Compact Farms: A Step Towards Sustainability

Whistle Stop Farm, Atascadero, CA

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California Polytechnic State University, San Luis Obispo

Acknowledgements

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“A nation that destroys its soil destroys itself.”- Franklin D. Roosevelt

1.0 Introduction

Agriculture is the only industry that provides humans with two basic necessities of life, food and shelter. Since the dawn of the agricultural revolution in the 18th century, the production of food, feed, and fiber has allowed for the Industrial Revolution and human growth, however, the agricultural industry has also manifested negative and unsustainable repercussions. Sustainable agriculture today, is meeting society’s food and textile needs in the present without compromising the ability of future generations to meet their own needs, while integrating three main objectives: a healthy environment, economic profitability, and social equity (Feenstra). Currently, the agricultural sector has negative effects in all three aspects of sustainability. The effects on the environment include; climate change, soil degradation, water pollution, and the decrease of aboveground and belowground biodiversity. Economically, small family farms, which make-up over 90 % of farms in the United States have been closing at an alarming rate (Kassel). The closure of family farms is also intensified by the aging population of farmers. The average age of farmers in the United States is fifty-eight years old and young individuals do not want to fill the void (Fursdon). Ethically, the agricultural industry produces labor conditions and wages that are unsustainable for the farm working community. The question arises, how can agriculture achieve the three e’s of sustainability? Compact farms can be a potential solution for the present calamities faced by agriculture. A compact farm refers to any operation that is five acres or less and due to their size, can have multiple benefits that can enhance sustainability. Compact farms are human scaled, which means they can be more manageable and easily approached (Volk). A business, which can be easily and affectively managed lends itself to having a better chance of achieving the spheres of sustainability. Farmers who operate compact farms, can focus on diversifying their operation, tending to the land, adding value to products, and connecting to the local community. Compact farms also have lower startup costs, which can attract new, young farmers. In an age when agriculture accounts for 10.0 % of greenhouse gas emissions (USDA), soils are eroding at a rate of 18 times faster than they are being replenished (NRCS), a disconnection exists between farmers and people, land prices are high, and food prices are low, looking into compact farms as a potential solution needs to be done. This project outlines the first steps in which I have taken to creating my own compact farm, Whistle Stop Farm. The steps are broken down into two of the three e’s of sustainability, with the hope that the information can be used as a potential source for new farmers and a model of sustainability for the present and future agricultural industry.

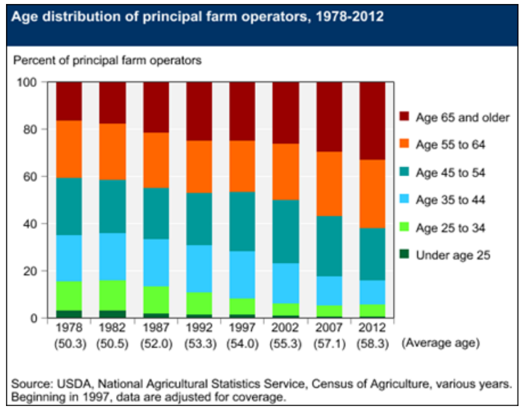

Figure 1: Average age of farmers in U.S.

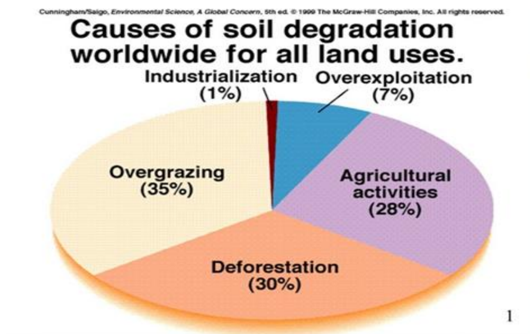

Figure 2: Soil degradation by industry sector.

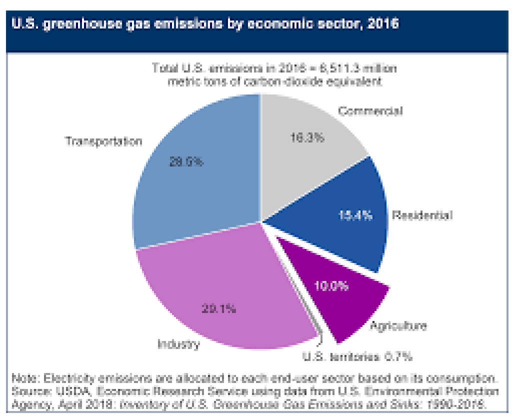

Figure 3:Greenhouse gas emissions by sector.

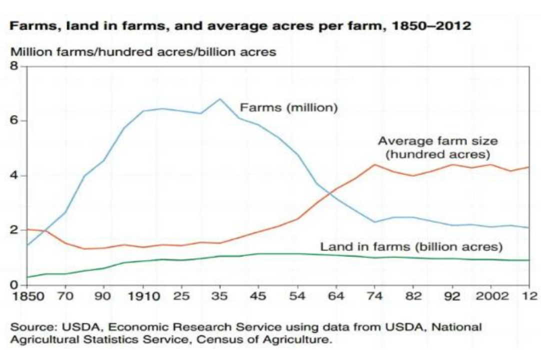

Figure 4: Number of farms in the U.S.

2.0 Site Description

Whistle Stop Farm is in Atascadero, California and has a growing zone of 9a. The farm has 2.8 acres of arable land. Whistle Stop Farm has a still clay loam soil, with a slope of 0 to 2 %, and is naturally well drained. There is 200-day frost-free period and when irrigated the land is classified as prime farmland. The average precipitation is 12 to 20 inches and the land is located in a Mediterranean climate. A soil description of Whistle Stop Farm was provided by the Natural Resource Conservation Service (NRCS) and can be seen in figure 5.

San Luis Obispo County, California, Paso Robles Area

208—Still clay loam, 0 to 2 percent slopes

Map Unit Setting

National map unit symbol: hbvz
Elevation: 600 to 1,500 feet
Mean annual precipitation: 12 to 20 inches
Mean annual air temperature: 60 degrees F
Frost-free period: 200 days
Farmland classification: Prime farmland if irrigated

Map Unit Composition

Still and similar soils: 75 percent
Minor components: 21 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Still

Setting

Landform: Alluvial flats
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium derived from sedimentary rock

Typical profile

H1 - 0 to 25 inches: clay loam
H2 - 25 to 60 inches: stratified loam to clay loam

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water storage in profile: High (about 9.8 inches)

Interpretive groups

Land capability classification (irrigated): 1
Land capability classification (nonirrigated): 4c
Hydrologic Soil Group: C
Hydric soil rating: No

Figure 5: Site description of Whistle Stop Farm (NRCS).

3.0 Economic Sustainability

3.1 Background

Whistle Stop Farm was designed as a part-time, sixteen hour a week, supplementary business, with potential expansion to a full-time business on successful completion of milestones, while living on the Central Coast. The business will be operated as an LLC, however, most of the management and operation occurs by myself. For Whistle Stop Farm to be profitable for myself, I would need to be making approximately $20 an hour. Twenty dollars an hour at sixteen hours a week (after implementation) equates to $1,280 a month. To obtain this sum, Whistle Stop Farm diversified its operations, while including niche products. Diversification reduces the amount of risk in the farming operation by allowing for multiple different outlets of potential income. Whistle Stop Farm sells via Community Supported Agriculture (CSA) and restaurants. The CSA at the farm is a CSA-lite (niche from other CSAs), which is designed to feed one to two people. The CSA contains six to eight items, which are incorporated from approximately 0.3 acres of vegetable crops and 0.25 acres of permaculture orchard and costs each member eighteen dollars per week. Whistle Stop Farm's gourmet mushroom production consists of 400 square feet of growing room. At 400 square feet, Whistle Stop Farm can produce upwards of 10,000 pounds of mushrooms per year, however, the initial goal is to produce 40 - 60 lbs. per week with distribution to two to three restaurants at $8 - 10 per pound. At full production Whistle Stop Farm at a part-time business could gross $3,000. A general principle for net income for a farm is 60 % of the gross income, which would be $1,800 per month. An additional benefit of starting compact at Whistle Stop Farm is lowered startup costs due to the size of the land, reduction of needed labor and mechanization.

