Bare Ranch

CARBON FARM PLAN

Spring 2016

Photo by Debra Cockrell

Carbon Cycle Institute

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2016

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INTRODUCTION

Largely taken for granted, carbon has been absent from discussion of elements essential to agriculture and the management of working lands; yet carbon is the basis for all agricultural production. Carbon enters the farm system from the atmosphere through the process of plant photosynthesis, which uses the energy of sunlight to capture carbon dioxide from the air and combine it with water and nutrients from the soil to produce the products of agriculture. In addition to food, fiber, fuel and flora, photosynthates (sugars) produced by the crop are moved to the soil: directly as exudates from plant roots; indirectly through plant roots to beneficial soil mycorrhizal fungi; via the sloughing of plant parts such as leaves and roots, and through deposition on the soil surface of above ground plant parts and the bodies and manures of animals.

In addition to its transformation from carbon dioxide into the sugars, cellulose and lignin of the harvestable crop, carbon can also be beneficially stored long-term (decades to centuries or more) in soils and woody vegetation in a process known as terrestrial carbon sequestration. While the importance of carbon to soil health and fertility has long been understood, its significance has begun to be increasingly recognized in recent years. Today, managing for increased soil organic matter, which is about 50% carbon, is the core of the USDA-Natural Resources Conservation Service (NRCS) healthy soils program and the California Department of Food and Agriculture's 2015 Healthy Soils Initiative.

While Carbon Farm Planning includes identifying opportunities to decrease the production of greenhouse gases on farm whenever possible, Carbon Farming involves implementing on-farm practices that increase the rate of photosynthetically-driven transfer of carbon dioxide (CO2) from the atmosphere to plant productivity and/or soil organic matter. Enhancing working land carbon, whether in plants or soils, results in beneficial changes in a wide array of system attributes, including; soil water holding capacity and hydrological function, biodiversity, soil fertility, and resilience to drought and flood, along with increasing agricultural productivity. Increasing carbon capture on working lands also helps to slow rising levels of carbon dioxide and other greenhouse gases in the atmosphere, currently contributing to climate destabilization and unpredictability through global warming.

CARBON FARMING

Technically, ***all*** farming is "carbon farming," because all agricultural production depends on plant photosynthesis to move CO2 out of the atmosphere and into the plant, where it is transformed into agricultural products, whether food, flora, fuel or fiber. Carbon entering the farm from the atmosphere can end up in several locations: in the harvested portion of the crop, in the soil as root exudates and soil organic matter, in "waste" materials such as compost or manure, in standing carbon stocks, such as grassland vegetation or woody perennials (trees, vines, orchards, etc.), or in other permanent woody or herbaceous vegetation such as windbreaks, vegetated filter strips, or riparian systems, forests and woodlands.

While all farming is completely dependent upon atmospheric CO2 in order to produce its products, different farming practices, and different farm systems, can lead to very different amounts of on-farm carbon capture and storage. ***The Carbon Farm Planning (CFP) process differs from other approaches to land use planning by focusing on increasing the capacity of the working farm or ranch to capture carbon and to store it beneficially; in the crop, as standing carbon stocks in permanent vegetation, and/or as soil organic matter.***

While agricultural practices often lead to a gradual loss of carbon from the farm system, particularly from working land soils, CFP is successful when it leads to a net increase in farm-system carbon. By increasing the amount of photosynthetically captured carbon stored, or "sequestered," in long-term carbon pools on the farm or ranch, including soil organic matter, perennial plant roots and standing woody biomass, carbon farming results in a direct reduction in the amount of CO2 in the atmosphere, while supporting crop production and farm resilience to environmental stress, including flood and drought.

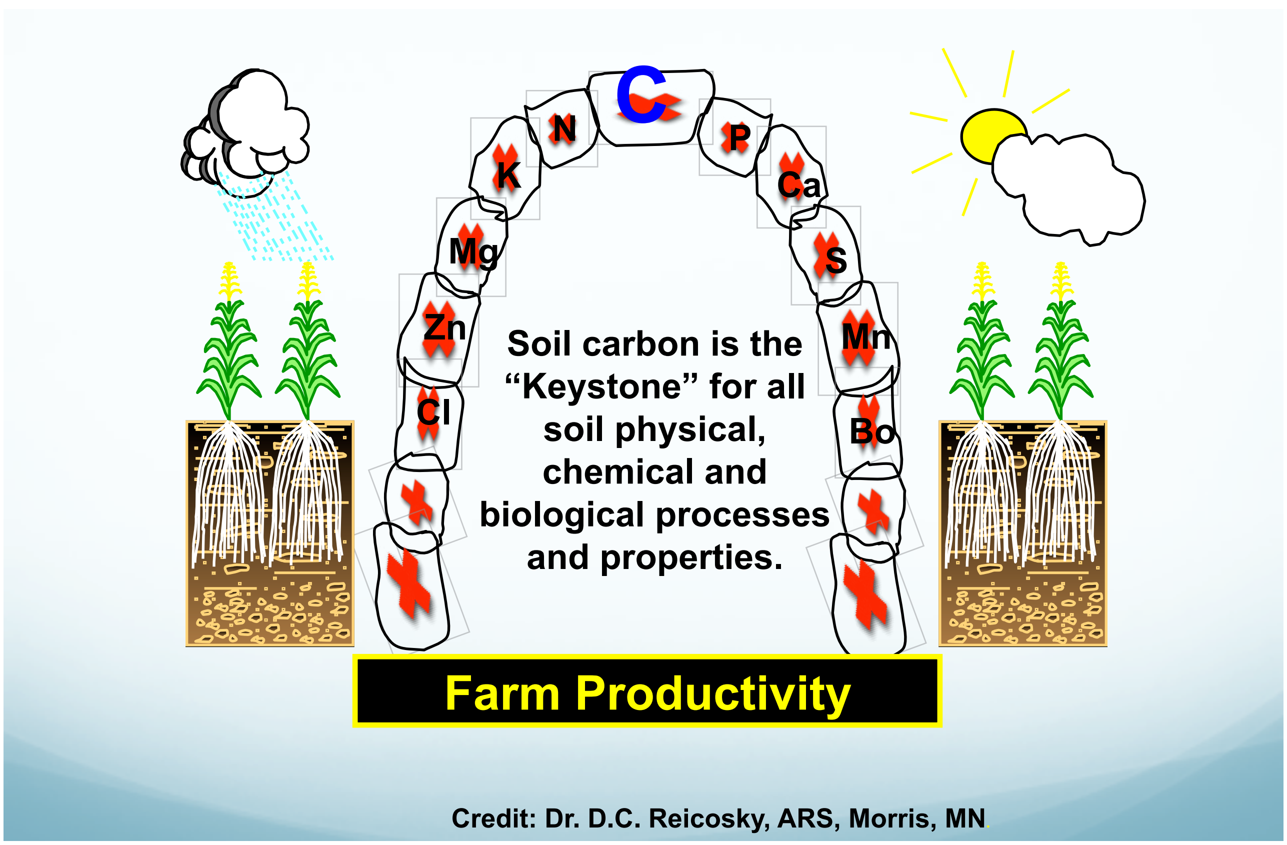
On-farm carbon in all its forms (soil organic matter (SOM), perennial and annual herbaceous vegetation, plant roots, root exudates and standing woody biomass), contains energy, which originated as the solar energy used by the plant to synthesize carbohydrates from atmospheric CO_2 and water and nutrients from the soil. The carbon in plants and SOM can thus be properly understood as the embodied solar energy that drives on-farm processes, including the essential soil ecological processes that determine water and nutrient holding capacity and availability for the growing crop. ***Consequently, CFP places carbon at the center of the planning process and views carbon as the single most important element, upon which all other on-farm processes depend (figure 1).***

Carbon Farm Planning (CFP) is based upon the USDA Natural Resource Conservation Service (NRCS) Conservation Planning process, ***but uses carbon and carbon capture as the organizing principle around which the Farm or Ranch Plan is constructed.*** This simplifies the planning process and connects on-farm practices directly with ecosystem processes, including climate change mitigation and increases in on-farm climate resilience, water holding capacity, soil health and agricultural productivity.

The Carbon Farm Planning Process

Increasing on-farm carbon capture as biomass and, most importantly, soil carbon, is the resource concern of overriding importance for the CFP process. Like NRCS Conservation Planning, CFP begins with an overall inventory of natural resource conditions on the farm or ranch, but with a focus on identification of opportunities for reduction of greenhouse gas (GHG) emissions and enhanced carbon capture and storage by both plants and soils. Building this list of opportunities is a brain-storming process; it should be as extensive as possible, including everything the farmer and planners can think of that could potentially reduce emissions and capture and sequester carbon on the farm. While actions proposed in the Plan should reflect the inherent limits of the farm ecosystem, financial considerations should not limit this initial brainstorming process, as one goal of the CFP process is to identify potential funding, above and beyond existing resources, to realize implementation of the Plan.

Figure 1. Carbon as the Key to Working Land Productivity and Resilience



During this process, a map, or maps, of the ranch is/are developed, showing existing ranch infrastructure and natural resource conditions. These maps can be used to locate potential carbon capture practices on the ranch and to envision how the ranch may be expected to look years down the road, following plan implementation. Next, the carbon benefits of each practice, as potentially applied at the farm scale, are quantified using the on-line USDA greenhouse gas model, COMET-Farm (**cometfarm.nrel.colostate.edu**), COMET-Planner, (**comet-planner.com**), or similar tools and data sources, to estimate tons of carbon dioxide equivalent (CO2e) that would be 1) avoided or 2) removed from the atmosphere and sequestered on farm by implementing each practice. A list of potential practices and their on-farm and climate mitigation benefits is then developed.

Finally, practices are prioritized based on needs and goals of the farm or ranch, choosing high carbon-benefit practices wherever possible. Economic considerations may be used to filter the comprehensive list of options, and funding mechanisms are identified, including; cap and trade, CEQA, or other greenhouse gas mitigation offset credits, USDA-NRCS and other state and federal programs, and private funding. Projects are implemented as funding, technical assistance and farm scheduling allow. Over time, the CFP is evaluated, updated, and altered as needed to meet changing farm objectives and implementation opportunities, using the fully implemented plan scenario as a goal or point of reference. Where plan implementation is linked to carbon markets or other ecosystem service markets, periodic Plan evaluation may be tied to those verification or monitoring schedules.

Additional information about Carbon Farming can be found on line at: www.marincarbonproject.org and www.carboncycle.org.

BARE RANCH

In the winter of 2015, Bare Ranch sought assistance from the Carbon Cycle Institute and Fibershed to develop a Carbon Farm Plan for the historic Ranch. As a participant in the Carbon Farm Planning program, the Ranch has agreed to an ongoing partnership with Fibershed through the Carbon Farm Planning Process and beyond, focusing on the potential to produce Climate-Beneficial™ wool through implementation of a carbon farm plan for approximately 4,500 mostly irrigated acres of the historic Ranch, located within Washoe (Nevada), Modoc and Lassen (California) counties.

Photo courtesy of Bare Ranch

BACKGROUND (by Ceci Dale-Cesmat)

Bare Ranch is located in eastern Lassen county, southern Modoc county and in western Washoe county, approximately 12 miles south of the town of Eagleville, CA, (see location map). The ranch is within the Great Basin, located in Major Land Resource Area (MLRA) 23, Malheur High Plateau. This region is part of the northern Lahontan hydrologic unit but is within a closed basin, with Bare Creek (flowing east from the Warner Mountains, traversing northerly through the Ranch) draining into Lower Alkali Lake. Most water on the ranch is from Bare Creek and springs originating on the ranch. There are two reservoirs off Bare Creek that are used for irrigation storage: Sworinger and Upper Newland.

The climate on the ranch is typical Great Basin type, with most rainfall occurring as high-intensity, convective thunderstorms during the growing season. The average annual precipitation is 9 to 12 inches in most areas of the ranch. It is about 18 to 36 inches in the mountains, just west of the ranch. The driest period is from midsummer to mid-autumn. The average annual temperature is 34 to 52 degrees F. The freeze-free period averages 125 days and ranges from 80 to 170 day

Wildlife

Some of the major wildlife species in this area are mule deer, coyote, American badger, bobcat, beaver, jackrabbit, cottontail, sage grouse, and quail. The species of fish in the area include trout, dace, shiners, and suckers. Migratory species include Sandhill cranes, American avocet, bald eagle, yellow-headed blackbird, red-winged blackbird, common snipe, Canada goose, pintail, cinnamon teal, mallard, Great blue heron, white-faced ibis and many other resident bird species.

HISTORY OF BARE RANCH

Archaeological evidence suggests occupation of the Bare Ranch landscape, on at least a seasonal (late fall to early spring) basis, for approximately 7,000 years (BLM 2004). Bare Ranch itself was founded in 1873 (John Estill, personal communication) by Thomas Bare, who entered Surprise Valley among the flood of settlers emigrating along the Applegate Trail at that time (BLM 2004). While the main emigrant trail passed either across or north of Middle Lake, depending upon time of year (BLM 2004), Bare settled south of Lower Lake on what was then called Wood Creek (renamed Bare Creek), building the first Euroamerican cabin within that portion of the Valley. Lands south of Eagleville settled by John Bordwell and Hill later became part of the Bare Ranch as well. Conflicts between Euroamerican immigrants and Native American inhabitants of Surprise Valley began early on, but intensified throughout the 1860s, culminating in the Modoc War of 1872-73, which terminated in victory for the immigrants and the cessation of armed conflict between the two cultures.

In 1895, Louis Gerlach incorporated his holdings in Nevada as the Gerlach Livestock Company, including some 30,000 acres of grazing land in Washoe County, Nevada, and northern Modoc and Lassen counties, California. He purchased the Bare Ranch in the early 1900's, stocking some 18,000 cows and sheep (John Estill, personal communication). At the time of Gerlach's death in 1923, there were some 15,000 head of sheep and 5,000 head of cattle on that range.

Irrigated alfalfa became a significant land use in the Valley in the late 1800s and early 1900s, and heavy grazing impacts occurred in the upland rangelands during this period. By 1912, the Patterson sawmill was established on the eastern front of the Warner Mountains, southeast of Lower Lake, but by the 1930s, dwindling timber supplies and the Depression brought an end to the lumbering era.

Current Land Use

The Estills purchased the Bare Ranch in 2001. The Ranch currently runs mother cows, calves, yearlings and sheep on most of the property, as well as a small herd of horses. The Ranch also leases significant acreage of sagebrush steppe and juniper woodland rangeland from the Bureau of Land Management for seasonal grazing.

Grass and alfalfa hay are also grown on the loams and clay loams of the four pivot irrigated fields, wheel line fields and flood-irrigated fields making up most of the approximately 4500 acres that are the subject of this Plan (see appendix, Bare Ranch Field Map).

SURPRISE VALLEY HYDROGEOLOGY

http://www.water.ca.gov/pubs/groundwater/bulletin_118/basindescriptions/6-1.pdf

The Surprise Valley basin is approximately 50 miles long and 12 miles wide, with no hydrologic outlet. The central portion of the valley floor consists of basin and lake deposits. Most of the streams draining into Surprise Valley originate along the eastern slopes of the Warner Mountains and empty into the Upper, Middle, and Lower Alkali lakes. These lakes are shallow and alkaline and usually become dry in summer months. Annual precipitation in the basin ranges from 13 to 17 inches, increasing to the north. (SWRCB 2004).

Photos by Paige Green

SOILS AND ECOLOGICAL SITES OF BARE RANCH

Implementation of conservation practices within the Carbon Farm framework is based upon the grouping of land management activities by ecological site. An ecological site is an area of land with distinct geophysical characteristics, determined by slope, soil type, and aspect. Because a farm or ranch tends to consist of a mosaic of ecological sites that reoccur across the farm landscape, the farm or ranch can be described using just a few ecological site categories. Similar ecological sites can be expected to respond similarly to similar management, and to support similar types of vegetation and ecosystem processes, including carbon sequestration potential, assuming similar management history and similar management into the future.

Ecological site delineation helps identify those sites most likely to yield significant carbon benefits given specific practices, and those for which specific practices may not be particularly productive. For example, increasing soil organic carbon (SOC) with compost applications may be a very productive strategy on many sites on Bare Ranch, mapped as having soil organic matter of 3% or below, and where slopes allow access for equipment. Compost additions would be of little value, however on the 11% of the Ranch mapped as having Cumivar muck soils, with 40% SOM (table 1). Figure 2 shows ecological sites on Bare Ranch as delineated by the NRCS. Some sites are not designated because not all ecological sites have been defined or identified by alphanumeric designation or nomenclature at the time of this plan's development. Numbers refer to soil mapping units; note that ecological sites are mapped at a coarser scale than soils, so that a single ecological site may appear to include several soil types. However, soils within an ecological site map unit will be similar enough that a separate site designation was not considered necessary at current resolution of ecological site mapping.

