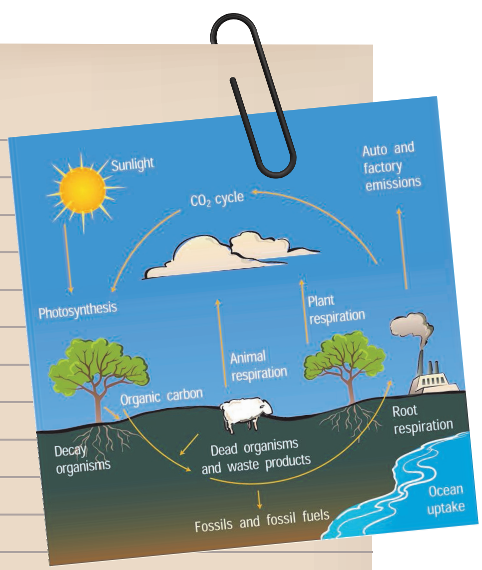
Carbon Storage in Rangelands

RANCHING SUSTAINABILITY ANALYSIS INFO SHEET

Carbon sequestration is the long-term storage of carbon in soils and living plants. Through the process of photosynthesis, plants take in atmospheric carbon dioxide (CO_2) and store the carbon in their living tissue—both above and below the ground. Some of this organic carbon becomes part of the soil as plant parts die and decompose, and some is lost back to the atmosphere as gaseous carbon emissions through plant respiration and decomposition. Herbaceous grassland plants contribute to rangeland carbon stores primarily by the growth and sloughing of roots, a cyclical process in the case of perennial species and especially when grazed. When such a plant is pruned back, as with grazing, a roughly equivalent amount of roots dies off (adding carbon to the soil) because the remaining top-growth can no longer photosynthesize enough food to feed the plant's entire root system. If given adequate rest from grazing, both roots and top-growth recover and the cycle begins again. With good grazing management, perennial plants can live and reproduce for many years with an ongoing cycle of pruning, root-sloughing, and regeneration—adding more and more carbon to the soil indefinitely. Woody plants, particularly trees, sequester relatively more carbon in above-ground growth but also add to the topsoil via downed wood and litter and to much deeper soils via roots. Browsing woody plants helps sequester carbon by encouraging new growth. Carbon from plant matter consumed by grazing animals is redeposited as waste; some carbon is lost back to the air but much is incorporated into the soil by hoof action (poop and stomp) and dung beetles for a net gain. Carbon from sloughed roots generally remains in the soil if left undisturbed, therefore relatively deeper and more extensive root systems can contribute more carbon to the soil on a per-plant basis, although annual range plants also can play a significant role. Mycorrhizal fungi take soluble carbon directly from plant roots and add it to the soil as humus, increasing the amount of gaseous carbon that plants remove from the air during



This diagram shows the carbon cycle. All life is based on the carbon atom. It can exist in a solid, a liquid, or a gas. Carbon constantly moves through all living things, as well as through the oceans, atmosphere, and Earth's crust. Carbon dioxide in the atmosphere plays a vital role in regulating air temperature on Earth.
Source: *Carbon Cycle Illustration (DI01054), copy-right University Corporation for Atmospheric Research.*

photosynthesis. Stable grasslands and forests typically serve as carbon sinks because they store more carbon than they emit, although extended dry periods and continuous excessive grazing can deplete carbon stocks and increase emissions of gaseous carbon. Importantly, ecosystem carbon storage capacity can be restored and enhanced through management.

Photo by Christine Jones
The roots of grasses form a mirror image of the tops. When the plant is grazed (left), it prunes its own roots. These then become new soil.

Why is carbon sequestration important?