3.2 Business Plan

Creating and implementing a well-constructed business plan is the first step to creating any business (Small Business Administration). A business plan can help an entrepreneur receive financing, prioritize, set goals, and provide a road map to what works and what doesn't. Business plans will vary in detail and length depending on the type, size, and complexity of business being created. At Whistle Stop Farm, the agricultural enterprise was created as a part-time, supplementary, limited liability company. Due to the company's size, a less complex, non-traditional business plan, called a lean startup plan was created with help from the Small Business Administration. The lean startup plan is fast to write, contains key elements, and can be used for a simple business design (Small Business Administration). Table 1 is Whistle Stop Farm's lean, business, start-up plan.

Whistle Stop Farm	
Identity Whistle Stop Farm is a small, 1-acre, bio-intensive farm that produces fruits, vegetables, and gourmet mushrooms, while incorporating sustainable management practices.	**Problem** Communities are looking to connect more directly with their local food and farmers to create a healthier more sustainable agricultural industry.
Our solution Our crops are grown locally with organic and sustainable practices.	**Target market** The target audience is adults, specifically people who live alone or with another partner and who enjoy healthy, locally grown, delicious food.
The competition Whistle Stop Farm has competition from one other producer of gourmet mushrooms. Other large and small vegetable producers are prominent in the area.	**Revenue streams** Whistle Stop Farm will sell directly to customers via a CSA and gourmet mushrooms to restaurants.
Marketing activities Whistle Stop Farm will advertise and communicate on social media platforms such as Facebook and Instagram and have a website for the public.	**Expenses (day to day.. not including permanent infrastructure)** • Propagation Materials- Trays, potting soil, seed • Off farm inputs- Compost, blood meal • Irrigation- (drip and overhead) • Hand tools- rakes, shovels, hoes, etc. • Packaging for CSA- reusable bags • Mushroom Materials- Polyethylene sleeves, straw (substrate), spawn (rye grain), propane (pasteurization), packaging (reusable), laboratory materials (agar, petri dish, etc.) • Electricity- pumps, environmental control in mushroom grow room and cold storage unit
Team and key roles Currently, Whistle Stop Farm has three team members involved in the ownership and operation of the farm; Todd Porter, Janeen Porter, and Chad Porter. Overall production, management, and marketing is overseen by Chad Porter.	**Milestones** As the business begins to take shape, Whistle Stop Farm will have 10-15 CSA members and have two restaurant accounts for gourmet mushrooms. After successful operation within these markets, Whistle Stop Farm will look at the viability of expanding its operation to a full-time business.

Table 1: Lean start-up business plan for Whistle Stop Farm.

3.3 Design

Prior to implementing the farm, it is important to design the overall layout. Although the implementation of the farm will not be "exact" to the design, having a sketch or map of the farm can help reduce errors, costs, and frustration when implementing. Having a design layout can also help create a budget for the overall "permanent" infrastructure of the farm. The following design was created through arc gis and is a to scale map of Whistle Stop Farm. The design includes the different plots for fruit trees and vegetables, fencing, irrigation, mushroom cultivation rooms, and refrigeration room. Ten vegetable plots are included with five 4' X 50' rows with 18" spacing. Twenty-nine trees are included in the permaculture planting and are spaced at twenty-two feet apart, which provides an extra 20 % space for an understory planting and include stone fruit, apples, and persimmons. The trees along the fence line are a mix of fig, pomegranate, and native species to provide a wind break. The mushroom production consists of two structures made of cob, which are each 10' X 20'. All vegetable and fruit crops are watered with drip irrigation. Mainline 1" PVC pipe runs underground from the well to above ground access locations. One-half inch mainline polyethene tubing is used to connect ½" emitter tubing to the crops. Emitters are spaced 12" apart (note: I invested in higher grade, longer lasting irrigation tubing to reduce future cost). A cold-room will be constructed out of earthen materials (i.e. cob) and be 5'X10.' The refrigeration room uses a coolbot cooling system. A 10'X20' hoop house and 8' deer fencing are also located on the property.

Figure 6: Implementing drip irrigation and permanent, raised vegetable beds. Drip irrigation is ½" polyethylene tubing.

Figure 7: Overall layout of Whistle Stop Farm.

Legend	
	Vegetable plots
	Tree Plantings
	Property Line
	Deer Fence Line
	Shipping Containers
	Cold Storage Room
	Well
	Electric Board

3.5 Schedule Plantings for Continued Harvest

Planning the planting schedule for a compact farm is an important aspect to a farm's success as it ensures a continuous harvest and satisfaction for customers. A planting schedule also allows the manager to schedule workflow on the farm. Below is an example of Whistle Stop Farm's year-round planting schedule for zone 9a.

	Corn	Tomatoes	Melons	Tomatillos	Summer S	Beans	Cucumber	Peppers	Basil
Week	Direct See	Trensplant	Trensplant	Trensplant	Transplant	Direct See	Transplant	Transplant	Transplant
1									
2									
3									
4									
5									
6									
7									
8		Seed	Seed	Seed				Seed	Seed
9					Seed		Seed		
10									
11									
12									
13									
14		X	X	X	X		X	X	X
15	X					X			
16									
17		X	X	X	X		X	X	X
18									
19									
20	X	X	X	X	X	X	X	X	X
21									
22									
23	X	X	X	X	X	Harvest (X)	X	X	X
24		Harvest		Harvest	Harvest	Harvest	Harvest		Harvest
25	Harvest	Harvest		Harvest	Harvest	Harvest	Harvest		Harvest
26	Harvest (X	Harvest (X)	X	Harvest (X	Harvest (X	Harvest (X)	Harvest (X	X	Harvest (X)
27	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest		Harvest
28	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest		Harvest
29	Harvest (X	Harvest	Harvest (X	Harvest	Harvest (X	Harvest (X)	Harvest (X	X	Harvest (X)
30	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest		Harvest
31	Harvest	Harvest (X)	Harvest	Harvest (X	Harvest	Harvest	Harvest	Harvest	Harvest
32	Harvest	Harvest	Harvest	Harvest	Harvest (X	Harvest (X)	Harvest (X	Harvest	Harvest (X)
33	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest
34	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest
35	Harvest	Harvest	Harvest	Harvest	Harvest (X	Harvest	Harvest	Harvest	Harvest
36	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest
37	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest
38	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest
39	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest
40	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest
41	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest
42		Harvest		Harvest	Harvest	Harvest		Harvest	Harvest
43								Harvest	
44									
45									
46									
47									
48									
49									
50									
51									
52									

Figure 1: Farm schedule for warm season crops. Xs represent transplanting dates, with the red X being the first week of transplants. Seeding occurs 5-6 weeks before transplanting and can be found in blue. Transplanting and seeding takes place every 2-3 weeks to ensure a continuous harvest.

	Beets	Brocolli	Carrots	Chard	Cauliflower	Kale	Radish	Salad Greens	Snap Peas	Turnip	Winter squash
Week	Transplant	Trensplant	Direct seed	Transplant	Transplant	Transplant	Direct Seed	Transplant	Direct	Direct	Transplant
1	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest		Harvest	Harvest
2	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest		Harvest	Harvest
3	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest		Harvest	Harvest
4	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest		Harvest	Harvest
5	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	X	Harvest	Harvest
6	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest		Harvest	Harvest
7	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest		Harvest	Harvest
8	Harvest		Harvest	Harvest		Harvest	Harvest	Harvest		Harvest	Harvest
9	Harvest		Harvest	Harvest		Harvest	Harvest	Harvest		Harvest	Harvest
10	Harvest		Harvest	Harvest		Harvest	Harvest	Harvest		Harvest	Harvest
11	Harvest		Harvest	Harvest		Harvest	Harvest	Harvest		Harvest	Harvest
12	Harvest		Harvest	Harvest		Harvest	Harvest	Harvest		Harvest	Harvest
13	Harvest		Harvest	Harvest		Harvest	Harvest	Harvest		Harvest	Harvest
14	Harvest		Harvest	Harvest		Harvest	Harvest	Harvest	Harvest	Harvest	
15	Harvest		Harvest	Harvest		Harvest	Harvest	Harvest	Harvest	Harvest	
16	Harvest		Harvest	Harvest		Harvest	Harvest	Harvest	Harvest	Harvest	
17	Harvest		Harvest	Harvest		Harvest	Harvest	Harvest	Harvest	Harvest	
18	Harvest		Harvest	Harvest		Harvest	Harvest	Harvest	Harvest	Harvest	
19	Harvest		Harvest	Harvest		Harvest	Harvest	Harvest		Harvest	
20	Harvest		Harvest	Harvest		Harvest	Harvest	Harvest		Harvest	
21	Harvest		Harvest	Harvest		Harvest	Harvest	Harvest			
22											
23											
24											
25											Seed
26											
27											
28											
29											Seed
30											X
31											
32											
33											
34	Seed			Seed	Seed	Seed					
35		Seed									
36			X					Seed			
37											
38											
39	X			X		X					
40		X			X						
41							X	X		X	
42											Harvest
43											Harvest
44											Harvest
45	Harvest		Harvest	Harvest		Harvest	Harvest	Harvest		Harvest	Harvest
46	Harvest		Harvest	Harvest		Harvest	Harvest	Harvest		Harvest	Harvest
47	Harvest		Harvest	Harvest		Harvest	Harvest	Harvest		Harvest	Harvest
48	Harvest		Harvest	Harvest		Harvest	Harvest	Harvest		Harvest	Harvest
49	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest		Harvest	Harvest
50	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest		Harvest	Harvest
51	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest		Harvest	Harvest
52	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest	Harvest		Harvest	Harvest

