Feasibility Assessment of Compost Addition on Alameda County Rangelands: Compost Sourcing and Spreading Costs

Alyssa Gomez[1], Ian Howell[1], Stephanie Lew[1], Hillary Sardiñas[1], Kelly Schoonmaker[2], and Megan Verner-Crist[1].

1- Alameda County Resource Conservation District; 2- Alameda County Waste Management Authority.

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Introduction

What is carbon farming?

Carbon farming is the use of traditional or novel agricultural practices to increase carbon sequestration of farm and ranch operations. One promising carbon farming practice, compost addition on arable lands and grasslands, can be adapted to a variety of agricultural operations with promising results. Traditionally used in cropland systems, there is growing interest in the application of compost in rangeland systems to improve soil health and sequester carbon. The impacts of compost application in rangeland settings are still being studied, and compost application is not considered appropriate for all rangelands. Compost application is considered most appropriate in degraded or disturbed rangeland systems rather than intact native grassland systems. However, compost application has been shown to have beneficial effects when applied in the right settings. For instance, a one-time application of compost has been shown to improve soil health, increase crop and forage productivity, and sequester atmospheric carbon dioxide in soils (Ryals and Silver 2013; Ryals et al. 2015). Compost addition also increases soil water holding capacity, which reduces runoff and improves water quality (Brown and Cotton 2011).

In this feasibility study, we discuss important factors for landowners to consider when planning compost application on rangelands. In Part I, we discuss the factors that influence compost quality, and the how to interpret the various standards and technical data that accompany compost purchases. In Part II, we carry out a cost analysis of compost application on rangelands in Alameda County. And in Part III, we combine the preceding information in practice, highlighting two case studies of application of quality compost in Eastern Alameda County, evaluating their costs and discussing lessons learned.

I. Understanding Compost

Compost is the product of controlled aerobic biological decomposition of organic materials. The composting process is characterized by high and moderate temperature phases, during which thermophilic and mesophilic microorganisms decompose the feedstock, killing weed seeds and pathogens. Common feedstocks used to produce compost include yard waste, food scraps, paper, manure, agricultural residues, and biosolids. Finished or "stable" compost bears no resemblance to the feedstock from which it was created. More mature compost is typically dark brown, has an even texture, and an earthy smell. Maturity and other characteristics are measured through lab tests. Although commercial composting facilities are highly regulated at the state and local level, compost products vary in their attributes, depending on the feedstock (or source material), processing method, local conditions, and other variables. Composts with different attributes are appropriate for different applications. Quality for any application is evaluated by multiple measurements and indicators. In this section, we discuss various important measures of compost quality as it pertains to surface application on California rangeland.

Compost State Regulations

CalRecycle oversees permitting and regulation of the composting process and products for the State of California. Direct enforcement is conducted by the local enforcement agency, which conducts regular inspections of facilities to verify, among other things, that the facility is maintaining constant temperatures above 55 degrees Celsius for the required amount of time to reduce pathogens to safe levels. To sell or give away a product, composters must have the product analyzed by a certified laboratory to verify that the compost meets standards for pathogens, heavy metals, and inert contaminants (plastic, glass, and metal).

Compost Certifications

In addition to standards set by the state, the following certification programs can help provide additional information about a compost facility: US Composting Council's Seal of Testing Assurance (STA) certification and Organic Materials Review Institute (OMRI) listing and/or California Department of Food and Agriculture (CDFA) Organic Registration. The STA certification ensures compost facilities:

1) Comply with all state, federal, and local regulations
2) Sample and test their product regularly using a standardized suite of tests following the Test Methods for the Examination of Compost and Composting manual (TMECC)
3) Use approved labs
4) Make their test results available upon request.

Both OMRI and CDFA Organic Registration standards defer to USDA National Organic Program (NOP) standards for organic input material and allow these composts to be used as input for organic agricultural operations. However, the OMRI listing is a voluntary registration primarily used for branding, while CDFA Organic Registration is required by the State of California. In practice, most facilities maintain both certifications for organic composts. Similar to the state regulations, the NOP standards recommend other aspects of the composting process, including starting C:N ratio and temperatures for pathogen reduction.

Compost Technical Data Sheets

In addition to testing required by the state, Compost facilities that are part of the US Composting Council's STA Program are required to test their compost regularly. The results of these tests are available upon request as Compost Technical Data Sheets[1] (CTDS). CTDS are useful tools for evaluating quality of compost produced by a specific compost facility. It should be noted CTDS do not reflect the data for a specific batch of compost purchased from each facility-- instead, they are lab analyses conducted every 1-3 months on batches of compost produced by the facility. As such, one important measure of compost quality that can be assessed by reviewing the Technical Data Sheet is consistency—are the measures of compost quality reported on the sheet relatively consistent across multiple sheets, or do these measures vary widely over time? Tested characteristics include levels of pH, soluble salts, nutrients, moisture, organic matter content, and trace metals, as well as characteristics discussed in more detail below such as particle or screen size, maturity, stability, inert contaminants, and the presence of pathogens. CTDS also include information on the feedstock from which the compost is developed. Each of these characteristics help determine the best use for that batch of compost. For compost use on rangelands, we have focused on the attributes discussed below.

Feedstock

Feedstock denotes the source material from which compost is developed. The composition of the feedstock can affect multiple attributes of compost, including time to stability and maturity, nutrient content, levels and types of contaminants, and appearance. Commercially available compost is produced from a variety of feedstocks, including green waste, food waste, manures, agricultural residues, wood waste, biosolids, municipal solid waste (MSW), and a small but increasing amount of digestate from anaerobic digestion facilities. In the Bay Area and Northern California, common acceptable feedstocks for use in CDFA Organic and OMRI compost include yard trimmings, food, paper, crop residues, manures, and wood. Unacceptable feedstocks for Organic Input Material include biosolids, mixed solid waste (MSW), and synthetic materials, including compostable plastics.

Contamination

Compost feedstocks can be contaminated with materials that do not break down and can be harmful to ecosystems. Common types of contaminants vary with feedstock. Plastic and glass are the most common contaminants ("inert contaminants") in commercial and residential food scraps, and composters go to great lengths to minimize this type of contamination by rejecting contaminated loads, pre-processing material before composting, and screening material out after composting. CalRecycle has set strict limits on inert contamination: 0.5% total contaminants >4

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[1] For more information on Compost Technical Data Sheets, see the US Composting Council's "Understanding Compost Technical Data Sheets" webpage: https://www.compostingcouncil.org/page/UnderstandingCTDS

mm by weight with 0.1% plastic (also by weight). Still, even with strict standards and technology, compost made from feedstock with inert contaminants will retain some of those inert contaminants. At this time, this issue is present mainly in compost made from curbside collections of food scraps, although certainly not in all food scraps composts. As curbside organics programs become required across the state, more food waste is being composted, which reduces methane emissions but can increase the challenge of avoiding contaminants. Other compost feedstocks have their own specific contamination concerns. In particular, PFAS has been identified in composts sourced from biosolids.[2] Manure and green waste composts could be contaminated with persistent herbicides.

