Managing Open Space in Support of Net Zero:

Carbon Sequestration Opportunities and Tradeoffs in the Alameda Watershed

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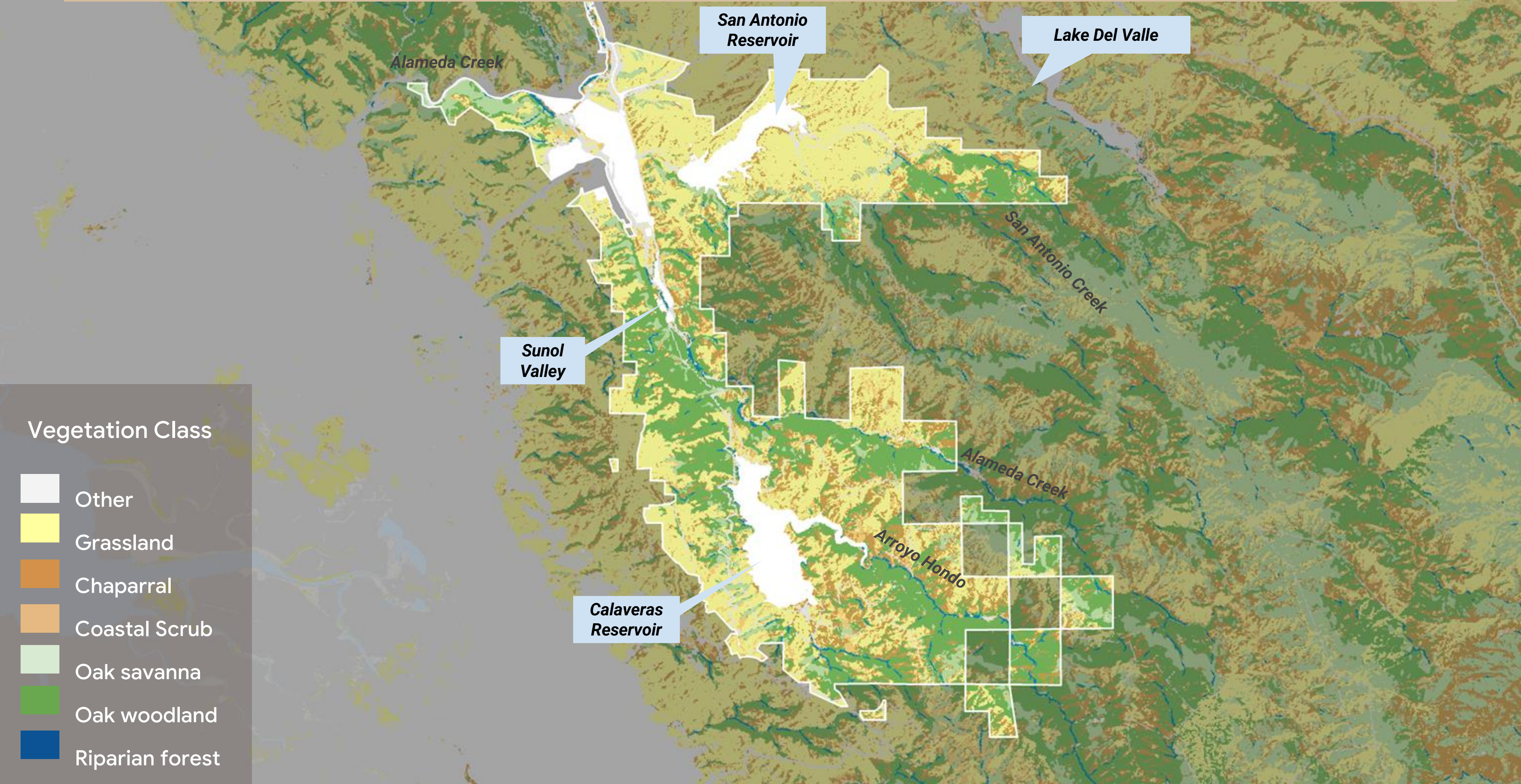
Goals