Figure 8: Farm schedule for cool season crops. Xs represent transplanting dates, with the red X being the first week of transplants. Seeding occurs 5-6 weeks before transplanting and can be found in blue. Transplanting and seeding takes place every 2-3 weeks for continuous harvest.

3.6 Whole Farm Budget

A whole farm budget is a detailed report of the costs and returns of running a farm operation and should be done prior to embarking on the business venture (Harper et al., 2019). Completing a budget will allow for the manager to analyze and make decisions. The Penn State University Extension provides the following benefits to creating a farm budget; itemize the receipts (income) received for an enterprise, list the inputs and production practices required by an enterprise, evaluate the efficiency of farm enterprises, estimate benefits and costs for major changes in production practices, provide the basis for a total farm plan, and support applications for credit. Figure nine is an example of Whistle Stop Farm's farm budget.

Vegetable/Fruit Production	**Cost (per month)**	**Revenue Sources**	**Income (per month)**
Electricity- Well, Cold Room	$78	CSA (10-15 members per week @ $18.00 a member) - Vegetables	$720 - 1080
Seed/Plants	$40	Resturant Accounts (2-3, 20 lbs per week per @ $8.00 a lb) - Mushrooms	$1280 - 1920
Irrigation	$25		
Soil Prep (compost and blood meal)	$35.50		
Packaging/Storage	$30		
Potting Soil	$32		
Gourmet Mushroom Produciton	**Cost (per month)**		
Electricity- Environmental Control, Cold Room	$186		
Packaging/Storage	$40		
Polyethlene bags	$40		
Bulk substrate (straw)	$80		
Spawn	$50		
Propane	$30		
Sterilizing (i.e. bleach)	$5		
Business	**Cost (per month)**		
LLC Registration	$67		
Website	$5		
CSA Registration	$6.25		
Miscellaneous	$100		**Gross Income (per month)**
	Total Cost (per month)		$2,000 - 3,000
	$848		**Net Income (per month)**
	Total Cost Vegetable Production (per month)		$1,152 - 2,152
	$290		**Net Income from Vegetable Production (per month)**
	Total Cost of Mushroom Production (per month)		$430 - $790
	$481		**Net Income from Mushroom production (per month)**
			$799 - $1,439

Figure 9: An example of Whistle Stop Farm's whole farm budget.

4. Environmental Sustainability

4.1 Soil Test/Fertility

Prior to planting crops, it is important to conduct a soils test. A soil test can help promote crop health and yield, reduce environmental damage, and save money by adding the correct amount of fertilizer. Most soil tests are done by professional soil laboratories, however, for Whistle Stop Farm, all soil samples were conducted by me, with the aid of Dr. Decock at the California Polytechnic State University, San Luis Obispo Soil Laboratory. The soil test, tested for macro and micronutrients, pH, cation exchange capacity (CEC), and organic matter. The results can be seen in figure 3. To interpret the soils report, a guideline from A & L Western Agricultural Laboratories, Inc. was used. Of the analytes measured, organic matter, phosphorous, and nitrogen were low (other nutrients were low; however, the above nutrients are the most important for plant growth). To solve these deficiencies, compost was added, and recommendations were taken from the California Department of Food and Agriculture Healthy Soils Initiative program. The Healthy Soils Initiative, which was enacted by Governor Brown of California to increase the health of soils and reduce greenhouse gases, recommends applying 3-5 tons/acre/year of high nitrogen compost (C:N ≤ 11) for annual crops or 6 - 8 tons/acre/year of low nitrogen compost (C:N > 11) (CDFA). For trees, the CDFA recommends 2- 5 tons/acre/year of high nitrogen compost and 6 -8 tons/acre/year of low nitrogen compost. Blood meal was also applied for the first year at a rate of 200 lbs. of dried blood per acre. The application of blood meal was meant to supplement the compost, as only a small amount of nitrate is immediately available to plants, however, due to the function of nitrogen fixing bacteria, more nitrate will become available to the plant overtime from the compost application, while also supplying organic matter and phosphorus. Having the slow, natural release of nitrogen, helps to the reduce environmental problem of adding large amounts of nitrate to the soil, which can cause leaching and groundwater pollution.

Analyte	Description	Units	Value	Low-High	Solution
OM	orgranic Matter	% total	1.986	Low	Add compost, cover crop, etc.
P	NaHCO2-phosphorus	PPM	3.4	Vlow	Add manure compost
K	Potassium	% cation exchnage/PPM	11.77%/1,105.70	High	None
Mg	Magnessium	% cation exchnage/PPM	32.4%/944.4	Vhigh	None
Ca	Calcium	% cation exchnage/PPM	55.3%/2660	Low	None
Na	Sodium	% cation exchnage/PPM	0.48%	Low	None
S	Sulfur	PPM	6.4	Low	None
Cu	Copper	PPM	1.08	Medium	None
Fe	Iron	PPM	19.44	Medium-High	None
Mn	Manganese	PPM	3.12	Low	None
Zn	Zinc	PPM	1.68	Low-Medium	None
pH	pH		6.8	Neutral	None
Total CEC	CEC	meq/100g	24.058	High	None
N	Nitrogen	% total	0.189	Low	Add blood meal and compost

Figure 10: Soils test for Whistle Stop Farm.

SOIL ANALYSIS

General Guidelines for Interpreting Soil Analysis Ratings

Comments: Note that the cations potassium, magnesium, calcium and sodium are rated according to what percentage of the total cation exchange capacity they take. A clay soil may have 4,000 ppm calcium whereas a sandy soil may have only 400 ppm and both may be rated as "medium" in terms of their percent cation saturation.

These ratings are not crop-specific. However, when soil fertility guidelines are requested, specific crop requirements and tolerances are taken into account.

Analyte	Description	Units	VLow	Low	Medium	High	VHigh
OM	Organic Matter	percent	0.3	2.2	3.7	5.2	15.0
pH	Soil pH	pH	5.0	6.0	7.5	8.5	10.0
	Buffer pH		Shown only if soil pH is 6.5 and below				
P1	Weak Bray-phosphorus	ppm	8.0	17.0	26.0	39.0	90.0
HCO_3-P	$NaHCO_3$-phosphorus	ppm	3.0	7.0	13.0	22.0	50.0
	If soil pH is 6.4 to 6.5 (÷ 2)		e.g. 20 ppm ÷ 2 = 10 ppm = M				
	If soil pH is 6.2 to 6.3 (÷ 3)		e.g. 18 ppm ÷ 3 = 6 ppm = L				
	If soil pH is 6.1 and below		No rating is provided. Refer to Weak Bray				
K	Potassium	% Cation Sat.	0.6	2.0	5.0	10.0	15.0
Mg	Magnesium	% Cation Sat.	5.0	10.0	20.0	25.0	35.0
Ca	Calcium	% Cation Sat.	35.0	60.0	70.0	75.0	85.0
Na	Sodium	% Cation Sat.	1.0	3.0	5.0	10.0	30.0
NO_3-N	Nitrate-Nitrogen	ppm	4.0	12.0	25.0	40.0	65.0
S	Sulfate-Sulfur	ppm	3.0	10.0	25.0	35.0	60.0
Zn	Zinc	ppm	0.5	1.0	3.0	6.0	9.0
Mn	Manganese	ppm	1.0	2.0	12.0	30.0	40.0
Fe	Iron	ppm	5.0	10.0	16.0	25.0	35.0
Cu	Copper	ppm	0.3	0.8	1.2	2.5	5.0
B	Boron	ppm	0.3	0.5	1.2	2.0	5.0
Ex. Lime	Excess Lime	percent	1.0	2.0	3.0	4.0	7.0
SS (ECe)	Soluble Salts	mmhos/cm	0.3	0.7	2.0	4.0	6.0
Cl	Chloride	ppm	70.0	170.0	350.0	900.0	999.9
Mo	Molybdenum	ppm	0.05	0.1	0.2	0.4	1.0

Example: Organic matter = "Medium" between 2.3% and 3.7% (inclusive of numbers)

A & L Western Agricultural Laboratories, Inc. 10/09

Figure 11: Soil interpretation guide (A & L Western Agricultural Laboratories, Inc.).