Spreading contaminated compost on farm or rangelands could injure cattle or other species utilizing the area, and introduce contaminants, such as microplastic, to a natural landscape. To minimize risk, we are not currently recommending compost made from food waste or biosolids, and recommending green waste compost, which has cleaner feedstock. However, for the purposes of this feasibility study, in Section 1 we also evaluated costs for compost produced from curbside organics because it is widely available, and may work in other applications, such as row crop farming.

Screen size

Particle size or "screen size" is another critical factor to consider when choosing compost. Particle size affects the cost of compost and its practical use. Material that has gone through the composting process includes a large fraction of woody material, with the size of the largest particles ranging from 4 to 6 inches. This material is then screened to different sizes, depending on the application. The finest screened material (1/8 to 3/8 inch) is typically used for top-dressing turf. Compost used as a soil amendment can range from ¼ to ½ inch. Compost screened to ¾ inch or greater (referred to as "mids," "overs," "coarse compost," "composted mulch," or "screened overs") is typically used for erosion control as a mulch, or as a filler for sediment control socks (Faucette et al., 2006; Crohn et al., 2013; Archuleta and Faucette, 2014). Coarse compost has the appearance of a dark, smooth-textured mulch with many larger (~2-4 inch) woody particles covered in dark brown to black compost fines. It is also notable that different compost specifications may have different requirements for the percentages of material that pass pre-determined screen sizes (e.g., BASMAA specification for non-floating mulch; CalTrans medium compost specification). The screening process and smaller screen size can also filter out some contaminants, particularly pieces of plastic film and glass.

Table 1: Particle Size and Compost Use

Particle Size	Use
1/8-3/8"	Top-dressing turf
1/4-1/2"	Soil amendment

[2] PFAS refers to per- and polyfluoroalkyl compounds (also known as "forever chemicals") used in nonstick pans, water-resistant coatings, and many other household and industrial substances. PFAS contamination has been found in watersheds throughout the U.S. and is an emerging environmental concern due to its health and environmental effects.

>3/4" ("coarse compost")	Erosion/sediment control (mulch)

Stability and Maturity

Stability and maturity are also important characteristics to consider when choosing compost. Compost is considered finished or "stable" when raw feedstocks are no longer actively decomposing and are biologically and chemically stable. Common indicators for stability are oxygen consumption and temperature over time. Stable or finished compost will have completed the Process for the Further Reduction of Pathogens (PFRP) to remove pathogens, which also destroys weed seeds and most toxins.

Maturity is characterized by a variety of indicators, including but not limited to: stability, phytotoxicity, CO_2 evolution, ammonia production, and decrease in starting C:N ratio (Cooperband, 2002; Sullivan et al., 2018). More mature composts are considered suitable for most applications, while immature composts have more limited applications. Mature compost should have an earthy smell, and not resemble the feedstock from which it was produced or be hot to the touch. Microorganisms in immature compost can outcompete plants for nutrients. Based on current understanding of compost quality and rangeland needs, a mature compost is likely the preferred option for rangelands, although this may change as more research becomes available. See Appendix A for an example specification sheet from our 2019 compost application, which addresses all of the quality factors discussed in this section.

II. How Much Does Compost Addition on Rangelands Cost?

The cost of compost application on large expanses of rangeland has not been well-documented and may present a significant barrier to the adoption of compost addition as a carbon farm practice. Factors that can affect cost include application rate, material type and availability, site location, prevailing wage, site access, parcel size, and substrate complexity. Other considerations include the slope of the site, weather and soil conditions, all of which affect site access and the type of spreading that is possible on a particular site. In this study we evaluate the feasibility of rangeland compost application in Alameda County by evaluating the variability of these costs. To do so, we estimated costs based on rates from a number of compost suppliers in the Bay Area, and then implemented two compost application projects to explore how these estimates compared to actual project implementation costs.

How we gathered cost information

The Alameda County Resource Conservation District (ACRCD) contacted eleven compost manufacturers (Table 2) and eleven compost-spreading companies (Table 3) in early 2019 to gather estimates on the cost of compost material, delivery, and application. We first compiled a list of all compost facilities within 70 miles of the county boundary that maintain the certifications discussed above: U.S. Composting Council's Seal of Testing Assurance (STA) and Organic Materials Review Institute (OMRI) listing or California Department of Food and Agriculture Organic Registration (CDFA Organic Registration). We also gathered information about the type of feedstocks used for compost production due to feedstock's importance in determining the final quality of the compost.

Material Cost

We asked for cost estimates based on a standard volume of compost – 680 cubic yards – to ensure uniformity. Studies in other California counties have identified that a ¼-inch application of compost to rangelands provides measurable benefits to soil health and forage quality while sequestering carbon (Ryals et al. 2015). Approximately 34 cubic yards of compost are needed to spread a ¼-inch treatment over one acre. Thus, 680 cubic yards would be needed to apply a standard compost treatment across 20 acres. While there may be economies of scale associated with purchasing larger quantities of compost, the 680-cubic yard volume can be used as a baseline quantity for pilot project planning. Different levels of compost application may be more appropriate depending on the landscape.

Compost facilities provided either a cost per ton or per cubic yard. To simplify cost comparison, we used a conversion factor of 2.2 cubic yards per ton to convert cost per ton to cost per cubic yard. The 2.2 cubic yard per ton conversion assumes a fine compost (screened to 3/8 to ½ inch) with moderate moisture. One compost facility included the cost of delivery in the price per cubic yard; that price was excluded in the average pricing for material alone.

Delivery Cost

Delivery costs were estimated assuming Sunol, CA as the delivery location. Sunol was chosen as the default delivery location due to its centrality within Alameda County. The facilities were situated in all directions but were mostly located in the Central Valley or in the southern San Francisco Bay Area. We limited the distance to Sunol to 70 miles because of the increased costs of delivery, the increased carbon emissions of longer transportation distances, and the prevalence of high-quality composting facilities within the area. For reference, the Compost Emission Reduction Factor prepared by CARB uses a 100-mile round-trip to calculate their GHG benefits. Trips longer than this would result in higher emissions for the project.

Delivery pricing was either included in the price of the compost per cubic yard, or as an additional charge. Some facilities provide delivery with their own trucks, others arrange delivery with separate trucking companies, and others use a combination.

Application Cost

We requested application cost estimates that reflected conditions most likely to be encountered in Alameda County rangelands: moderate slopes with moderately good access on mainly dirt roads. We gathered estimates for two different methods of applying compost to a landscape, mechanical spreading and blowing. Mechanical spreading is done using a compost spreader that is loaded with material and pulled by tractor over the desired area of coverage, while blowing compost requires a truck equipped with pneumatic hoses that can blow compost out onto the landscape. Compost blowing trucks, with their varying hose lengths, may allow for compost addition on areas inaccessible to mechanical compost spreaders (extreme slopes, for example), although some degree of truck access is still required to accommodate the blower trucks.

Some compost-spreading companies purchase compost from a provider and include the material cost in their fee for services, while other compost spreaders expect compost to be provided by the customer. Regardless, compost-spreading companies were flexible in using different composts that fit the project, given certain compost quality requirements were met, such as no rock or sand being part of the compost.

Five out of eleven companies contacted were able to provide cost estimates. Topographic variability (specifically steep terrain) greatly impacted the number of operators capable of providing services. Mechanical spreading companies gave their estimates either in cost per cubic yard or as a total price. For ease of comparison, these costs were converted into cost per cubic yard as discussed above.