DATA SOURCES

Maps: NRCS Field Office, Alturas; Websoilsurvey;

http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

Name: Surprise Valley-Home Camp Area, California and Nevada

Area Symbol: CA685

Data Available: Tabular and Spatial, complete

Version:

Survey Area: Version 8, Sep 16, 2014
Tabular: Version 6, Sep 16, 2014
Spatial: Version 3, Dec 14, 2013

SOIL MAPPING UNITS

Importantly, Cumivar Mucks, soil mapping units 356 and 357, are not presently provided an ecological site delineation in figure 2. They may ultimately be included within the Ecological Site, Wet Meadow, RO23XYO25NV, as these soils are the only Histosols (organic/muck soils) currently included in Bare Ranch Ecological Site descriptions (see appendix, Ecological Sites at Bare Ranch). Ecological site delineation is an ongoing and evolving process, and anomalies such as this are not unusual.

At 40% organic matter (table 3) in the surface layer (0-8 inches), the muck soils of Bare Ranch represent a uniquely important carbon sink; preservation of this significant pool of soil carbon is recognized as a high priority within the Carbon Farm Plan. Muck soils, also called organic soils or Histosols, have a low Bulk Density, meaning they weigh much less per unit volume than mineral soils, for example, 0.2 – 0.3 grams per cubic centimeter (g/cc), or 12.5-18.73 pounds per cubic foot, compared with mineral soils, with a typical Bulk Density in the range of 1.2 – 1.5 g/cc, or 75 to 94 lbs/ft3 (NRCS 2006, Cowan nd). As a result, an acre furrow slice (6.7" depth) of muck soil weighs approximately

400,000 pounds, while a comparable layer of mineral soil weighs two million pounds. This is an important consideration when interpreting soil tests or evaluating the carbon content of muck soils.

With over 913 acres of Bare Ranch mapped as Cumivar Muck at 40% organic matter (20% organic carbon) to 8" depth (NRCS), these soils contain approximately 49 metric tons of organic carbon per acre, representing 181 metric tons of CO2e. Across the 913 acres of muck soils on Bare Ranch, this represents approximately 165,683 metric tons of sequestered CO2e in the soil surface horizon alone (table 3 and soil map unit description, appendix). Avoiding conversion of these muck soils from permanent pasture to tilled cropland, and careful management of livestock to insure continued capture of atmospheric carbon through optimal forage production, are the best strategies for insuring maintenance of this important Bare Ranch carbon sink[1].

SODIUM ABSORPTION RATIO

Of significant importance in defining ecological sites at Bare Ranch is the soil Sodium Absorption Ratio (SAR, table 2, 3). SAR is derived from relative concentrations of sodium (Na), calcium (Ca), and magnesium (Mg) in the soil solution. The equation at right is used to calculate SAR.

$$SAR = \frac{[Na^+]}{\sqrt{\frac{1}{2}([Ca^{2+}]+[Mg^{2+}])}}$$

When SAR is greater than 12, soil physical problems arise and crops have difficulty absorbing water, which negatively impacts production (Montana State U, 2010) and thus the ability of growing vegetation to capture atmospheric CO2. **http://ecorestoration.montana.edu/mineland/guide/analytical/chemical/solids/sar.htm#**

Up to 25% of Bare Ranch soils have a SAR high enough to negatively impact plant growth (table 1). Strategies for reducing SAR, and/or moderating the effect of high SAR soil conditions include gypsum (calcium sulfate) applications and additions of organic matter, such as compost. Importantly, organic matter used for this purpose should be tested for sodium content, to avoid further aggravating saline soil conditions. Compost tends to have a lower salt content than manure, and this is one of several reasons why compost may be preferred over manure as a source of organic matter on high SAR soils.

Another strategy for reducing soil SAR is to irrigate with sufficient fresh water to flush salts, particularly sodium, out of the crop root zone. This tends to result in accumulation of salts, and thus higher SAR, lower in the soil profile. There is a risk of bringing this higher SAR sub-soil to the surface if soils are subsequently leveled or deeply cultivated. Drip irrigation, though a good technology to reduce water use and energy use associated with pumping, by design involves flushing less fresh water through the soil profile, potentially leading to increases in soil salinity over time. Therefore, projects to install drip irrigation and level or till cropland on Bare Ranch should probably only take place on those soils with a SAR of 9 or below (Lacolla and Cucci 2008, Orloff 2007).

As of Summer, 2016, Bare Ranch was considering installing sub-surface drip irrigation, as a water and energy conservation measure, on some 200 acres in the Trailer House Field, Cook House Field, Hay Field and a small portion of the Upper Murphy Field. As shown in table 3, the Hay Field is mapped as having a SAR of 9, while Upper Murphy has a SAR of 9-40. Based on the above considerations, these fields may be unsuitable for drip irrigation; at a minimum, soil sampling should be carried out to determine if the SAR levels reported in the NRCS-USDA soil report are accurate. The Trailer House and Cook House fields are not reported as having high SAR levels, and therefore may be suitable for underground drip irrigation. ***Soil sampling and consultation with a saline soils irrigation specialist is recommended prior to installing drip irrigation in this potentially sodic/saline soil environment.***

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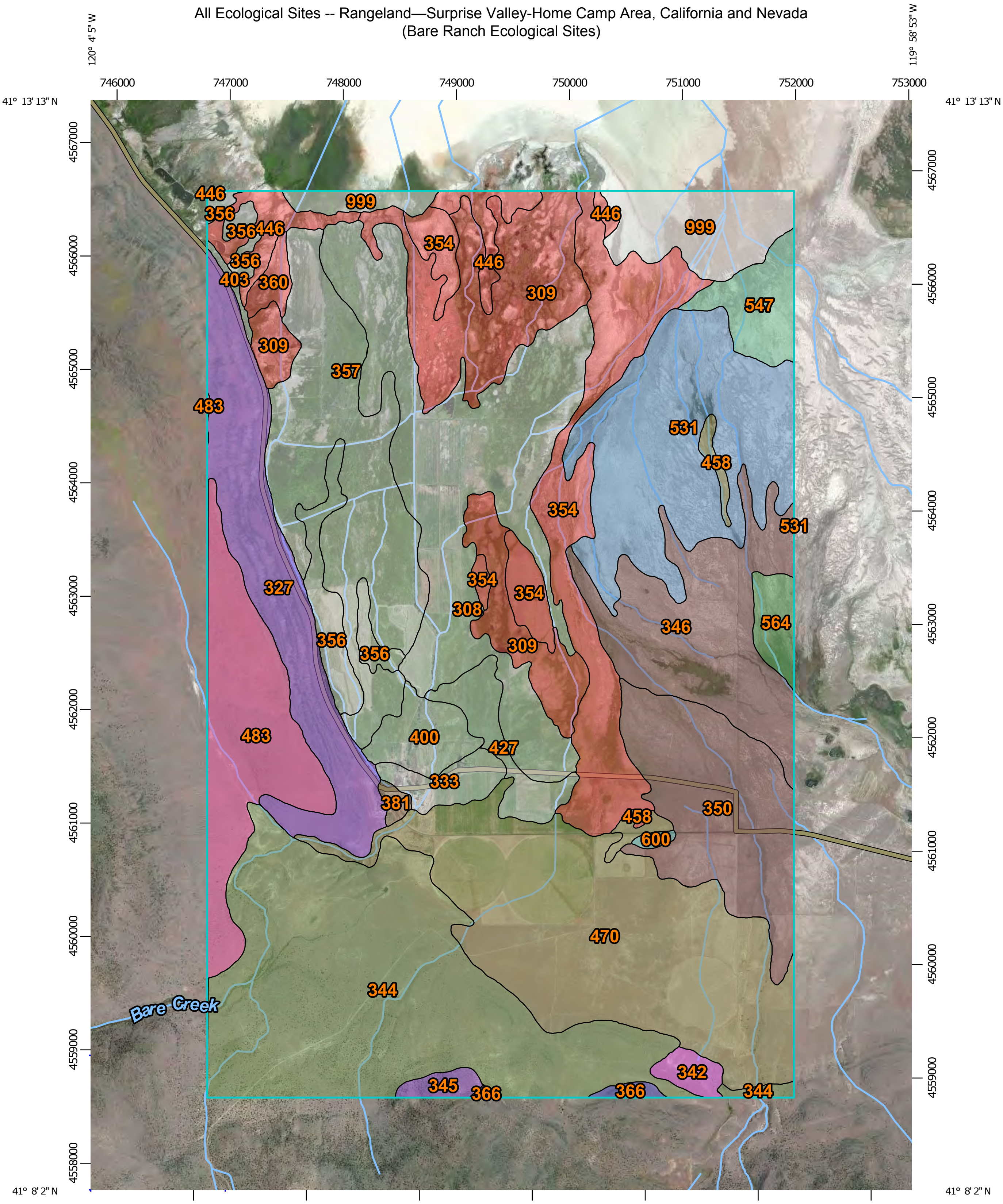
[1] A "carbon sink" in this plan refers to the biophysical storage of carbon in soils or vegetation, as opposed to a "carbon source," which refers to a source of carbon emission to the atmosphere.

Figure 2. Mapped and Unmapped Ecological Sites of Bare Ranch

All Ecological Sites -- Rangeland—Surprise Valley-Home Camp Area, California and Nevada
(Bare Ranch Ecological Sites)



Map Scale: 1:46,800 if printed on A portrait (8.5" x 11") sheet.

N

0 500 1000 2000 3000 Meters

0 2000 4000 8000 12000 Feet

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 10N WGS84

Table 1. Ecological Site Designations, Bare Ranch (NRCS WebsoilSurvey)

R023XY002NV	SALINE MEADOW
R023XY010NV	SALINE BOTTOM
R023XY011NV	DUNES 8-10 P.Z
R023XY022NV	WELL DRAINED FAN 12-14 P.Z.
R023XY039NV	LOAMY SLOPE 10-14 P.Z.
R023XY060NV	LOAMY 8-10 P.Z
R023XY093NV	GRAVELLY CLAY 10-12 P.Z.
R023XY097NV	LOAMY FAN 8-10 P.Z.
R023XY098NV	DEEP LOAMY 10-12 P.Z.
R024XY003NV	SODIC TERRACE 6-8 P.Z.
R024XY011NV	SODIC FLAT 6-8 P.Z.
R024XY022NV	SODIC TERRACE 8-10 P.Z.
Not rated or not available	P.Z. = Precipitation Zone, inches

Large amounts of sodium salts are especially problematic in agricultural soils because excess sodium destroys drainage and aeration by breaking down porous soil aggregates. Leaching to remove salt or adding gypsum (calcium sulfate) and then leaching to remove sodium are remedies for salt-affected soils that typically require adequate drainage and abundant high-quality irrigation water. Gypsum works by chemically replacing sodium ions with calcium ions, so may not work well on soils that are already very high in calcium (Norton, 2009). Determining how far the water table is from the soil surface is important because during the growing season evaporation pulls moisture to the surface from varying depths, depending on soil texture. As water evaporates from the soil, it leaves the salt behind.

Every effort should be made to avoid increasing SAR on Bare Ranch soils generally in order to avoid reducing forage production and photosynthetic capture of CO2 by cropland, pasture and rangeland vegetation. Tillage aggravates salt problems by bringing additional salt to the surface, destroying soil surface structure, reducing water infiltration, and destroying vegetation, including weeds, which can help maintain a lower water table through evapotranspiration. A cover crop, even of weeds, is generally better for reclaiming saline soils than a tilled fallow (Holzworth 2009).

While 38 distinct soil mapping units have been mapped on Bare Ranch (see appendix, Soils) this plan focuses on 12 to 15 ecological sites representing soils that occupy 100 acres or more of the Ranch (table 2, figure 2), or 89% of the Ranch (see map, appendix Soils, for complete soil listing).

Table 2. Bare Ranch Soils and Ecological Sites

(NRCS Designations)

Map Unit	Soil Type	Ranch Area	SOM %	Ecological Site	SAR
308	Bicondoa Clay	12%	3	Saline Bottom	9
309	Bicondoa-Crutcher	9%	1 to 3	Saline Bottom-	9 to 40
327	Bucklake-Mcwatt Association	8%	2	Loamy Slope 10-14 P.z.	-
344	Coppersmith-Bareranch Assoc.	5%	2	Deep Loamy 10-12 P.z.	2
346	Couch ashy fsl 0-2% slope	2%	2	Sodic Terrace 8-10 P.z	21
350	Couch-Nevadash Assoc.	4%	2	Sodic Terrace 8-10 P.z	21
354	Crutcher ashy vfsl	8%	1	Saline Bottom	40
356	Cuminvar muck	2%	40	-	-
357	Cuminvar muck-drained	9%	40	-	-
400	Four Star Ashy Loam	1%	3	-	-
427	Hussa ashy cl 0-2%	2%	2	Dry Meadow	-
444	Keddie loam 0-2%	2%	2	Semi- wet Meadow 16+ P.z.	-
446	Lolak silty clay	2%	2	Saline Bottom	14
460	Macnot-Nomazu	2%	0-2	Droughty Loam 8-10 P.z.	7
470	Nevadash-Couch Assoc.	13%	2	Loamy Fan 8-10 P.z.	2
483	Nitpac-Tuinnison-Devada Assoc	4%	2	Cobbly Claypan 8-12 P.z. ; Churning Clay	-
583	Warnermount grav- ashy loam, 4-15%	6%	3	Ashy Slope 16-30 P.z.	-
Total		86%			
Ranch Total		100%			

Table 3. Bare Ranch Field, Soils and Organic Matter

Field	Acres	Soil Map Unit	SAR	SOM	Compost Suitability
Upper Hot Meadow	135	356	-	40	N
Middle Hot Meadow	122	356/357	-	40	N
Lower Hot Meadow	181	356/357	-	40	N
Bare Meadow	136	357/356	-	40	N
Camp 40 Field	91	357	-	40	N
Camp 12 Field	83	357	-	40	N
Rodriguez Field	369	357/308	9	40	N
Work Horse Field	276	356/357	-	40	N
WRP Patterson	1016	308/309	9 - 40	1-3	N
Wheat (East) Field	173	308	9	1-3	Y
Lower Murphy	122	308	9	1-3	Y
Upper Murphy	168	308/309	9 - 40	1-3	Y
Murphy East	261				
Upper East	85	308	9	1-3	Y
Hayfield	45	308	9	1-3	Y
Silver Tank	78				
East Silver Tank	209	309/350/346	21	2	Y
Redwood Tank	215	354/309	40	1	Y
Horse Pasture	46	357	-	40	N
Sheep Pasture	31	381	-	-	Y
Wheel Line Field	127	333/427/470	2	2	Y
Cook House	35	400	-	3	Y
Trailer House	25				
Greg	61	350	21		Y
R.R.R. Field	43	470	2	2	Y
Swamp	53				
Pivot 1	87	470	2	2	Y
Pivot 2	125	470	2	2	Y
Feedlot	77	350	21	2	Y
Compost	100	350	21	2	Y
Sheep Camp	73	470	2	2	Y
Sheep Camp Field	310				
88 Field	88				
Pivot 4	157	470	2	2	Y
Bare Creek Field	210	344/470	2	2	Y
Sand Pit	25				
Dump Field	99				

SOM 40% = Cumivar Muck Soils
Sodium Absorption Ratio (SAR) > 9 = sodic/saline soils

GRAZING

Goals and Objectives

Maximize forage production, increase soil carbon and soil water holding capacity, protect water quality, improve pasture nutritional profile and increase length of grazing season.

Grazing and Carbon

The Carbon Farm grazing plan combines overall ranch livestock carrying capacity with ecological site potentials and limitations to manage for optimum carbon capture - as forage production and soil carbon - within site-specific management constraints. In general, increasing forage production from permanent pastures on farm will tend to result in an increase in soil carbon, assuming good or excellent pasture management. Practices that reduce or repair soil erosion, reduce area of bare soil, reduce trailing, and provide grazed vegetation sufficient rest for adequate regrowth between grazing periods, will tend to result in both more overall forage production and more carbon sequestered in vegetation and soils over time.

Grazing management strategies within this plan, therefore, include increasing pasture divisions to allow longer rest periods and increase livestock harvest efficiency, restore degraded pasture areas, and increase production through improved pasture rotation, compost applications, nutrient management and improved irrigation technology by replacing flood irrigation with gated pipe. Intensification of pasture management will require development of additional watering points on the ranch, as well as additional fencing, whether permanent or temporary.

Photo by Paige Green

Installation of cross fencing in Bare Meadow to create eight separate pastures will include installation of additional water troughs to supply fresh water to each of those pastures. This will both enable pasture rotations and allow periodic relief of livestock pressure on the Hot Meadow irrigation canal, as cattle will prefer to drink fresh water from the troughs rather than warm water from the canal. While the canal will remain an important source of winter livestock water, the diversion of livestock use from the canal to the troughs in the warmer months, in conjunction with rest between rotational use of each section of the canal, is expected to allow significant recovery of herbaceous vegetation along the canal without requiring seasonal livestock exclusion beyond that achieved through pasture rotation.