4.2 Soils

When discussing environmental sustainability and agriculture it is vital that farms focus on soil health. Soils are a complex ecosystem that support plant, animal, human life, and are involved in ecological processes such as photosynthesis, nutrient cycling, and decomposition, which support four ecosystem services; provisioning, regulating, cultural, and supporting (Lazcano). The goal of agriculture should be to shift from agricultural intensification to ecological intensification to create a healthy soil, while still producing healthy, nutritious food. A healthy soil is defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans (NRCS). Three broad management strategies exist for increasing soil health; reduce disturbance, increase soil organic matter, and increase diversity (Lazcano). Within these overlying management strategies, six specific strategies exist for increasing soil health; no tillage, organic amendments, perennial crops, diversification of cropland, land sharing, and agroforestry or afforestation. Listed below are the strategies Whistle Stop Farm utilizes and employs for beneficial management practices.

4.2.1. No till

Whistle Stop Farm utilizes a no till management strategy. All vegetable plots were created as raised permanent beds. No tractor or heavy equipment will be used on the beds and all bed shaping and management is done manually. The permaculture orchard is a permanent planting, which requires no tilling.

Tilling the soil has negative effects on the physical, chemical, and biological components of the soil. (Nunes et al., 2018) compared no till and tilled soils and found that no till cropping systems increased nitrogen, phosphorus, zinc, protein content, water aggregate stability, and organic matter. The study also reported increases in yield overtime in the no till system. No till management also has benefits for belowground biodiversity. (Schmidt et al., 2018) found that no till had positive effects on soil organisms, increasing beneficial populations of soil fungi, which perform vital ecosystem services such as nutrient cycling and decomposition. Incorporating a no till strategy reduces the disturbance on the physical properties of the soil, which increases micro and macro habitat for soil organisms.

Note: Prior to owning and managing Whistle Stop Farm, the soil was compacted due to heavy equipment on wet soil, increasing the bulk density levels and negatively affecting the structure of the soil. To temporarily, mitigate this problem, the soil was ripped and tilled. This will be the only time tilling is used at Whistle Stop Farm.

Figure 12: Raised bed at Whistle Stop Farm.

Figure 13: Prepping soil at Whistle Stop Farm by subsoiling in order to reduce the bulk density.

4.2.2 Organic Amendments

At Whistle Stop Farm, plant, mushroom, and manure compost are added to the soil to increase the soil organic matter (SOM). Increasing the SOM in the soil has positive effects for all three spheres of the soil, physical, chemical, and biological. Organic matter is the first entry point of food for the soil food web. Without a stable amount of active carbon (i.e. labile organic matter), a healthy soil food web cannot be supported. (Mondini et al., 2018) evaluated the effectiveness of organic amendments in the recovery of soil functionality and vine status in disturbed soils and concluded that organic amendments such as vermicomposting are effective in restoring degraded soils. In the study, organic amendments benefited all three components of the soil, by increasing water content, soil organic matter, available nitrogen, and microbial biomass and activity.

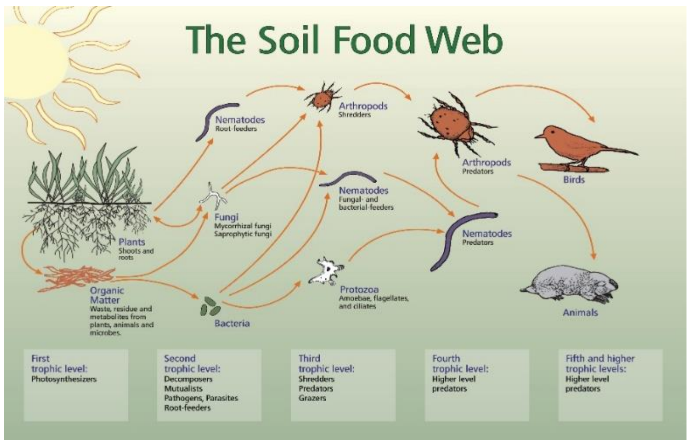

Figure 14: Example of the soil food web. Organic matter is the first entry point of food and vital to a healthy, diverse, and functional food web (Lazcano).

Figure 15: Adding plant-based compost to raised vegetable beds at Whistle Stop Farm.

4.2.3 Agroforestry/Perennial Crops

Whistle Stop Farm has incorporated a permaculture planting into the farm. The permaculture orchard consists of varying fruit trees and will include understory plantings. The purpose of the orchard is to mimic the diverse, permanent, natural ecosystem of a forest. Each understory of the tree will contain four different groupings of plants, accumulators, repelers, mulchers, and attractors. Accumulators are deep rooted plants that can bring nutrients up from deep within the soil. Yarrow, a native plant to the Central Coast of California will be added for this effect. Repelers are plants that repel damaging pests through aroma and include herbs such as mint and the allium family. Mulchers are "chop and drop" plants, which include artichokes and rhubarb. Attractors, attract pollinating insects and include plants such as fennel. Incorporating agroforestry and perennial crops has shown to have multiple benefits to farming and is an area of interest for sustainable agriculture. Perennial crops have been shown to build root density, diversify the soil food web, increase available nutrients for plants, and positively affect the physical structure of the soil (Lazcano). (Culman et al., 2009) compared the long-term effects of annual cropping systems versus perennial grasses and found that perennial grass systems had higher soil organic carbon, total nitrogen, water stable aggregates, and microbial biomass carbon.

4.2.4 Diversification of cropland

Diversification of cropland is the management strategy of utilizing a polyculture. At Whistle Stop Farm multiple different vegetables are grown simultaneously on the farm, while incorporating a crop rotation between each plot. Having a crop rotation and diversity between each plot allows for higher resource heterogeneity, such as root exudates and litter quality (Lazcano). In a mono-cropping system, growing the same crop over and over increases the need for the intensive input of fertilizers, reduces soil biology, and increases pest pressure and the need for pesticides. A Sample of Whistle Stop Farm's crop rotation can be found in figure 17. Also included in Whistle Stop Farm's diversification strategies are cover crops. (Nunes et al., 2018) reported increases in soil organic matter, protein, water stable aggregates, zinc, iron, and respiration in a cropping system that incorporated grass-legume cover crops.

Figure 16: The use of cover crops at Whistle Stop Farm during the winter of 2018.

Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
Cucurbits	Cucurbits	Cucurbits	Cucurbits	Cucurbits
Root crops/legumes	Root crops/legumes	Root crops/legumes	Root crops/legumes	Root crops/legumes
Solanaceae/legumes	Solanaceae/legumes	Solanaceae/legumes	Solanaceae/legumes	Solanaceae/legumes
Greens/brassicas/legume	Greens/brassicas/legume	Greens/brassicas/legume	Greens/brassicas/legume	Greens/brassicas/legume
Cucurbits	Cucurbits	Cucurbits	Cucurbits	Cucurbits

Plot 6	Plot 7	Plot 8	Plot 9	Plot 10
Solanaceae	Solanaceae	Solanaceae	Solanaceae	Solanaceae
Greens/brassica/legumes	Greens/brassica/legumes	Greens/brassica/legumes	Greens/brassica/legumes	Greens/brassica/legumes
Cucurbits/legume	Cucurbits/legume	Cucurbits/legume	Cucurbits/legume	Cucurbits/legume
Root crops/legumes	Root crops/legumes	Root crops/legumes	Root crops/legumes	Root crops/legumes4 Solanaceae
Solanaceae	Solanaceae	Solanaceae	Solanaceae	

Figure 17: Crop rotation for Whistle Stop Farm.