Findings

Materials cost for compost was $11.00 per cubic yard on average. The cost varied substantially by company; with a range of $4.50-$18/ cubic yard. For 680 cubic yards of compost, the cost estimates ranged from $3,060 to $13,600, with an average cost of $7,430 (see Table 2).

Compost facilities' locations ranged from 17 miles (Livermore, CA) to 70 miles (Vacaville, CA) from Sunol (see Figure 1, right). Delivery prices were dependent on mileage and/or hours from compost facility, accessibility of the site, and number of hauls needed to transport the material. Delivery prices ranged from $4,060 to $12,240, with an average of $7,047 (see Table 2). Generally, more distant facilities had higher total delivery fees, though this did not hold true for every location. Combined, the average cost for compost material plus delivery was $14,562 ± $6,061. The median cost was $14,606.

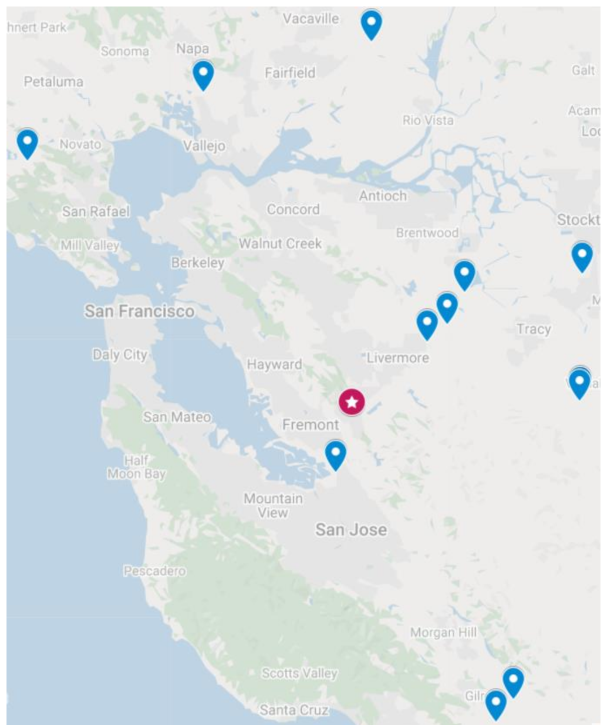

Figure 1. Google-generated map of STA-certified compost facilities within ~70 miles of Sunol, CA (starred). Open an interactive map at: https://www.google.com/maps/d/edit?mid=1XtEwBEF3jwgL4W8IrRfMrJCCEh8-fW8k&usp=sharing.

Only five out of the eleven spreading companies that we contacted provided cost estimates. Quoted prices to *spread* 680 cubic yards of compost across our hypothetical 20-acre project ranged from $2,720 to $8,000 (see *Table 3: Costs of Mechanical vs. Blown-on Compost Spreading*). Only two services provided estimates for blowing compost onto the landscape, these were significantly greater than mechanical spreading: $23,686 and $24,324. See additional discussion of the costs of blown-on vs. mechanical spreading in our *Discussion* section.

Table 2. *Local Compost Facilities within 70 miles of the hypothetical project location that are STA and OMRI participants, with Compost Type and Associated 2019 Costs*

Compost Facility	Feedstock	Location (miles from Sunol)	Cost per cubic yd ($) *	Cost of 680 cubic yds ($)*	Delivery Price ($)*	Total Cost (680 CY + Delivery)*
California. Soils, Inc. [a]	Self-haul yard waste & wood	Vernalis (45)	--	--	--	--
Harvest Power [b]	Curbside & self- haul yard &food waste	Lathrop (47)	5.85	3,978	4,896	$8,874
Napa Recycling	Curbside & self-haul yard & food waste	Napa (59)	10	6,800	--	--
Oliveira Enterprises, Inc. [a]	Self-haul yard waste	Byron (32)	--	--	--	--
Recology – Blossom Valley Organics [b]	Curbside yard & food waste	Modesto (48)	4.5	3,060	5,200	$8,260
Recology – Jepson Prairie Organics	Curbside yard & food waste	Vacaville (63)	12	8,160	8,296	$16,456
Recology – South Valley Organics [a]	Curbside yard waste	Gilroy (52)	--	--	--	--
Republic Services – Newby Island Resource Recovery Park	Curbside yard & food waste	San Jose (18)	9	6,120	4,060	$10,180
Vision Recycling	Self-haul yard waste	Livermore (17)	--	--	--	$14,606[c]
West Marin Compost	Self-haul yard waste & dairy manure	Nicasio (69)	20	13,600	12,240	$25,840
WM Earth Care	Curbside yard & food waste	Livermore (21)	18	12,240	7,684	$19,924
Z-Best Recycling Organic Compost	Curbside & self-haul yard waste	Gilroy (53)	12	8,160	7,000	$15,160
Average			**$10.92**	**$7,430**	**$7,047**	**$14,562**

*Costs may have changed since 2019 from those listed here.
[a] California Soils, Inc., Oliveira Enterprises, and Recology: South Valley Organics were contacted after initial data collection was completed, and we do not have cost estimates for these facilities. We do have real costs used in our 2019 and 2021 case studies, discussed below.
[b] These compost facilities provided cost per ton which were converted to cost per cubic yard using a conversion factor of 2.2 cubic yards per ton. Harvest Power in Lathrop was purchased by Waste Management since we conducted our survey.
[c] Cost provided as total only and includes delivery fee.

Table 3. Costs of Mechanical versus Blown-on Compost Spreading

Application Method	Company	Location	Total Cost for 680 cubic yards
Mechanical	Dores Ag Services	Stevinson	$ 2,720
	Holsapple's Fertilizer Spreading Inc.	Turlock	$ 4,760
	Santucci General Engineering	Livermore	$ 8,000
	AVERAGE		**$ 5,160**
Blown-on	Applied Landscape Materials Inc.	Rocklin	$23,686
	JetMulch Inc.	Capitola	$24,324
	AVERAGE		**$24,005**

Combining these factors, we found that the total average cost for the purchase, delivery, and mechanical spreading of 680 cubic yards of compost as a ¼-inch top dressing over 20 acres at our hypothetical site would be $19,723, or approximately $1,000 per acre.[3] The total average cost for purchase, delivery, and *blown-on* spreading over 20 acres would be $38,568.

III. In Practice: How much did application of quality compost in Alameda County cost?

In December 2019, ACRCD partnered with two landowners to implement compost addition projects on rangeland. These projects provided real costs to compare against the cost estimates we collected. At the time of printing, a third major compost addition project was being carried out. We include some preliminary discussion of this project (Project 3) below, but more a more in-depth analysis will be available after the project is completed.

For application on rangelands at these properties, we specified a mature green waste compost screened to ½ or 3/8 inch (see Appendix A for our full specification requirements). Yard waste compost was appropriate for rangelands because: 1) nitrogen release from green waste compost has been shown to closely match nitrogen uptake by California native plants in the Bay Area (Claassen, 2009), 2) inert contaminants are much less common in this feedstock, and 3) the screen size allows for a relatively consistent top-dressing application of material and would minimize disturbance to the existing plant community and wildlife in the application area.