RESIDUAL DRY MATTER

Residual dry matter (RDM) (Bartolome et al 2006) is the herbaceous plant material -living or dead- left standing or on the ground at the end of the grazing year (typically measured in October, or just before the start of the water year). RDM measurement is commonly used to assess the year's grazing use on annual rangeland, whether moderate, excessive or light. The recommended standards are based on the observation that the amount of RDM remaining in the fall interacts with site conditions and weather to influence rangeland vegetation species composition and forage production in the coming year. This is particularly true of annual-dominated pastures, but the principle has some relevance for perennial pastures as well. For purposes of this plan, a "take half, leave half" rule of thumb was applied, suggesting one half of annual above ground pasture production is available for livestock use (see below and appendix, Bare Ranch Grazing Management Plan, Dale-Cesmat, 2016).

While leaving appropriate amounts of RDM can appear to represent lost grazing opportunity in any given year, consistently low levels of RDM over time can be expected to result in gradual loss of soil organic matter and soil carbon, soil water holding capacity and rangeland productivity. Insufficient soil cover, whether live or dead material, can result in a downward spiral of declining rangeland condition. In this sense, RDM can be understood as an investment in the long-term productive capacity of the land, albeit at the "cost" of current season's total grazing capacity. Because of the limited amount of site-specific research information, however, RDM standards normally have to be developed using local experience and general guidelines, particularly on perennial pastures. RDM standards have not been developed for irrigated pasture or for grazed agricultural fields, however, maintaining some RDM on both is highly recommended to avoid depleting existing soil carbon stocks through exposure of bare soils to water, wind and sunlight.

With warmer and drier average conditions experienced over the past few years, and anticipated in the future, it may be necessary to consider both historic norms and dry year precipitation when setting RDM targets on Bare Ranch.

RDM is based upon a percentage of total annual above ground production. Thus, while total recommended RDM may decline from wetter to drier rangeland types, RDM, *as a percentage of total production*, should actually *increase* on drier annual rangelands. The long-term implications of reduced RDM should be considered when adjusting RDM targets downward, as reducing RDM *as a percentage of total annual production* will tend to drive a downward spiral of soil degradation, reduced water-holding capacity and reduced rangeland productivity over time.

This speaks to the need to manage livestock forage utilization in relation to forage availability, including the need for destocking under low production conditions, in order to insure RDM targets are met. It also speaks to the potential to "bank" soil carbon—and future forage production—by increasing RDM in favorable years and using concentrated herd impacts to facilitate the transfer of that accumulated "surplus" above-ground biomass to the soil carbon pool via manuring and trampling. If followed by sufficient rest to allow adequate regrowth prior to the next grazing period and/or plant establishment in the following season, forage production, and overall carbon capture, can *gradually increase* over time. See further discussion under Prescribed Grazing, below.

PRESCRIBED GRAZING

Prescribed grazing practices are designed to improve livestock production by improving grassland condition and productivity, which is expected to increase soil carbon stocks over time. This process generally involves planning both pasture grazing periods and rest periods to meet long-term management objectives, as pasture conditions and infrastructure allow. Successful grazing prescriptions often involve dividing pastures, thus reducing pasture size while increasing pasture numbers. Decreasing the number of herds on the ranch, by combining herds where possible, can also facilitate this process, again by increasing the number of pastures that are rested from livestock use at any one time, and by increasing the length of the rest period between grazing periods.

Changing the length of grazing periods and rest periods with season is a key strategy to optimize forage production and utilization. As rapid forage growth begins in spring, grazing periods (time animals stay in each pasture) can be shortened. This accelerates the rotation, which leads in turn to fewer days of rest between grazing periods. Rest periods during the rapid growth period can be as short as 3 or 4 weeks, while grazing periods can be shortened to as few as 3 days, depending upon rate of forage growth, which is a function of soil moisture and soil temperature, and days of rest, which again depends on number and size of pastures, number of herds and herd size.

Ideally, cattle are moved rapidly enough to prevent grazing of plant regrowth within the same grazing period, which allows more rapid plant recovery from grazing impact and, ultimately, more total forage production. This approach also tends to favor perennial grasses, if adequate time for carbohydrate storage and foliage regrowth is allowed between grazing periods. Rapid early season rotation may allow complete deferment of grazing in some pastures, which may not all need to be included in the rotation at this time of year. This in turn enables “banking” of forage for later in the year, whether as standing forage in the field, or as conserved forage (hay, haylage, silage).

As forage growth begins to slow in late spring or summer, pasture rotations should also slow, and the time animals remain within a given pasture can increase, depending upon forage availability. Rest periods necessarily increase accordingly, so that by summer, periods of rest may be 90-120 days or more, assuming sufficient forage is available. All else being equal, it is better, with respect to long-term pasture productivity, to hold animals longer than ideal on a given pasture (assuming adequate forage) –and thus lengthen the rotation- than to bring them back to a pasture before it has achieved adequate regrowth (Voisin 1961).

Opportunities for enhanced carbon sequestration through prescribed grazing exist throughout Bare Ranch. Water developments and fencing are essential to achieve intensification of pasture management, as outlined in excerpts from the Grazing Management Plan (Dale-Cesmat), following page (for full Grazing Management Plan see appendix).

GRAZING MANAGEMENT PLAN, BARE RANCH

By Ceci Dale-Cesmat
Spring 2016

Current Management

Sections redacted in consideration of Ranch privacy.

The ranch is used for grazing cattle and sheep. It is grazed in conjunction with several public lands grazing permits and relies on those permits for much of the spring and summer grazing. With the grazing permits and the deeded land, the ranch runs sheep and mother cows, plus a fluctuating number of stocker cattle and a replacement heifer herd. A rotational grazing system is used on the irrigated pasture fields. All wheat or alfalfa fields are grazed late season after haying is completed. The upland fields are used early or late season for short periods of time while livestock transition to the public land grazing permits. The following is a breakdown of each of the rotations of those herds:

1. Sheep -
   a. Ewes/lambs – Most of their time is spent on public lands permits. The grazing dates on the BLM, Forest Service and deeded lands are as follows:
      i. Dec – June they are on BLM desert permits east and south of the home ranch. This is where they lamb.
      ii. June – Sept/October they are on a Forest Service permit in the Warner Mountains.
      iii. October – November or early December they are on the home ranch, broken into 4 to 6 bunches spread out on hay ground during the fall. About 1000 are placed on the 173-acre Wheat field (see map). When it is grazed down to approximately 3-4 inch stubble they are moved to the crop fields (alfalfa and wheat) to graze on crop aftermath. This does not include the meadow systems on the ranch. The crop field grazing cleans up material left after harvest, and organic matter and nutrients from sheep manure and urine is incorporated into the soil.
   b. Rams – Stay on the ranch year-round. After they service the ewes in the fall, they are used for weed control around the ranch. They are moved frequently from one area to the next to meet weed management objectives.
2. Cow/calf herd – The mother cows run on the ranch as well as on public lands permits and another deeded ranch just north of the Bare Ranch. The grazing dates vary annually with weather and forage production; typically the following are grazing dates:
   a. BLM herd – This herd grazes both BLM grazing permits in the spring and summer, then moves back to the ranch in the fall/winter.
      i. March 1-July, most animals go to the BLM Permits
      ii. July – November they graze the East Silver Tank field and the Greg field.
      iii. December – end of February animals are fed hay at the Bare Ranch until BLM turnout.
      iv. These cows calf March/April of each year on BLM leased land. Calves are weaned in October.
   b. Forest Service Herd – This herd grazes on the Mountain permit, the high elevation deeded meadows, the leased lands and then come back to the Bare Ranch.
      i. May 15 – November – Mountain and high elevation rangeland grazing.
      ii. When they come off the high elevation range, some are moved to a nearby ranch.
      iii. Another group grazes the Work Horse field (276 acres), Rodriquez field (360 acres) and Swamp Field

(53 acres) during the fall into early winter, then they are moved to uplands on the ranch and fed hay until they are moved to the public lands grazing permits.

   iv. The cows calf in February and March and calves are weaned around September.

3. Replacement heifer herd – The replacement heifers consist of animals that rotate between the Redwood Tank and Murphy fields until they calve and join the cow herds. These fields are grazed all summer.
4. Another herd of 1st calf heifers with calves is on the Ranch all year, rotated in the summer between the Silver Tank, East Silver Tank and Hay Field.
5. The cows are fed hay through the winter and turned out to the BLM permits, high country deeded ground, or the meadows in the spring.
6. Stocker cattle – Yearlings are broken up into three herds. These herds graze in an approximate 30-day rotation starting as 500-700 pound cattle and being sold as 800 pound cattle in late September or early October. Two of the herds graze the fields west of Bare creek. These are known as the west side fields, consisting of six irrigated pastures totaling 748 acres. Due to the poor condition of the fences, the two herds are kept separated by at least two fields. The third stocker herd is kept on the east fields (east of Bare creek) and consists of 350 acres of irrigated meadow, broken up into 4 fields. All stockers are grazed on the ranch from late spring through early fall, at which time they are sold.

Goals & Objectives

After consultation with John and Lani Estill, they described their ranch goals and objectives as follows:

- Increase biodiversity on the ranch, including plant and animal diversity
- Maintain or improve carbon sequestration by:
  - Increasing plant growth (roots and shoots)
  - Increase living ground cover at the potential of the climate and site.
- Increase the carrying capacity of the ranch by:
  - Improving grazing management thus increasing plant health and vigor
  - Optimizing rest and recovery times between grazing cycles
  - Improving soil health & water holding capacity to increase photosynthesis.

Resource Concerns

Resource concerns are items identified on the ranch that may be preventing the landowner from reaching their goals and objectives. The resource concerns are based on factors inhibiting the full potential of the soil, water, plants, animals, or economics of the ranch. These are identified during a site inspection and landowner interviews. The following are items identified on the Bare Ranch:

1. Noxious or invasive weeds – A few weedy species exist on the ranch including hoary cress, phragmities, tall whitetop, clasping pepperweed and mustard. While these were not in large numbers, they are occupying spaces that could be taken up with preferred forage or native species.
2. Riparian – Some of the riparian areas along Bare Creek are fenced, but others are not. Those that aren't have exposed areas of bare soil and are subject to erosion and downcutting.

3. Water use efficiency – Current irrigation system is open ditch and wild flood in all the irrigated pastures. If most of these open ditches were switched to pipeline with risers, water use efficiency would increase greatly. Tom Hill, the NRCS engineer at the NRCS field office can calculate the amount of water saving by converting to pipeline.
4. Improved forage harvest efficiency/livestock distribution – Currently irrigated pastures are very large (up to 360 acres). Because of the size of these fields, grazing is uneven. Some areas are grazed short while other less desirable species are grazed little. If fields were smaller[2], grazing use would be uniform and harvest efficiency would be increased. Each field would be allowed longer rest periods between grazing so plant roots and shoots could recovery to their pre-grazing condition. This will increase forage production and photosynthesis on the ranch.
5. Decrease wind erosion and bare soil on the eastern most portions of the ranch (includes the feedlot, compost pad and upland fields. Low production and current conditions cause wind erosion to occur in these areas. The landowners would like to plant a windbreak on at least 1/4 mile section to reduce wind erosion near the feedlot, compost pad and Sheep Camp field.
6. Increase species diversity in Lower, Middle and Upper hot pastures. Currently areas of bare ground occur. This may be due to high pH soils. Several new cultivars could be interseeded into existing stand to increase ground cover and species diversity.
7. Increase wildlife habitat values for sage grouse, waterfowl, neotropical migrant songbirds and shorebirds.

Forage Inventory

The ranch is made up of 39 fields of varying size. Most of the land is irrigated pasture with primarily native species. There are (12-15) ecological sites on the ranch. On the following page is a table showing grazed field names, size, vegetation type, ecological site, forage production and AUM value.

Photo by Paige Green

[2] Reducing pasture size via cross fencing, or reducing number of herds by combining herds are two potential strategies for increasing forage harvest efficiency and lengthening periods of rest between grazing periods.

Table 4. Field names, size, ecological site, forage production and AUM value

1 AUM (animal unit month) is the amount of forage needed to support a 1,000 lb cow and her calf for one month; here it is assumed to be 900 pounds of dry forage. 1 AUY (animal unit year) is the amount of forage needed to support one animal unit (cow with calf, or equivalent) for one year.

Animal Inventory

These values are based on the time each herd is actually on the ranch. Animal numbers are based on personal communication with the landowner.

1. Sheep
   a. Rams
   b. Ewes – 4000/2.5 months (4000 x .2 x 2.5) = 2000 AUMs
2. Stockers
3. Replacement heifers
4. Cow herd
   a. Desert herd are only on the ranch for a total of 5 months
   b. Mountain herd are on the ranch for approximately 4 months

Forage/Animal Balance

The forage/animal balance describes how close the forage produced on the ranch meets the animal demand or forage requirement. As with all forage production calculations, these are based on an average production year. The numbers may vary from year to year. Because most of the Bare Ranch is irrigated pasture, values may not be the same as those described in the Soil Survey and ecological site data. The ecological site data is based on rangeland conditions, where not inputs are made to enhance production such as irrigation, improved forage species, fertilizer, etc. Animal numbers and season of use described above is based on personal communication with the landowner and may be approximate only.

Grazing Strategy

In order to meet the ranch objectives and address resource concerns, a grazing strategy should be implemented that will allow intensive rotations between fields with the goal of at least 21-28 days rest between grazing cycles. This should be adequate time for the plants to regrow to their pre-grazing height prior to being grazed again.[3] As plant shoots recover from grazing so will the roots, allowing carbohydrate storage, nutrient cycling and carbon sequestration. This type of grazing strategy will be implemented in all the irrigated pastures on the ranch.

Upland fields are not as important for rotational grazing since without irrigation, recovery from grazing will be very slow. Upland fields should only be grazed once during the year or in some cases, could be a place where hay is fed early in the growing season, then move cattle off during the peak of the growing season to allow vegetation to set seed. Return back in these fields at the end of the grazing season to harvest this year's growth and have the animals' plant seeds that have fallen on the ground through hoof action.

All crop fields will be grazed as aftermath forage, i.e. forage that is remaining after mechanical harvest.[4]

Infrastructure Needed to Increase Forage production, Implement Grazing Strategy and Increase Carbon:

- **Convert 163 acre East Field to irrigated alfalfa to increase hay production.**
- Cross fence the Hot Meadows to break them up into eight new pastures. This will allow intensification of current grazing management. It will increase rest periods between grazing, improve uniformity of utilization, increase photosynthesis thus increasing carbon sequestration, nutrient cycling and soil health. **Anticipated 50% increase forage production.**
- Add additional water facilities to newly created fields.
- Interseed improved salt tolerant forage species in irrigated pasture fields within the Saline Bottom ecological site. These could include Newhy and AC Saltlander wheatgrass as well as Birdsfoot trefoil. **Anticipated 10% increase in forage production on approximately 2430 acres of pasture on the Saline Bottom ecological site.**
- Improve open ditch flood irrigation system and convert it to gated pipe. This will allow improved irrigation efficiency and save water as well as allowing irrigation to occur after livestock leave a pasture, not when they are on the field, thus decreasing trampling and compaction damage. **Anticipated 50% forage production increase.** Not quantified due to partial overlap with above categories and uncertainty regarding number of flood-irrigated acres.
- Fence all of the riparian area along Bare Creek.[5] With intensification of grazing system, make sure livestock don't have access to the live stream. This will improve wildlife habitat within the stream corridor and decrease stream bank erosion.

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[3] 21-28 days rest should be adequate on irrigated pasture during the rapid-growing season, but rest periods will need to be longer as regrowth begins in spring and slows in the fall. Ultimately, increasing pasture numbers by increasing pasture divisions, as described in this plan, will enable increased rest periods in each pasture.

[4] Grazing of aftermath should be managed to retain some degree of residue for soil cover at all times whenever possible. Where supplemental feeding occurs on these sites, spoiled or uneaten supplemental forage can be included in the category of residue for soil cover.

[5] Consider designing riparian exclusion fencing to enable short-duration grazing by sheep within the riparian area on a once per year, end of growing season, basis to manage riparian vegetation as needed. Complete livestock exclusion, or protective caging of young trees, for up to 3 years may be needed to insure establishment of trees and shrubs within the Riparian Forest Buffer (see agroforestry practices).

CARBON BENEFITS OF GRAZING LAND PRACTICES

Prescribed Grazing (CPS 528). Implement prescribed grazing program on approximately 4,411 acres of pasture and rangeland. Sequester an additional 790 Mg CO2e per year.

Range Planting (CPS 550). No-till interseeding of salt tolerant forage species in irrigated pasture fields within the **Saline Bottom** ecological site (2,107 acres). Sequester an additional 720 Mg CO2e/yr.

Improved irrigation on approximately 1,000 acres of pasture (CPS 443). This will allow irrigation to occur after grazing periods, decreasing grazing on saturated soils, reduce trampling and compaction and increasing photosynthetic efficiency, resulting in an estimated increase in forage production of 50%. Sequester an additional 780 metric tons of CO2e per year.