5.0 Implementation

In December 2018, a cover crop of 100 lbs, containing rye and legumes was seeded by hand at Whistle Stop Farm to add organic matter and nitrogen to the soil. The cover crop was mowed under in March 2019. A well was drilled in April of 2019 by Miller Drilling and electricity was added to the property by PG&E. The construction of the 8' deer fencing and 1" PVC underground irrigation was contracted out to Madrone Landscapes. The creation of the ten vegetable plots, measuring 1,300 sq. ft each, for a total of 13,000 sq. ft or 0.298 acres, was done by hand. All beds were marked out using string and stakes. Soil was added from the 18" paths in-between the 4' X 50' rows with a shovel to raise the beds 6 - 8" off the ground. Rain Bird ½," mainline, polyethylene, tubing was connected to the irrigation outlets for the vegetable beds and orchard crops. Connected to the mainline polyethylene tubing, was ½", Rain Bird drip tubing with emitters spaced every 12." Compost and blood meal were added to the first two vegetable plots. Transplants, which were seeded in 75 plug trays, were planted into the first two vegetable plots on May 28, 2019. Vegetable plantings will occur every 2 – 3 weeks after the first transplanting date and follow the farm schedule. Twenty-nine bare-root fruit trees were planted on May 6, 2019. Each tree was spaced 20 – 22 feet apart and upon plating, compost was added. The implementation of the mushroom grow rooms and refrigeration room has not yet occurred but will take place during the 2019 year. All three rooms will be built from cob, which is a sustainable mixture made of clay, sand, and straw and will include further insulation. All vegetable beds and orchard crops will be mulched soon with wood chips (for the orchard) and straw (for the vegetable beds) to help prevent erosion, retain water, and cool the soil.

Figure 18: Example of the mushrooms to be grown at Whistle Stop Farm. These mushrooms are King Oyster and were grown in Los Osos, CA.

Figure 19: 1/2" emitter tubing at Whistle Stop Farm.

6.0 Discussion/Conclusion

The creation and implementation of Whistle Stop Farm as a compact farm has demonstrated potential in achieving the three e's of sustainability. Compact farms are small and manageable. Each day, I have the privilege and opportunity of walking across the dark, rich clay loam soil, tending to its needs with all but a wheelbarrow, rake and broad fork. Each day, I walk through all rows, pruning, trellising, transplanting, harvesting, pest inspecting, and caring for each plant, with all but a hoe, a Hori Hori knife, stakes, string, and harvesting boxes. Each day, I dig my hands into the soil, feeling the texture and knowing millions of micro and macro organisms are teeming below me. With the evident deep, passionate, and intimate connection to the land, that a compact farm provides, it is hard not to care for the environment and attempt to develop an agroecosystem that function for the benefit of life. Upon marketing my crops, I will have the ability to market directly to customers. Direct markets cut out retail suppliers and creates a

higher market price on crops, which allows for a smaller, more confined operation. Marketing directly to customers also develops a personal connection between the farmer, local community, and food. Current movements, such as farm to fork or the slow food movement, have been pushing for the purchase and consumption of locally grown food. A close relationship with the community can also further develop marketing and support. The overall "minimal" investment, due to a reduction in land costs, labor, and mechanization compared to large farms and the potential for crop diversification, make compact farms an appealing choice for beginning, young farmers. Although the abatement of high intensive input and mono-cropped farms will not occur, due to their necessity in providing food to an expansive population, compact farms can be an important source of mitigation and equalization against the negative impacts of agriculture. To continue a movement into sustainable agriculture, awareness and education needs to be spread about the current effects of agriculture and how people can work to better the industry. Included in the appendix is a more detailed report of the physical, chemical, and biological components of the soil that are important to agriculture, how to measure them, and management strategies to create sustainability.

Appendix

1.0 Soil Physical Properties

1.1 Texture

Background

Soil texture is used to classify the amount of sand, silt, and clay or "mineral material" in a soil. The amount of sand, silt, and clay within a soil will define the soils potential for water holding capacity, nutrient concentration, structure, bulk density, aggregate stability, and a diverse and abundant soil food web. Soils are classified based off their mineral make-up and concentration. To classify a soil into a certain textural group, the amount of sand, silt, and clay must be measured.

Methods/Procedure

At Whistle Stop Farm, the texture was estimated through the touch method and a Natural Resource Conservation Service (NRCS) report was used to further specify the soil type.

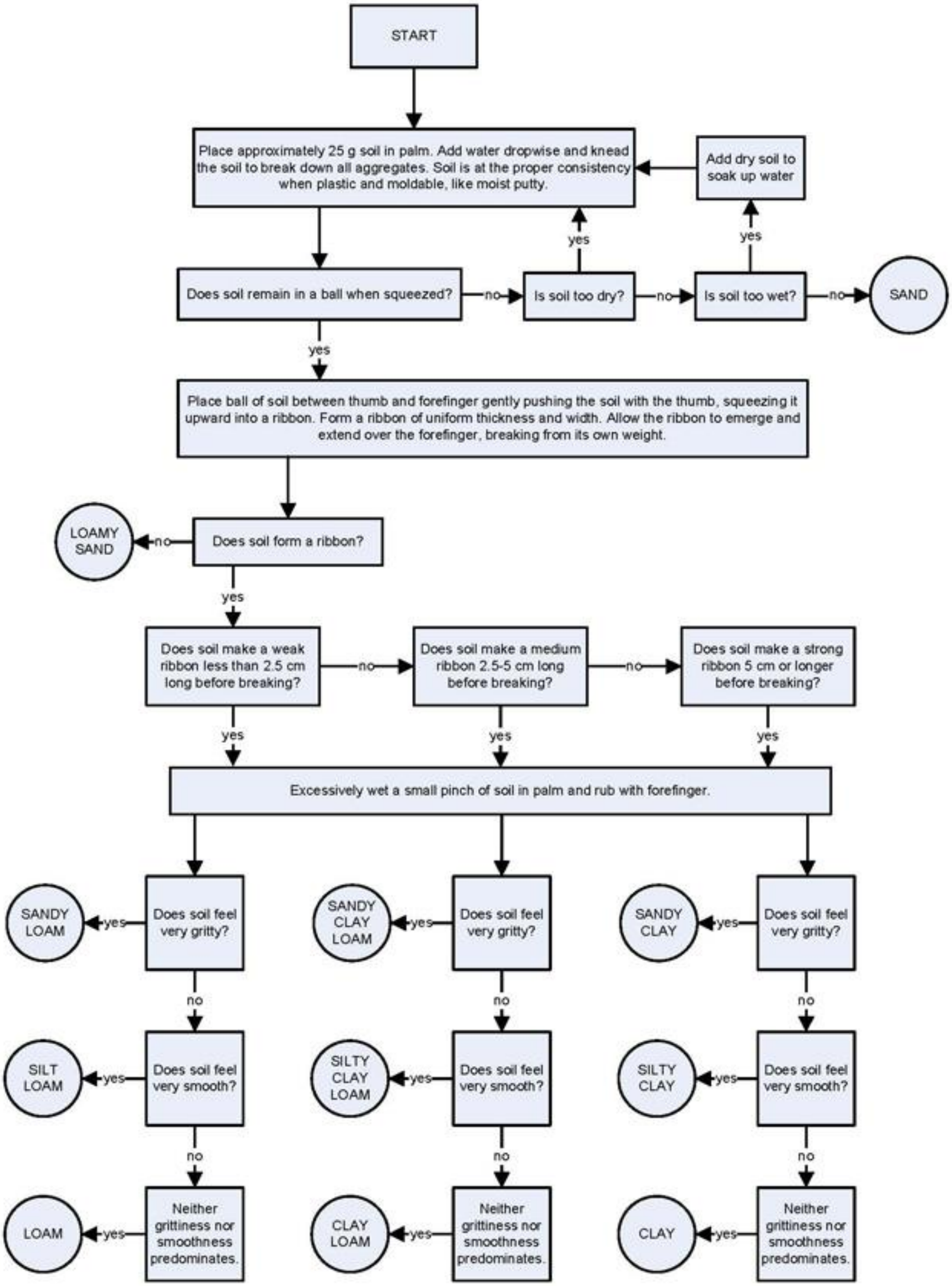

Figure 20: Texture by feel flow chart (NRCS).