CO_2 is the primary greenhouse gas contributing to rapid global climate change, a warming of the earth's surface that is causing significant changes in sea levels, precipitation, wind, and freeze/thaw cycles. Sequestering carbon in plants and soil and limiting its release back into the atmosphere will help offset greenhouse gas emissions (e.g., methane [CH_4] and nitrous oxide [N_2O] from livestock production and CO_2 from feedstock and crop production) and slow down climate change. Given the vast total land area of pasture and rangelands, which include many drylands, mixed or extensive patches of grasslands, shrublands, and woodlands and account for about half of the land use in California, the U.S., and the world (and about 70 percent of the world's agricultural area), maintaining and improving carbon sequestration in rangelands can help significantly in offsetting the rising levels of atmospheric carbon that contribute to our changing climate. Grazing lands represent 20-30% of the global capacity to sequester carbon in soil and they offset about 20% of annual carbon dioxide emissions from deforestation and land-use changes without even considering the substantial (though lesser) additional storage provided by above-ground plant matter. Sequestering carbon in rangelands promises to be cost-effective for climate change mitigation in part because the additional benefits, such as improved soil quality, structure and water-holding capacity, better nutrient cycling, and less erosion, can improve net income potential for grazing operations.

What can the rancher do?

Private ranchers can be part of the solution to climate change by using management practices that improve soil organic matter and plant productivity, minimize erosion, and optimize carbon sequestration. Specific management recommendations for carbon sequestration will depend on many factors including climate, soil type and depth, current conditions and practices, land use history, and so on, similar to what ranchers have always known about their management practices, namely that it is not "one size fits all" because of complex relationships within rangeland ecosystems. However, it is likely that maintaining a habitat mosaic of diverse herbaceous plants (especially perennials), woody shrubs, and trees might be optimal for carbon sequestration in balance with sustainable livestock production, associated enterprises (e.g., agroforestry, hunting clubs, etc.), and ecosystem function. Well managed grazing in tune with nature can increase plant productivity and sloughing of perennial roots into the soil, thereby increasing carbon storage. From a "whole-ranch" perspective, consider reducing your overall carbon footprint by improving household energy efficiency, reducing use of fossil fuels, using or generating alternative energies like solar and wind power, and becoming part of local food systems (reduced transportation emissions).

A complete life-cycle analysis reveals that appropriately managed rotationally grazed perennial grasslands, where atmospheric carbon is sequestered in soil as stable humus, result in more carbon sequestered than emitted, easily compensating for the methane produced by livestock.

Christine Jones, Ph.D.,
Founder of Amazing Carbon
In *A Carbon Friendly Beef Enterprise –Is It Possible?*
www.amazingcarbon.com

Practices that sequester carbon in grasslands often enhance productivity <and> can enhance adaptation to climate change.

- Grazing management
- Sowing appropriate species
- Adding organic matter and water
- Restoring degraded lands
- Including grass in crop rotations

Grazing practices can be used to stimulate diverse grasses and the development of healthy root systems; feed both livestock and soil biota; maintain plant cover at all times; and promote natural soil forming processes. Grazing practices that ensure adequate plant recovery before regrazing will enhance soil and biomass carbon, capitalize on animal based nutrients and offset ruminant methane emissions.

Richard T. Conant, Colorado State University
In *Challenges and opportunities for carbon sequestration in grassland systems: A technical report on grassland management and climate change mitigation,*
Food and Agriculture Organization of the United Nations

Co-benefits of enhancing ecosystem carbon storage

Managing grazing intensity, timing, and distribution can lead to better plant productivity (increasing carbon storage in the soil), higher quality mixed forage (reducing methane emissions per animal), less use of feed stocks (reduced emissions from crop production and transportation), and better operational productivity (efficiency and profit). Grazing during times of rapid plant growth results in more efficient digestion, with a higher proportion of material being used for animal maintenance and growth, less waste (and gas emissions therefrom), and lower gas emissions from digestion. Higher quality forage leads to better weight gains and healthier animals. Herd health management is beneficial because healthier animals emit less carbon in the form of methane, a green-house gas many times more potent than CO_2, and are more profitable. Timely culling of under-performing animals improves profitability and herd grazing efficiency, which brings about more rapid range improvements and therefore carbon storage potential. Practices used to distribute livestock can provide even grazing pressure (improved plant diversity and productivity as well as carbon storage), spread out manure deposition (better range fertilization and water quality as well as reduced methane and nitrogen emissions), and reduce erosion (keeps soil carbon in place and improves air quality

Oak Rangelands and Carbon Storage

In general, forests and woodlands store more carbon per unit area than do grasslands. Studies at the UC Sierra Foothill Research and Extension Center (SFREC) have found that oak woodlands store more carbon than adjacent grasslands, but that the carbon pools in grassland soils (as compared to woodland soils) were more stable, i.e., better protected from later release into the atmosphere.