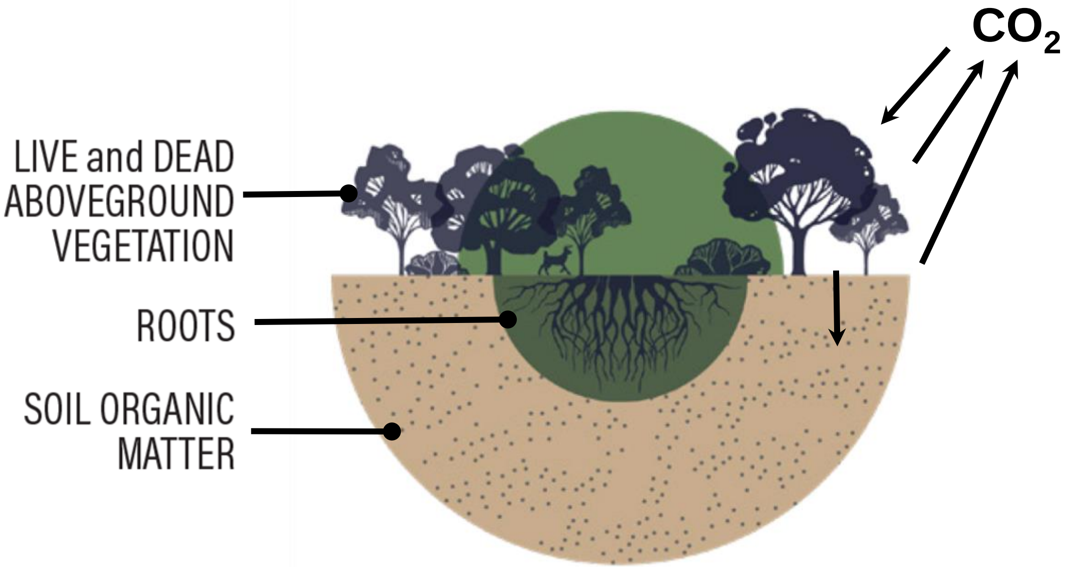
1 Quantify existing carbon stocks in the Alameda Watershed

2 Evaluate opportunities to enhance carbon sequestration in the Watershed's vegetation and soil

Vegetation mosaic is characteristic of the northern Diablo range



Carbon Cycle



Goal 1:
Quantifying ecosystem carbon storage in the Alameda Watershed

Carbon storage in woody ecosystem types

Oak woodland, oak savanna, riparian forest, coastal scrub and chaparral

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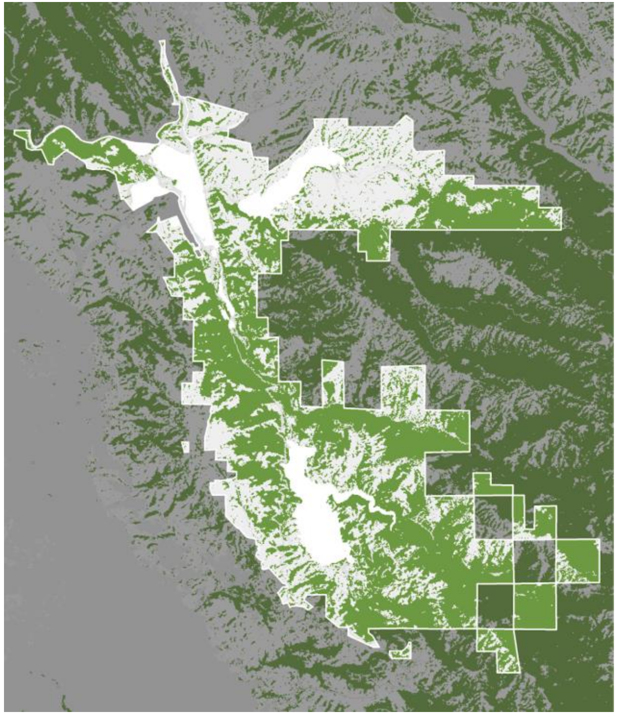
Carbon pool	Data/method - woody vegetation
Woody canopy	Modeled from LANDFIRE existing vegetation type, canopy cover, and canopy height (Gonzalez et al 2015)
Understory	Fuel Characteristics Classification System (FCCS) values
Dead wood	Fuel Characteristics Classification System (FCCS) values
Litter	Fuel Characteristics Classification System (FCCS) values
Roots	Root:shoot ratios applied to canopy and understory biomass
Soil organic matter	Literature synthesis



