenTEAM does not appear to be ready for broad implementation at this time. As their work progresses, this platform should become a rich source of tools and data to improve soil health.

Following are two tables; first comparisons of farm planning tools, and second a summary of soil tests and treatments on the BBB to date.
## Comparison of Farm Planning Tools

<table>
<thead>
<tr>
<th>Tool/Approach:</th>
<th>Description:</th>
<th>Pros:</th>
<th>Cons:</th>
</tr>
</thead>
</table>
| NRCS Conservation Planning                | “A conservation plan is the record of decisions and supporting information for treatment of a unit of land meeting planning criteria for one or more identified natural resource concerns as a result of the planning process. The plan describes the schedule of implementation for practices and activities needed to solve identified natural resource concerns and takes advantage of opportunities.” (Source: NRCS) | • Whole farm planning  
• Widely accepted in farming circles  
• Abundant supporting material  
• Required for NRCS grant support | • Focused on management activities rather than outcomes.  
• Guidance is somewhat generic; prescriptions based on general NRCS guidance. |
| Holistic Resource Management (HRM)        | “Holistic Management is a whole farm planning system that helps farmers, ranchers and land stewards better manage agricultural resources in order to reap sustainable environmental, economic, and social benefits. This “triple bottom line” of benefits can be achieved by maximizing the management of current resources. Whether land is used for ranching, food production or public land | • Whole farm planning  
• Robust adaptive management framework  
• Integrates biological, financial & social aspects  
• ID's weakest links and stress test of management options  
• Adaptive framework that includes regular monitoring and adjustment | • Limited guidance on developing monitoring framework  
• Broad scope may be more than required for narrower application |
<table>
<thead>
<tr>
<th><strong>Open Standards for the Practice of Conservation</strong></th>
<th><strong>COMET-Farm</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>“...an adaptive management approach that helps project teams systematically plan their projects, determine if their projects are on track, why they are on track or not, and what adjustments they need to make. To be successful, a project must be based on both sound project assumptions (theory) and good implementation.” (Source: cmp-openstandards.org)</td>
<td>“COMET is the official greenhouse gas quantification tool of USDA. COMET-Farm uses information on management practices on an operation together with spatially-explicit information on climate and soil conditions from USDA databases (which are provided automatically in the tool) to run a series of models that evaluate sources of greenhouse gas emissions and carbon”</td>
</tr>
<tr>
<td>• Widely accepted in farm circles, especially ranching/grazing.</td>
<td>• Widely used farm carbon accounting tool</td>
</tr>
<tr>
<td>• Robust adaptive management framework</td>
<td>• Based on best available models of emissions &amp; sequestration; useful for first approximation of carbon dynamics and prediction.</td>
</tr>
<tr>
<td>• Especially strong for developing monitoring and evaluation around key attributes &amp; indicators of current and desired condition.</td>
<td>• Uses greenhouse gas models grounded in research</td>
</tr>
<tr>
<td></td>
<td>• Modules nested within the model</td>
</tr>
<tr>
<td>• Not widely known in farming circles</td>
<td>• Estimation tool rather than empirical.</td>
</tr>
<tr>
<td>• Originally built for biodiversity conservation; guidance must be adapted to farming</td>
<td>• A useful tool but not a whole farm planning framework.</td>
</tr>
</tbody>
</table>
sequestration.” (source: NRCS)  

include: Croplands, Livestock, Agroforestry, Energy

| **PastureMap** | “Using PastureMap on their phones, ranchers manage grazing history and planning, keep track of herd information like weights and health issues, document grass and soil health, and keep their whole ranching team informed. The information is stored in one place and is easy to analyze, for short-term decisions like where to graze the herd that day, to long-term decisions like planning out future pastures or placing water tanks and fencing.” (from Stanford Business Insights article) | • Excellent tool for planning, execution, and monitoring of pasture-based grazing system.  
• Spatially-explicit; allows field observations and livestock moves to be connected to specific pastures and locations.  
• Well designed for rotational grazing systems. | • Not a whole farm planning framework  
• Recurring monthly cost |
| **LandPKS** | “LandPKS delivers tools and knowledge through an app with a series of data modules in order to manage land to be productive, resilient, and healthy. LandPKS currently has two modules available: LandCover and LandInfo. LandCover is used to monitor vegetation cover and LandInfo helps determine | • Simplified assessment of soil in the field  
• Modules for soil health and land management forthcoming  
• Land capability assessment for low expertise farmers | • Likely too simple a tool for many applications |
the potential of the soil. Both are available globally.

