Carbon Dynamics in Rangeland Soils

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Why is soil organic carbon (SOC) important?

Nutrient cycling

- -organic matter a food source for microbes
- -time release fertilizer
- -protects against nutrient leaching

Helps regulate the water supply

- -improves infiltration
- -decreases evaporation as part of mulch
- -increases water holding capacity

Structure

- -improves the root zone in many ways
- -reduces susceptibility to erosion

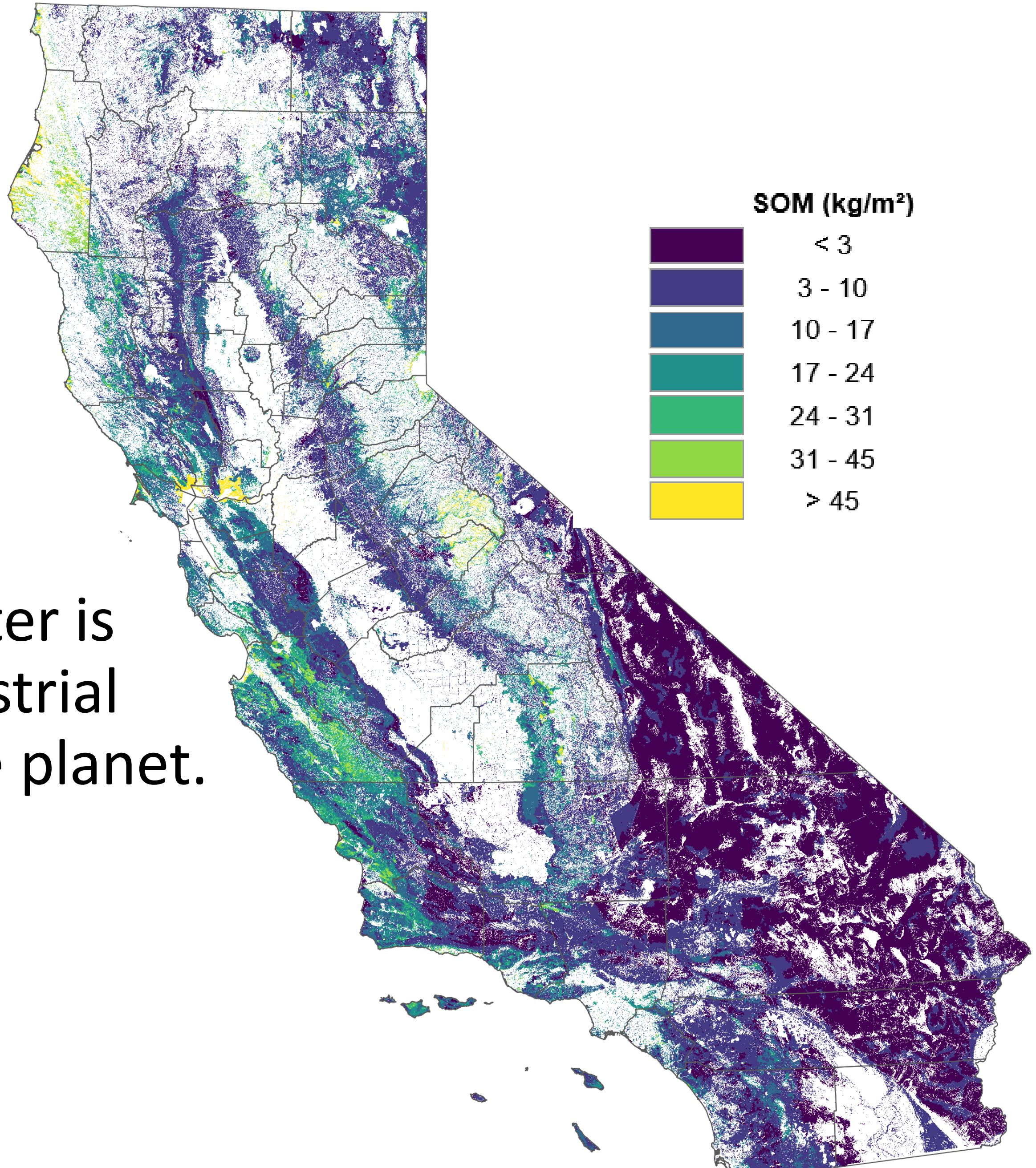
Other

- -large and stable carbon stock
- -promotes biodiversity

~44% of State's soil organic carbon is stored in rangeland soils

Rangeland soils ≅1.12 Tg
Soils statewide ≅ 2.54 Tg

Soil organic matter is the largest terrestrial stock of C on the planet. Larger than the atmosphere and vegetation.