[3] Compost purchase, delivery, and application costs may have changed since 2018.

Project 1

We applied a ¼-inch top-dressing of compost to 12 acres (non-contiguous) on the Alameda County Waste Management Authority's ("StopWaste") property in the Altamont Pass. This project was funded by StopWaste and a CDFA Healthy Soils Program Demonstration Type A grant (no. 19-0670-000-SO) awarded to ACRCD.

Compost Purchase and Delivery

We added 20% to our total compost order because of concerns about compost losses during spreading due to transfer between the loader and the spreader, as well as loss to the ground where material was stockpiled. Thus, instead of purchasing 340 cubic yards, we purchased 420 cubic yards, or 20 percent extra material. Our material costs totaled $5,880 or $14/cy, excluding delivery and sales tax. This was slightly above the average estimate. Including delivery and tax, it cost $7,189 for 420 cubic yards of compost, or $17/cy. We had excess compost after applying a ¼" to 10 acres. We used this extra compost on an additional 2 acres. We also used it to cover impacts in staging areas and locations where heavy equipment was used (e.g., along dirt roads and shoulders). In the future, we would limit the extra compost purchased to 5 percent.

We utilized compost from a nearby facility located just 4.5 miles from the property. Vision Recycling, Livermore provided a STA OMRI-listed compost developed from a greenwaste feedstock. We predicted that their proximity to the project location would help lower delivery costs. Because of the distribution of compost addition plots throughout the property and the capacity of the trucks (~60 yards/truck), we needed seven deliveries in total. Ranches with unimproved or steep roads may require smaller trucks or stockpiling of compost in one accessible location, which would increase time and costs associated with loading the spreader. For our project, each delivery truck was estimated at $175 for a total of $875 in freight. However, final delivery costs were discounted and totaled only $700. Final compost costs with delivery and tax totaled $7,188.65. This price was significantly lower than estimates, even when multiplied by a factor of 1.65 to approximate the 680 cubic yard amount we provided in our hypothetical scenario. The project site's improved road system accommodated the largest walking-floor semi-trailer trucks, minimizing the total number of trips. Proximity to the project site can significantly reduce costs. For instance, at $14/ yard, Vision Recycling had significantly higher costs per yard than many other facilities, but the overall costs were lower than expected due to the proximity to the project site (only 4.5 miles).

Compost Spreading

To select a spreading contractor, we solicited cost estimates. A month before spreading, we held a project tour that was attended by four contractors. Together they toured the application sites across the property, discussed application timing and reviewed potential equipment. One contractor declined to bid; two provided quotes for mechanical spreading, and one for blown-on compost. The mechanical spreading quotes were $7,400 and $14,300 respectively. As we found with the estimates, the cost for blown-on compost was again more expensive, at $20,580; however, this quote included a significant mark-up as it was submitted by a professional landscaping company that would have had to subcontract to a blower-truck service. The spreading costs for both types were significantly more expensive than the hypothetical 20-acre project cost estimates, despite the project involving less compost than the hypothetical project. We believe this resulted, in part, from contractors seeing a real site and developing estimates that more accurately reflected the complexity of applying compost on steep slopes across the property.

Based on these quotes, we planned to use the lowest-cost tractor-pulled mechanical spreader to apply compost. The Altamont Pass property is windy; therefore, we reviewed wind data and decided to wait until early December to apply compost. However, storms in late November into early December 2019 led to soil saturation and damp, cloudy weather conditions did not provide significant soil dry-out. Our grant funding from CDFA required that we spread the compost before December 31, precluding a project delay in the hopes of dryer conditions after a few weeks. Using a tractor-pulled spreader would have caused soil compaction and disturbance; therefore, we opted for blown-on compost spreading to reduce soil impacts.

Blown-on compost spreading requires a specially equipped blower truck. For this project, JetMulch provided up to three blower trucks at one time to complete application. Additionally, JetMulch rented a high-lift loader to fill the blower trucks with compost. The compost was applied relatively evenly and took three days to apply to the full 12.0 acres. The cost for blown-on compost spreading was $18,879, and the loader rental cost $1,200 for a total of $20,079.

Project implementation costs totaled $27,268 (direct costs, excluding labor and overhead costs for ACRCD, StopWaste, NRCS, and the grazing operator), $12,018 more than we had budgeted in grant funds due to the need to utilize blown-on techniques to apply the compost.

Table 4. 2019 StopWaste Compost Delivery & Spreading Costs (HSP Demo)

Project	1) StopWaste – HSP Demo
Compost Vendor	Vision Recycling
Total days and crew members	2.5 days 9 crew members each day
Spreading Type	Blown-on
Compost Amount	420
Total Acres	12
Spreading Cost	$20,079
Delivery Cost	$700
Tax	$609
Total Cost	$27,268
Total Cost/ acre	$2,272
Total Cost/ cubic yard	$65

Project 2: Private Ranch Compost Application

We applied a ¼-inch application to two acres, and 1/10-inch application to 3.7 acres on a private ranch in Livermore, CA. This project was funded by two state programs: the ¼ inch application was funded by the Department of Water Resources (AgWUE grant no. 4600011919 awarded to ACRCD), while the 1/10-inch application was funded by a CDFA Healthy Soils Program Incentives contract between CDFA and the landowners.

As in Project 1, we added approximately 20% to our total compost order because of concerns about compost losses during spreading. Thus, we purchased 134 cubic yards of compost at $14/cy for a total of $1,876, excluding delivery. Including delivery and tax, the total cost was $2,836.13, or $21/cy. There was excess compost which was spread on 0.7 acres adjacent to an original plot. In the future, we would limit excess compost purchased to 5 percent.

We utilized the same compost company from Project 1, which was located 14 miles from the property. The project required four deliveries in total. Each delivery cost $180 ($5 more per delivery for a 10-mile increase in distance with smaller trucks relative to Project 1) for a total of $720.

Compost was applied in early December 2019 by mechanical spreader on the property, where soils were less saturated and the topography less steep compared to Project 1. The cost to spread 134 yards of compost by a two-person crew using a tractor and spreader over one day, supported by a standard front-end loader, cost $2,560. The total cost for compost application in 2019 was $5,396 which was approximately $400 more than anticipated. The compost was applied relatively evenly over a total of 5.7 acres (2 acres at the 1/4-inch rate, and 3.7 acres at the 1/10-inch rate) and took about a half-day to complete.

In 2020, an additional 48 cubic yards of compost was applied at 1/10-inch across three of the acres that received 1/10 inch of compost in 2019. This application cost $3,861 total, with a per-acre cost of $1,221, reflecting cost increases as well as potential cost-savings for delivering and applying larger quantities of compost. An additional 1/10-inch application across these three acres will be applied in 2021 as part of the HSP grant program requirements. We anticipate that 2021 costs for compost application will be similar to the 2020 application. Including compost application in 2020 and 2021, anticipated costs for three years of compost application at approximately a quarter inch rate across 5.7 acres is $13,118, averaging $2,301 per acre (see *Table 5,* below). Note that 0.7 acres received only 1/10-inch of compost over this time, 2 acres received ¼-inch of compost, and 3 acres received 3/10-inch of compost. This project highlights that while mechanical spreading may be less costly than blown-on compost, other project requirements can result in high overall application costs. In this case, the HSP program requirement to apply 1/10-inch of compost in each of three consecutive years, rather than 1/4 -inch of compost in one year, resulted in relatively high costs per acre (or per cubic yard of compost).