***Total carbon benefits:* 2290 metric tons CO2e = 623 metric tons of C = 1246 metric tons of above and below ground biomass.**

Irrigation Improvement Discussion

Alternate wetting and drying (AWD) has been shown to have significant potential for reduced GHG emissions in flooded rice production (Richards and Sander 2014), and may offer similar benefits in a flood irrigated pasture system. Soils may emit both methane (CH_4) and nitrous oxide (N_2O), with CH_4 occurring under anaerobic (without air) conditions and N_2O emissions occurring in the presence of oxygen (aerobic conditions). CH_4 has a global warming potential (GWP) 25 times greater than CO_2, over 100 years, while N_2O has a GWP 298 times greater than CO_2 over the average 114 year life of that molecule in the atmosphere (EPA 2016).

Intermittent irrigation is a strategy to reduce CH_4 emissions by allowing aerobic conditions unfavorable for methane production (Eve et al 2014). Aerobic conditions can favor N_2O emissions, but studies suggest CH_4 reductions outweigh N_2O emission increases with AWD (Richards and Sanders 2014). While saturated soils are expected to support maximum CH_4 production, soil water content close to field capacity (60-70% saturation) is expected to support maximum N_2O emissions (Eve et al 2014). This suggests the value of avoiding soil saturation and minimizing the length of time soil moisture is at or near field capacity.

Data Gap: Emissions of GHG from flood irrigated vs pipe irrigated pastures at Bare Ranch

Soil organic carbon can increase more rapidly on irrigated than non-irrigated pastures due to enhanced productivity, and net GHG benefits can be maximized if N_2O and CH_4 emissions can be minimized while increasing pasture productivity. Richards and Sanders (2014) report a 43% reduction in GWP with a shift to AWD in rice production. Because data for N_2O and CH_4 emissions on irrigated pasture at Bare Ranch have not been recorded, their GWP was ignored for this analysis. Only the increased CO_2 sequestered in response to a 50% improvement in irrigated pasture production was included.

Data Gap: Per acre production of forage on irrigated permanent grasslands at Bare Ranch.

Estimated minimum forage production increase on 1,000 acres of irrigated pasture from conversion to pipe irrigation from flood:

(0.5 x 1700 lbs/acre) = 850 pounds/acre x 1000 acres = 850,000 pounds
= 425 short tons of additional forage.

Estimated additional CO2e sequestered on 1,000 acres of irrigated pasture from conversion to pipe irrigation from flood irrigation: assuming below-ground allocation of organic matter equivalent to above ground, net SOC increase would be 0.5 x 425 tons = 193 metric tons, or 708 metric tons of CO2e per year.

This is an extremely conservative estimate, as it does not consider avoided emissions of CH4, and almost certainly underestimates actual soil carbon increases associated with improved irrigation management. Actual forage production increases associated with this practice may also be significantly greater than estimated here.

AGROFORESTRY SYSTEMS AT BARE RANCH

Agroforestry is the practice of integrating trees and woody shrubs into crop and animal production systems. Agroforestry practices can increase on-farm biological and structural diversity; help control pests by providing habitat for beneficial insects and birds; protect crops and livestock by creating microclimates; reduce cold and heat stress on animals by providing shade and shelter; slow water runoff to reduce flooding, soil erosion, and water pollution while increasing water infiltration; reduce crop evapotranspiration by reducing windspeed; trap snow for soil moisture improvement, and provide multiple products, including forage, fruit, nuts, timber, fence posts and wildlife habitat.

Useful agroforestry practices for Bare Ranch include: Silvopastures, Windbreaks, Shelterbelts and Riparian Forest Buffers, discussed below (figure 3).

Figure 3. Common Agroforestry Practices (Schoeneberger et al 2012)

Riparian forest buffers are streamside plantings of trees, shrubs and grasses that reduce water pollution and bank erosion, protect aquatic environments, and enhance wildlife habitat.

Silvopasture systems combine trees with forage and livestock production on the same field. The trees are managed for wood while at the same time provide shade and shelter for livestock.

Forest farming is the cultivation of high-value non-timber crops (food, medicinal, and crafts) under the protection of a forest canopy that has been managed to provide a favorable crop environment.

Windbreaks are rows of trees and shrubs that reduce wind speed. They improve crop yields, reduce soil erosion, improve water-efficiency, protect livestock and conserve energy.

Alley cropping systems are widely-spaced rows of high-value trees that create alleyways for crops. This system benefits trees and crops and provides annual and long term cash flow.

Special applications are plantings used to solve unique problems. Examples include the utilization of wastewater to produce a short rotation woody crop and plantings to help stabilize streambanks.

Table 5 . Reducing On-Farm Climate Risk Through Agroforestry

(USDA National Agroforestry Center)

http://nac.unl.edu/documents/workingtrees/infosheets/WTInfoSheet-ClimateAdaptation.pdf

Risk	Adaptation	Agroforestry Practice
Intense rainfall events	Slow water runoff to reduce flooding, soil erosion, and water pollution	Riparian forest buffers; alley cropping
Increased temperatures	Reduce heat stress on animals by providing shade	Silvopasture
Increased frequency and intensity of drought	Reduce evapotranspiration by reducing windspeed; trap snow for soil moisture improvement.	Windbreaks
Increased storm intensity (wind & precipitation)	Protect crops, livestock and pasture from wind	Windbreaks; alley cropping
Changes in length of growing season due to temperature and precipitation	Protect crops and livestock by creating microclimates	Windbreaks; alley cropping; forest farming
Winter storms and cold temperature extremes	Reduce cold stress on animals by providing shelter	Silvopasture; windbreaks
Increased insect and disease problems	Control pests by providing habitat for beneficial insects	Windbreaks; riparian forest buffers; alley cropping
Increased possibility of crop failure due to other risks	Reduce total crop loss by increasing crop diversity	All agroforestry practices

SILVOPASTURE

Silvopasture systems are defined by the integration of woody species, particularly trees, into grazed pastures. Trees can provide long-term economic returns, shade and other benefits, while livestock and forages generate an annual income from the same pasture. Silvopasture systems have three management components: trees, forages, and livestock. Correctly managed, the combined production from a silvopasture can be greater than traditional forestry and forage-livestock systems. Intensive livestock management is required, particularly in the early years during tree establishment, (http://nac.unl.edu/practices/silvopasture.htm).

Trees in pastures provide evaporative cooling, reduce radiant heat loss at night, and reduce wind speed. These improved conditions allow animals to spare energy for growth, particularly under hot conditions. Increased weight gain, milk yield, and conception rates have been reported for cattle and sheep grazing pastures with trees in warm environments. Forage nutritive value, digestibility, and botanical composition can be improved in silvopasture systems. In the winter, trees can provide protection from cold and reduce wind velocity (http://nac.unl.edu/practices/silvopasture.htm). Trees can also be a direct source of livestock forage, including foliage, twigs and fruits.

According to the University of Missouri Center for Agroforestry:

> "Shade has been shown to improve animal performance, with primary emphasis placed upon heat stress amelioration. McDaniel and Roark (1956) conducted a shade experiment with Angus (black hair coat) and Hereford (red and white hair coat) cows comparing artificial or natural shade to open pastures. The natural shade consisted of abundant, savannah-type tree spacing, and scanty shade, clusters of trees in the grazed pasture, treatments. Cows of both hair coat colors gained more than cows without shade, as did their calves. During the daylight hours from 6 am to 7 pm, the cows on the abundant shade treatment spent the most time grazing, with grazing time decreasing concomitantly with decreasing shade. McIlvan and Shoop (1971) measured improved gains in yearling Hereford steers on rangeland given access to shade. Of particular interest in their findings was that shade could be used to create more uniform, or less spot grazing by cattle. Shade was noted to be nearly as effective as water placement or supplemental feeding location to promote uniform grazing within a pasture. Silvopastoral practices could be extrapolated to encourage more uniform grazing and waste nutrient deposits within a pasture compared to open pasture or range. The natural shade areas, particularly the abundant shade treatment, resulted in superior weight gain of cattle compared to the artificial shade treatment.
>
> Protection from cold can be especially important for livestock in northern climates. Properly positioned trees and shrubs or natural forest stands can provide much needed protection for pastures, feedlots and calving areas. Reducing wind speed lowers animal stress, improves animal health and increases feeding efficiency of livestock. Canadian researchers have demonstrated that cattle on winter range require an additional 20% increase in feed energy, above maintenance, to offset the direct effects of exposure to a combination of cold temperatures and wind. Adequate wind protection has been found to reduce the direct effects of cold by more than half (Webster 1970). Similar findings have been reported for swine and dairy animals (Hintz 1983)." (Garrett et al, n.d.).

Silvopasture at Bare Ranch

Integrating trees into pastures at Bare Ranch could provide a number of benefits to grazing livestock, as described above, as well as increasing carbon capture on those pastures. This practice presents unique challenges however, suggesting the value of starting with smaller pastures closer to Ranch headquarters. To this end, the Sheep, Horse, Milk Cow, Cookhouse and Trailer House pastures all offer initial silvopasture potential, as outlined in table 6.

Table 6. Estimated CO2e Potential, Initial Silvopastures Bare Ranch
(Mg = megagrams, one metric ton, or 2,200 lbs)

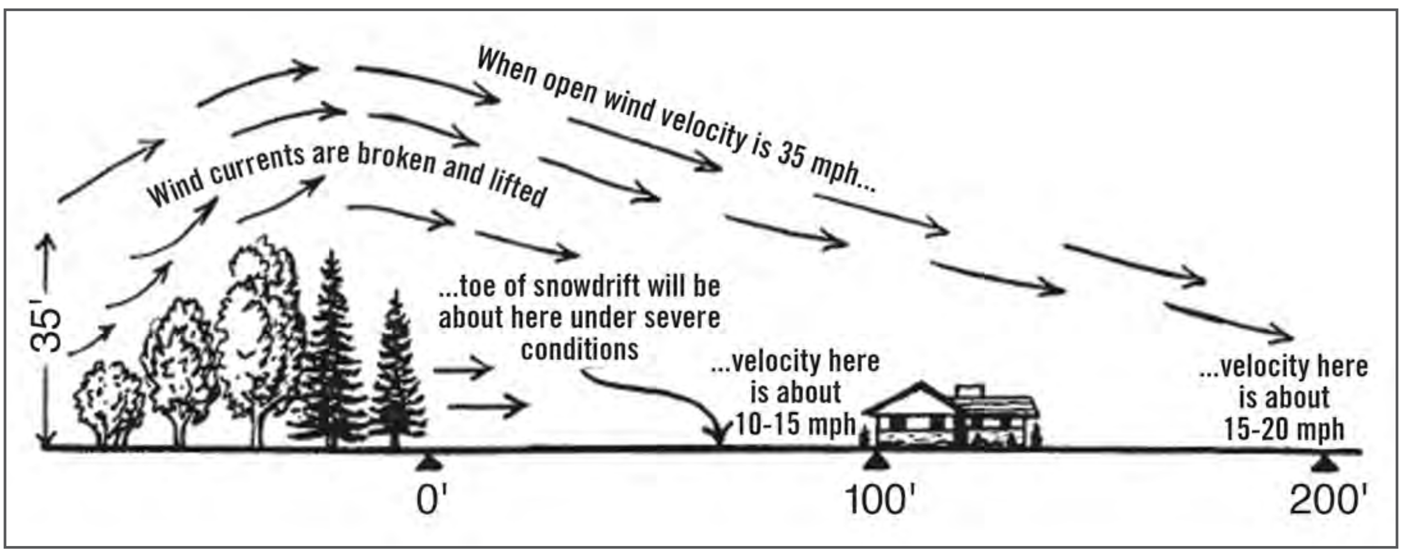
Pasture	Acres	CO2e @ 0.7 Mg/ acre/yr	Mg CO2e @ 20 years	Mg Co2e @ 80 years
Sheep	31	20.46	409.2	1736.00
Horse	46	30.36	607.2	2576.00
Milk Cow	16	10.56	211.2	896.00
Cookhouse	16	10.56	211.2	896.00
Trailer House	25	16.5	330	1400.00
TOTAL	**134**	**88**	**1768.8**	**7504.00**

WINDBREAKS AND SHELTERBELTS

NRCS defines both hedgerows and shelterbelts as, "single or multiple rows of trees or shrubs planted in linear configurations." These plantings can increase carbon storage in biomass and soils, reduce soil erosion and loss of soil moisture from wind, protect pastures and crops from wind related damage, improve the microclimate for plant growth, provide shelter for livestock, enhance wildlife habitat, provide noise and visual screens, improve irrigation efficiency, increase biodiversity, increase production, and act as shaded fuel breaks to limit the spread of wildfire (see *Windbreaks for Livestock Operations:* **http://nfs.unl.edu/documents/windbreaklivestock.pdf**).

Windbreaks are hedgerows or shelterbelts that are planted approximately perpendicular to the prevailing winds and structured to dissipate or deflect wind energy away from the area "behind," or downwind of, the windbreak. In addition, windbreaks can be configured to capture or distribute snow to optimize moisture retention and minimize inconvenience associated with accumulating or drifting snow (figure 4; see *Windbreaks for Snow Management:* **http://nac.unl.edu/documents/morepublications/ec1770.pdf**).

Figure 4. Windbreaks and Living Snow Fences



Windbreaks and Shelterbelts at Bare Ranch

Windbreak at Feedlot

- Plant row of Cedar, Juniper or other evergreens along N-S access road to provide winter windbreak.
- Deciduous species planted along north and south corral fences for summer shade include cottonwood, black locust, Mulberry, Box Elder, etc.
- 4000' feet of pollinator habitat hedgerow, parallel with feedlot windbreak, with irrigation.

Shelterbelt at Ranch Entrance

- Enhance Ranch Entrance while capturing carbon
- Chose varieties that will provide for pollinators (see appendix, agroforestry species list).

Shelterbelt, Surprise Valley Roadside

- Expand existing resident species as appropriate (see appendix, agroforestry species list), along highway from RRR Field to Work Horse Field.

Shelterbelt along gravel road, north side of Pivot #4

- 2640 feet of shelterbelt

Other

- There are a number of opportunities for additional windbreaks and Shelterbelts on the Ranch, which may be considered in the future.

Table 7. Estimated Initial Shelterbelt/Windbreak CO2e Potential, Bare Ranch

(Mg = megagrams, one metric ton, or 2,200 lbs)
Acreage estimates assume 20' Shelterbelt/Windbreak width.

Pasture	Linear Feet	Acres*	CO2e @ 1.0 Mg/acre/yr	Mg CO2e @ 20 years
Feedlot West	4000	1.84	2.02	40.40
Feedlot East	2400	1.10	1.21	24.24
Sheep Camp W	6300	2.89	3.18	63.64
Sheep Camp E	1500	0.69	0.76	15.15
Compost Area W	3200	1.47	1.62	32.32
Surprise Valley Road	19,000	8.72	9.60	191.92
Ranch Entry	1000	0.46	0.51	10.10
Pivot 4	2640	1.21	1.33	26.67
TOTAL	**40,040**	**18.38**	**20.22**	**404.44**

*includes 4000 feet of pollinator habitat hedgerow integrated into shelterbelt

-acreage assumes 20 foot shelterbelt width

RIPARIAN SYSTEMS AT BARE RANCH

Stream restoration projects typically focus on streambank stabilization, in-stream grade control structures and vegetation establishment. As structural practices and planted shrubs and trees mature over multiple decades, atmospheric carbon is sequestered in both the soil and vegetation within the riparian area (Lewis et al 2015). Consistent with the relatively high productivity of rangeland riparian systems, carbon capture in the soils and woody vegetation of rangeland stream and river corridors is typically several times greater than in the mixed woodland and grassland of associated upland areas (Lewis et al 2015, Leonard et al 1997).

BARE CREEK AND BARE CREEK DITCH

Bare Creek flows east from the Warner Mountains and enters the Ranch at its southwest corner in the Bare Creek Field. Originally, the creek appears to have fanned out across what is today the Wheel Line, Milk Cow and Cook House Fields, helping to form the productive class 4 soils of the Upper East and adjacent fields. Today, the creek flows within defined banks generally northeasterly through the Sheep Pasture and passes east of the Main House, before meandering northerly between the Upper East Field and Bare Meadow. Toward the north end of Bare Meadow, the Creek is channeled into the northwesterly-trending Bare Creek Ditch, flowing along the northeast corner of the meadow. The Ditch passes between the Camp 12 and Camp 40 Fields to the west and the Wheat Field to the East, continuing due north along the east boundary of the Rodriguez Field before leaving the Ranch at its northern boundary and joining the alkali Lower Lake (Appendix, Bare Ranch Field Map).