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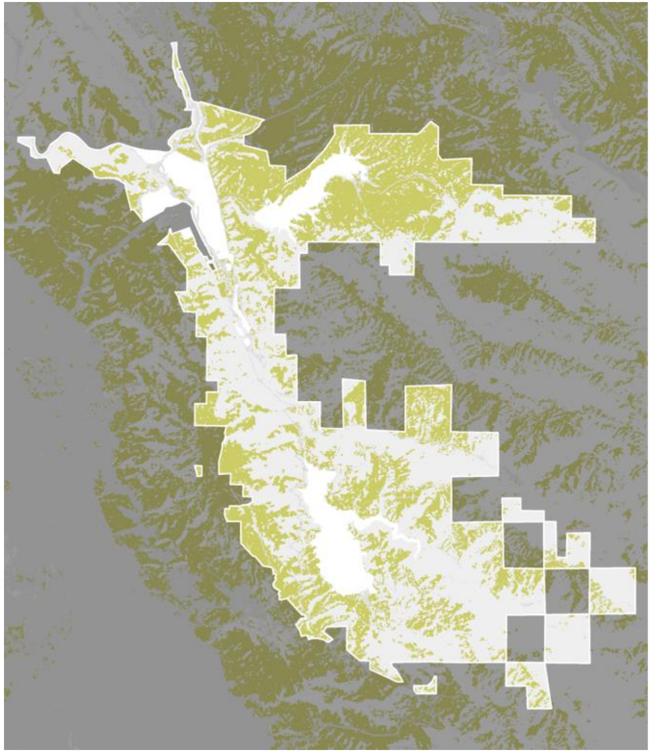
Carbon storage in grassland

Carbon pool	Data/method - grasslands
Woody canopy	Fuel Characteristics Classification System (FCCS) values (shrubs only)
Understory	Fuel Characteristics Classification System (FCCS) values
Dead wood	Fuel Characteristics Classification System (FCCS) values
Litter	RDM measurements (simple average of ~100 plots across the watershed grazing leases)
Roots	Root:shoot ratios applied to RDM values
Soil organic matter	Literature synthesis



The Alameda Watershed stores ~ 2.5 million metric tons of carbon in its vegetation and soil

Ecosystem Type	Area (acres and percent of total)	Average Vegetation Carbon Storage (MT C/acre ± 1 σ)	Soil Carbon Storage (MT C/acre ± 1 SE)	Total Ecosystem Carbon (MT C and percent of total)
Grassland	12,744 (38%)	1.2 ± 0.14	46.5 ± 3.9	601,700 (24%)
Coastal Scrub	1,815 (5%)	6.1 ± 0.25	64.1 ± 6.3	127,300 (5%)
Chaparral	4,777 (14%)	13.5 ± 3.5	64.1 ± 6.3	370,600 (15%)
Oak savanna	3,988 (12%)	21.4 ± 10.8	64.1 ± 6.3	340,900 (14%)
Oak woodland	9,557 (29%)	33.5 ± 10.8	64.1 ± 6.3	932,800 (38%)
Riparian Forest	653 (2%)	64.4 ± 11.8	64.1 ± 6.3	83,900 (3%)
Total	**33,534**			**2,457,000**