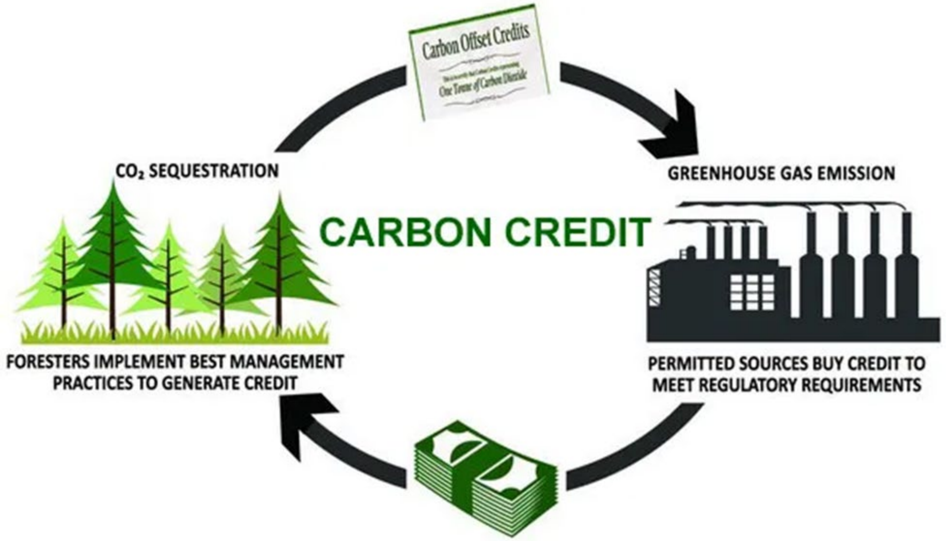


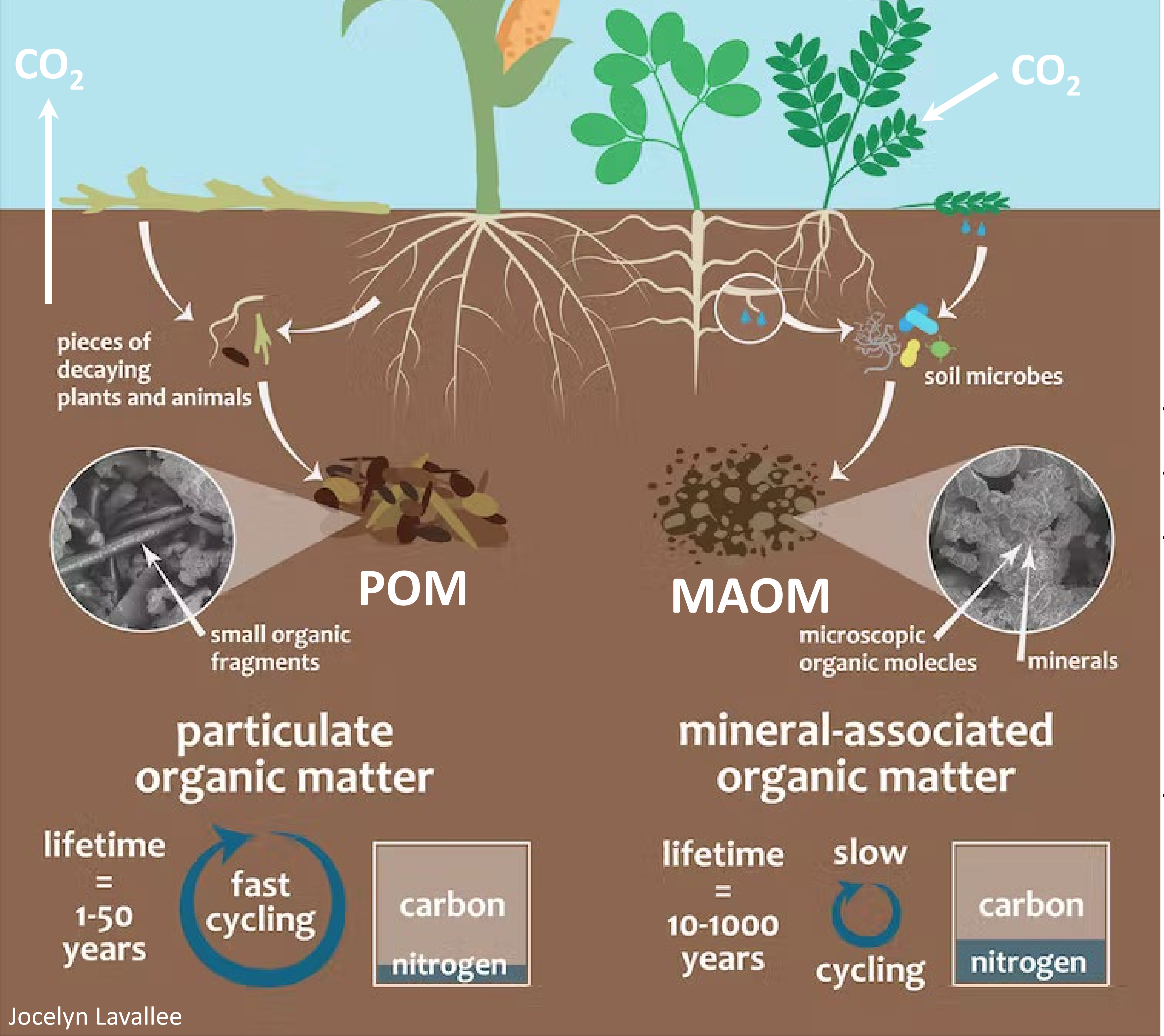
A lot of interest in natural solutions to offset greenhouse gas emissions by boosting SOC