Table 5. Compost Delivery and Spreading Costs at a Private Ranch, 2019-2021

Year	2019	2020	2021 (estimated)	Total across years
Compost Vendor	Vision Recycling	Vision Recycling	Vision Recycling	--
Total days and crew members	<1 day at two crew members	<1 day at two crew members	<1 day at two crew members	3 days of two crew members
Spreading Type	Mechanical	Mechanical	Mechanical	Mechanical
Compost Amount (cubic yards; CY)	134	48	48	230
Total Acres	5.7	3	3	5.7*
Spreading Cost	$2,560	$2,560	$2,560	$7680
Delivery Cost	$1876	$1,061	$1,061	$3,998
Tax	$240	$240	$240	$720
Total Cost	$5,396	$3,861	$3,861	$13,118
Total Cost/ Acre	$947	$1,221	$1,221	$2,301*
Total Cost/ CY	$40	$80	$80	$57

*Approximately ¼-inch of compost was applied over 5.7 acres over three years: ¼-inch across 2 acres in 2019, 1/10" over 3.7 acres in 2019, and 1/10" over 3 of the same acres in 2020 and again in 2021.

Project 3. Extensive Compost Application at StopWaste Parcel 4

This project is being carried out in November 2021 at Parcel 4 of the StopWaste property (described in Project 1, above). 91 acres of the property were deemed appropriate for further compost addition. Compost is being provided by three suppliers: Recology- South Valley Organics and Z-Best, both located approximately 75 miles away in Gilroy, and Oliveira Enterprises, located 16 miles away in Byron.

Each compost product is produced from 100 percent green waste, free of food and manure inputs, and is OMRI-listed as organic. 700 cubic yards of compost from Recology is being applied across 20.5 acres of the property (34 yards per acre), and another 700 cubic yards from Z-Best Organics is being applied across 20.5 acres of the property. Oliveira Enterprises is supplying 1700 cubic yards that is being spread over the remaining 50 acres. All compost is being applied as a ¼-inch top dressing.

Santucci General Engineering is providing mechanical compost spreading services. Santucci participated alongside three other contractors in 2019 to provide cost estimates for Project 1.

Costs vary by supplier, with estimated total costs per cubic yard (including compost, delivery, and tax) of $21.32 and $21.40, respectively, for Recology and Z-Best, and $15.74 per CY for Oliveira (see *Table 6*, below). The lower unit cost for Oliveira could reflect several factors:

Oliveira is significantly closer to the project site and is also an integrated operation, with their own delivery operation. These factors may result in lower overall costs for providing and delivering compost.

While this project isn't completed at the time of printing, total costs including delivery, spreading, and tax are estimated at $111,656, or $1,240 per acre.

Table 6. 2021 Compost and Delivery Costs to StopWaste Parcel 4 (Project 3)

Vendor	Distance from site	Compost Cost/ Cubic Yard	Compost Amount (CY)	Compost Cost	Delivery Pricing	Delivery Cost	Tax*	Total Cost	Total Cost/ CY
Recology (South Valley Organics)	75 miles	$7.50	700	$5,250	$525/ truck	$9,187	$486	$14,923	$21.32
Z-Best Organics	75 miles	$9.00	700	$6,300	$540/ truck	$8,100	$575	$14,975	$21.40
Oliveira Enterprises	16 miles	$8.00	1700	$13,600	$7 per CY	$11,900	$1,258	$26,758	$15.74
Total/ Average	**--**	**$8.11**	**3,100**	**$25,150**	**$9.42 per CY**	**$29,187**	**$2,319**	**$56,656**	**$18.28**

***** 9.25% of the cost of compost materials.

Table 7. Compost Spreading Costs at StopWaste (Project 3)

Project	Spreading Type	Total Acres	Compost Amount (CY)	Spreading Cost*	Days of Spreading	Spreading Cost/ acre*	Spreading Cost/ cubic yard
3)	Mechanical	91	3,100	$55,000	7 days	$604.40	$17.74

***** Including loader operator and tractor operator, mobilization, fuel costs, and prevailing wage.

IV. **Discussion**

Lessons Learned in Practice

We learned several key lessons about successfully implementing compost application projects on rangelands. As in other construction and restoration projects, we found that bottlenecks cost time and money. In Project 1, blower trucks were limited not only by the labor-intensive, narrow spreading apparatus, but also by the loading process. Blower trucks used in our project required a high-reach loader to refill the trucks. One loader struggled to keep three trucks operating simultaneously in different areas without long delays between finishing spreading one load of compost and the next. The mechanical spreading operator who applied compost at Project 2 was slowed somewhat in commencing work because of a delay in receiving all truckloads of compost material. Although compost can be spread as material is delivered to the site, a critical mass of compost must be stockpiled to allow maximum efficiency by the applicator.

As discussed briefly above, compost suppliers that operate integrated facilities may be more cost-effective. For suppliers that sub-contract with delivery companies, the costs of delivery, timing, and expertise of the delivery company can vary significantly by delivery company, even if the compost facility remains the same. Engaging a company that also performs spreading could reduce costs further. However, many companies are not able a to perform the full range of services (purchasing, delivery, and spreading) and using such a company could limit the choice of compost products. While there may be economies of scale associated with purchasing compost in bulk, we found that freight fees are likely to affect overall costs more significantly than bulk discounts. With this is mind, distance of a facility from your project site is an important cost factor. Variables such as compost screen size, moisture content, and seasonality can affect both how much material you receive, the number of trucks required to transport it, and overall freight costs. For instance, moisture content and screen size affect both the weight and density of the compost. If your compost is heavier than expected and you purchased compost by cubic yard, you will need more deliveries than expected to deliver the desired amount of compost.

We unexpectedly found a marked difference in the costs associated with application method. Blown-on compost was more than twice as expensive as mechanical spreading. However, blowing compost may be useful in specific situations, such as on steep slopes or in wet conditions that can limit equipment access or pose a safety risk. The higher costs for blown-on compost may be due in part to the labor required for each method. For mechanical spreading, one loader operator and one tractor operator may be typical, while blown-on compost requires a crew of 3-4 per blower truck.

While the different costs across projects are informative, their costs per cubic yard/ acre cannot be directly compared, due to differences in application rate, additional years' applications of compost at Project 2, and differences in site access, conditions and project scale.

Factors that contribute to the high cost of rangeland compost application include the project location, experience of contractors with the application method, and variability in the cost of compost and delivery (freight) from different suppliers. Although the project scenario that we developed was streamlined to help limit costs by assuming a single purchase and single application of compost versus multiple applications over consecutive years, we found that prices were high, and that spreading prices were the most variable cost. Spreading costs likely increase based on project site characteristics such as terrain and remoteness. Slope, site accessibility, staging area availability, time required to complete the job, and landscape uniformity are all factors that are likely to impact contractor estimates. Contractors were limited in their ability to accurately project costs associated with carrying out this type of work because we did not define a specific application location. This is borne out by the actual project costs from the 2019 examples, in which spreading costs were higher than anticipated compared to those quoted based on the ease of access and topographic features of the site. We did not take prevailing wage into account, but it could also inflate spreading costs above what we recorded. It should be noted that costs are likely to increase with inflation over time.

