CARBON FARM PLANNING
WHY CARBON FARM PLANNING?

- Carbon can be beneficially stored long-term in soils and vegetation: “terrestrial carbon sequestration”

- Agriculture can transform itself from a net GHG source, to a net sink, becoming a key element in climate change reversal.

- Increasing global soil OM by 0.4% annually would offset *all* global CO2 emissions each year (4‰ Initiative: Ministry of Agriculture, Agrifood and Forestry, France)
WHAT IS CARBON FARM PLANNING?

CONSERVATION PLANNING through a carbon lens:

- *Increase terrestrial carbon*
- *Reduce GHG emissions*
- *Quantify carbon (and water and other co-benefits) of GHG-reducing conservation practices*
CREATING A CARBON FARM PLAN

1. Whole-Farm Assessment
2. Identify Carbon Capture Opportunities
3. Identify Conservation Practice Options
4. Prioritize Options into a Working Plan
Farms/ Ranches have unique GHG emissions and sequestration opportunities.

A Carbon Farm Plan can evaluate both but typically focuses on Terrestrial Carbon Sequestration.

- Soils & Vegetation
Farm Assessment through a Carbon Lens
Understand the Producer’s:
- Objectives
- Operations
- Interest in Carbon Farming
- Resource Concerns
- Other?
Site analysis
Identify potential to
- increase Vegetation C?
- increase Soil C
- Maps: Google Earth, GIS, Soil Survey, other plans
- NRCS COMET-Planner – 34 climate beneficial practices (and growing...)
Prioritize options into a working Plan

- Grower’s priorities
- Crop production
- Farm ecology
- Quantitative impacts of practices
- Costs

Goal is Implementation
CREATING A CARBON FARM PLAN

- **General Factors**
  - Resource Concerns
  - Vegetation Types
  - Species of Special Concern
    - Vegetation, Wildlife, Invasive Species
  - Ecological Sites
    - Slope
    - Aspect
    - Soil
    - Elevation

- **Site Specific Factors**
  - Erosion/ Sedimentation
  - Oak Woodland Recruitment
  - Salmonid Habitat
  - Weeds
  - Access
    - Slope < 30% (Compost Application)
  - Soil Carbon/Organic Matter
  - Wind
  - Waste management
  - Water quality
  - Etc.
34 Climate Beneficial Practices, COMET-Planner

**2015**

**Cropland Management**
- Conventional Tillage to No-Till
- Conventional Tillage to Reduced Till
- Improved Nutrient Management
- Conservation Crop Rotation
- Cover Crops
- Strip cropping
- Mulching

**Combustion System Improvement (Improved Fuel Efficiency of Farm Equipment)**

**Cropland to Herbaceous Cover**
- Conservation Cover
- Forage and Biomass Planting
- Herbaceous Wind Barriers
- Vegetative Barriers
- Riparian Herbaceous Cover
- Contour Buffer Strips
- Field Border
- Filter Strip
- Grassed Waterway

**Cropland to Woody Cover**
- Tree/Shrub Establishment
- Windbreak/Shelterbelt Establishment
- Windbreak/Shelterbelt Renovation
- Riparian Forest Buffer Establishment
- Hedgerow Planting
- Alley Cropping
- Multistory Cropping

**Grazing Lands**
- Range Planting
- Silvopasture Establishment on Grazed Grasslands
- Restoring Degraded Rangeland with Compost Addition
- Prescribed Grazing

**Restoration of Disturbed Lands**
- Land Reclamation – Abandoned Mine Land
- Land Reclamation – Currently Mined Land
- Land Reclamation – Landslide Treatment
- Critical Area Planting
- Riparian Restoration
SITE VISITS: LIMITATIONS

- How to decide where carbon practices can and cannot be applied?

1. Ecological Sites

2. Management Limitations

3. NRCS Practice Standards
New Interagency Definition

An Ecological Site (ES) is a conceptual division of the landscape that is defined as a distinctive kind of land based on recurring soil, landform, geological, and climate characteristics that differs from other kinds of land in its ability to produce distinctive kinds and amounts of vegetation and in its ability to respond similarly to management actions and natural disturbances.
MANAGEMENT LIMITATIONS

- Land Use
- Producer’s Perception
- Ecological Site
Should we be sampling our soils? Depending upon the level of detail needed.

Yes:
To track change over time
To verify or inform a model
To establish a C-baseline
For Nutrient Management

What do you test for?
Depends on your purpose.
1. Bulk Density
2. Soil Organic Matter/ TOC
3. Nutrients

NRCS Web Soil Survey
4. MONITORING SOIL CARBON

**Background:** Use this table to monitor and track soil health over time.

<table>
<thead>
<tr>
<th>Date</th>
<th>Sample Location (show on map if possible)</th>
<th>Bulk Density</th>
<th>Total Organic Carbon</th>
<th>Active Carbon</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>gm/cm³</td>
<td>%</td>
<td>Tons per acre</td>
<td>%</td>
</tr>
</tbody>
</table>

This protocol measures soil organic carbon from a representative soil and land use. It uses composite samples from a grid to establish the baseline, and then monitors changes following new management. It may monitor carbon sequestration by total organic carbon, soil health by active organic carbon, or may inform a model with additional sampling. It includes a form to make a record of a sampling event.
CARBON FARM PLANNING
EXAMPLE: STRAUS BLAKES LANDING

PROCESS: Web Soil Survey

Area of Interest (AOI)

- Create AOI
  - From Shapefile (.shp, .shx and .prj)
- Navigate and Draw

http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm
WEB SOIL SURVEY MAP
SOIL ORGANIC MATTER
(SOM/2 = SOC * 3.67 = CO2e)