Bare Creek Riparian Forest Buffer

- Plant new trees to replace fallen trees and to fill gaps. Species could include: Poplar, Willow, Box Elder, Black Locust, Black Walnut, etc. (see appendix, species list).
- Fence Creek in Patterson and Rodriquez fields to protect plantings and meet landowner criteria.
- Grazing within the fenced riparian area would be of short-duration and timed to enhance the riparian area (late summer and/or mid-winter grazing).

HOT MEADOW IRRIGATION CANAL

This hot spring-fed canal provides significant year-round flow along the westerly boundary of Upper Hot, Middle Hot and Lower Hot Meadows, before dividing into two channels, one heading east-northeast to the Camp 40 Field, where it joins the Bare Creek Ditch, and the other continuing northerly across the Work Horse Field to the north Ranch boundary, ultimately dissipating at Lower Lake. Continuous natural flow and warm temperatures have supported year-round growth in the meadows irrigated by these waters for millennia, resulting in significant accumulation of organic matter, leading to the formation of the Cumivar Muck soils of Upper (356), Middle (356/357) and Lower Hot Meadows (356/357), much of Bare Meadow (357/356), both Camp Fields (357), much of the Rodriguez Field (357) and portions of the Work Horse Field (356, 357) (see table 3; Appendix, field map).

Irrigation Canal Riparian Forest Buffer

The Irrigation Canal runs down the west side of Bare (Hot) Meadow and is from a warm water spring. It provides ice-free open water in the winter to cattle being fed on the meadow.

- Drill Stock water wells to provide fresh water to livestock and reduce grazing pressure on the canal.
- Plant woody species along canal; protect with fencing as needed during plant establishment

QUANTIFYING RIPARIAN CARBON CAPTURE POTENTIAL AT BARE RANCH

Three methods were used to quantify riparian carbon capture potential at Bare Ranch: 1) the USDA on-line quantification tool COMET-Planner's Riparian Restoration module; 2) combined results from COMET-Planner modules for: Riparian Forest buffer, Riparian Herbaceous Cover, Critical Area Planting and Riparian Restoration; and 3) soil and vegetation model data developed by University of California Cooperative Extension (Lewis et al 2015). An average total restoration project width of 60' was assumed (table 8, Riparian Carbon Capture Potential Bare Ranch).

It is important to note that annual carbon capture values shown are an average derived from a 20-year project scenario, rather than an amount of carbon actually expected to accumulate annually beginning in year one, when carbon capture by a newly established riparian restoration project would be extremely small (or even negative, if carbon costs associated with project implementation are considered). The very large differences among the three model outputs shown in table 8 is consistent with Lewis et al 2015, who found an order of magnitude greater carbon accumulation in restored north coast riparian systems when compared with the COMET-Planner model Riparian Restoration output alone.

Riparian system response on Bare Ranch is expected to fall somewhere between northern coastal California results reported by Lewis et al (2015) and those projected by the COMET-Planner Riparian Restoration model, which represents broad regional climate values, in this case for northern California and Oregon. It is particularly important to note that Lewis et al's 2015 results were published *after* COMET-Planner was launched, and that the reference cited within COMET-Planner supporting Riparian Restoration as a carbon-beneficial practice states "… few studies have investigated carbon storage in riparian zones" (George et al 2011). Lewis et al's 2015 study investigated precisely this question, and is probably the most accurate assessment of carbon capture potential in restored riparian systems in California available at this point.

Though likely to differ from carbon capture actually achieved on riparian projects in Marin, Napa and Sonoma Counties (Lewis et al 2015), the perennial Bare Ranch riparian systems included in this analysis are likely to have carbon capture potential equal to or greater than the majority of the ephemeral gullies and stream channels included in the Lewis et al (2015) analysis. At the same time, projected Bare Ranch riparian system carbon capture values (table 8) reflect the assumption of uniform restoration potential along the entire length of both of the Ranch riparian systems named here, which is unlikely to be the case. Values derived from Lewis et al (2015) therefore should probably be viewed as an upper limit on carbon capture in the Bare Ranch riparian systems. It should also be noted, however, that several other ephemeral stream channels on the Ranch were not included in this analysis, suggesting that, overall, table 8 values are a reasonable, and possibly a conservative, estimate of overall riparian carbon capture potential at Bare Ranch, particularly if smaller, ephemeral, riparian systems were also included in the restoration process.

Table 8. Riparian Carbon Capture Potential Bare Ranch

Metric Tons (Mg*) CO2e per Year

Riparian System	Stream length (miles)	Acres	Mg CO2e Riparian Restoration (/Comet Planner) 1 Mg/acre/yr			Mg CO2eCombined Riparian Forest, Herbaceous, Critical Area Planting and Riparian Restoration (/Comet Planner) 4.36 Mg/acre/yr)			Riparian Restoration, Mg CO2e (Lewis et al 2015) 18.36 Mg/acre/yr,		
			annual	*20 years*	*45 years*	*annual*	*20 years*	*45 years*	*annual*	*20 years*	*45 years*
Bare Creek	2.45	17.82	17.82	356.36	801.82	77.69	1553.75	3495.93	327.14	6542.84	14721.38
Hot Meadow Creek	2.00	14.55	14.55	290.91	654.55	63.42	1268.36	2853.82	267.05	5341.09	12017.45
TOTAL	**4.45**	**32.36**	**32.36**	**647.27**	**1456.36**	**141.11**	**2822.11**	**6349.75**	**594.20**	**11883.93**	**26738.84**

1 Mg = one megagram =1000 kilograms (kg) = one metric tonne = 2,200 pounds

Metric Tons (Mg*) CO2e per Year

COMPOST APPLICATIONS AT BARE RANCH

RANGELAND COMPOST

Research conducted on northern California rangelands by the Silver Lab at the University of California at Berkeley has shown significant, ongoing, increases in forage production, soil carbon, and soil water holding capacity over multiple years in response to a single ½" compost application on grazed sites in both coastal and foothill rangelands (Ryals and Silver 2013). Forage production increased by approximately 40% and 70%, respectively, and soil water holding capacity increased by nearly 25%, while soil carbon increased by about 0.4 metric tons (1.49 Mg CO_2e) per acre per year. These changes have persisted across six years of data collection, and ecosystem models suggest this improvement will continue for at least 20-30 years in response to the single compost application in year one, reflected in improved forage and improved soil water holding capacity. Compost application therefore, is recognized as an effective means of increasing carbon capture, through increased forage production, on grazed rangelands, particularly where low soil organic matter is a limiting factor.

Importantly, compost applications enable increasing soil carbon stocks above what could otherwise be achieved through management of vegetation and soils on a given site. Improved management alone, such as application of a carbon-focused grazing program, increased use of cover crops, implementation of a no-till program, etc., can all lead to soil carbon increase. Over time, the carbon content of soils under consistent management will tend to reach equilibrium, where annual carbon inputs and losses tend to balance out. Addition of offsite sources of carbon, such as compost, can elevate soil carbon levels and, in some cases, enable increased carbon capture above that of equilibrium conditions (Ryals and Silver 2013). Compost can thus be a powerful tool for soil carbon increase, but is not always a realistic option. This is especially the case where target fields are far from sources of compost. However, on-farm compost production is one option that allows for increasing conservation of on-farm carbon and its addition to origin-farm soils at relatively low cost.

Photo by Paige Green

Compost production at Bare Ranch: juniper chips and feedlot manure.

Based on soil criteria alone, an estimated 2,140 acres of Bare Ranch are potentially suited for compost application (table 3), of which some 540 acres are cropland and 1600 acres are pasture. The principal limiting factor for compost application on the Ranch is soil type. Muck soils are unsuitable for compost applications because they are already very high in organic matter. Also excluded from consideration for compost application were the 1016 acres of WRP land in the Patterson Field, as this land is not currently being actively managed for agricultural production. Fields with SOM below 3% should be considered priority for receiving compost applications.

For this analysis it was assumed up to 1,600 acres of Bare Ranch pasture would receive compost over a period of several years. Assuming approximately 4,000 cubic yards of finished compost available for pasture application on farm annually, the Ranch could treat about 112 acres per year (table 9) at the rate of ¼" of compost (about 35 cubic yards) per acre, requiring about 14 years to treat all available pasture acreage on the ranch. Data developed through ecosystem models suggest the ¼" application rate would be as effective in increasing grazed grassland productivity as the ½" application rate (Ryals et al 2015). As shown in table 9, (predicted cumulative CO_2e from compost applications on grasslands), using the ¼" application rate results in more CO_2e being sequestered in less time than the ½" rate, as more acreage can be treated each year, resulting in overall greater carbon capture over fewer years.

Note that yearly values in table 9 represent the amount of CO_2e sequestered *in that year only for all acres treated up to that point in time*. Cumulative CO_2e, on the other hand, represents *all* CO_2e sequestered by *all treated acreage for all years up to the current year*. Thus year 15 includes all eligible acreage, all CO_2e for all acreage that year, *and* all CO_2e for all acres treated *in every previous year.* This ongoing cumulative increase in soil sequestration of atmospheric CO_2 in response to a single compost application is expected to continue for up to 30 years following the original application (Ryals et al 2015).

Table 9 estimates of carbon sequestration increases in Bare Ranch rangeland soils in response to compost application were based on increased photosynthetic capture of CO_2 from enhanced forage growth alone (Ryals and Siler 2013). Not included was any CO_2e reduction resulting from avoided emissions of methane or nitrous oxide associated with diversion of manure or other organic wastes to aerobic composting (Delonge et al 2013), nor was the carbon contained in the compost itself included in this analysis. Overall, this suggests CO_2e sequestration values presented in table 9 are conservative.

CROPLAND COMPOST

Compost use on cropland is a widely accepted agronomic practice that enables the partial or complete elimination of synthetic fertilizer use and results in improvement in a wide range of soil and water quality factors, as well as a reduction in GHG emissions from cropland. Soil aggregation and aggregate stability, fertility, water holding capacity, aeration, organic matter and resilience in the face of drought and flood are all improved by compost applications to cropland. Carbon sequestration effects of compost applications to cropland are highly variable because cropland management is itself highly variable, including variation among tillage practices, crop species, cover crops, irrigation, and post-harvest grazing practices, among many other factors. Therefore, no attempt was made to evaluate increased photosynthetic capture of CO_2 from enhanced crop growth in response to compost application, as was done for Bare Ranch pastures.

Instead, potential increases in Bare Ranch cropland soil carbon (and thus CO_2e sequestered) in response to compost application were evaluated *solely on the carbon content of the added compost.* Because the value of compost as a SOC enhancement strategy increases when combined with other carbon-beneficial soil management practices, such as minimizing tillage, using cover crops rather than bare fallows, and practicing crop rotations, this approach to quantification of CO_2e sequestered through compost application to cropland is considered conservative.

Photo by Paige Green

Table 9. Predicted Cumulative CO2e Sequestration From Compost Application on Grazed Grassland, Bare Ranch

Year	Cumulative Acres 1/4" Rate	Metric Tons CO2e/yr 1/4" Rate	Cumulative CO2e	Cumulative Acres 1/2" Rate	Metric Tons CO2e/yr 1/2" Rate	Cumulative CO2e
1	112	166.88	166.88	56	83.44	83.44
2	224	333.76	500.64	112	166.88	250.32
3	336	500.64	1001.28	168	250.32	500.64
4	448	667.52	1668.80	224	333.76	834.40
5	560	834.40	2503.20	280	417.20	1251.60
6	672	1001.28	3504.48	336	500.64	1752.24
7	784	1168.16	4672.64	392	584.08	2336.32
8	896	1335.04	6007.68	448	667.52	3003.84
9	1008	1501.92	7509.60	504	750.96	3754.80
10	1120	1668.80	9178.40	560	834.40	4589.20
11	1232	1835.68	11014.08	616	917.84	5507.04
12	1344	2002.56	13016.64	672	1001.28	6508.32
13	1456	2169.44	15186.08	728	1084.72	7593.04
14	1568	2336.32	17522.40	784	1168.16	8761.20
15	1600	2384.00	19906.40	840	1251.60	10012.80
16	1600	2384.00	22290.40	840	1251.60	11264.40
17	1600	2384.00	24674.40	896	1335.04	12599.44
18	1600	2384.00	27058.40	952	1418.48	14017.92
19	1600	2384.00	29442.40	1008	1501.92	15519.84
20	1600	2384.00	31826.40	1064	1585.36	17105.20
21	1600	2384.00	34210.40	1120	1668.80	18774.00
22	1600	2384.00	36594.40	1176	1752.24	20526.24
23	1600	2384.00	38978.40	1232	1835.68	22361.92
24	1600	2384.00	41362.40	1288	1919.12	24281.04
25	1600	2384.00	43746.40	1344	2002.56	26283.60
26	1600	2384.00	46130.40	1400	2086.00	28369.60
27	1600	2384.00	48514.40	1456	2169.44	30539.04
28	1600	2384.00	50898.40	1512	2252.88	32791.92
29	1600	2384.00	53282.40	1568	2336.32	35128.24
30	1600	2384.00	55666.40	1624	2419.76	37548.00

Photos by Paige Green

Top: Applying compost to certified organic alfalfa, spring, 2016. Above: Surface application of compost to standing alfalfa, Spring, 2016.

Compost application rate on cropland should be based on an agronomic assessment of the soil's need for organic matter, which is both a soil and crop-specific evaluation process. For the current analysis, a goal of 5% SOM for Bare Ranch croplands was assumed, based on the NRCS Soil Health program, which suggests 5% SOM as an indicator of soil health. Note that portions of the East Field (Wheat Field) currently contain 5% or greater SOM, according to 2015 soil analysis results (see appendix). One possible explanation for why this soil has such a high SOM content (though modest compared with the muck soils of Bare Meadow) is that this field may be located along the former course of Bare Creek. Because riparian systems accumulate organic carbon over time, this would explain the high SOM in this area (Pollock et al 2014).

Other explanations are of course possible, but whatever the origin of its SOM, goals for the East Field should include maintaining this level of SOM going forward. This can be achieved by minimizing or eliminating tillage, maintaining a growing crop on the field at all times, and integrating grazing into the annual rotation. Current management of this field, which is now supporting an alfalfa crop, appears to meet these criteria very well.

Data Gap: identify strategy for crop rotation in alfalfa fields that does not require periodic tillage yet maintains overall crop yields.

As an alternative to using a SOM goal to drive compost application rates, the nitrogen (N), phosphorus (P) or potassium (K) content of the compost can also be used to determine the desired application rate, based upon crop demand for those nutrients. However, it is important to note that organic forms of nutrients are not as readily available, nor as likely to be lost to ground or surface waters, as are their synthetic forms. As a rough rule of thumb, about 10% of compost nutrient content can be expected to become available each year following its application. For example, at 2% N, a ton of compost will contain 40 pounds of nitrogen in organic form, but only about 4 pounds of that will be available in any given year. This underscores the importance of viewing compost as a soil amendment that improves overall soil quality and water holding capacity, and as a source of energy (carbon) to support soil ecosystem processes, rather than as a fertilizer in the conventional sense. Nevertheless, compost can have a notable beneficial impact on soil fertility and crop productivity due to its beneficial impacts on soil ecology.

Estimated Nitrogen Release (ENR)

ENR is sometimes, but not always, reported in soil analyses. ENR is a calculated estimate of how much N will be released through the growing season from soil organic matter (SOM) as it decomposes. As SOM levels increase, ENR also increases. The rate at which compost decomposes and releases plant available nutrients depends on many factors, but soil type, moisture, temperature and management practices all influence the process.

Compost applications to cropland per crop cycle (as compared with pastures or rangeland) are typically less than about 1" per acre (140 cubic yards or about 70 tons/acre), though rates as low as 3 tons per acre per year are common in almond orchards, for example. Where water quality considerations are paramount, this quantity should be modified as needed, depending upon which nutrient is most likely to be over-applied, given increasing volumes of compost per acre, particularly where multiple cropping cycles per year result in multiple or larger applications of compost annually. In general, mature compost, as defined by CalRecycle, presents negligible water quality risk when applied at agronomic rates to cropland or rangeland with appropriate buffers adjacent to surface waters.

Cropland Compost Sequestration Potential

Recent Bare Ranch cropland soil data (see appendix) shows a range of SOM in the Ranch cropland soils tested, from 1.53% to 5.95%. SOM is roughly 50% carbon. As noted above, NRCS has suggested 5% SOM as an indicator of a healthy agricultural soil. Table 10 shows potential additional carbon sequestered, in the plow layer (top 6.7") only, of cropland soils of Bare Ranch if all the ranch croplands were elevated to 5% SOM from 2015 field data baseline SOM levels. Increasing the target depth of SOM increase in the Ranch cropland soils would further increase overall carbon sequestration achieved in these soils.

Again, these values are based on carbon added to the soil as compost (compost is assumed to be 50% organic matter and thus 25% carbon), and do not reflect carbon gained from increased production, as was the case for compost applied to rangelands (table 12). This assessment assumes 5% SOM is achieved using only compost additions. As noted throughout this Plan, compost is only one of many strategies, although a particularly powerful one, for achieving soil C increases. Other strategies for achieving soil C increases are discussed throughout this plan.