Our results indicate that compost addition to rangelands in Alameda County would be an expensive endeavor which would not be practical for many agricultural producers without cost-share opportunities like the one offered through the California Department of Food and Agriculture's (CDFA) Healthy Soils Program (HSP) Incentives. CDFA's HSP Incentives repayment rate in 2020 was $1,200 per acre. This repayment rate would total $24,000 for a 20-acre project. Our estimates totaled an average of $19,812 for purchase, delivery, and application of 20 acres of mechanically spread compost, and $38,657 for blow-on compost. Depending on the facilities chosen from the above list (see Table 2), the 2020 HSP reimbursement rate could cover between 54-100% of costs of compost application[4]. As we found in our case study, actual costs will vary from estimates, due to factors like site conditions, proximity to the compost facility, and changes in compost pricing. However, our real costs displayed a similar range to those of our estimates. In our case studies, total costs ranged from $1,240-$2,301 per acre, which would have been covered at rates of 52-97% under the 2020 HSP repayment rates.[5] If this repayment rate were to be coupled with other financial incentives, such as federal Farm Bill programs or a potential carbon credit exchange that pays ranchers to sequester carbon via compost addition, it could make implementing the practice more appealing and potentially profitable for agricultural producers. Although we tried to account for all foreseeable variables that could impact cost, there may be other costs associated with compost spreading that we did not consider. For example, as discussed above, some companies may have access to support equipment, such as dump trucks and loaders to facilitate spreading compost to multiple areas of a property, or the ability for suppliers to deliver their own compost. In other cases, this equipment may need to be rented separately or subcontracted, inflating rates quoted to us. We did not specifically inquire about equipment ownership nor how that might impact the rates provided by potential contractors; some farmers might own some of their own equipment, which could reduce spreading costs.

Although we did not investigate how the price of compost may change within a year, compost example, composters who market their material to farm operations experience higher demand just prior to seasonal crop planting. Changes to California's rules for diverting organics from landfill (discussed below) are anticipated to significantly increase compost production demand, with as-yet unknown effects on prices. Regulations limiting the siting of new licensed compost facilities and expansion of existing facilities do not appear to support rapid growth of the industry capacity. It is likely that prices will increase in the near term due to competing demands from traditional purchasers (e.g., farms) and municipalities compelled to participate by regulations. Transportation and spreading services may be less elastic than compost costs. Ultimately, increased use of compost on rangeland and reporting of rates should improve price forecasting. suppliers indicated that their prices are dynamic and can vary seasonally based on supply and demand. For

Making compost addition more feasible in California rangelands

Carbon farm practice adoption needs to expand dramatically among farmers and ranchers to meet the State's carbon sequestration goals. Reducing the cost of project implementation to

[4] Compost purchase, delivery, and application costs may have changed since 2018-2019.
[5] Note that HSP repayment currently requires three consecutive years of compost application.

farmers and ranchers will be key to encouraging producer participation and ultimately helping to mitigate climate change in California.

Widespread adoption of compost addition on rangeland in Alameda County is likely to be limited by cost and high-quality compost. Cost-share programs such as the California Department of Food and Agriculture's (CDFA) Healthy Soils Program Incentives provide a portion of the costs to incentivize practice adoption. Based on the results of this study, these costs cover between 52-100% of the actual total project costs. Further, CDFA requires that compost be spread for three consecutive years at a rate of 6.7 tons per acre in each year, equivalent to an annual rate of approximately 0.1 inches. The costs of compost delivery and spreading—and producers' time commitment—are thus tripled under CDFA's HSP schedule for compost application on rangelands, while the cumulative compost applied per acre would be nearly the same as a single application of compost at 0.25 inches (approximate 33.6 cubic yards or 15 to 17 tons per acre). These increased costs are reflected in our Project 2 case study, which had the highest overall cost/ acre of our projects. It is our understanding that CDFA's application schedule is driven by caution to avoid a one-time increase of nutrients that could favor non-native grasses and weeds over native grassland species. It is unclear whether the effects of operating equipment on grasslands for three years have been studied for potential impacts, such as soil disturbance or the spread of weed seeds, but this could be an important consideration in weighing the most appropriate approach for compost application on rangelands.

In 2021, the Natural Resources Conservation Service (NRCS) added a Soil Carbon Amendment Conservation Practice Standard (CPS 808), which will allow compost addition to rangelands to be supported through its Environmental Quality Incentives Program (EQIP), a cost-share program that targets voluntary conservation activities on working lands. It's important to note that this practice is written very narrowly, with limited reimbursement (on the first 3 tons added per acre) and is only applicable to slopes of 8% or less on non-irrigated rangelands. EQIP strives to reimburse a fixed percentage of *typical* costs, but those costs tend to be averages for the entire US. In practice, EQIP and CDFA's HSP Incentives pay a standard rate per acre of compost application, regardless of actual expenses. If NRCS adjusted its payment rate to reflect site-specific conditions and actual project costs on a regional basis, this would reduce the financial burden on ranchers. NRCS could also fund a higher application rate of compost on non-irrigated rangeland of at least six tons per acre to better align with CDFA's HSP. While these programs help offset costs for producers, participation in these cost-share programs also increases the amount of paperwork, planning, coordination with program staff, and time required by livestock producers to implement carbon-beneficial practices. In addition, the CDFA's HSP Incentives requires ranchers to collect soil samples for each contract year, and currently does not allow a one-time compost application to rangelands. While we appreciate that both NRCS and CDFA wish to approach compost on grassland systems cautiously to avoid unintended negative outcomes for native grassland, we do not believe that NRCS' low application reimbursement rate and CDFA's application schedule provide adequate financial incentives to substantially increase practice adoption by livestock operators. Ultimately, we believe that additional field studies are needed to better inform application rates, schedules, and payment programs.

Another important factor in the California compost market is SB 1383, which takes effect January 1, 2022, and sets a target of 75% reduction of organic waste from 2014 levels by 2025.

In addition to requiring organics recycling through composting or anaerobic digestion, the regulations institute a requirement for all cities and counties to procure annually a minimum amount of recovered organic waste products. The procurement target is based on jurisdiction population, and eligible products include compost and mulch. The targets are very high, and many jurisdictions do not have sufficient open space to meet the target in their own communities. Therefore, they may look to partner with farmers and ranchers to subsidize compost and mulch use. This could be an opportunity for on-going cost-sharing to fund compost application in the long term. However, by setting the procurement target higher than most jurisdictions can meet, the regulations create an incentive for jurisdictions to look to put as much compost on the ground in the fewest locations and choose the compost with the lowest price. This may lead to pressure to apply compost in higher rates than is appropriate for grassland habitat, or in areas where compost might be contraindicated. While it is not always the case that price directly reflects quality, it could lead to a preference for lower priced and potentially lower quality material that will be eligible for cost share. By increasing the volume of commercial food going to composting, the state could see an increase in glass and plastic contamination. Although the state limits contamination in finished compost to 0.5% total inert contaminants and 0.1% film plastic by weight, it could become harder to find compost that is entirely free of these materials. Poorly developed projects could lead to greater scrutiny from agencies such as the California Department of Fish and Wildlife and the Regional Water Quality Control Boards. Ranchers and land managers will need to familiarize themselves with compost and indicators of quality. We recommend that readers consult with agricultural advisors familiar with compost use in rangelands settings before developing projects. Procurement requirements present a potential funding stream for rangeland projects and stand to increase the amount of carbon sequestered in soils, regardless of costs and other benefits or drawbacks.