- **Producers Soil Sample**
  - Upper Field = 6%

- **Soil Web Soil Survey**
  - Upper Field = < 2%

- **MCP Soil Sample**
  - TBD
ABOVE GROUND BIOMASS

- Web Soil Survey:
  Estimating Forage Production (Normal Year)
CARBON FARM PLANNING

Potential Practices (COMET-Planner)

- Compost Application
- Critical Area Planting
- Riparian Restoration
- Rangeland/Grazing Management
- Windbreaks/Hedgerows
- +Nitrous Oxide Reduction (Waste Water Irrigation)
- +Anaerobic digester
Local Data if available; e.g., compost & creek carbon data

LOCAL DATA; other sources
CREEK CARBON: D.Lewis et al 2015
### CARBON FARMING RESULTS

<table>
<thead>
<tr>
<th>Practice</th>
<th>Average Annual CO2e Reduction</th>
<th>20 yr CO2e Reduction</th>
<th>CO2e Reduction at Maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anacrobic Digester (366)</td>
<td>1.645 Mg</td>
<td>32,900 Mg</td>
<td>32,900 Mg</td>
</tr>
<tr>
<td>Pasture Seeding (512)</td>
<td>44 Mg</td>
<td>880 Mg</td>
<td>880 Mg</td>
</tr>
<tr>
<td>Windbreaks (380)</td>
<td>10.65 Mg</td>
<td>213 Mg</td>
<td>511 Mg</td>
</tr>
<tr>
<td>Prescribed Grazing (528)</td>
<td>42 Mg</td>
<td>840 Mg</td>
<td>840 Mg</td>
</tr>
<tr>
<td>Rangeland Compost (484/590)</td>
<td>88 Mg</td>
<td>1760 Mg</td>
<td>1760 Mg</td>
</tr>
<tr>
<td>Riparian Forest Buffer (391)</td>
<td>21.9 Mg</td>
<td>438 Mg</td>
<td>1758 Mg</td>
</tr>
<tr>
<td>Nutrient Management (590)</td>
<td>56.65 Mg</td>
<td>1,133 Mg</td>
<td>2,834 Mg</td>
</tr>
<tr>
<td>Riparian Herbaceous Cover (390)</td>
<td>8 Mg</td>
<td>160 Mg</td>
<td>160 Mg</td>
</tr>
<tr>
<td>Pasture Planting (512)</td>
<td>44 Mg</td>
<td>880 Mg</td>
<td>880 Mg</td>
</tr>
<tr>
<td>Critical Area Planting (342/390)</td>
<td>2.2 Mg</td>
<td>44 Mg</td>
<td>88 Mg</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>1,962.40 Mg</strong></td>
<td><strong>39,248 Mg</strong></td>
<td><strong>42,611 Mg</strong></td>
</tr>
</tbody>
</table>
CARBON FARM PLANNING EXAMPLE: CACHUMA RANCH
**CONSERVATION PRACTICE: COMPOST APPLICATION**

**ESTIMATED TOTAL = 4300 ACRES**

<table>
<thead>
<tr>
<th>Year</th>
<th>Cumulative Acres 1/4&quot; Rate</th>
<th>Metric Tons CO2e 1/4&quot; Rate</th>
<th>Cumulative Acres 1/2&quot; Rate</th>
<th>Metric Tons CO2e 1/2&quot; Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>428</td>
<td>637.72</td>
<td>214</td>
<td>318.86</td>
</tr>
<tr>
<td>2</td>
<td>856</td>
<td>1275.44</td>
<td>428</td>
<td>637.72</td>
</tr>
<tr>
<td>3</td>
<td>1284</td>
<td>1913.16</td>
<td>642</td>
<td>956.58</td>
</tr>
<tr>
<td>4</td>
<td>1712</td>
<td>2550.88</td>
<td>856</td>
<td>1275.44</td>
</tr>
<tr>
<td>5</td>
<td>2140</td>
<td>3188.6</td>
<td>1070</td>
<td>1594.3</td>
</tr>
<tr>
<td>6</td>
<td>2568</td>
<td>3826.32</td>
<td>1284</td>
<td>1913.16</td>
</tr>
<tr>
<td>7</td>
<td>2996</td>
<td>4464.04</td>
<td>1498</td>
<td>2232.02</td>
</tr>
<tr>
<td>8</td>
<td>3424</td>
<td>5101.76</td>
<td>1712</td>
<td>2550.88</td>
</tr>
<tr>
<td>9</td>
<td>3852</td>
<td>5739.48</td>
<td>1926</td>
<td>2869.74</td>
</tr>
<tr>
<td>10</td>
<td>4280</td>
<td>6377.2</td>
<td>2140</td>
<td>3188.6</td>
</tr>
<tr>
<td>10 Yr Total</td>
<td>35074.6</td>
<td>17537.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>4280</td>
<td>41451.8</td>
<td>2354</td>
<td>3507.46</td>
</tr>
<tr>
<td>12</td>
<td>4280</td>
<td>47829</td>
<td>2568</td>
<td>3826.32</td>
</tr>
<tr>
<td>13</td>
<td>4280</td>
<td>54206.2</td>
<td>2782</td>
<td>4145.18</td>
</tr>
<tr>
<td>14</td>
<td>4280</td>
<td>60583.4</td>
<td>2996</td>
<td>4464.04</td>
</tr>
<tr>
<td>15</td>
<td>4280</td>
<td>66960.6</td>
<td>3210</td>
<td>4782.9</td>
</tr>
<tr>
<td>16</td>
<td>4280</td>
<td>73337.8</td>
<td>3424</td>
<td>5101.76</td>
</tr>
<tr>
<td>17</td>
<td>4280</td>
<td>79715</td>
<td>3638</td>
<td>5420.62</td>
</tr>
<tr>
<td>18</td>
<td>4280</td>
<td>86092.2</td>
<td>3852</td>
<td>5739.48</td>
</tr>
<tr>
<td>19</td>
<td>4280</td>
<td>92469.4</td>
<td>4066</td>
<td>6058.34</td>
</tr>
<tr>
<td>20</td>
<td>4280</td>
<td>98846.6</td>
<td>4280</td>
<td>6377.2</td>
</tr>
<tr>
<td>20 Yr Total</td>
<td>98846.6</td>
<td>84497.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 Yr Total</td>
<td>162618.6</td>
<td>148269.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Predicted Cumulative CO2e Sequestration From a single Compost Application on 4,300 acres of Grazed Grassland, Cachuma Ranch
<table>
<thead>
<tr>
<th>Riparian System</th>
<th>Stream Length</th>
<th>Acres</th>
<th>Mg CO2e/Comet Planner-Riparian Restoration only (1 Mg/acre/yr)</th>
<th>Mg CO2e/Comet Planner-Combined Riparian Forest, Herbaceous, Critical Area Planting and Riparian Restoration (4.36 Mg/acre/yr)</th>
<th>Riparian Restoration, Mg CO2e (18.36 Mg/acre/yr, Lewis et al 2015)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>annual</td>
<td>15 years</td>
<td>45 years</td>
</tr>
<tr>
<td>Sycamore</td>
<td>1 mile</td>
<td>12</td>
<td>12</td>
<td>180</td>
<td>540</td>
</tr>
<tr>
<td>Zaca</td>
<td>1.5 mile</td>
<td>18</td>
<td>18</td>
<td>270</td>
<td>810</td>
</tr>
<tr>
<td>Alamo Pintado</td>
<td>3.5 miles</td>
<td>42</td>
<td>42</td>
<td>630</td>
<td>1890</td>
</tr>
<tr>
<td>San Antonio</td>
<td>1.75 miles</td>
<td>21</td>
<td>21</td>
<td>315</td>
<td>945</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>94</td>
<td>93</td>
<td>1,395</td>
<td>4,185</td>
</tr>
</tbody>
</table>
Carbon Sequestration (Mg CO2e) Potential of Cachuma Ranch *Cropland* Soils at 5% SOM