In the winter of 2016 Bare Ranch began compost operations, using a blend of Bare Ranch stockyard manure, spoiled hay and straw and juniper chips from fire fuel reduction. Approximately 1000 cubic yards of compost is currently maturing in the Ranch compost yard. Approximately 200 cubic yards were applied to hay land in the spring of 2016.

Table 10. Carbon Sequestration (Mg CO2e) Potential At 5% SOM, Cropland Soils of Bare Ranch

(based on 2015 cropland soil data; see appendix;1 Mg = 1 metric ton = 1.1 short tons)

Field	Acres	Baseline SOM% (2015 Avg.)	Gap to 5%	Additional Mg C/acre at 5% SOM	Total Additional Mg CO2e at 5% SOM	Mg Compost per acre* to achieve 5% SOM	Total Mg Compost needed for 5% SOM*
Pivot 1	87	2.75	2.25	10.23	3265.14	40.91	3558.74
Pivot 2	125	2.61	2.39	10.86	4983.19	43.45	5431.28
Pivot 3	78	2.11	2.89	13.14	3760.04	52.54	4098.14
Pivot 4	120	2.21	2.79	12.68	5584.51	50.72	6086.66
Wheelline	100	3.07	1.93	8.77	3219.27	35.09	3508.74
E Wheelline	27	2.50	2.50	11.36	1125.91	45.45	1227.15
TOTAL	**537**				**21,938.07**		**23,910.70**

*Assumptions: 1% SOM = 0.5% SOC = 10 short tons = 9.09 metric tons (Mg) SOM per acre.
Compost = 50% OM, or 25% C; 1" compost = 70 short tons/acre x 0.25 = 17.5 x 3.67/1.1 = 58.39 Mg CO2e/acre.
Approximately one half of compost C is assumed lost annually under tillage.

Application of 1/4" (17 short tons) of compost to low OM cropland soils each year would sequester approximately15.6 metric tons (Mg) of CO2e per acre per year, or 8,376 Mg CO2e across all 537 acres each year, but would require 9,129 short tons of compost annually for several years to achieve 5% SOM across the croplands of the Ranch. Achieving 5% SOM on all 537 low SOM crop acres would sequester a total of 21,938 Mg CO2e, assuming no carbon losses from these soils (table 13). The rate at which this could be achieved is dependent upon rates of compost production and implementation of other carbon-beneficial practices on cropland at Bare Ranch.

CARBON BENEFICIAL PRACTICES AT BARE RANCH

Table 11 summarizes the estimated impacts of implementing carbon beneficial practices outlined in this Carbon Farm Plan.

Table 11. Bare Ranch Potential Carbon Beneficial Practices and Estimated Effects

PRACTICE	DESCRIPTION	CO2e SEQUESTERED	CO-BENEFITS	REFERENCE
1. Compost application on grazed grassland (NRCS interim practice standard in development) Bare Ranch	Application of 1/4" of compost to 112 acres of permanent pasture each year up to 1600 acres. Increase soil organic carbon, water and nutrient holding capacity	At a rate of 1.49 Mg CO2e per acre per year, sequester 166.88 Mg on 112 new acres each year, and 31,826.4 Mg over 20 years	Improved water holding capacity, soil quality and fertility, net primary productivity and forage production	Ryals and Silver 2013, DeLonge et al, 2014; Ryals et al 2015.
2. Compost application on Cropland (590) Bare Ranch	Application of compost to 537 acres of low OM cropland to reach 5% SOM. Increase soil organic carbon, water and nutrient holding capacity and crop production	At 5% organic matter on all 537 crop acres (by year 20?), sequester a total of 21,938 Mg CO2e	Improved water holding capacity, soil quality and fertility, and crop production	Ryals and Silver 2013, DeLonge et al, 2014; Lal, 2015.
3. Fencing or Access Control (328/ 472)	Temporary electric or permanent fence protection for tree and shrub cover establishment for windbreak, shelterbelt and riparian plantings	Increase soil and biomass carbon capture on protected sites	Stabilize soils, improve water capture, water quality and habitat structural and species diversity	Supporting practice
4. Shelterbelt/ Windbreak (380) Bare Ranch	40,040 (7.58 miles, 18.38 acres) of 20' wide shelterbelts/ windbreaks	Sequester 20 Mg CO2e/yr, 404 Mg CO2e over 20 years; 808 Mg CO2e at maturity at 40 years	Sequester C, improve microclimate stabilize soils, improve water quality, and habitat diversity, increase forage production; provide windbreak	COMET-Planner

PRACTICE	DESCRIPTION	CO2e SEQUESTERED	CO-BENEFITS	REFERENCE
5. Bare Ranch Riparian Restoration (Riparian forest buffer (391); Critical Area Planting (342); Riparian Herbaceous Vegetation Cover (390) (assumes co-application of all 3 conservation practices)	Restoration of 32.36 acres of riparian system along 4.45 miles of stream corridor Planting of native trees and shrubs	Sequester 141 to 594.2 Mg CO2e/ per year; 2,822-11,884 Mg CO2e at 20 years and 6,350-26,739 Mg CO2e at 45 years	Stabilize soils and stream banks and channels, aggrade stream channels, improve soil moisture and wildlife habitat structural and species diversity. Soil conservation and sediment reduction from eroding stream banks. Improved soil and biomass carbon capture from vegetation establishment, improved water quality, improved forage production.	COMET-Planner (@ 14.36 Mg/ acre/year); Lewis et al 2015 (@ 18.36 Mg/acre/year)
6. Prescribed Grazing (528) Bare Ranch	Grazing management to improve forage production on 4411 acres	Estimated enhanced CO2e-capture of 790 Mg per year, 15,800 Mg over 20 years	Enhanced pasture productivity, improved water holding capacity, climatic resilience and species diversity	COMET-Planner
7. Range Planting (CPS 550) Bare Ranch	No-till interseeding of salt tolerant forage species in irrigated pasture fields within the Saline Bottom ecological site (2,107 acres)	Estimated enhanced CO2e-capture of 720 Mg CO2e per year, 14,400 Mg over 20 years	Enhanced pasture productivity and climatic resilience	COMET-Planner
8. Water Development (516, 614)	Install tanks, pipeline and wildlife-friendly water troughs for plant establishment, livestock distribution and wildlife use	Soil and biomass carbon capture from woody vegetation establishment and pasture improvement	Improved wildlife habitat, improved pasture management capacity	Supporting practice

PRACTICE	DESCRIPTION	CO2e SEQUESTERED	CO-BENEFITS	REFERENCE
9. Minimum-Tillage (345) Bare Ranch	Practice minimum tillage on	Sequester 0.2 Mg CO2e/acre/year or 104 Mg CO2e/year on 537 acres, or 2080 Mg CO2e on 537 acres over 20 years	Permits increased accumulation of soil C, reduced losses of SOM to tillage	COMET-Planner
10. Bare Ranch Silvopasture (381)	Establish trees on approximately 134 acres) of treeless pasture	Sequester 0.66 Mg CO2e/acre/year, or 94 Mg on 134 acres per year, 1880 Mg CO2e at 20 years and 7504 Mg CO2e at maturity at 80 years	Increase soil and biomass carbon, provide shade for livestock and wildlife, improve soil water capture and water quality and enhance wildlife habitat structural and species diversity	COMET-Planner
11. Bare Ranch Conversion of flood irrigation to pipe irrigation (443)	Conversion of flood irrigation to pipe irrigation on 1,000 acres permanent pasture. Irrigate following grazing period and manage soil moisture to avoid prolonged saturation; avoid grazing under saturated conditions	Sequester an additional 708 metric tons of CO2e per year (0.708 Mg/acre/year); 14,160 Mg CO2e by year 20	Avoided emisssions of methane and nitrous oxide, Estimated minimum forage production increase on 1000 acres = 850,000 pounds, or 425 tons per year	Eve et al 2014.

SOIL, WATER, AND CARBON

NRCS suggests that a 1% increase in soil organic matter (SOM) results in an increase in soil water holding capacity of approximately 1 acre inch, or 27,152 gallons of increased soil water storage capacity per acre. A 1% increase in SOM represents roughly 20,000 pounds (10 short tons) of organic matter, or 5 short tons of organic carbon. Table 12 shows estimated additional water storage capacity associated with soil carbon increases on Bare Ranch resulting from implementation of the Bare Ranch Carbon Farm Plan. Practices from table 14 resulting in water holding capacity increases greater than one acre foot are shown in table 12.

Total estimated additional water storage capacity associated with soil carbon increases on Bare Ranch resulting from implementation of the Ranch Carbon Farm Plan are estimated to be 521 acre feet. This is a significant quantity of additional water storage capacity, yet represents an increase of less than 1.4 inches of water holding capacity per acre for the Ranch. This analysis is assumed to be conservative, yet reveals the potential significance of even small increases in soil carbon storage for overall Ranch dynamics.

Table 12. Estimated Additional Annual Soil Water Holding Capacity (WHC) At Bare Ranch With Carbon Farm Plan Implementation, Year 20

PRACTICE	DESCRIPTION	20 YEAR SOM INCREASE (Mg)	ANNUAL WHC INCREASE BY YEAR 20 (AF)
Compost application on Rangeland (NRCS practice standard in development)	Application of 1/4" of compost to 1600 acres of permanent pasture.	17344.09	158.99
Compost application on Cropland (590)	Application of compost to 537 acres of cropland to 5% SOM	11,955.00	109.59
Shelterbelts (380)	6.78 miles (16.44 acres) of 20' wide shelterbelts	98.35*	0.90*
Prescribed Grazing (528)	Grazing management to favor perennials and improve production on 4411 acres	8,610	78.93
Riparian Restoration	32.36 acres of riparian system along 4.45 miles	1,048.00*	9.60
Minimum-Tillage (345)	Conversion of tilled crop fields to minimum tillage on	1,134	10.39
Silvopasture (381)	Establish trees on approximately 134 acres of pasture	270**	2.35
Conversion of flood irrigation to pipe irrigation (443)	Conversion of flood to pipe irrigation on 1,000 acres permanent pasture	8,501.00	77.93
Range Planting (550)	No-till interseeding of forage species in irrigated pasture within the Saline Bottom ecological site (2,107 acres)	7,847.00	71.93
TOTAL		**64,274.44**	**521.63**

*includes soil C only (Lewis et al 2015)
** allocates ½ of sequestered C to soil pool

SUMMARY

Table 13 summarizes the overall potential for terrestrial carbon sequestration on Bare Ranch through implementation of the suite of conservation practices identified through the Carbon Farm Planning Process, as outlined above.

Table 13. 20-Year Estimated CO2e Reduction/Sequestration Potential, Bare Ranch

Practice	Average Annual CO2e Sequestration (Mg)	20 yr CO2e Sequestration
Rangeland Compost	167	31,826
Cropland Compost (590)	1,097	21,938
Shelterbelts (380)	20	404
Riparian Restoration*	368*	7353*
Prescribed Grazing (528)	790	15,800
Range Planting (550)	720	14,400
Minimum-Tillage (345)	104	2,080
Silvopasture (381)	94	1,880
Irrigation System (443)	708	14,160
Totals	**4,068**	**109,841**

* average of combined practice COMET-Planner values and Lewis et al 2015

DISCUSSION

Average annual CO_2e reduction values in table 16, above, are for illustrative purposes only. Actual sequestration of CO_2 in response to management interventions and conservation practices is not expected to be linear over time, and is expected to vary annually. Length of time during which practices will sequester carbon also varies among practices. For example, see table 14 above for variable ages of maturity for different practices. Terrestrial carbon sequestration resulting from each practice tends to increase cumulatively to maturity and then tends to decline, though remaining net positive relative to baseline conditions for many years (Ryals et al 2015). This underscores the value of periodic renovation of windbreaks and shelterbelts, periodic reapplication of compost, and long term maintenance of all carbon beneficial practices to maintain high levels of carbon accumulation in the farm system.

Values presented in table 13 are best understood as gross CO_2e sequestered through implementation of the various on-farm practices at the spatial and temporal scales outlined in table 14 and the Carbon Farm Plan as a whole. GHG emissions associated with these practices are generally accounted for in the models used (COMET-Farm, COMET-Planner, etc.). Exact emission reductions and carbon sequestration achieved from practice implementation at Bare Ranch cannot be determined precisely, however sequestration values presented here are based on conservative estimates and are likely to be exceeded in real world application.

In some cases, rates of accumulation of CO_2e may fall below emission rates, resulting in temporary net increases of GHG. For example, initial GHG costs of compost production or riparian restoration may exceed first year sequestration rates. Net sequestration associated with a single compost application to grazed grassland may also decline over time. Models suggest soil nitrous oxide, (N_2O) emissions may gradually overtake reductions in CO_2 associated with this practice, some three decades after initial compost application. This suggests reapplication of compost sometime before the third decade after initial application may be warranted for sustained GHG reduction benefits from this practice.

Improved soil hydrologic status, improved porosity, improved micronutrient status and other soil quality enhancements typically resulting from compost amendment are also not currently accounted for in the model. The ecosystem carbon team at CSU-NREL is in the process of updating the model to account for these important soil quality factors, shown by MCP research to be subject to positive influence by compost applications (Ryals and Silver 2013). Meanwhile, models will tend to undervalue the combined benefits of carbon sequestering practices.

As with positive feedbacks to pasture productivity associated with compost applications, total additional water storage capacity associated with soil carbon increases on Bare Ranch resulting from implementation of the Ranch Carbon Plan, estimated at 521 acre feet (table 15), can be expected to provide further feedback to higher productivity and increased carbon capture potential and increased soil water holding capacity over both the near and long term.

BARE RANCH CLIMATE-BENEFICIAL™ WOOL

As presented in table 16, implementation of this Carbon Farm Plan can be expected to result in additional sequestration in Bare Ranch soils and vegetation of 4,068 metric tons of CO_2e annually. For comparison, a typical passenger vehicle emits about 4.7 metric tons of CO_2e per year (EPA 2016), so this amount of CO_2 sequestered would offset the emissions of about 865 passenger vehicles annually.

More directly relevant for this Plan is emissions data from Wiedemann et al (2015), whose modeled on-farm GHG emissions from wool production resulted in 24–38 kg CO_2e/kg wool. Importantly, by substituting sheep wool and meat production for production of beef on the same acreage, a net negative GHG emission signature, relative to the beef baseline, was achieved (Wiedemann et al 2015).

Using Wiedemann et al (2015) on farm emission values for wool production, and assuming annual production of 40,000 pounds (18,182 kg) of wool at Bare Ranch, livestock-associated emissions from that production would be

436,364 – 690,909 kg, or 436 – 691 metric tons CO_2e. Implementation of the Bare Ranch Carbon Farm Plan, sequestering 4,068 metric tons of CO_2e annually, would effectively offset 6 to 9.3 times the GHG emissions associated with Bare Ranch wool production each year. This provides a robust framework for the Bare Ranch goal of producing Climate-Beneficial™ wool.

Photo by Paige Green

CONCLUSION

The Bare Ranch offers significant opportunity for enhanced capture of atmospheric carbon consistent with increased agricultural productivity, water quality and quantity enhancement, and wildlife habitat improvement.

Over the long term, applications of compost to grazed grassland offer the greatest potential for carbon capture on the Ranch (31,826 metric tons CO_2e over 20 years), due to the ongoing, cumulative effects of this practice. In addition, the Ranch croplands could hold significantly greater quantities of carbon (21,938 metric tons of CO_2e) as soil organic matter, with attendant benefits for water holding capacity and productivity. Compost offers a particularly direct and rapid -though certainly not the only- means to that end.

The Ranch riparian areas offer substantial restoration potential in the form of both soil carbon and increased tree, shrub and herbaceous perennial cover, accumulating an estimated 7,353 metric tons of CO_2e over 20 years while providing wildlife habitat, improved water quality, and potentially, over the long-term, providing a sustainable harvest of hardwoods for fence post and lumber production. While GHG benefits from shelterbelts and windbreaks are relatively small, they offer significant benefits in the form of wildlife habitat and microclimate amelioration for livestock in stockyards and on pasture.

Given the importance of pasture and rangeland production for the Ranch, it is perhaps not surprising that there is significant carbon capture potential on these Bare Ranch acres. Prescribed grazing alone presents the potential to capture 15,800 metric tons of CO_2e over 20 years, to which can be added the benefits improved irrigation (14,160 metric tons), Range Planting (14,400 metric tons) and Silvopasture (1,880 metric tons). Finally, maintaining or reducing minimum tillage practices on the Ranch croplands offers an additional benefit of some 2,080 metric tons over 20 years.

Overall, the carbon-beneficial practices identified for potential implementation on the 4,500 acres of the Ranch addressed in this plan, including compost applications, also offer significantly enhanced soil water infiltration rates and soil water holding capacity, along with improved water quality, and increased pasture, rangeland and cropland productivity, while simultaneously improving aquatic and terrestrial habitat.