Finally, another factor that could enhance compost addition implementation is increased awareness about carbon farming. A 2019 ACRCD survey of ranchers in Alameda County indicated that most had trouble defining carbon farming (see Appendix B). State organizations and local agencies, like resource conservation districts, can help inform ranchers about carbon farming, as well as financial incentive programs that can help offset implementation costs. CDFA's Healthy Soils Technical Assistance Program, which provides funding to organizations that support farmers and ranchers pursuing HSP funding, is likely to help address this knowledge gap.

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Appendix A: *Compost Specification- ACWMA – Altamont Property Carbon Farming Implementation*

SUBMITTALS

A. Submit the following to Owner for all compost:
   1. Product Data: Cut sheet verifying feedstock and producer
   2. Samples for Verification: One-gallon minimum sample in a sealed plastic bag. Label with weight and source.
   3. Lab Analysis Reports: Past six compost technical data sheets, including laboratory report and test data summary page.
   4. Tags/Receipts: Delivery tags/receipts to Owner at the completion of construction prior to project acceptance.

1.2 COMPOST

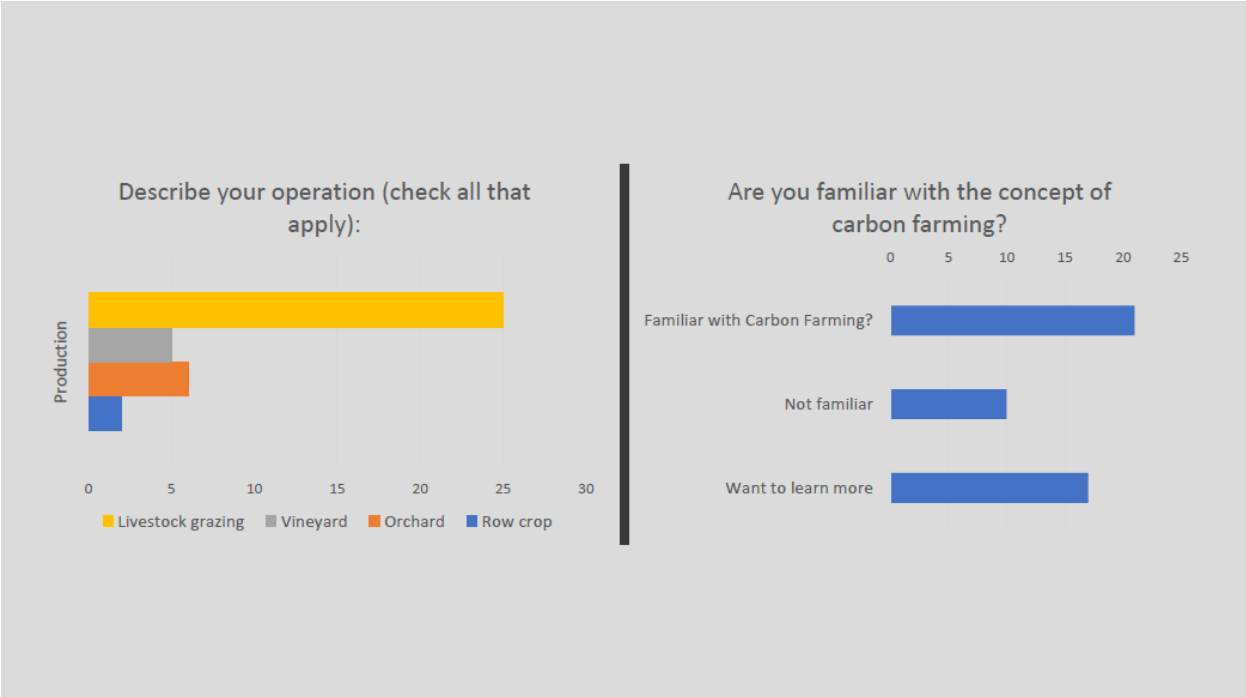
A. Only compost used in this project meeting the following criteria shall be used on this project:
   1. Mature, well decomposed, stable and weed free.
   2. Made from the following acceptable feedstocks: green material, vegetative food material, and/or agricultural materials
   3. Contain no substances toxic to plants.
   4. Acceptable color: dark brown to black.
   5. Acceptable odors: Soil-like, forest-like, moldy.
   6. Unacceptable odors: ammonia, rot, garbage, sourness.
   7. Not resemble the feedstock (original materials from which it was derived).
   8. Be listed by CDFA as an Organic Input Material (OIM) and/or be approved by OMRI.
   9. Be produced by a permitted facility and participant of the US Composting Council's STA Program.
   10. Be generated from feedstock/materials sourced within 100 miles or produced at a facility within 100 miles of the project site.
   11. Preference shall be given to compost produced by facilities implementing a contamination minimization plan on incoming feedstock.
   12. Acceptable suppliers include: West Marin Compost, Z-Best, Vision Recycling, or other, as approved by Owner.

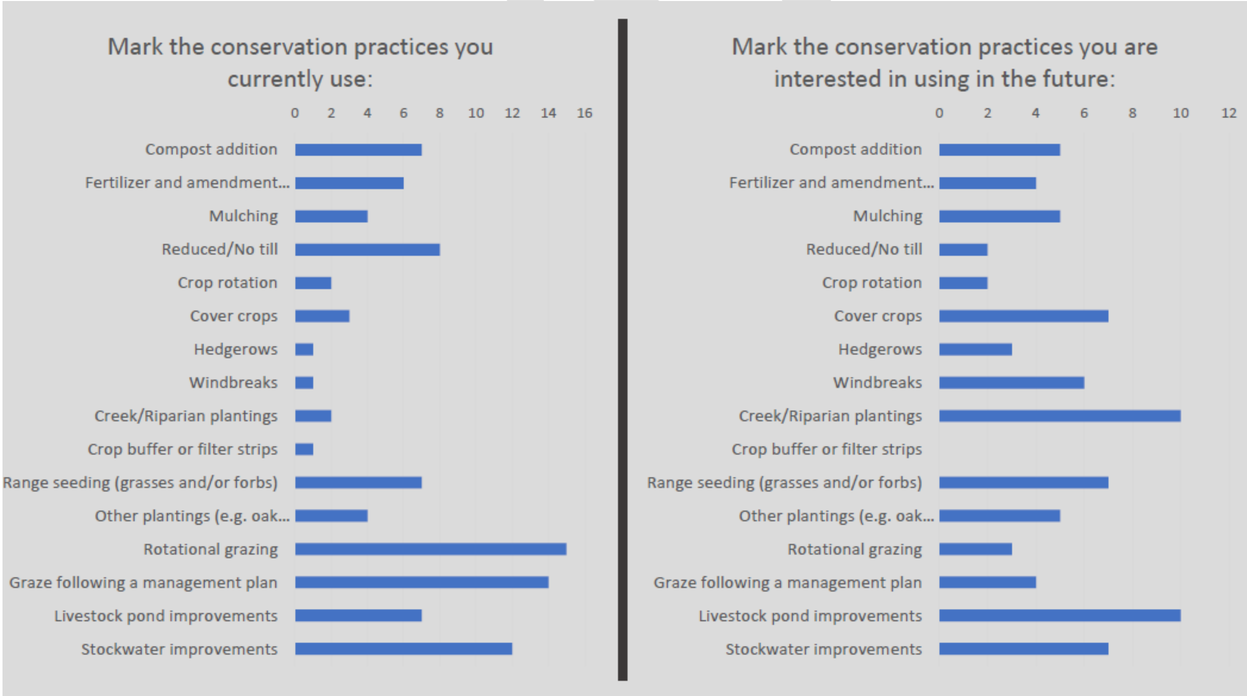
B. The compost laboratory report shall confirm the following compost parameters:

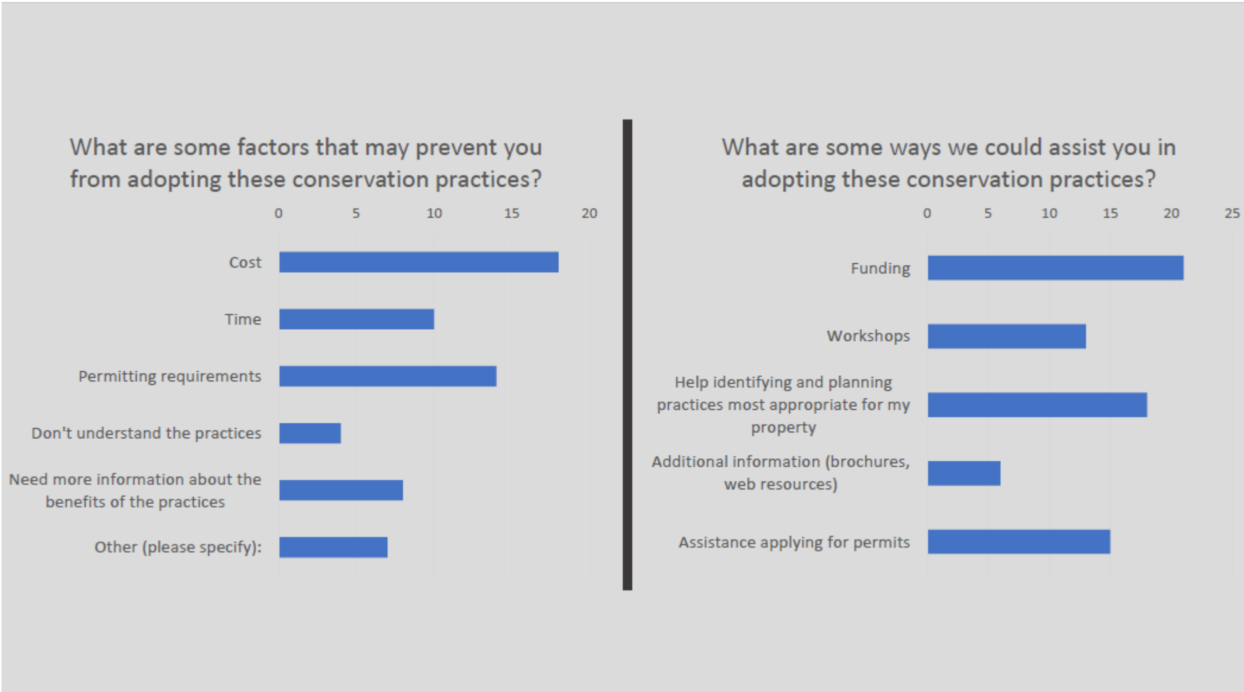
Note: TMECC refers to "Test Methods for the Examination of Composting and Compost," published by the United States Department of Agriculture and the United States Compost Council (USCC). (Table modified from the US Composting Council Landscape Architectural Specifications 2009.)

Property	Test Method	Unit of Measurement	Requirement
pH	TMECC 04.11-A Elastomeric pH 1:5 slurry method pH	units	6–8.5
Soluble salts	TMECC 04.10-A Electrical conductivity 1:5 slurry method	dS/m (mmhos/cm)	0– 5
Moisture content	TMECC 03.09-A Total solids & moisture at 70 ± 5 °C	% wet weight basis	30–60
Organic matter Content	TMECC 05.07-A Loss-on-ignition organic matter method (LOI)	% dry weight basis	30–70
Maturity	TMECC 05.05-A Germination and vigor	% relative to positive control	Seed emergence 80 or above Seedling vigor 80 or above
Stability	TMECC 05.08-B Carbon dioxide evolution rate	mg CO_2-C/g OM per day	4 or below
Pathogen	TMECC 07.01-B Salmonella < 3 MPN per 4 grams, dry weight basis	Pass/ Fail	Pass
Pathogen	TMECC 07.01-B Fecal coliform bacteria < 1,000 MPN per gram, dry weight basis	Pass/ Fail	Pass
Physical contaminants	TMECC 02.02-C Man-made inert removal and classification: Plastic, glass, and metal % > 2 mm fraction	% dry weight basis	combined total: < 0.5%
Physical contaminants	TMECC 02.02-C Man-made inert removal and classification: Sharps (sewing needles, straight pins and hypodermic needles) % 4 mm fraction	% dry weight basis	none detected
Particle size	TMECC 02.02-B Sample sieving for aggregate Size classification	% dry weight basis	Pass 2”-inch sieve 98% min Pass 1/4-inch sieve 90% min
Arsenic		mg/kg (ppm)	EPA 503 pass < 10 OMRI
Cadmium		mg/kg (ppm)	EPA 503 pass < 20 OMRI
Chromium		mg/kg (ppm)	EPA 503 pass < 100
Copper		mg/kg (ppm)	EPA 503 pass <400
Lead		mg/kg (ppm)	EPA 503 pass < 90 OMRI
Mercury		mg/kg (ppm)	EPA 503 pass <4
Nickel		mg/kg (ppm)	EPA 503 pass <80
Selenium		mg/kg (ppm)	EPA 503 pass <5
Zinc		mg/kg (ppm)	EPA 503 pass <2800
Ammonium (N or NH4-N)		ppm or mg/kg dry weight	<450
Sodium (Na)		% dry weight	<0.5
Carbon:Nitrogen Ratio		Carbon : Nitrogen	≤20:1
Bulk Density		lbs/CY dry weight lbs/CF dry weight	>19 and <41 >500 and <1100

Appendix B*: Survey of Alameda County Ranchers Concerning Compost Addition on Rangelands*






What are some factors that may prevent you from adopting these conservation practices?
0
5
10
15
20
Cost
Time
Permitting requirements
Don't understand the practices
Need more information about the benefits of the practices
Other (please specify):
What are some ways we could assist you in adopting these conservation practices?
0
5
10
15
20
25
Funding
Workshops
Help identifying and planning practices most appropriate for my property
Additional information (brochures, web resources)
Assistance applying for permits