Figure 21: Ribbon formed using the texture by feel method.

Results

The soil at Whistle Stop Farm is a clay loam, containing approximately 30 % sand, 38 % silt, and 32 % clay.

Management at Whistle Stop Farm

Soil texture is an inherent property, which cannot be changed (NRCS).

1.2 Structure

Background

Soil structure refers to how soil particles are grouped together into aggregates. Aggregates are units of soil particles bonded together through organic molecules and physically supported by plant roots and fungal networks (Lazcano). In agriculture, the more structured and stable the aggregates are in the soil, the healthier the soil is. For example, with more structure and a higher percent stable aggregates, the more macro and micro pores there are in the soil. A balance of macro and micro pores from higher percent stable arregates results in increased water holding capacity, infiltration, aeriation, provides roots stability, and diversifies the amount of potential habitat for soil organisms, which creates a healthier and more stable soil food web (Lazcano). Soil structure can be divided into six different categories, single grain, granular, blocky, platy, columnar, and massive. The ideal soil structure can be found in figure 4.

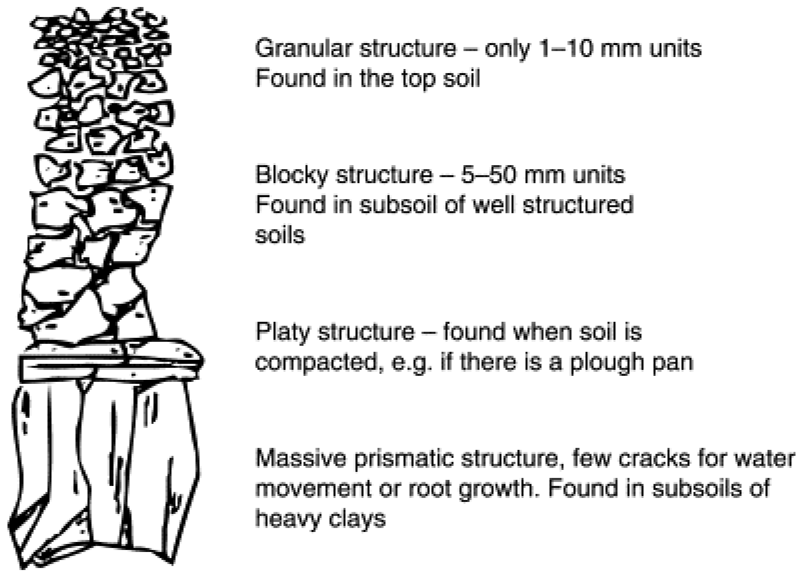

Figure 22: Soil structural units (Miedema).

In general, it is important for farmers to increase their soil structure to promote a healthy physical and biological soil ecosystem for crops. Most soil scientist agree that a granular soil is the best structure for growing crops as it has large soil aggregates and is high in organic matter (Miedema et al., 1997).

Methods/Procedures

At Whistle Stop Farm, the soil structure was measured by digging down with a shovel and removing "clumps" of soil to view the soil structure. Aggregate stability was measured by taking a composite sample from the farm and allowing a sub-sample to air dry for one week. The sub-sample was then sieved through a 2 mm sieve, 10 g of soil was collected, a terry cloth was wetted, and the 2 mm sieve was placed on the terry cloth to rewet the soil for five minutes. The wet sieve of soil was then held inside a tub of distilled water and the sieve with the soil was oscillated up and down at a rate of 30 oscillations per minute. The soil was removed from the sieve placed into a weighed drying can using DI water, and left in the oven at 105 degrees Celsius for a minimum of eight hours. The weight of the aggregates was then recorded after drying and the percent stable aggregates was calculated.

Results/Interpretation

The Natural Resource Conservation District provides the ideal percent stable aggregates for different textures of soil. At Whistle Stop farm the structure was blocky and the percent stable aggregates was 58 %.

Organic Matter (%)	Water Stable Aggregates (%)	Clay (%)	Water Stable Aggregates (%)
0.4	53	5	60
0.8	66	10	65
1.2	70	20	70
2	75	30	74
4	77	40	78
8	81	60	82
12	85	80	86

Aggregate stability values are based on 519 soil samples from the arid, semiarid, and subhumid regions of the United States and Canada. The majority of the samples were from cultivated areas, but a large number were taken from virgin or replanted grasslands (Kemper, 1966).

Figure 23: Ideal aggregate stability values (NRCS).

Management at Whistle Stop Farm

To increase the structure and the percent stable aggregates of the soil, Whistle Stop Farm employs two management strategies; adding organic amendments and reducing disturbance. To reduce disturbance of the soil, no till practices are employed. Tilling the soil, increases physical agitation and breaks down the soil structure. (Nunes et al., 2019) compared no till and plow tilling and found that no till soils showed significant increases in water stable aggregates. Organic amendments, such as compost or cover crops increase structure and aggregate stability by acting as a cementing agent. At Whistle Stop Farm while high nitrogen compost is incorporated at a rate of 3 – 5 ton/acre/year to aid with structure.

1.3 Bulk Density

Background

Bulk density is the measurement of the amount dried soil mass in a given volume and is dependent on soil texture and organic matter. Bulk density is an indicator of soil compaction, which can be created through the operation of heavy equipment on wet soils and can have negative effects on plant growth and soil health, such as root restriction, loss of soil pores, reduction in water holding capacity, infiltration, soil organism activity, and plant nutrient availability.

Measurement

To measure the bulk density at Whistle Stop Farm, a soil core was used to extract a sample. Prior to extracting the sample, the weight of the soil core was recorded and the volume was calculated. After extraction, the soil core was weighed for the wet weight of soil + weight of the cylinder and placed in a drying oven for a minimum of eight hours at 105 degrees Celsius. The soil core was then weighed to acquire the dried weight of soil + cylinder. The mass of the dried soil was then divided by the volume of the cylinder to obtain the bulk density in g/cm^3.

Results/Interpretation

The Natural Resource Conservation District provides values for ideal bulk density based off soil texture. At Whistle Stop Farm, the bulk density was 1.55 (grams/cm^3)

Soil Texture	Ideal bulk densities for plant growth (grams/cm^3)	Bulk densities that affect root growth (grams/cm^3)	Bulk densities that restrict root growth (grams/cm^3)
Sands, loamy sands	< 1.60	1.69	> 1.80
Sandy loams, loams	< 1.40	1.63	> 1.80
Sandy clay loams, clay loams	< 1.40	1.60	> 1.75
Silts, silt loams	< 1.40	1.60	> 1.75
Silt loams, silty clay loams	< 1.40	1.55	> 1.65
Sandy clays, silty clays, clay loams	< 1.10	1.49	> 1.58
Clays (> 45% clay)	< 1.10	1.39	> 1.47

Figure 24: Soil texture and bulk density levels (NRCS).

Management at Whisked Stop Farm

Bulk density can be managed by reducing the impact of heavy machinery on the land and reducing disturbance. Heavy machines, especially on wet soils, compact the soil, negatively affecting the bulk density. Tilling and traffic on the soil also creates a compacted plow layer, approximately 7 – 9 inches deep (NRCS). With the relatively high initial bulk density at Whistle Stop Farm, the soil was subsoiled to temporarily decrease the bulk density, however, the farm utilizes a no till strategy to help reduce bulk density and avoid compaction.

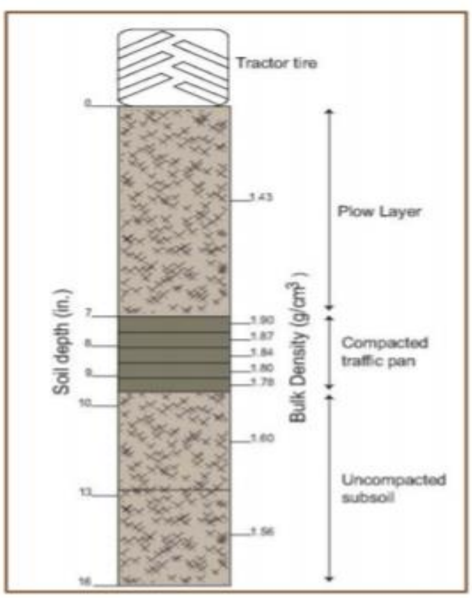

Figure 25: The impact of machinery on bulk density in soils (NRCS).