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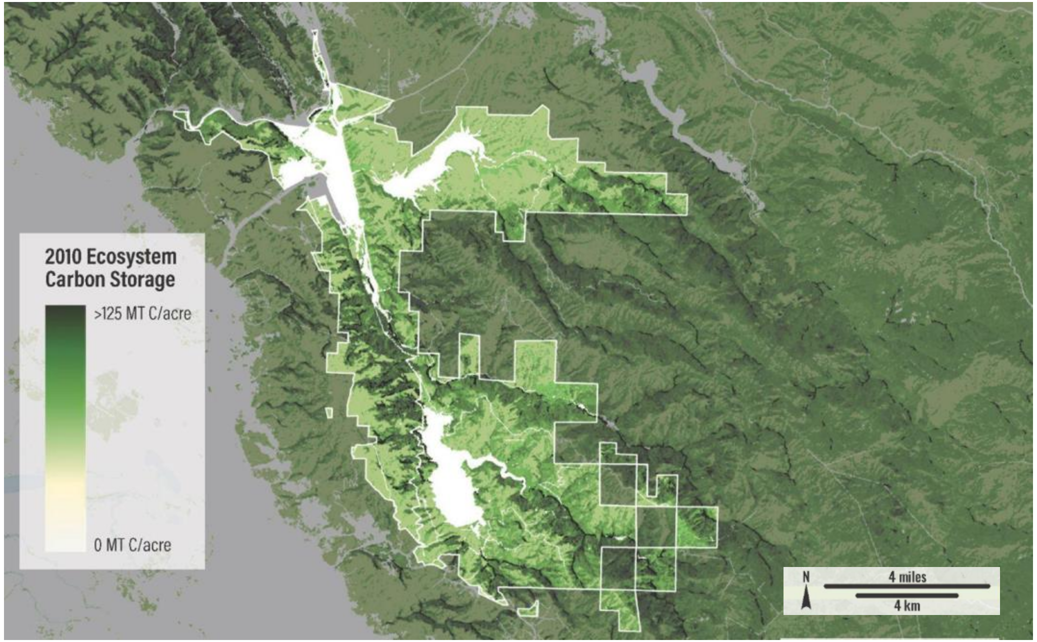
Carbon storage is concentrated in woodland areas

High carbon concentration in dense woodlands and along wooded riparian corridors

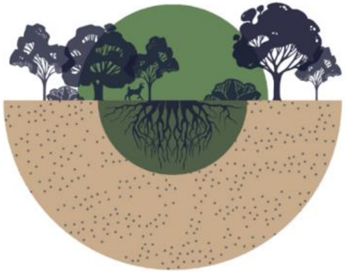


Most carbon is stored in the soil

RIPARIAN FOREST

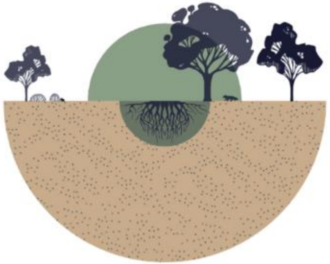
Vegetation carbon = 64.4 ± 11.8 MT C/acre
Soil carbon = 64.1 ± 6.3 MT C/acre

OAK WOODLAND



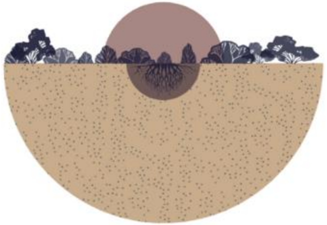
Vegetation carbon = 33.5 ± 10.8 MT C/acre
Soil carbon = 64.1 ± 6.3 MT C/acre

OAK SAVANNA



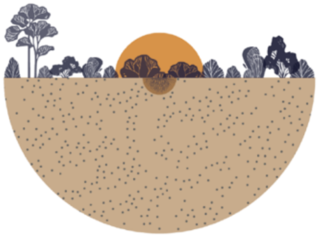
Vegetation carbon = 21.4 ± 10.8 MT C/acre
Soil carbon = 64.1 ± 6.3 MT C/acre

CHAPARRAL



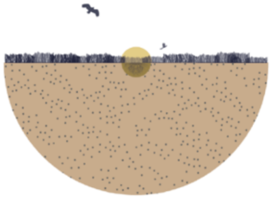
Vegetation carbon = 13.5 ± 3.5 MT C/acre
Soil carbon = 64.1 ± 6.3 MT C/acre