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Acres</th>
<th>Baseline SOM% (NRCS)</th>
<th>Additional CO2e Sequestered at 5% SOM Plow layer only</th>
</tr>
</thead>
<tbody>
<tr>
<td>BbC</td>
<td>34</td>
<td>0.82</td>
<td>2608</td>
</tr>
<tr>
<td>EmC</td>
<td>56</td>
<td>1.03</td>
<td>4080</td>
</tr>
<tr>
<td>SaA</td>
<td>149</td>
<td>1.14</td>
<td>10554</td>
</tr>
<tr>
<td>SaC</td>
<td>14</td>
<td>1.14</td>
<td>992</td>
</tr>
<tr>
<td>SdA</td>
<td>277</td>
<td>1.16</td>
<td>19519</td>
</tr>
<tr>
<td>SdC</td>
<td>62</td>
<td>1.30</td>
<td>4209</td>
</tr>
<tr>
<td>SvC</td>
<td>22</td>
<td>1.5</td>
<td>2608</td>
</tr>
<tr>
<td>TOTAL</td>
<td>614</td>
<td></td>
<td>43,374 Mg CO2e</td>
</tr>
</tbody>
</table>

**Assumptions:**

1% SOM = 0.5% SOC = 5 tons C/acre = 18.35 Mg CO2e/acre  
Compost = 33% OM, or 16.5% C;  
1” compost = 70 short tons/acre x 0.165 = 11.55 x 3.67/1.1 = 38.5 Mg CO2/acre.  
Approximately one half of compost C is assumed lost annually under tillage.
Woodlands and Silvopastures

Metric Tons (Mg) CO2e Sequestered in Mixed Oak Woodlands and Forests, Cachuma Ranch, Current Conditions. (Adapted from Gammon 2008)

<table>
<thead>
<tr>
<th></th>
<th>589 acres Mixed Oak Woodlands/Savannas</th>
<th>1,098 acres Mixed Oak Forests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree C Mg/acre</td>
<td>28.75</td>
<td>100.85</td>
</tr>
<tr>
<td>Non-Tree C Mg/acre</td>
<td>29.56</td>
<td>29.56</td>
</tr>
<tr>
<td>Total C Mg/acre</td>
<td>58.32</td>
<td>130.41</td>
</tr>
<tr>
<td>Total CO2e Mg/acre</td>
<td>214</td>
<td>478</td>
</tr>
<tr>
<td>Total Mg CO2e</td>
<td>126,066</td>
<td>525,508</td>
</tr>
</tbody>
</table>

Potential Metric Tons (Mg) CO2e Sequestered in new Mixed Oak Silvopasture, 1,000 acres, at maturity (80 years), Cachuma Ranch, Future Conditions. (Adapted From Gammon 2008)

<table>
<thead>
<tr>
<th>1000 acres Mixed Oak Silvopasture Chamberlin Ranch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree C Mg/acre</td>
</tr>
<tr>
<td>Non-Tree C Mg/acre</td>
</tr>
<tr>
<td>Total C Mg/acre</td>
</tr>
<tr>
<td>Total CO2e Mg/acre</td>
</tr>
<tr>
<td>Total Mg CO2e</td>
</tr>
</tbody>
</table>

LOCAL DATA; other sources

CREEK CARBON: D.Lewis et al 2015

Summary Table: CO2e sequestration potential from implementation of the Cachuma Ranch Carbon Farm Plan