2.0 Chemical Properties

2.1 Nutrients

Background

Plants require seventeen essential nutrients to grow; carbon, oxygen, hydrogen, nitrogen, phosphorous, potassium, sulfur, sodium, calcium, magnesium, boron, chlorine, copper, iron, manganese, molybdenum, nickel, and zinc. These nutrients are further broken down into three categories, primary nutrients, secondary nutrients, and micronutrients. Primary nutrients are carbon (C), oxygen (O), hydrogen (H), nitrogen (N), phosphorus (P), and potassium (K) and are required in higher concentrations for a plant to be productive and healthy. Carbon, oxygen, and hydrogen are supplied through the air and water, while nitrogen, phosphorus, and potassium are provided through the soil. Secondary nutrients are calcium (Ca), magnesium (Mg), and sulfur (S), while all other nutrients are micronutrients. These nutrients are provided through the soil.

Methods/Procedures

Determination of Soil Ca, Mg, K, Na:

The amount of plant available P, Na, Ca, and Mg was found by displacing the elements from soil colloid exchange site with ammonium acetate solution buffered to pH 7.0 Cation concentrations were then determined by using atomic absorption spectrometry.

Analyzing potential soil bioavailability of Zn, Cu, Mn and Fe:

The amount of soil bioavailability of zinc, copper, manganese, and iron was measured using the diethylenetriaminepentaacetic acid (DTPA) extraction method. Ten grams of < 2mm, air dried soil was placed in a 50-ml centrifuge tube. Thirty mL of DTPA extracting solution was added and shaken for 30 minutes and the tube was placed in a centrifuge and spun at 2000 rpm for 10 minutes. Using a syringe filter, 15-ml of the supernatant was transferred to a labeled scintillation vial for analysis.

Available Soil Phosphorus and Sulfur:

The available soil phosphorus and sulfur was measured using the Sodium Bicarbonate Extraction and ICP-AES method. Five grams of air-dried soil was put into a 125-ml Erlenmeyer flask, 50-ml of sodium bicarbonate extraction solution was added, and the flask was shaken for 30 minutes. Solution was filtered through a filter paper into a 200-ml beaker. Ten ml of filtered extract was poured into a 10-ml graduated cylinder and then transferred to a 100-ml beaker. Ten ml of nitric acid (1M HNO_3) was added slowly to the beaker and swirled for 15 seconds. Sample was then transferred to an autosampler tube and sent to the laboratory for analysis.

Results

The results for primary and micronutrients at Whistle Stop Farm can be found in figures 8 - 11.

Sample ID	Ca	K	Mg	Na
	meq/100 g soil			
CHAD P	13.3	2.835256	7.80625	0.117391

Figure 26: The amount of Ca, K, Mg, and Na in meq/100g soil.

Sample ID	Cu	Fe	Mn	Zn
	PPM			
CHAD	1.08	19.44	3.12	1.68

Figure 27: The amount of Cu, Fe, Mn, Zn in ppm.

Sample ID	P	S
	PPM	
CHAD P	3.40	6.40

Figure 28: The amount of P and S in ppm.

Sample ID	N			
	% total mineralized			
CHAD P	0.189			

Figure 29: The percent total mineralized nitrogen.

Management at Whistle Stop Farm

Of the primary and secondary soil nutrients at Whistle Stop Farm, phosphorus, nitrogen, sulfur, and calcium were low. To adjust for these nutrient deficiencies, high nitrogen mushroom and manure compost was added at a rate of 3 -5 tons/acre/year. Manure compost adds both phosphorous and nitrogen to the soil. Two hundred lbs of blood meal was also added per acre for an immediate organic source of nitrogen. A general guide for interpreting soils report can be seen in figure 9 and is provided by A & L Western Agricultural Laborites, Inc. A general rule when managing nutrients is to follows the four r's, right source, right time, right rate, and right placement (Hochmuth et al., 2018).

SOIL ANALYSIS

General Guidelines for Interpreting Soil Analysis Ratings

Comments: Note that the cations potassium, magnesium, calcium and sodium are rated according to what percentage of the total cation exchange capacity they take. A clay soil may have 4,000 ppm calcium whereas a sandy soil may have only 400 ppm and both may be rated as "medium" in terms of their percent cation saturation.

These ratings are not crop-specific. However, when soil fertility guidelines are requested, specific crop requirements and tolerances are taken into account.

Analyte	Description	Units	VLow	Low	Medium	High	VHigh
OM	Organic Matter	percent	0.3	2.2	3.7	5.2	15.0
pH	Soil pH	pH	5.0	6.0	7.5	8.5	10.0
	Buffer pH		Shown only if soil pH is 6.5 and below				
P1	Weak Bray-phosphorus	ppm	8.0	17.0	26.0	39.0	90.0
HCO_3-P	$NaHCO_3$-phosphorus	ppm	3.0	7.0	13.0	22.0	50.0
	If soil pH is 6.4 to 6.5 (÷ 2)		e.g. 20 ppm ÷ 2 = 10 ppm = M				
	If soil pH is 6.2 to 6.3 (÷ 3)		e.g. 18 ppm ÷ 3 = 6 ppm = L				
	If soil pH is 6.1 and below		No rating is provided. Refer to Weak Bray				
K	Potassium	% Cation Sat.	0.6	2.0	5.0	10.0	15.0
Mg	Magnesium	% Cation Sat.	5.0	10.0	20.0	25.0	35.0
Ca	Calcium	% Cation Sat.	35.0	60.0	70.0	75.0	85.0
Na	Sodium	% Cation Sat.	1.0	3.0	5.0	10.0	30.0
NO_3-N	Nitrate-Nitrogen	ppm	4.0	12.0	25.0	40.0	65.0
S	Sulfate-Sulfur	ppm	3.0	10.0	25.0	35.0	60.0
Zn	Zinc	ppm	0.5	1.0	3.0	6.0	9.0
Mn	Manganese	ppm	1.0	2.0	12.0	30.0	40.0
Fe	Iron	ppm	5.0	10.0	16.0	25.0	35.0
Cu	Copper	ppm	0.3	0.8	1.2	2.5	5.0
B	Boron	ppm	0.3	0.5	1.2	2.0	5.0
Ex. Lime	Excess Lime	percent	1.0	2.0	3.0	4.0	7.0
SS (ECe)	Soluble Salts	mmhos/cm	0.3	0.7	2.0	4.0	6.0
Cl	Chloride	ppm	70.0	170.0	350.0	900.0	999.9
Mo	Molybdenum	ppm	0.05	0.1	0.2	0.4	1.0

Example: Organic matter = "Medium" between 2.3% and 3.7% (inclusive of numbers)

A & L Western Agricultural Laboratories, Inc. 10/09

Figure 30: Guideline for soil test and nutrients (A & L Western Agricultural Laboratories, Inc.).

2.2

Cation Ion Exchange Capacity (CEC)

Background

Cation Ion Exchange Capacity (CEC) is the soils ability to attract and hold positively charged ions such as Ca, Mg, K, and Na. These cations are held by negatively charged surfaces and become available for plants. In soils, organic matter and clay have negative charges. Soils with

higher organic matter and clay will attract and hold onto more positively charged cations. The negative charge of clay particles results in clay soils having a higher potential nutrient availability for crops. In sandy soils, which are have a net zero charge, nutrients such as Mg, P, Ca, and Na may become limited.

Methods/Procedures

Measuring CEC is an indirect, laboratory process. To measure CEC, the concentration of positively charged elements such as P, Na, Ca, and Mg are measured to provide an estimate of CEC. The amount of plant available P, Na, Ca, and Mg was found by displacing the elements from soil colloid exchange site with ammonium acetate solution buffered to pH 7.0 Cation concentrations were then determined by using atomic absorption spectrometry.

Results

The total cation exchange capacity, excluding hydrogen was 24.058 meq/100g.

Sample ID	Ca	K	Mg	Na
	meq/100 g soil			
CHAD P	13.3	2.835256	7.80625	0.117391

Figure 31: The amount of Ca, K, Mg, and Na in meq/100g.