Stability of Soil Organic Carbon Pools Across a Rangeland Agricultural Management Gradient
rangelandwatersheds.ucdavis.edu/ Recent%20Outreach/ chang%20sssa%20nov% 202%202010.pdf

Removal of oak trees from grassland results in fairly rapid decline in soil carbon pools and overall soil quality.

Blue oak enhance soil quality in California oak woodlands
rangelandwatersheds.ucdavis.edu/ publication%20list%20 and%20files/ dahlgren_CAg_2003.pdf

The nearly 13 million acres of oak woodlands and forests in California sequester over 675 million metric tons of carbon in live trees, snags, downed wood, understory vegetation, litter, and soil. Continued woody growth sequesters an additional 3 million tons of carbon per year. Trees in oak woodlands alone store 91 tons per hectare. Conserving our existing oak resources and ensuring adequate regeneration could lead to storage of a billion tons of carbon by the end of this century.

An Inventory of Carbon and California Oaks
californiaoaks.org/html/2040.html

by reducing airborne particulates). Retaining and building soil organic matter reduces compaction and improves water and root infiltration, water-holding capacity, and microbial activity; it yields optimal plant growth, more consistent forage production, and improved drought resistance. Increasing drought resistance extends the period of active plant growth and photo-synthesis, lengthening the grazing season and increasing carbon storage when conditions otherwise might lead to net losses of carbon. Emerging markets for carbon offsets or improved sequestration might provide financial benefits to some ranchers whose management results in good carbon storage. A healthy rangeland mosaic of grasses, wildflowers, shrubs, and trees enriches scenic viewsheds and supports a diversity of wildlife, both of which can enhance income through agritourism and nature-based enterprises. Diverse habitat supports pollinators up-on which most plants and many crops depend.

Here are a few habitat examples and their co-benefits:

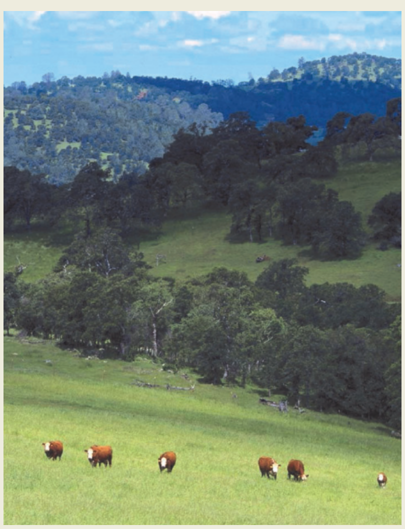
- Perennial grasses and forbs, with their deep root systems...improve soil water balance in seasonally dry environments and better support livestock and wildlife during drought.
- Hedgerows along cultivated field margins and near ranch structures...provide shade, serve as windbreaks, and benefit pollinators and other wildlife.
- Restoring riparian vegetation...helps keep soil and water on your ranch, intercepts sediments and pathogens in run-off (leading to cleaner water downstream), and is good for wildlife.
- Trees and large shrubs...provide shade for live-stock, improve soil quality, and are excellent wildlife habitat. Agroforestry can enhance income.

All of these things can improve your economic wellbeing, personal enjoyment and pride of place, and public relations. These are good ranching business practices that A) provide personal benefits, B) yield societal benefits for climate change mitigation, and C) improve your ranch's resilience to climate change and drought, thereby enhancing the sustainability of your operation.

According to the Intergovernmental Panel on Climate Change (IPCC—www.ipcc.ch) and the Food and Agriculture Organization of the United Nations (FAO—Rangelands and Climate Change: Mitigation, Adaptation, and Cobenefits), while historical livestock grazing in some areas of the world have led to degraded habitat and loss of soil carbon stocks, "improved grazing management, reversing degradation, and agroforestry are the most important technical <climate> mitigation solutions."