<table>
<thead>
<tr>
<th>Practice</th>
<th>Average Annual CO2e Reduction</th>
<th>20 yr CO2e Reduction</th>
<th>CO2e Reduction at Maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rangeland Compost</td>
<td>638 Mg</td>
<td>98,847 Mg</td>
<td>162,619 Mg (30 years)</td>
</tr>
<tr>
<td>Cropland Compost (590)</td>
<td>2,060 Mg.</td>
<td>23,200 Mg</td>
<td>43,374 Mg at 5% SOM</td>
</tr>
<tr>
<td>Shelterbelts (380)</td>
<td>98 Mg CO2e;</td>
<td>1,960 Mg</td>
<td>7,840-19,260 Mg at 80 years.</td>
</tr>
<tr>
<td>Hedgerows (422)</td>
<td>6 Mg CO2e</td>
<td>120 Mg</td>
<td>120 Mg CO2e</td>
</tr>
<tr>
<td>Prescribed Grazing (528)</td>
<td>1,460 Mg</td>
<td>29,200</td>
<td>29,200</td>
</tr>
<tr>
<td>Riparian Restoration</td>
<td>410 to 1,725 Mg</td>
<td>6,144-25,867 Mg at 15 years</td>
<td>18,431-188,117 Mg at 45 years.</td>
</tr>
<tr>
<td>No Till (329)</td>
<td>39 Mg</td>
<td>780 Mg</td>
<td>780 Mg</td>
</tr>
<tr>
<td>Minimum-Tillage (345)</td>
<td>100 Mg</td>
<td>2,000 Mg</td>
<td>2,000 Mg</td>
</tr>
<tr>
<td>Silvopasture (381)</td>
<td>660 Mg</td>
<td>13,200 Mg</td>
<td>214,000 Mg</td>
</tr>
<tr>
<td>Nutrient Management (590)</td>
<td>610 Mg</td>
<td>12,200 Mg</td>
<td>48,800</td>
</tr>
<tr>
<td>Totals</td>
<td>6,081-7,396 Mg</td>
<td>187,651 - 207,374 Mg</td>
<td>527,164-708,270 Mg</td>
</tr>
</tbody>
</table>

(*14,079 – 17,123 barrels of oil avoided each year)
Estimated Additional Soil Water Holding Capacity With Carbon Farm Plan Implementation, Cachuma Ranch, Santa Barbara County, CA

Table 15. Estimated Additional Soil Water Holding Capacity (WHC) With Plan Implementation

<table>
<thead>
<tr>
<th>PRACTICE</th>
<th>DESCRIPTION</th>
<th>20 YEAR SOM INCREASE (Mg)</th>
<th>ANNUAL WHC INCREASE BY YEAR 20 (AF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compost application on Rangeland (NRCS practice standard in development)</td>
<td>Application of 1/4&quot; of compost to 4300 acres of permanent pasture.</td>
<td>53867 Mg</td>
<td>493.78</td>
</tr>
<tr>
<td>Compost application on Cropland (590)</td>
<td>Application of 1&quot; of compost to 617 acres of cropland.</td>
<td>23637.05 Mg</td>
<td>216.67</td>
</tr>
<tr>
<td>Shelterbelt (380)</td>
<td>13.6 miles (90 acres) of 50' wide shelterbelts</td>
<td>1068.12 Mg</td>
<td>9.79</td>
</tr>
<tr>
<td>Prescribed Grazing (528)</td>
<td>Grazing management to favor perennials and improve production on 7300 acres.</td>
<td>15912.80 Mg</td>
<td>145.86</td>
</tr>
<tr>
<td>Riparian Restoration</td>
<td>Restoration of 94 acres of riparian system along 7.75 miles of stream corridor. Planting of native trees and shrubs.</td>
<td>3043.23 Mg (derived from Lewis et al 2015)</td>
<td>27.89</td>
</tr>
<tr>
<td>No-till system-Tillage Management (512)</td>
<td>Convert tilled forage fields to permanent pasture; minimize tillage on croplands</td>
<td>425.06 Mg</td>
<td>3.89</td>
</tr>
<tr>
<td>Minimum-Tillage (345)</td>
<td>Conversion of tilled crop fields to minimum tillage on</td>
<td>1089.91 Mg</td>
<td>9.99</td>
</tr>
<tr>
<td>Silvopasture (381)</td>
<td>Establish trees on approximately 1,000 acres of treeless pasture.</td>
<td>4027.24 Mg (derived from Gaman 2008)</td>
<td>36.91</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>917.52</td>
<td></td>
</tr>
</tbody>
</table>

1 Lewis et al 2015 model coefficients indicate annual increases of soil carbon = 0.2 kg/m². 1 acre = 4046.85642 m².
Carbon Farm Planning Example: Huichica Creek
Napa RCD Demonstration Vineyard
Charles Schembre Vineyard Conservation Coordinator
Vineyard Carbon Farm Plan Template

• Site Description
• Assessment of Potential Carbon Beneficial Practices
  – WATER-RELATED ENERGY
  – VINEYARD VEHICLES
  – VINEYARD FARMING PRACTICES
  – VINEYARD MANAGEMENT
  – VEGETATION IN AND AROUND THE VINEYARD
• Monitoring Soil Carbon
• Carbon Farm Plan Summary & Map
1. Farm Assessment

- Producer’s objectives
- Producer’s operations
- Producer’s interest
- Producer’s landscape
Huchica Creek Vineyard
Carbon Farming Practices

CPS 329 Conventional Tillage to No Tillage

CPS 391 Riparian Buffer

CPS 380/657 Wetland Restoration Wind Break
Huchica Creek Vineyard
Carbon Farming Practices