There is also potential for additional on-farm carbon capture over time through the implementation of other carbon-beneficial practices not currently included in this Plan. By stacking all of these practices, the greatest potential for capture and sequestration of carbon in soils and biomass at Bare Ranch can be realized. At least 521 acre-feet of additional soil water storage capacity on the ranch is one of many significant co-benefits expected to result from increasing soil carbon on the Ranch.

MONITORING AND RECORD KEEPING

Practice monitoring (plant survival, pasture management, RDM monitoring, compost applications, etc.) should be carried out in coordination with project managers from the NRCS or others involved in project implementation or monitoring, such as Point Blue Conservation Sciences, in conjunction with its Rangeland Monitoring Program:

http://www.pointblue.org/our-science-and-services/conservation-science/working-lands/rangeland-monitoring-network/

Soil C and other ecosystem services should be monitored in accordance with market or voluntary protocol requirements (if applicable). Baseline data and records of implementation activities, including locations, spatial extent of project(s), dates of implementation, etc. should all be included in plan implementation documentation.

This plan should be viewed as a living document. It should evolve as practices are implemented and new information and new tools become available. Additional carbon-beneficial practices may be considered for inclusion in the plan in the future. GHG values presented here, as associated with specific practices, are considered to be both realistic and conservative, based upon the best available information at the time of this plan's completion (June, 2016).

SHORT TERM ACTION PLAN and TIMELINE

Because the scope of the Carbon Farm Plan is extensive, practices are likely to be implemented over time, based upon GHG and co-benefits, available funds, and Ranch priorities. Table 14 provides a framework for prioritizing and recording Carbon Farm Plan practices at they are implemented.

Table 14. Bare Ranch Carbon Beneficial Practices Implementation Record

PRACTICE	LOCATION & EXTENT	CO2e BENEFIT	CO-BENEFITS	DATES
Shelter Belt/ Wind Break	Feed Lot West	2.02 Mg/yr	Pollinators, Wind Break, Shade	September 2016 – May 2017
Shelter Belt/ Wind Break	Sheep Camp West	3.18 Mg/yr	Pollinators, Wind Break, Shade	September 2016 – May 2017
Compost Application	Outer East side Pivot 4 ≅ 40 acres	59.6 Mg CO2e/yr	Improved soil water holding capacity, avoided black carbon emissions, reduced methane and nitrous oxide from manure. Potential increased life of alfalfa stand (TBD).	April/May 2016
Compost Application	South & East side Pivot 4 ≅ 80 acres	119.2 Mg CO2e/yr PLUS a **1x** CO2e benefit of 624 metric tons from avoided CO2 from diversion of juniper chips from burning to compost production.	Improved soil water holding capacity, avoided black carbon emissions, reduced methane and nitrous oxide from manure. Potential increased life of alfalfa stand (TBD).	October 2016

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APPENDICES

AGROFORESTRY SPECIES FOR BARE RANCH

Dye Plants

Within the recommended lists of trees, shrubs, and riparian corridor restoration plants, the following are known to have dye and fiber properties. All of the plants below are recommended to the general region; we've added a few extra dye plants to this list, all of which have pollinator forage benefits, and some provide migratory bird food sources. However, when the time comes to plant, referencing local native plant nurseries and verifying these plant choices in light of the exact planting site will be critical.

Black Oak (*Quercus kelloggii*) – Galls of the black oak are a very strong source of tannin, very useful in dyeing.

Redbud (*Cercis occidentalis*) – Redbud is a pre-imenent basketry plant, pollinator forage species.

Blue Elderberry (*Sambucus nigra* ssp. *caerulea*) – The berries do provide a fugitive but beautiful dye on cotton, pollinator forage species, and source of migratory bird food, used as a medicinal for humans.

Northern California Black Walnut (*Juglans hindsii*) – A preeminent and colorfast dye, the hulls can be soaked in water to extract color, also a food source.

Black Elderberry (*Sambucus racemosa* var. *melanocarpa*) – A fugitive but beautiful source for dye on cottons, pollinator forage species and migratory bird food, used as a medicinal for humans.

Vine Maple (*Acer circinatum*) – Leaves make 'eco-prints' on fabric with iron mordants.

Big Leaf Maple (*Acer macrophyllum*) – Leaves make 'eco-prints' on fabric with iron mordants.

Chaparral currant (*Ribes malvaceum*) – Dye plant, migratory bird food source, pollinator forage species

Birch leaf mountain mahogany (*Cercocarpus betuloides*) – Roots are a dye source, pollinator forage species

Green rabbitbrush (*Chrysothamnus viscidiflorus*) – Pollinator forage species, dye plant

Hop sage (*Grayia spinosa*) – Dye plant, pollinator forage species

Silver bush lupine (*Lupinus albifrons*) – Dye plant, pollinator forage species

Ninebark (*Physocarpus capitatus*) – Pollinator forage, basketry species

Siskiyou mountains huckleberry (*Vaccinium coccineum*) – Dye plant, human and migratory bird food source

Trees

Tamarack (*Pinus contorta* ssp. *murrayana*) – Native that to grows to 112 feet at elevations from 5000-11000 feet.

Green Ash (*Fraxinus dipetala*) – Fragrant yellow flowers, deciduous, height to 23 feet, 15 feet wide; medium density, moderately drought tolerant, moderate growth rate.

White Ash (*Fraxinus Americana*) – Timber, tool handles.

Yellow Poplar (*Liriodendron tulipifera L.*) – Lumber.

Black Locust (*Robinia pseudoacacia*) – The wood of black locust is strong, hard, and extremely durable, it is extensively utilized for fence posts, mine timbers, and landscaping ties. This tree also serves as a good erosion control plant on critical and highly disturbed areas, due to its ease of establishment, rapid early growth and spread, and soil building abilities. It provides excellent wildlife cover when planted in spoil areas, excellent bee forage and firewood. Nitrogen fixer; some livestock forage value. PREFERRED

Western Chokecherry (*Prunus virginiana* var. *demissa*) – Native, fast growing and short-lived. Upright to a height of 20 feet, deciduous. Rocky slopes, from 0-8200 feet.

Klamath Plum (*Prunus subcordata*) – Native at altitudes of 300-6000 feet. Deciduous shrub or small tree growing to 25 feet in height. Sprouts from its roots and can form dense, spiny thickets. The plums are small and tart but edible. However, seeds and leaves of Prunus. spp. can be fatal to livestock.

Black Oak (*Quercus kelloggii*) – California Black Oak is a deciduous tree, typically growing from 30 to 80 feet in height and 1 to 4.5 feet in diameter. Large trees may exceed 120 feet in height and 5 feet diameter. In open areas the crown is broad and rounded, with lower branches nearly touching the ground or forming a browse line. In closed stands, the crown is narrow and slender in young trees and irregularly broad in old trees. Trunks are usually free of branches for 20 to 40 feet in closed stands. This oak grows from one to several vertical roots which penetrate to bedrock, with large, laterally spreading roots extending off from vertical ones. It also has a number of surface roots. Acorns are relatively large in this species, from 1 to 1.2 inches long and 0.6 to 0.7 inches wide and take two years to mature. They were considered the best acorns for food by the Native Americans. The deeply lobed leaves are typically 4 to 8 inches long. California black oak can live up to 500 years.

Incense Cedar (*Calocedrus decurrens*) (California Incense-cedar; syn. *Libocedrus decurrens Torr.*) – A native species of conifer. It grows at altitudes of 50 to 2900 meters. It is a large tree, typically reaching heights of 120 to 200 feet and a trunk diameter of up to 9 feet, with a broad conic crown of spreading branches. If given deep, infrequent watering when young it will develop drought tolerance. Tolerates a wide variety of rainfall levels, soil types over most of California. Sun, Part Shade. Prefers deep woodland soil with high organic content.

Shrubs

Utah Service Berry (*Amelanchier utahensis*) – Native shrub, grows in varied habitats, from scrubby open slopes to woodlands and forests. It is a deciduous spreading plant, reaching 13 feet. The fruits are edible pomes. The Utah serviceberry is eagerly browsed by desert bighorns, elk, and mule deer, as well as many birds and domesticated livestock. Hedges; open rocky slopes.

Saskatoon Serviceberry (*Amelanchier alnifolia*) – A beautiful shrub that grows primarily in northern California and the Sierra mountains. It tends to grow in well drained open places and hillsides at elevations from 200 to 8500 feet. Saskatoon Serviceberry grows in an upright form to a height of 15 to 35 feet. It usually has a rounded shrubby form, though it can sometimes grow more upright especially in shadier areas. The serviceberry fruit tastes a lot like blueberries. It is an important food source for birds and animals, was an important food source for northwestern Native Americans and is still grown commercially for human consumption. Great for attracting birds and other small animals. It's fairly easy to grow as long as it is in a spot with excellent drainage, though it prefers loam or sandy loam. In its natural range, it prefers full sun, and is fast growing and long lived—reaching 6 feet in 3 to 6 years and lasting about 60 years.

Beaked Hazelnut (*Corylus cornuta*) – Deciduous shrub or small tree. In California it is found primarily in the central and northern parts of the state where it grows in dry woodlands and forest edges of the Coast Ranges and Sierra Foothills. It can reach 12 to 25 feet tall. The spherical nuts, which are surrounded by a hard shell, are edible.

Redbud (*Cercis occidentalis*) – Deciduous small tree to 15 feet, plant 10 to 15 feet apart, multi-trunk, very showy; N fixer.

Wax Currant (*Ribes cereum*) – Native, grows in several types of habitat, including mountain forests in alpine climates, sagebrush, and woodlands. It can grow in many types of soils, including sandy soils and soil made of clay substrates, serpentine soils, and lava beds. This is a spreading or erect shrub growing 20 centimeters (8 inches) to 2 meters (80 inches) tall. It is aromatic, with a "spicy" scent. The stems are fuzzy and often very glandular, and lack spines and prickles. The fruit is a rather tasteless red berry up to a centimeter (0. 4") wide. Dry slopes, rocky places, forest edges; sun, part shade, adaptable.

Sierra Gooseberry (*Ribes roezlii*) – Native shrub, moderately fast growing and long-lived. Semi-upright to a height of 5 feet. Flowers are white and striking, late spring. Leaves are dark green and deciduous. It tends to grow at elevations from 0 to 9200 feet.

Blue Elderberry (*Sambucus nigra* ssp. *caerulea*) – Native deciduous shrub or small tree, to as tall as 30 feet. Purple berries are one of the most important source of food for birds in California. Blue Elderberry is tough, easy to grow, and can grow from a 1 gallon container to a 15-foot tree in 3 years if happy. It can handle permanently moist soil near stream sides or seeps, and once established, it also grows well in fairly dry soils; in drier conditions it will normally go deciduous or semi-deciduous in the summer and fall and green up in the early winter. It likes part shade or sun, and will tolerate full shade. Streambanks, slope bottoms, canyons, slightly moister places throughout the state. It occurs in conjunction with a variety of vegetation types including chaparral, sage scrub, grassland, and wetland-riparian.

Riparian Species

Oregon Ash (*Fraxinus latifolia*) – Native, to 82 feet, width 30 feet, fast growth, winter deciduous. Excellent multi-use hardwood.

Big Leaf Maple (*Acer macrophyllum*) – Deciduous tree to 100 feet tall, more commonly 50-60 feet. Trunk up to 3 feet in diameter. Native, deciduous, Very fast growing. Sap used for syrup.

Box Elder (*Acer negundo*) – Deciduous, to 66 feet, 40 feet wide, fast growth. Tolerates cold to -15° F, moderately drought tolerant.

Black Hawthorn (*Crataegus douglasii*) – A native thorny compact, erect bushy shrub. Thorns along the branches are one to two centimeters long. The fruit is a very dark purple pome up to about a centimeter across. The fruits were a food source for Native American peoples. Streamsides, meadows, grassy places. Sun, Part Shade. Prefers deep, moist, fine-textured soil.

Vine Maple (*Acer circinatum*) – Native, large shrub to 15-25 feet, occasionally a small to medium-sized tree, exceptionally to 60 feet. Typically grows as understory below much taller trees, but can sometimes be found in open ground, and occurs at altitudes from sea level up to 5000 feet. Cold and drought tolerant.

Creek Dogwood (Cornus sericea) – Native shrub, formerly known as *Cornus stolonifera*. Moderately fast growing and moderately long-lived. It grows in a semi-upright form to a height of up to 15 feet, noted for its red bark, especially on new growth. Moist places, at elevations from 0 to 9000 feet. Requires moist soil and partial shade.

Mountain Alder (*Alnus incana* ssp. *tenuifolia*) – Native tree or shrub, fast growing and moderately long-lived. Upright to a height of 20 feet. Wet places, at elevations from 4500 to 8000 feet. Nitrogen fixer; possible forage species.

Northern California Black Walnut (*Juglans hindsii*) – Native, large tree to 60 feet, with a single erect trunk commonly without branches for 10 to 40 feet. Specimens commonly reach 5 to 6 feet in diameter near the base. The nut has a smooth, brown, thick shell containing a small edible nutmeat. It is commercially important as a rootstock for English walnut orchards all over the world, both on its own and as a parent to the *J. hindsii* x *J. regia* hybrid, commonly called "Paradox." The wood of *Juglans hindsii*, sometimes called Claro walnut, is used for furniture making and gunstocks because of its good working properties and beautiful grain patterns.

Black Cottonwood (*Populus trichocarpa*) – Native, fast growing and moderately long-lived. Upright to 100 feet. Alluvial bottomlands and streamsides, from 0 to 9000 feet. Tough and easy to grow as long as it is in sun, near a water sources and has very good drainage. Black Cottonwood is a great choice to help build a natural irrigation system—its long shallow roots will reach out to the water source and pull underground water molecules through the soil. It needs moist soil until mature, and then becomes moderately drought tolerant. Possible forage species.

Fremont Cottonwood (*Populus fremontii*) – Native tree from 36 to 120 feet, trunk up to 6 feet diameter; an important plant for birds and butterflies. Requires moist soil and plenty of sun, but tough and easy to grow. When properly situated and with access to plenty of water, they can grow 10 to 20 feet in a year and reach up to 100 feet in height and 35 feet in canopy width. Best to plant these trees by creeks, in seeps, or in areas with plenty of natural water. Tolerates occasional flooding. Almost always found in riparian or other wetland habitats such as alluvial bottomlands, streamsides and seeps, up to 6,500 feet. Sun and sandy or clay soil as long as there is sufficient water. Tolerates Saline Soil. Tolerates cold to 5° F

Hall's Sticky Currant (*Ribes viscosissimum*) – Native to mountain forests, streambanks, and plateau sagebrush. It is a spreading to erect shrub growing 40 to 80 inches in height, its stem coated in sticky glandular hairs but lacking spines and bristles. The fruit is an edible blue-black berry a centimeter (0. 4 inch) long or longer. Wet places, sun.

Northern Black Currant (*Ribes hudsonianum*) – Grows in moist wooded areas, such as mountain streambanks and in swamp thickets. Upright to erect shrubs growing 20 to 80 inches tall. Aromatic, with a strong scent generally considered unpleasant. Fruits are bitter black berries, about a centimeter (0. 4 inch) wide.

Woods' Rose (*Rosa woodsii* ssp. *ultramontana*) – Native shrub to 10 feet. Sun, part shade, full shade. Moist places, from 3500-11500 feet.

Black Elderberry (*Sambucus racemosa* var. *melanocarpa*) – Native shrub to 7 feet; streamsides and edges of meadows, at elevations from 6000 to 12000 feet.

BEAVER, WATER AND CARBON

One significant factor in the drying of the West (Taylor 2015) has been the virtual eradication of the region's native hydrological engineer—the beaver. Loss of the beaver from most of its former habitat in the Western US is associated with initiation of an "epicycle of erosion" (Leopold 1976) throughout the region, as beaver dams decayed and washed away, wet beaver meadows were incised and subjected to drying and soil loss, and as watersheds responded to the resulting changes in hydrology with flashier flood events, increased erosion and less water retention (Smith 1940).