Analyte	Description	Units	Value	Low-High	Solution
Total CEC	CEC	meq/100g	24.058	High	N/A

Figure 32: Total CEC in meq/100g.

\Management at Whistle Stop Farm

As stated in the background, total CEC is a function of the amount of clay particles and organic matter found in the soil. Although the texture of the soil in inherent, organic matter, such as compost can be added to the soil to increase the CEC. At Whistle Stop Farm, high nitrogen mushroom and manure compost is incorporated at 3 – 5 tons/acre/year for the vegetable crops for nutrients, however, the CEC was already high and does not need managing.

2.3 pH

Background

pH is a measure of how acidic or basic a substance is. pH is measured on a range from 1-14, with 1 being most acidic and 14 being most basic. pH levels are based off the hydrogen concentration in the soil. The more hydrogen ions present, the more acidic a substance is. In agriculture, pH is important because crops prefer a certain pH level. Most crops prefer a pH of 6.5-7.5, while some, such as blueberries prefer a slightly more acidic soil. The pH of the soil is important for agricultural crops because of nutrient availability. At a near neutral pH, primary nutrients such as N, K, and P become most available to the plant. As the pH becomes more acidic or basic the nutrients are tied up in the soil. This relationship is represented in figure 9.

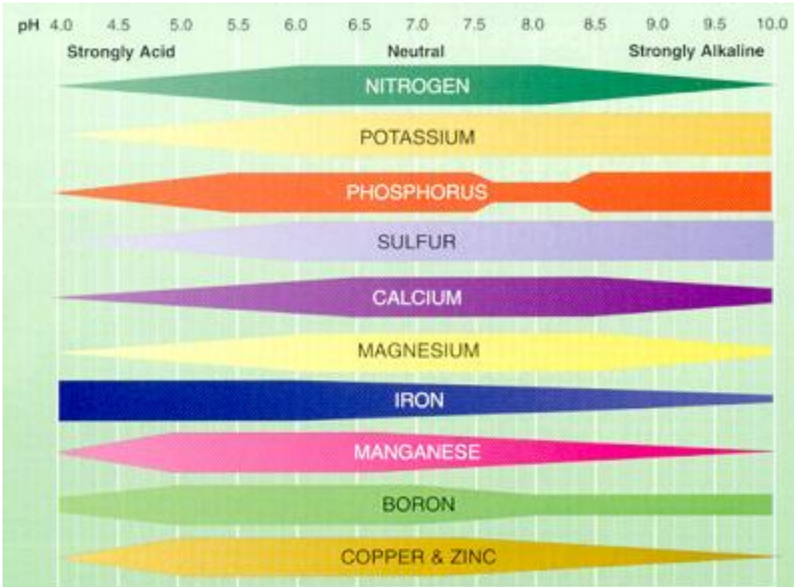

Figure 33: Availability of nutrients at different pH levels (Rosen).

Methods/Procedures

A liquid pH tester was used to test the pH level of the soil at Whistle Stop Farm. Three different locations were tested. A small subsample of the soil was placed inside a small, clear plastic container and droplets of pH indicator were placed on the soil. The color of the soil was then used to determine the pH level.

Figure 34: pH test of soil at Whistle Stop Farm.

Results

The pH for Whistle Stop Farm was 6.8.

Management at Whistle Stop Farm

No immediate management strategy will be taken at Whistle Stop Farm to change the pH as it is at a desirable level, however, if a soil is too acidic or basic, lime or sulfur can be added to the soil to adjust pH. Liming materials are used to raise the pH and sulfur is used to lower the pH. The University of California, Davis provides recommendations for adjusting soil pH, which can be seen in figure 9 and 10.

	Lime Requirements (Tons per Acre)	
Soil Texture	**From pH 4.5 to 5.5**	**From pH 5.5 to 6.5**
Sand and loamy sand	0.5	0.6
Sandy loam	0.8	1.3
Loam	1.2	1.7
Silt loam	1.5	2.0
Clay loam	1.9	2.3
Muck	3.8	4.3

Figure 35: Lime requirements for raising soil pH. Based off of soil texture and initial pH level (Vossen).

Original pH	Sandy Soil	Clay Soil
8.5	0.7 - 1.0	1.0 - 1.3
8.0	0.5 - 0.7	0.7 - 1.1
7.5	0.2 - 0.3	0.4 - 0.5

Figure 36:Figure 17: Sulfur requirements in tons per acre. Based off of initial pH (Vossen).

3.0 Soil Biology

3.1 Soil Organic Matter

Background

Soil Organic Matter (SOM) is the amount of animal or plant tissue found within in a soil. In natural, undisturbed, soils, the average total amount of SOM is 5 %, however, in today's agricultural industry, the total amount of SOM is between 1 – 3 %. This reduction in SOM is due primarily to the erosion of topsoil. Soil organic matter is important to all three categories of the soil; physical, chemical, and biological. In terms of the biological sphere, SOM is the first entry

point of food for the soil food web, which can be seen in figure 18. Without proper levels of SOM

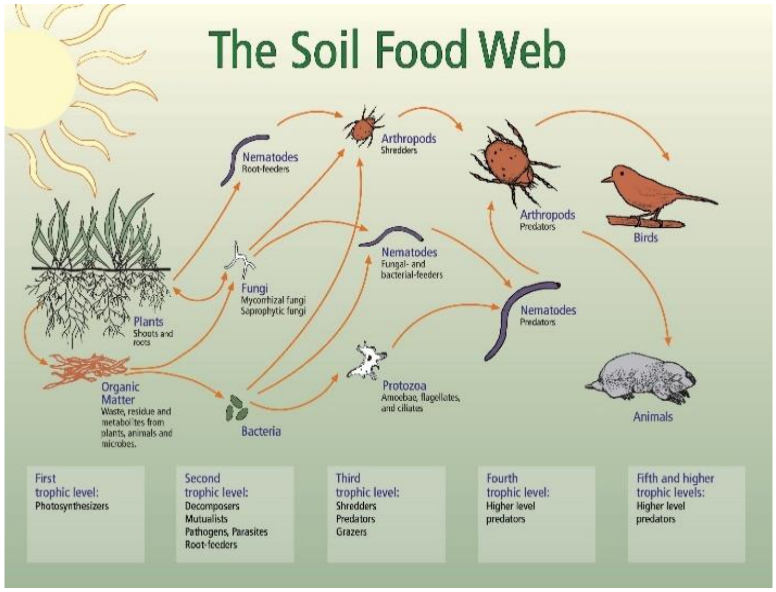

Figure 37: Soil food web (Lazcano).

in the soil, a complex and diverse soil food web cannot be sustained, which reduces the ecological health of the soil, enhances disease and pest pressure for crops, reduces the amount of available nutrients for plants, decreases water holding capacity, lowers the CEC, and negatively affects the soil structure.

Methods/Procedures

A composite soil sample consisting of three different locations on the farm was taken to a depth of twelve inches using a shovel. The sample was mixed together, and a subsample was obtained and allowed to air dry for one week. The air-dried subsample was sieved through a 2 mm sieve and placed within a small metal capsule. The soil and capsule were then placed within a combustion chamber, combusted, and the amount of CO_2 released was measured inside the chamber.

Results

The SOM at Whistle Stop Farm made up 1.986 % of the total soil.

Analyte	Description	Units	Value	Low-High	Solution
OM	orgranic Matter	% total	1.986	Low	Add compost, cover crop, etc.

Figure 38: The amount of % total organic matter at Whistle Stop Farm.

Management at Whistle Stop Farm

To increase the amount of soil organic matter, organic amendments such as compost and cover crop rotations can be added to fertilize the soil and provide a food source for soil organisms. (Mondini et al., 2018) evaluated the effectiveness of organic amendments in the recovery of soil functionality and vine status in disturbed soils and concluded that organic amendments such as vermicomposting are effective in restoring degraded soils. In the study, organic amendments benefited all three components of the soil, by increasing water content, SOM, available N, and microbial biomass and activity. Tilling also adds oxygen to the soil, which increases microbial activity and decomposition, which accelerated decomposition to unnatural levels (White et al., 2019). At Whistle Stop Farm, high compost, such as mushroom and manure compost, was incorporated to each row with the recommendation of the Healthy Soils Initiative and a no till management strategy is followed.

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