CPS 379 Multistory Cropping/ Diversifying

CPS 340 Cover Crop Establishment

CPS 590 Nutrient Management / Compost

CPS 422 Hedgerow Planting
Huichica Creek Vineyard
Carbon Farming Practices

• Fuel and Energy Usage

• Graze Livestock for weed management and soil fertility

• More Multistory cropping and Diversification

• Compost and Biochar applications to promote carbon sequestration and soil fertility.
Practice map: planned and implemented practices

Legend and Current Practices
- Blocks A-E: Alternate Row Till
- Block G - No Till
- Replant Block F - No Till
- Apple Cider Orchard
- 5 Foot Contour
- Huichica Creek
- Deer Fence
- Existing Hedgrow

Planned Conservation Practices
- Compost Application in all vineyard blocks
- Riparian & Wetland Restoration
- Future Hedgerow
- Multistory Cropping
- Conventional Tillage to No-Till

Carbon Farm Practices (NRCS Practice)
1. Compost Application Mulching (484)
2. Conventional Tillage to No Till (329)
3. Hedgerow Planting (422)
4. Nutrient Management (590)
5. Riparian Forest Buffer (391)
<table>
<thead>
<tr>
<th>NRCS CPS</th>
<th>Practice Description</th>
<th>Field Location</th>
<th>Acres</th>
<th>Current Practice</th>
<th>Proposed Practice</th>
<th>Implementation Date</th>
<th>CO2e per acre per year</th>
<th>CO2e Annual Total</th>
<th>CO2e 20yr Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>329</td>
<td>Conventional Tillage to No Tillage</td>
<td>Blocks A,B,C,D,E</td>
<td>4</td>
<td>Alternate row tillage. Alternate no till &amp; alternate till</td>
<td>Full no tillage. Very minimal tillage may be incorporated from time to time for breaking up tractor compaction and for soil amendments</td>
<td>2017-2010</td>
<td>0.74</td>
<td>2.96</td>
<td>59.20</td>
</tr>
<tr>
<td>391</td>
<td>Riparian Forest Buffer Establishment</td>
<td>Huichica Creek top of banks</td>
<td>2.76</td>
<td>Restoration plantings and volunteers have re-vegetated the creek</td>
<td>Restore areas that with native plantings where noxious weeds have populated or where there open areas.</td>
<td>2016-2025</td>
<td>16.34</td>
<td>45.10</td>
<td>901.97</td>
</tr>
<tr>
<td>379</td>
<td>Multi-story Cropping</td>
<td>Block F - Apple Orchard</td>
<td>0.75</td>
<td>Vineyard</td>
<td>Plant cider apples on standard rootstock. Establish a diverse grassland understory.</td>
<td>2016</td>
<td>1.63</td>
<td>1.22</td>
<td>24.45</td>
</tr>
<tr>
<td>422</td>
<td>Hedgerow Plant</td>
<td>Along access road and Block F</td>
<td>0.15</td>
<td>grasses</td>
<td>Plant native flowering shrubs</td>
<td>2017-2018</td>
<td>1.32</td>
<td>0.20</td>
<td>3.96</td>
</tr>
<tr>
<td>590</td>
<td>Nutrient Management/Compost Application</td>
<td>All blocks</td>
<td>14</td>
<td>No compost application</td>
<td>Apply 10-15 tons compost per acre, every 2-3 years.</td>
<td>2015-Lifetime of vineyard</td>
<td>0.44</td>
<td>6.16</td>
<td>123.20</td>
</tr>
<tr>
<td>340</td>
<td>Cover Crop establishment</td>
<td>Blocks A,B,C,D,E</td>
<td>4</td>
<td>Alternate row tillage. Alternate no till &amp; alternate till</td>
<td>Maintain annual and/or perennial soil cover. Very minimal tillage may be incorporated from time to time for breaking up tractor compaction and for soil amendments</td>
<td>2017-2018</td>
<td>0.37</td>
<td>1.48</td>
<td>29.60</td>
</tr>
<tr>
<td>380</td>
<td>Windbreak/Shelterbelt Establishment</td>
<td>Block A</td>
<td>0.5</td>
<td>No windbreak/shelterbelt</td>
<td>Replace one row vines in replant. Establish shelterbelt at windward fenceline</td>
<td>2018-2020</td>
<td>2.09</td>
<td>1.05</td>
<td>20.90</td>
</tr>
</tbody>
</table>

Monitor and Evaluate fuel and electricity usage
Entire Vineyard Operation
Planning

TOTAL 66.52 1330.48
<table>
<thead>
<tr>
<th>Conservation Practice</th>
<th>NRCS Practice Title</th>
<th>Current Practice</th>
<th>Planned Implementation Date</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Conduct soil analysis for organic matter</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Reduce tillage (permanent perennial or no-till annual cover crop is ideal for reducing GHG emissions and improving soil health and carbon sequestration).</td>
<td>Residue and Tillage Management (329, 345), Conservation Cover (327), Cover Crop (340)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Incorporate grazing animals into vineyard management to reduce equipment needs, increase nutrient cycling and enhance cover crop performance.</td>
<td>Prescribed Grazing (528)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Utilize organic contact herbicide, hand hoe, mow or graze to control vegetation under the vines.</td>
<td>Integrated Pest Management (595)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Apply ≥ 4 inches of mulch under vine rows to suppress weed growth, conserve water and increase soil organic matter.</td>
<td>Mulching (484)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Apply ½” – 1” of compost in alleys and 1”-2” in vine rows to increase soil organic matter, conserve water and improve soil</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NRCS/CPS</td>
<td>Practice Description</td>
<td>Field Location</td>
<td>Acres</td>
<td>Current Practice</td>
</tr>
<tr>
<td>---------</td>
<td>-------------------------------------------</td>
<td>----------------</td>
<td>-------</td>
<td>----------------------------------------------------------------</td>
</tr>
<tr>
<td>329</td>
<td><strong>Conventional Tillage to No Tillage</strong></td>
<td>Blocks A,B,C,D,E</td>
<td>4</td>
<td>Alternate row tillage. Alternate no till &amp; alternate till</td>
</tr>
<tr>
<td>391</td>
<td>Riparian Forest Buffer Establishment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>379</td>
<td>Multistory Cropping</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>422</td>
<td>Hedgerow Plant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>590</td>
<td>Nutrient Management/Compost Application</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>340</td>
<td>Cover Crop establishment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>380</td>
<td>Windbreak/Shelterbelt Establishment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>657</td>
<td>Wetland Restoration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Monitor and Evaluate fuel and electricity usage</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL =**
Relative Impact of Practices