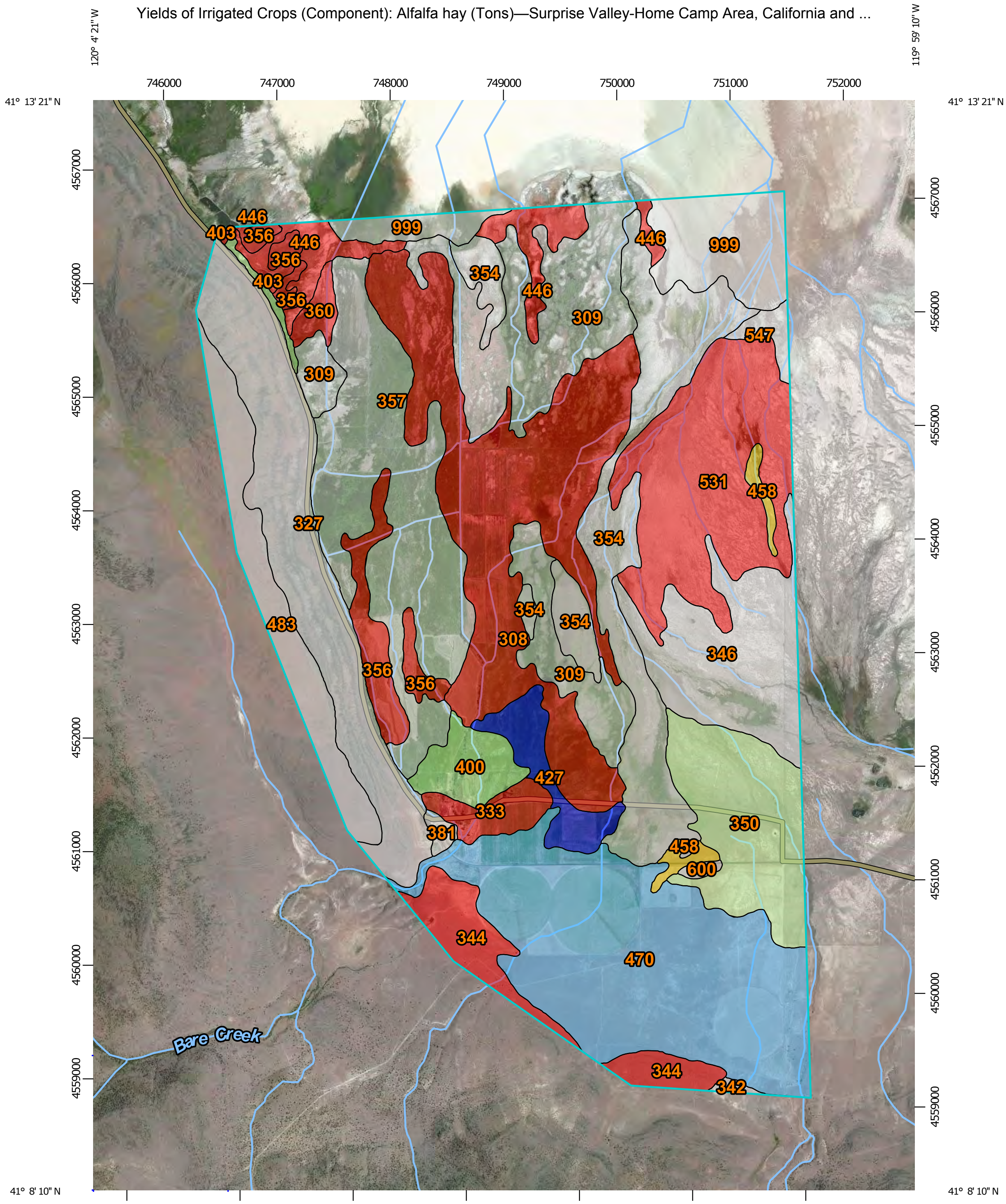
Today, beaver are increasingly recognized as a "keystone species;" ecosystem engineers that play a critical role in watershed dynamics where they are present, including benefiting fish populations. Beaver ponds can replenish aquifers, allowing groundwater to recharge streams and meadows in dry summers, and providing perennial pools for over-summering trout smolt. Fish abundance and size have been found to increase when beaver are present (Rosell et al 2005, Pollock et al 2003, Collen and Gibson 2001).

In the context of carbon farm planning, beaver can have a significant positive impact on soil carbon within their zone of influence, both through enhanced production associated with increased soil water adjacent to beaver impoundments and through increased allocation of woody biomass to the soil at the beaver-constructed wetland interface (Rosell et all 2005). While beaver already occur on upland sites on Bare Ranch, opportunities for enhancing beaver habitat in the uplands exist and will be explored in the future.

IRRIGATED LAND PRODUCTION, BARE RANCH

Yield of Irrigated Crops: Alfalfa Hay (tons/acre)

Yields of Irrigated Crops (Component): Alfalfa hay (Tons)—Surprise Valley-Home Camp Area, California and ...



Map Scale: 1:46,700 if printed on A portrait (8.5" x 11") sheet.

Meters: 0, 500, 1000, 2000, 3000

Feet: 0, 2000, 4000, 8000, 12000

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 10N WGS84

CARBON FARM PLAN

List of Projects Developed from Tour of Bare Ranch, Eagleville, CA
Estill Ranches, LLC
January 7, 2015

Take Soil Samples to establish a base-line and determine what fields would benefit most from compost application.

Establish a monitoring plan for measurement of carbon sequestration and program success.

Compost Production and Application

- Compost to be produced from materials on site. Ranch has manure, stockpile of old down trees, old hay from stack yards and access to off-site inoculate.
- Field application location to be determined but most likely the grass pivots which are utilized by sheep to start.
- Apply where soil samples would indicate need for fertilization.

WindBreak at Feedlot

- Plant row of Cedar or other evergreen to provide winter wind break and summer shade.
- Other species to be considered include cottonwood, black walnut or poplar

Trees and Shrubs planted along front entrance

- Enhance Visual appearance of ranch
- Chose varieties that will provide for pollinators

Underground Drip Irrigation System

- Replace flood irrigated system with underground drip system or pivots. NB; coordinate with soil evaluation to avoid installing drip in saline soils to prevent increased soil salination.
- Benefits include up to 30% less water usage and increased production.
- Projects would be phrased in when funding and crop rotations allow.

Bare Creek Riparian Restoration

- Plant new trees to replace century old trees that are falling down. Species could include: Black Locust, Black Walnut, Poplar, Willow.
- Fence Creek in Patterson and Rodriquez fields. Fence to meet landowner criteria.
- Grazing within the fenced riparian area would be short-duration and timed to enhance riparian area (late summer and/or mid-winter grazing).

Irrigation Canal Riparian Restoration

Canal runs down the west side of Bare Meadow and is from a warm water spring. Provides ice-free open water in the winter to cattle being fed on the meadow.

- Drill Stock water wells to provide fresh water to livestock and reduce grazing pressure on the canal.

No-Till planting of the 200 acre North Field to alfalfa or other permanent crop

- Consider a cover crop to reduce wind erosion while alfalfa is getting established
- Plant last two checks and leave for wildlife and to increase organic matter.
- Consider compost application

Gerlach Springs Restoration

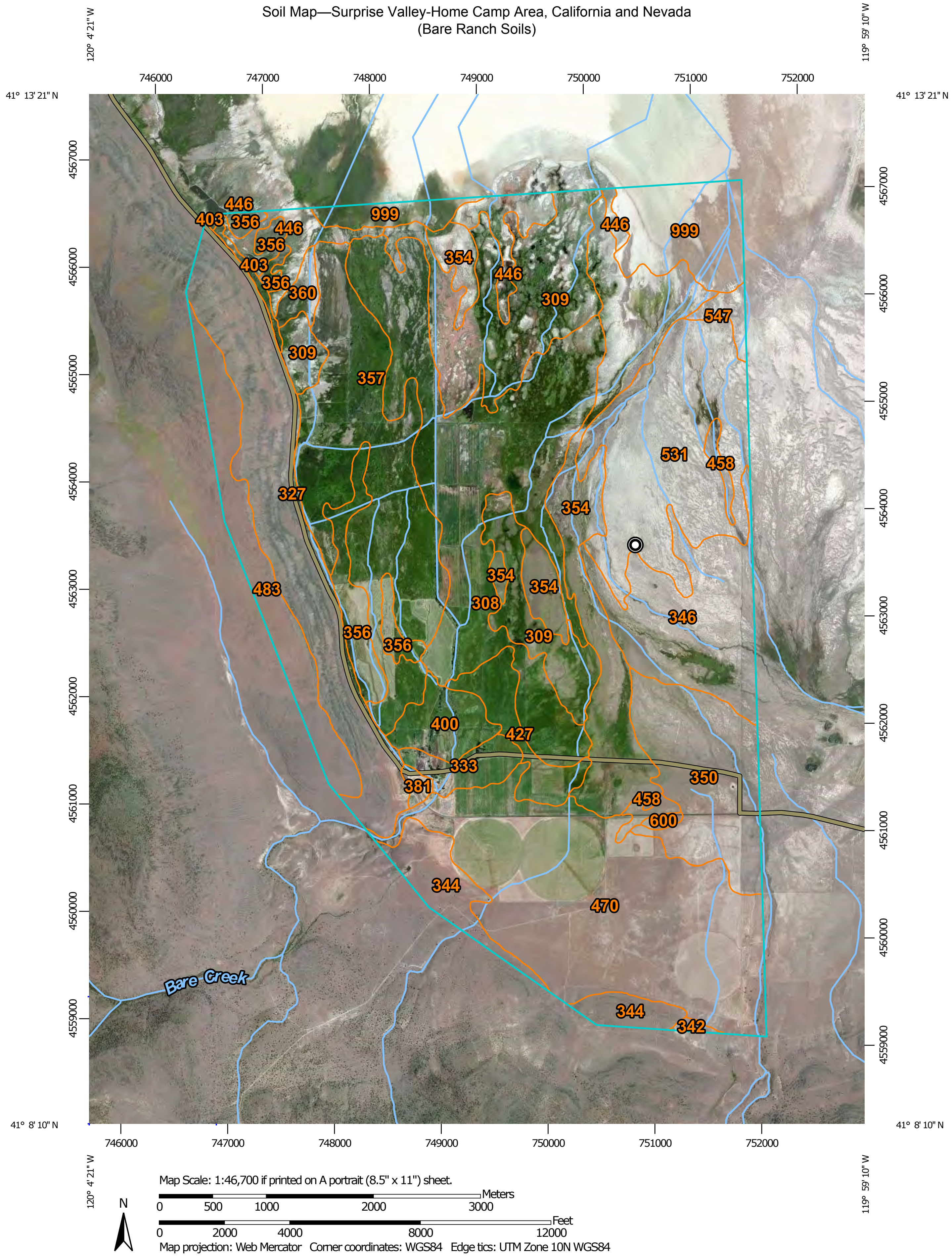
- This is approximately a 160 acre parcel with a fantastic spring fed water source. Project would include fencing, rebuild spring development, construct water troughs and remove Juniper Trees.
- Project is already in EQUIP application process with Eric Periz, NRCS, Susanville Office.

COMPOST RECORD

Batch #:
Date of assembly:
Ingredients:

Date	H_20 (y/n)	Turn (y/n)	Temperatures					Comments/ Special Occurrences
			1	2	3	4	5	

Soil Map—Surprise Valley-Home Camp Area, California and Nevada
(Bare Ranch Soils)



MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Surprise Valley-Home Camp Area, California and Nevada
Survey Area Data: Version 8, Sep 16, 2014

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Jul 10, 2011—Aug 4, 2011

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Surprise Valley-Home Camp Area, California and Nevada (CA685)			
Map Unit Symbol	Map Unit Name	Acres in AOI*	Percent of AOI
308	Bicondoa clay	1,010.4	12.3%
309	Bicondoa-Crutcher complex	715.6	8.7%
327	Bucklake-Mcwatt-Rubble land association	678.7	8.3%
333	Buntingville ashy loam, 0 to 2 percent slopes	84.8	1.0%
342	Chalco-Saraph-Tuffo association	9.0	0.1%
344	Coppersmith-Bareranch association	204.4	2.5%
346	Couch ashy fine sandy loam, 0 to 2 percent slopes	430.4	5.2%
350	Couch-Nevadash association	412.7	5.0%
354	Crutcher ashy very fine sandy loam	696.6	8.5%
356	Cuminvar muck	196.6	2.4%
357	Cuminvar muck, drained	751.9	9.2%
360	Dangvar ashy loam, 0 to 2 percent slopes	39.4	0.5%
381	Donica gravelly ashy sandy loam, 15 to 30 percent slopes	17.2	0.2%
400	Four Star ashy loam	120.8	1.5%
403	Four Star ashy loam, seeped	19.6	0.2%
427	Hussa ashy clay loam, 0 to 2 percent slopes	127.7	1.6%
446	Lolak silty clay	197.1	2.4%
458	Macnot-Jesayno-Nevadash association	45.2	0.6%
470	Nevadash-Couch association	1,115.6	13.6%
483	Nitpac-Tunnison-Devada association	294.2	3.6%
531	Raglan-Isolde association	662.3	8.1%
547	Saltmount silty clay loams, 0 to 30 percent slopes	37.4	0.5%
600	Zorravista fine sand, 4 to 15 percent slopes	10.3	0.1%
999	Water	325.3	4.0%
Totals for Area of Interest		**8,203.1**	**100.0%**

*Exceeds scope of this CFP

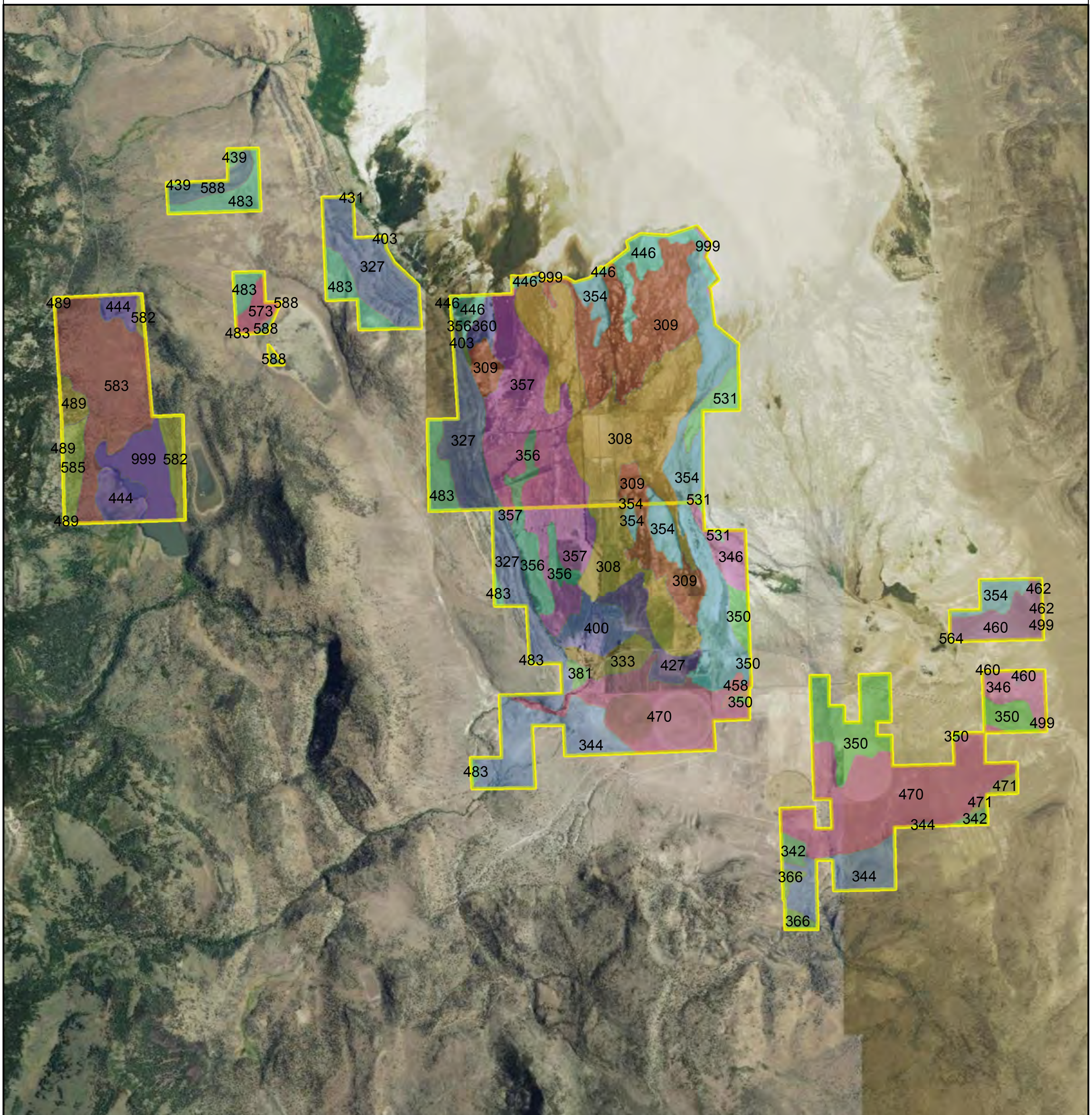
Bare Ranch Soils Map

Customer(s): ESTILL RANCHES LLC

Date: 4/3/2015

Assisted By: BRIANA SCHNELLE

Agency: USDA--NRCS



3,400 0 3,400 6,800 10,200 13,600 Feet

N

Bare Ranch
Field Acreage

Customer(s): ESTILL RANCHES LLC

Date: 4/19/2016

State and County: Washoe County, Nevada

Agency: USDA--NRCS

Field Office: ALTURAS SERVICE CENTER

USDA

0 0.3 0.6 0.9 1.2 1.5

Miles

N