COASTAL SCRUB

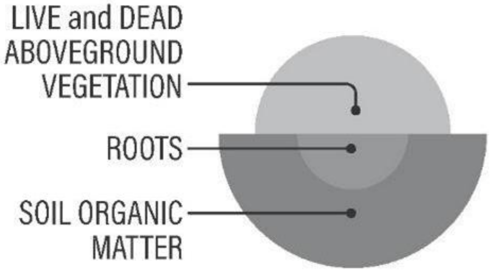


Vegetation carbon = 6.1 ± 0.25 MT C/acre
Soil carbon = 64.1 ± 6.3 MT C/acre

GRASSLAND



Vegetation carbon = 1.2 ± 0.14 MT C/acre
Soil carbon = 46.5 ± 3.9 MT C/acre



Carbon Quantification: summary of findings

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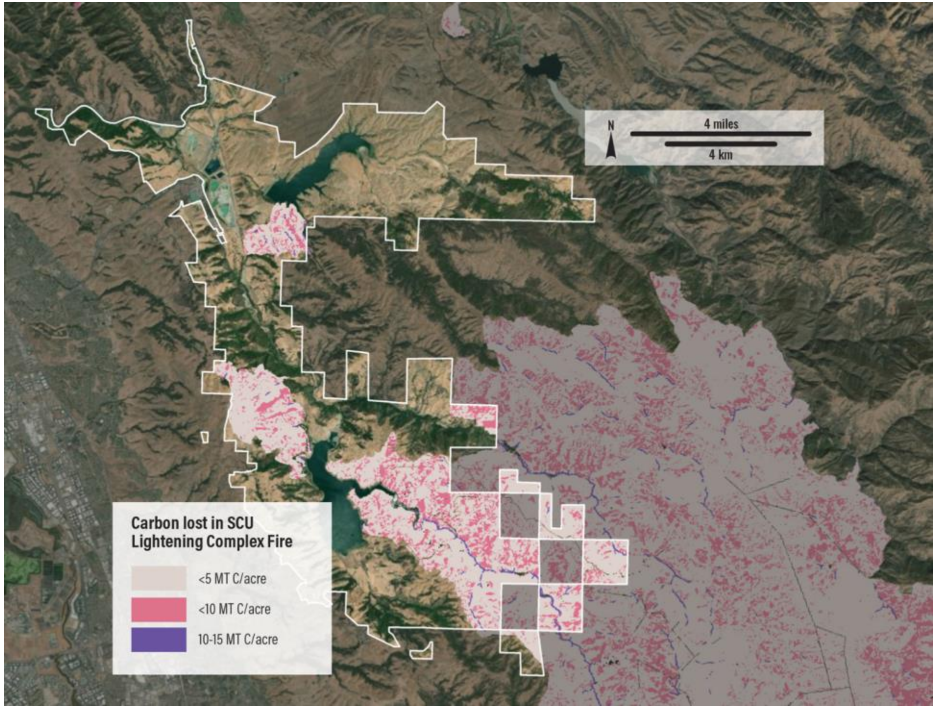
- The watershed stores ~2.5 MMT of carbon in soils and vegetation
- High carbon storage in woodlands and riparian areas
- High variability within and among vegetation types
- 80% of carbon stored in soil

Ecosystem carbon may be vulnerable to fire

Loss of 33,100 MT C (~8% of total vegetation carbon) during 2020 SCU Lightning Complex fires



Goal 2:
Evaluating carbon management strategies in the Alameda Watershed

Strategy 1: Rangeland Compost

Introduction to the strategy

Definition: amending grazed lands with organic matter to enhance productivity and improve soil health

On the Alameda Watershed: spreading compost with a high C:N ratio on grasslands absent of sensitive vegetation species

Sequesters carbon in soil

Provides a net GHG benefit if appropriate material and practices are used

Enhances fertility and can buffer against drought

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Introduction to the strategy

Definition: restoring ecosystem functions adjacent to channels or other water bodies

On the Alameda Watershed: excluding cattle and planting trees to restore riparian forest communities dominated by coast live oak, sycamore, alder, or willow

Sequesters carbon in trees and soil

Provides numerous benefits for wildlife, soils, and water resources

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Strategy 3: Silvopasture

Introduction to the strategy

Definition: adding trees to rangeland to increase overall productivity

On the Alameda Watershed: planting oaks in grazed grassland to expand savanna or open-canopy woodland

Sequesters carbon in trees and soil

Provides numerous benefits for wildlife, soil, and livestock

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Strategy 4: Cattle exclusion

Introduction to the strategy

Definition: reducing or eliminating cattle access to portions of the watershed to promote woody vegetation growth