- Conventional Tillage to No Tillage: 68%
- Riparian Forest Buffer Establishment: 13%
- Multistory Cropping: 9%
- Hedgerow Plant: 4%
- Nutrient Management/Compost Application: 2%
- Cover Crop establishment: 2%
- Windbreak /Shelterbelt Establishment: 2%
- Wetland Restoration: 0%
Lesson Learned: Vineyard Carbon-Soil-Water-Climate Connection

IF
CA’s vineyards (~ 500,000 acres) increase SOC by 1% (1% to 2%) in the plow layer

THEN
• Water holding capacity increases by ~41,667 acre feet
• CO2e sequestered > 16 million metric tons (MMT).

WHICH MEANS
• 25% reduction in CA’s annual vineyard water use (1.7 million AF)
• 38% of the CA’s annual Commercial/Residential energy emissions offset (~ 42 MMT CO2e) O r all of CA’s annual livestock emissions

ASSUMPTIONS
• Based on plow layer (top 6.7”) only; including deeper soil strata increases potential
• 1% increase in SOM results in 1 acre-inch increase in soil water holding capacity per acre;
• 1% increase in SOC represents 2% increase in SOM;
• 1 metric ton (2,200 lbs) of soil C represents 3.67 metric tons of CO2e;
• 1% increase in (plow layer only) SOC is about 10 short tons or 9 metric tons SOC/acre.
CARBON FARM PLAN EXAMPLE: TK RANCH, PESCADERO

TK Ranch Resource Concerns:

- Erosion/ Sedimentation
- Coastal Scrub Protection/ Encroachment
- Oak Woodland Recruitment
- Bird Habitat
- Salmonid Habitat
- Weeds
- Slope ≥ 30% (Compost)
- Soil C/OM

1800 acres
EXAMPLE CARBON FARM PLAN: TK RANCH, PESCADERO

- Resource Concerns
- Vegetation Types
- Species of Special Concern
  - Vegetation, Wildlife, Invasive Species
- Ecological Sites
  - Slope
  - Aspect
  - Soil

- Potential Practices based on farm scale reconnaissance.
  - Compost Application
  - Critical Area Planting
  - Windbreaks
  - Riparian Restoration
  - Silvopastures
  - Rangeland/Grazing Management
PROCESS: Web Soil Survey

Soil Map, TK Ranch

http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm
Map used to determine accessibility for tractor driven compost equipment.
SLOPE MAP (DEM DATA)
VEGETATION MAP
SOIL ORGANIC MATTER (SOM/2=SOC)  
(WEB SOIL SURVEY)
SOIL CARBON
(POINT SAMPLES 0-10 CM DEPTH, INCLUDES SURFACE OM)
POTENTIAL COMPOST APPLICATION SITES
(BASED ON SLOPE, ACCESS AND BASELINE SOM)
ESTIMATED TKR TOTAL = 635 ACRES
1. Aerial Assessment (Google Earth)

2. Ground Truth

Total Acres: 25.55
TKR Riparian Systems

- Riparian Forest Buffer: 38 acres (COMET-Planner)
- Riparian Restoration: 27 acres (2.3 stream miles) (D.Lewis et al, UCCE 2015)
OTHER POTENTIAL CARBON-BENEFICIAL PRACTICES AT TKR

- Prescribed Grazing: 766 acres
- Windbreak Establishment: 10.78 acres (+)
- Silvopasture: 2.73 acres (+)
### LOCAL DATA

**COMPOST:** R.Ryals et al 2013; M.DeLonge et al 2013  
**CREEK CARBON:** D.Lewis et al 2015
TOTAL CARBON ESTIMATED:
Average Annual CO2e Capture = 1,193.5 MT
20 Year CO2e Capture = 45,063 MT
WHAT'S MISSING?

**WHAT ABOUT:**

**COASTAL SCRUB?**

**WOODLANDS?**

**EUCALYPTUS?**

**FIRE?**

---

**Estimated Annual MT CO2e Sequestration Potential**

- Grasslands: 5%
- Coastal scrub: 14%
- Riparian: 2%
- Oak Woodland: 33%
- Douglas Fir, mixed hardwood: 1%
- Eucalyptus stands: 45%

**Estimated 20 Year MT CO2e Sequestration Potential**

- Compost Application*: 18923
- Prescribed Grazing: 21740
- Windbreak Establishment: 520
- Riparian Forest Buffer: 820
- Silvopasture/Tree Establishment: 220
- Riparian Restoration*: 2800
- Critical Area Planting: 40
Carbon Farm Plan Example: Modoc Ranch
# Estimated CO2e Reduction/Sequestration Potential, Modoc Ranch