| **OpenTEAM** | OpenTEAM is a farmer-driven platform to provide the best possible knowledge to improve soil health. The platform will include field-level carbon measurement, digital management records, remote sensing, predictive analytics, and input and economic management decision support in a connected platform that reduces the need for farmer data entry while improving access to a wide array of tools. The platform will support adaptive soil health management for farms of all scales, geographies and production systems. | • Promises to be a powerful integrated platform to improve soil health and agricultural management. • Strong data capture and management; useful for tracking monitoring information • Supports research by allowing data to be bundled and analyzed across many farms and geographies. | • Platform in early stages of development; tools not yet available |
# Appendix 6 - Summary of________ Ranch Soil Treatments to Date

<table>
<thead>
<tr>
<th>Location:</th>
<th>Size (ac):</th>
<th>Treatment:</th>
<th>Treatment Notes:</th>
<th>Date:</th>
<th>Notes:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main Field</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>East 2.5 ac and narrow areas to E and SE of driveway, not including .45 ac eyebrow</td>
<td>2.85</td>
<td>No till drill</td>
<td></td>
<td>Fall 2017</td>
<td></td>
</tr>
<tr>
<td>Entire main field plus .25 ac narrow area E of driveway; not including eyebrow</td>
<td>4.25</td>
<td>Fertilizer</td>
<td></td>
<td>Spring 2018</td>
<td></td>
</tr>
<tr>
<td>West portion of main field</td>
<td>1.5</td>
<td>No till drill</td>
<td></td>
<td>Fall 2018</td>
<td></td>
</tr>
<tr>
<td>All except eyebrow</td>
<td>4.7</td>
<td>Fertilizer</td>
<td></td>
<td>Fall 2018</td>
<td></td>
</tr>
<tr>
<td><strong>Oak Pasture</strong></td>
<td>1</td>
<td>No till drill</td>
<td></td>
<td>Fall 2018</td>
<td></td>
</tr>
<tr>
<td><strong>North Barn pasture</strong></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Oak Valley</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>No till drill</td>
<td>Spring 2018</td>
<td>Conser</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Fertilizer</td>
<td>Fall 2018</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>West Pasture</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central portion</td>
<td>4</td>
<td>No till drill</td>
<td></td>
<td>Fall 2018</td>
<td>Conser</td>
</tr>
<tr>
<td>Location</td>
<td>Seed Mix</td>
<td>Fertilizer?</td>
<td>Remarks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------</td>
<td>-------------------</td>
<td>-----------------------------</td>
<td>---------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northern portion</td>
<td></td>
<td>No till drill</td>
<td>Fall 2019</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northwest Pasture</td>
<td>2.3</td>
<td>No till drill</td>
<td>Fall 2019</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steer Winter Pasture</td>
<td>.65</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lake Pasture</td>
<td>3.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D &amp; H Pasture</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W &amp; D Pasture</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Seed mix (from A’s 10/17/2019 invoice):
- PGG Crusader Ryegrass (15#/ac)
- Atom Brom Prairie Grass (10#/ac)
- Gala Brome FGrass (10#/ac)
- Haifa White Clover (3#/ac)
- Kakariki New Zealand White Clover (3#/ac)
- Medium Red Clover (3#/ac)
- Vernal Alfalfa (5#/ac)

Fertilizer blend (from A’s 10/17/2019 invoice; application rates are approximate):
- 4-4-2 Perfect Blend (250#/ac)
- Fish Bone Meal 4-13-0 (250#/ac)
- Sulfate of Potash (56.25#/ac)
- Calpril (400#/ac)
(Note Map removed from this version)