Healthy grasslands, livestock and associated livelihoods constitute a win-win option for addressing climate change in fragile dryland areas where pastoralism remains the most rational strategy for maintaining the wellbeing of communities. Despite increasing vulnerability, pastoralism is unique in simultaneously being able to secure livelihoods, conserve ecosystem services, promote wildlife conservation and honour cultural values and traditions... Pastoral and agropastoral systems provide a win-win scenario for sequestering carbon, reversing environmental degradation and improving the health, well-being and long-term sustainability of livestock based livelihoods. Ruminants convert vast renewable resources from grasslands that are not otherwise consumed by humans into human edible food.

In *Review of Evidence on Drylands Pastoral Systems and Climate Change: Implications and Opportunities for Mitigation and Adaptation*
Food and Agriculture Organization of the United Nations (FAO), 2009
ftp://ftp.fao.org/docrep/fao/012/i1135e/i1135e00.pdf



In 2010, the Society for Range Management *(www.rangelands.org)* published a special issue of their journal Rangeland Ecology and Management entitled "Global Grazinglands and Greenhouse Gas Fluxes"*(www.srmjournals.org/toc/rama/63/1.)* Some articles can be viewed for free but full access is by subscription only *(www.srmjournals.org/page/subscribe)*, with discounts to Society members *(www.rangelands.org/membership.shtml)*.

Among other benefits, building soil organic matter improves habitat for soil biota. Aerobic, biologically active soils contain methanotrophic bacteria that oxidize methane and thereby return carbon back to the soil. This activity offsets much of the methane emissions from ruminant grazing animals and has done so for millennia, with some grazing lands acting as methane sinks. In California, greenhouse gas (GHG) emissions from ruminant livestock on open range (aerobic conditions under which manure breaks down easily) come primarily from the enteric fermentation process that digests plant matter and emits methane. This amounts to less than 1.5% of California's total GHG emissions and does not factor in the beneficial activity of soil biota. Unfortunately, methanotrophic bacteria are sensitive to chemicals such as the herbicides, pesticides, and nitrogenous fertilizers that are so prevalent in modern agriculture. Therefore, avoiding chemical inputs in rangeland management not only will save purchase costs, permit expenses, and the greenhouse gas emissions associated with chemical production, transport, and application, but also will reduce the carbon footprint of rangeland livestock production.

Sources: *Soil Carbon—Can It Save Agriculture's Bacon?*
www.amazingcarbon.com

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amazingcarbon.com

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csite.esd.ornl.gov

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treesearch.fs.fed.us/pubs/34234

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Challenges and Opportunities for Carbon Sequestration in Grassland Systems
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Marin Carbon Project
marincarbonproject.org

Ranching to Produce Tacos Sin Carbon: The Low Carbon Footprint of Grass-fed Beef and Sheep Production in the Semi-Arid West, Tacos Sin Carbon Project of the Flavors Without Borders Foodways Alliance
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groups.ucanr.org/RangeSoilsCarbon/index.cfm

- Workshop Presentations
  groups.ucanr.org/RangeSoilsCarbon/Carbon,_Soils_&_Your_Ranch
- *Carbon Storage in California's Rangeland Soils: A Landscape Scale Perspective*
- *Introduction to the Marin Carbon Project*
- *Rangeland and Livestock Management Options and Tools*
- *What is a Carbon Market and How Could It Affect Me?*
- *What is Carbon Sequestration and How Does It Work in Grassland Soils?*