<table>
<thead>
<tr>
<th>Practice</th>
<th>Average Annual CO2e Sequestration (Mg)</th>
<th>20 yr CO2e Sequestration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rangeland Compost</td>
<td>167</td>
<td>31,826</td>
</tr>
<tr>
<td>Cropland Compost (590)</td>
<td>1,097</td>
<td>21,938</td>
</tr>
<tr>
<td>Shelterbelts (380)</td>
<td>20</td>
<td>404</td>
</tr>
<tr>
<td>Riparian Restoration*</td>
<td>368*</td>
<td>7353*</td>
</tr>
<tr>
<td>Prescribed Grazing (528)</td>
<td>790</td>
<td>15,800</td>
</tr>
<tr>
<td>Range Planting (550)</td>
<td>720</td>
<td>14,400</td>
</tr>
<tr>
<td>Minimum-Tillage (345)</td>
<td>104</td>
<td>2,080</td>
</tr>
<tr>
<td>Silvopasture (381)</td>
<td>94</td>
<td>1,880</td>
</tr>
<tr>
<td>Irrigation System (443)</td>
<td>780</td>
<td>15,600</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>4,140</strong></td>
<td><strong>111,581</strong></td>
</tr>
</tbody>
</table>
Estimated Additional Annual Soil Water Holding Capacity
Modoc Ranch With Carbon Farm Plan Implementation, Year 20

<table>
<thead>
<tr>
<th>PRACTICE</th>
<th>DESCRIPTION</th>
<th>20 YEAR SOM INCREASE (Mg)</th>
<th>ANNUAL WHC INCREASE BY YEAR 20 (AF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compost application on Rangeland (NRCS practice standard in development)</td>
<td>Application of 1/4” of compost to 1600 acres of permanent pasture.</td>
<td>17344.09</td>
<td>158.99</td>
</tr>
<tr>
<td>Compost application on Cropland (590)</td>
<td>Application of compost to 537 acres of cropland to 5% SOM</td>
<td>11,955.00</td>
<td>109.59</td>
</tr>
<tr>
<td>Shelterbelts (380)</td>
<td>6.78 miles (16.44 acres) of 20' wide shelterbelts</td>
<td>98.35*</td>
<td>0.90*</td>
</tr>
<tr>
<td>Prescribed Grazing (528)</td>
<td>Grazing management to favor perennials and improve production on 4411 acres</td>
<td>8,610</td>
<td>78.93</td>
</tr>
<tr>
<td>Riparian Restoration</td>
<td>32.36 acres of riparian system along 4.45 miles</td>
<td>1,048.00*</td>
<td>9.60</td>
</tr>
<tr>
<td>Minimum-Tillage (345)</td>
<td>Conversion of tilled crop fields to minimum tillage on</td>
<td>1,134</td>
<td>10.39</td>
</tr>
<tr>
<td>Silvopasture (381)</td>
<td>Establish trees on approximately 134 acres of pasture</td>
<td>270**</td>
<td>2.35</td>
</tr>
<tr>
<td>Conversion of flood irrigation to pipe irrigation (443)</td>
<td>Conversion of flood to pipe irrigation on 1,000 acres permanent pasture</td>
<td>8,501.00</td>
<td>77.93</td>
</tr>
<tr>
<td>Range Planting (550)</td>
<td>No-till interseeding of forage species in irrigated pasture within the Saline Bottom ecological site (2,107 acres)</td>
<td>7,847.00</td>
<td>71.93</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>64,274.44</td>
<td>521.63</td>
</tr>
</tbody>
</table>
Using published (Wiedemann et al 2015) farm GHG emission values for wool production, implementation of the Modoc Ranch Carbon Plan would offset 6 to 9.5 times the GHG emissions associated with its wool production each year.

This provides a robust framework for production of Climate-Beneficial™ wool.
CO-BENEFITS

Benefits of a Carbon Farm Plan, in addition to GHG reductions

- Soil Water Holding Capacity
- Soil Quality and Fertility
- Increased Productivity
- Improved Water Quality
- Habitat and Species Diversity.
- Climate Change Resilience
SUMMARY: KEY ELEMENTS OF A CARBON FARM PLAN

- Identifies Resource Concerns - through a Carbon Lens!
- Reflects producer priorities
- Provides recommendations for practices
- Provides implementation strategies
- Quantifies GHG benefits
- Identifies Co-benefits
- Is evolving and dynamic
By March 2017:

- Vineyard Carbon Farm Plan Template (complete - Napa RCD)
- Rangeland Template (complete - Sonoma RCD)
- Orchard Template (in progress - Goldridge RCD)
- Forestry Template (in progress - Mendocino RCD)
Thank You
www.carboncycle.org
MarinCarbonProject.org
California Cropland Soil Carbon Sequestration Potential With Compost Additions (Compost C Only)

3.96 million hectares (9.8 million acres) of cropland in California: virtually all is suitable for compost application.

At a rate of 3 tons Compost ac\(^{-1}\)y\(^{-1}\) = 27 MMT (Tg) of CO\(_2\)e/y\(^{-1}\)

At a rate of 6 tons Compost ac\(^{-1}\)y\(^{-1}\) = 54 MMT (Tg) of CO\(_2\)e/y\(^{-1}\)

At a rate of 20 tons Compost ac\(^{-1}\)y\(^{-1}\) = 180 MMT (Tg) of CO\(_2\)e/y\(^{-1}\) (and over 27,000 gallons per acre of increased water holding capacity)

Does not include avoided CH4 or N2O, or increased photosynthetic capture of CO2.

- Livestock
  \sim 15\ MMT\ CO_2e\ y^{-1}

- Commercial/residential
  \sim 42\ MMT\ CO_2e\ y^{-1}

- Electrical generation
  \sim 112\ MMT\ CO_2e\ y^{-1}

Assumptions: 1 Mg compost = 0.5 Mg OM = 0.25 Mg OC
**STARTING POINT**

1. Know your producer’s **objectives**.
2. Understand your producer’s **operations**.
3. Understand your producer’s **interest** in Carbon Farming.