Increases the likelihood that grassland will transition to shrubland or woodland

Sequesters carbon in woody vegetation and soil

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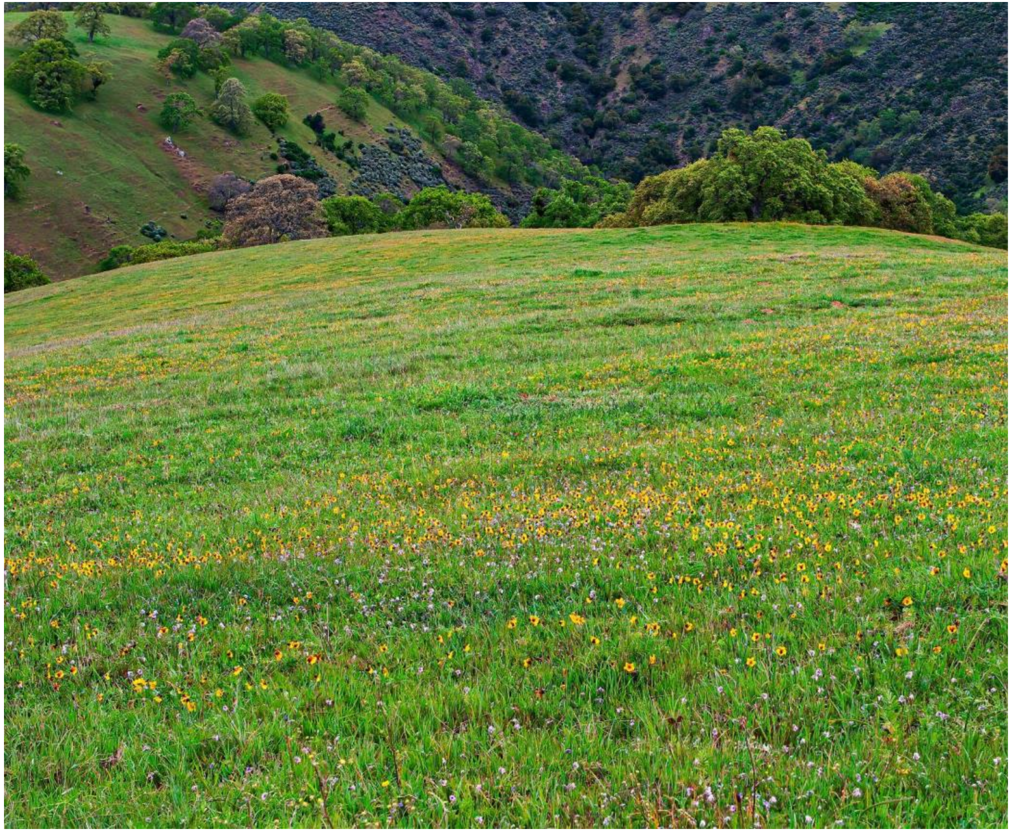
Strategy 5: Native Grassland Restoration

Introduction to the strategy

Definition: restoring native vegetation communities in invaded, barren, or otherwise degraded sites

Restoring grassland cover enhances aboveground and belowground carbon inputs and restores soil processes

Restoring native species may increase soil carbon in certain situations: high soil carbon storage in native perennial grasslands



Strategy 6: Open space conservation

Carbon and GHG benefits

Definition: conserving existing open space that supports biodiversity, protects water resources, and stores carbon in its vegetation and soil

In addition to maintaining a clean water supply and supporting biodiversity, conservation of the watershed's ~39,000 acres has avoided potential carbon losses due to urban and agricultural development.