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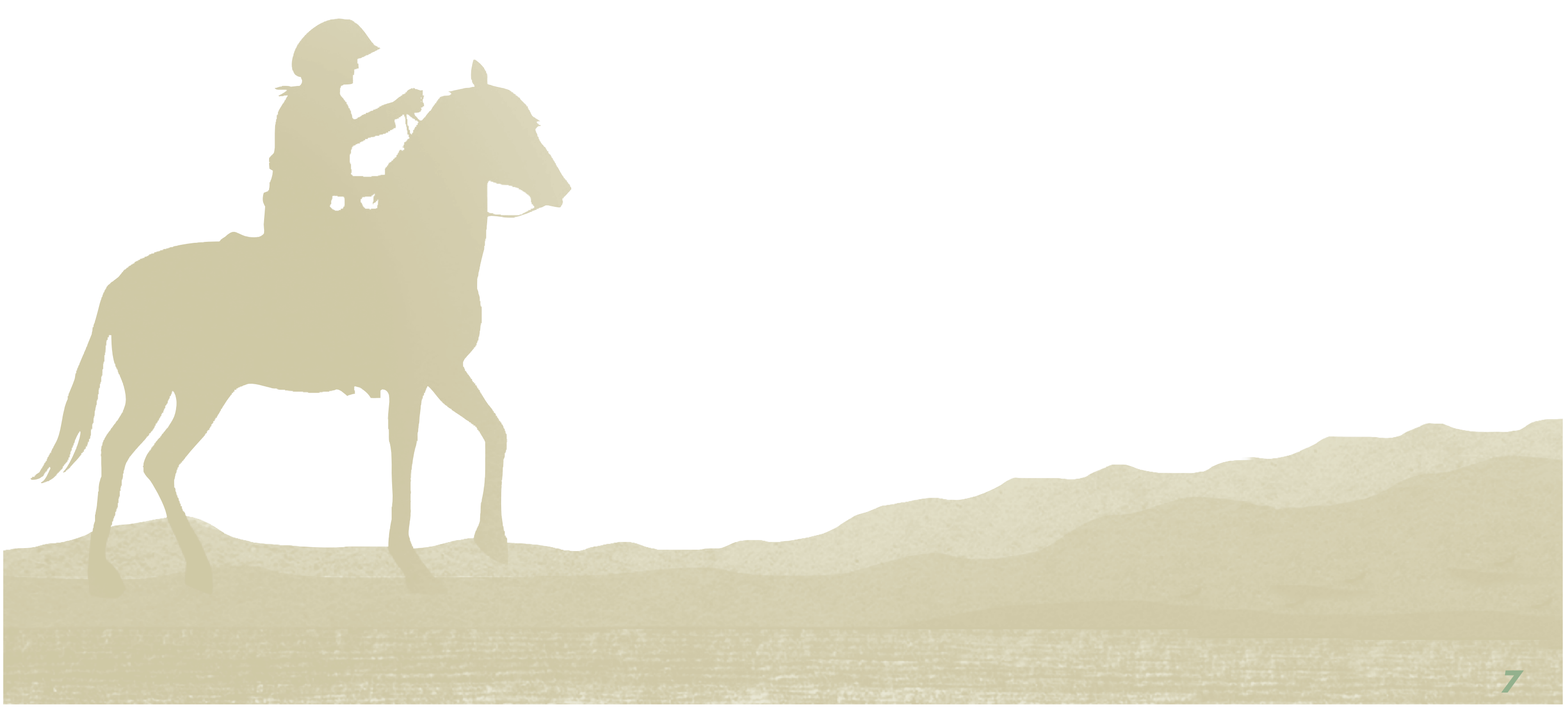

Productive, sustainable grazing lands provide high-quality vegetation and soils, which lead to high rates of carbon sequestration and low levels of carbon dioxide emissions. The total soil carbon sequestration potential for grazing lands in the United States is approximately 70 million metric tons of carbon per year. This store of carbon is about 1.6 times the size of the carbon dioxide emission from all other agricultural activities in the United States (Lal et al 1998) and about 4.4 times the carbon dioxide emission for all grazing land agriculture.

From Using Livestock Grazing as a Resource Management Tool in California, Contra Costa Water District

ccwater.com/files/LivestockGrazingFinal72005.pdf

What is the RSA?

A voluntary program developed by California ranchers for use by the California ranching community, the Ranching Sustainability Analysis is a proactive self-assessment tool to foster successful practices and help ranchers achieve sustainability–**long-term economic, environmental, and social viability.**

Assessment Categories

- Livestock Management
- Soil Management
- Forage Management
- Biodiversity and Wildlife Conservation
- Regulations and Regulators
- People and Relationships
- Economics
- Energy
- Monitoring
- Pest Management
- Water Quality