**TK Conservation Plan**

1. **Objectives:**
   - Increase Perennials
   - Reduce Bare Ground
   - Save Coastal Scrub, Grassland and Oak Woodland
   - Address Erosion
   - Improve Salmonid Habitat
2. **Operations:**
   - Beef & Chicken Production
3. **Interests:**
   - Ecological Restoration
   - Education
1. Farm Assessment: Through a Carbon Lens

- Producer’s objectives
- Producer’s operations
- Producer’s interest
- Resource Concerns
  - Producers’s
  - Other
CREATING A CARBON FARM PLAN

- Explore the Ranch with a **Carbon Lens**!
  - Tools
    - Ranch Maps ✓
    - Google Earth ✓
    - Web Soil Survey ✓
    - Ground Truth
    - GIS
    - Comet-Planner

- Potential for:
  - Soil C Increase?
  - Vegetation C Increase?
CARBON FARM PLANNING

- WHY?
  - Because CARBON can be beneficially store long-term (decades to centuries or more) in soils and vegetation through biological carbon sequestration.

- HOW?
  - Implementing on-farm practices that:
    - Decrease the production of greenhouse gases on farm
    - Increase the rate at which the farm supports photosynthetically-driven transfer of carbon dioxide (CO2) from the atmosphere to:
      - plant productivity and/or
      - soil organic matter
CREATING A CARBON FARM PLAN

STARTING POINT

Understand the producer’s:
- objectives.
- operations.
- interest in Carbon Farming.
- landscape.
CREATING A CARBON FARM PLAN

- Explore the Ranch with a Carbon Lens!
  - Tools:
    - Ranch Maps
    - Google Earth
    - Web Soil Survey
    - Ground Truth
    - GIS
    - COMET-Planner
    - Baseline Soil Sampling

- Identify potentials for Soil C increases?
- Identify potentials for Vegetation C increases?
C16. Tillage is minimized or no-tillage is practiced in efforts to promote a healthy soil ecosystem for maximizing soil carbon sequestration potential.

☐ Yes – Describe current practice:

☐ No (Consider practice # 2 in Table C4 below)

Opportunities and farming practices to reduce tillage:

E.g. use alternative equipment, reduce depth, reduce frequency
## TOMKAT POTENTIAL CARBON

### LANDUSE

<table>
<thead>
<tr>
<th>LANDUSE</th>
<th>Total</th>
<th>Unit</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOMKAT Area</td>
<td>1800</td>
<td>acres</td>
<td>100</td>
</tr>
<tr>
<td>Grasslands</td>
<td>776</td>
<td>acres</td>
<td>45</td>
</tr>
<tr>
<td>Coastal scrub</td>
<td>563</td>
<td>acres</td>
<td>33</td>
</tr>
<tr>
<td>Riparian</td>
<td>26</td>
<td>acres</td>
<td>1</td>
</tr>
<tr>
<td>Oak Woodland</td>
<td>78</td>
<td>acres</td>
<td>5</td>
</tr>
<tr>
<td>Douglas Fir, mixed hardwood</td>
<td>242</td>
<td>acres</td>
<td>14</td>
</tr>
<tr>
<td>Eucaluptus stands</td>
<td>38</td>
<td>acres</td>
<td>2</td>
</tr>
</tbody>
</table>

### POTENTIAL CARBON BENEFICIAL PRACTICE

<table>
<thead>
<tr>
<th>PRACTICE</th>
<th>Acreage</th>
<th>GHG Component</th>
<th>Average Annual CO2 e Reduction</th>
<th>20 Year CO2 e Reduction</th>
<th>Reduction at Maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td>RANGELAND SYSTEM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compost Application*</td>
<td>635</td>
<td>CO2</td>
<td>946.15</td>
<td>18923</td>
<td>?</td>
</tr>
<tr>
<td>Prescribed Grazing</td>
<td>776</td>
<td>CO2 140</td>
<td>140</td>
<td>2800</td>
<td>?</td>
</tr>
<tr>
<td>AGROFORESTRY SYSTEMS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Windbreak Establishment</td>
<td>10.78</td>
<td>CO2 11</td>
<td>11</td>
<td>220</td>
<td>?</td>
</tr>
<tr>
<td>Riparian Forest Buffer</td>
<td>38</td>
<td>CO2 38</td>
<td>41</td>
<td>820</td>
<td>?</td>
</tr>
<tr>
<td>Silvopasture/ Tree Establishment</td>
<td>2.73</td>
<td>CO2 2</td>
<td>2</td>
<td>40</td>
<td>?</td>
</tr>
<tr>
<td>RESTORATION OF LAND</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Riparian Restoration*</td>
<td>27</td>
<td>CO2 27</td>
<td>27</td>
<td>21740</td>
<td>?</td>
</tr>
<tr>
<td>Critical Area Planting</td>
<td>25.55</td>
<td>CO2 26</td>
<td>26</td>
<td>520</td>
<td>?</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1515.06</td>
<td></td>
<td>1193.15</td>
<td>45063</td>
<td></td>
</tr>
</tbody>
</table>

### FIRE AVOIDED EMISSIONS


*Compost Application: 1.4 MT CO2e/acre/year
R.Ryals et al 2013

*Riparian Revegetation: 2.3 stream miles over 15 years =
- 1,185 MT CO2e in soil and 16,207 MT CO2e in biomass
D.Lewis et al, UCCE 2015
Each Farm/ Ranch has unique GHG emissions and sequestration opportunities.

A Carbon Farm Plan can evaluate both

Focus on Carbon Sequestration:
- Soils
- Vegetation