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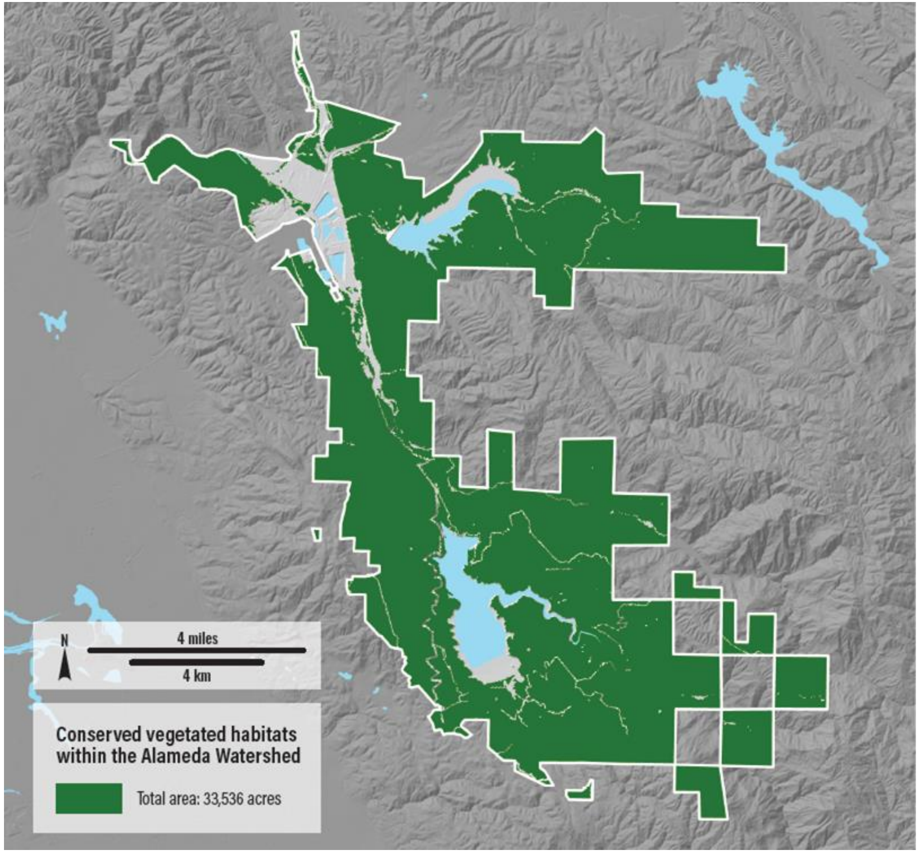
Strategy 6: Open space conservation

Conserved land

Protected, undeveloped land in the watershed covers 52.4 mi^2

Additional open space acquisition would protect carbon stocks and provide the numerous co-benefits associated with conservation.



Comparing across carbon management strategies

	Carbon and GHG benefits	Co-benefits	Tradeoffs	Feasibility
Rangeland Compost	Low to moderate per-acre carbon benefits*	Likely benefits: forage production, soil quality, soil water retention	Key concerns: native biodiversity, residual dry matter control, water quality	Low to moderate concern: access to remote or steep sites
Riparian Restoration	High per-acre carbon benefits**	Likely benefits: native biodiversity, soil quality, water quality	Moderate concerns: native biodiversity (including risk of pathogen introduction), water supply, wildfire risk, cattle water access	Moderate concern: tree establishment and survival, fencing maintenance, limited opportunity space
Silvopasture	Low to moderate per-acre carbon benefits**	Likely benefits: shading, soil quality	Moderate concerns: forage production, native biodiversity (including risk of pathogen introduction), water supply	Moderate concern: tree establishment and survival
Cattle Exclusion	Low to moderate per-acre carbon benefits**	Potential benefit: water quality	Key concerns: agriculture, wildfire risk, native biodiversity	Moderate concern: fencing maintenance
Grassland Restoration	Low, uncertain carbon benefits	Likely benefit: native biodiversity	Moderate concern: risk of pathogen introduction if container stock is used	Key concern: likelihood of restoration success
Open Space Conservation	High per-acre carbon benefits	Likely benefits: recreation, agriculture, native biodiversity, water quality, soil quality	Low concern: opportunities for alternate land uses	No major concerns

*Assumes the material applied is composted green or animal waste. If biosolids are used, assumes material is amended to increase C:N ratios and limit N_2O emissions

**Potential increased wildfire risk may decrease sustainability of carbon benefits.

Summary and recommendations

Protecting existing carbon stocks in forests, grasslands, and other natural and managed lands can help limit climate change and maintain healthy, resilient ecosystems.

Ecosystems within the Alameda Watershed store an estimated 2.5 million metric tons of carbon (equivalent to a year's emissions from 500,000 cars). 80% of the watershed's carbon is stored belowground in soil organic matter.

Open space conservation is the only carbon management strategy with high carbon benefits and few risks. All of the other strategies entail some tradeoffs and feasibility concerns, but may provide GHG benefits and important co-benefits if implemented strategically.

Because of uncertainties associated with both the potential carbon benefits and the co-benefits and tradeoffs of each management strategy, an adaptive management approach is highly recommended in order to systematically monitor and assess the effects of each strategy. Pilot studies can be employed to test the effects of management strategies at a small scale before strategies are broadly applied across the watershed.

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