-Limited research in annual rangelands, most suggests minimal potential to increase SOC

-Building SOC is difficult in CA

-There is agreement that restoration of degraded soils will be important



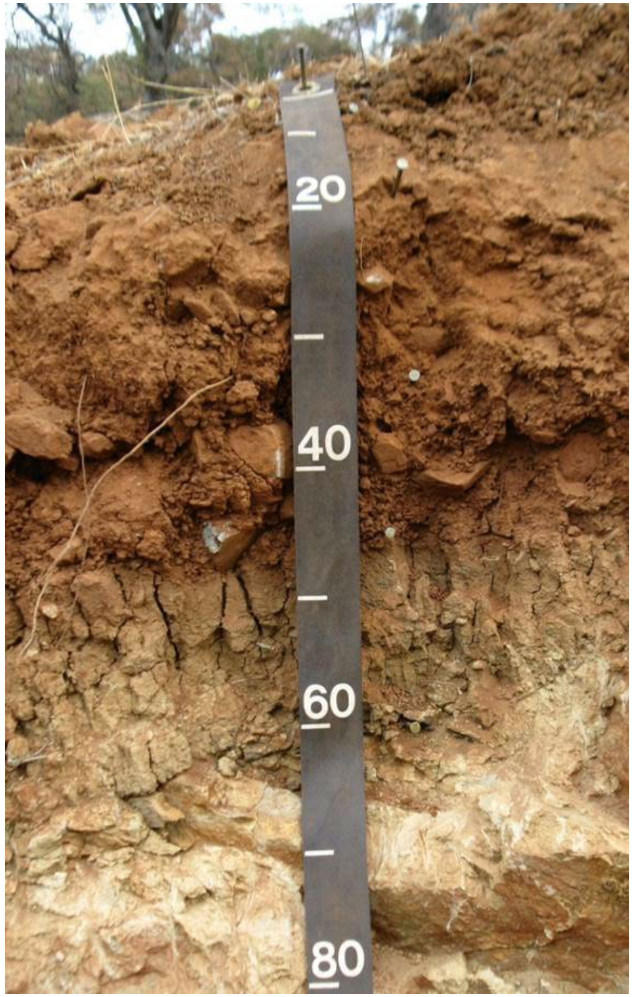


Details of the SOC cycle help explain fate of C in soil

-POM vs MAOM
-SOC residence times
-SOC stocks are at steady state, the balance is maintained by soil and climatic factors
-C sequestration depends on practices that target MAOM

Soil properties influence C sequestration

Poorly crystalline minerals = high SOM



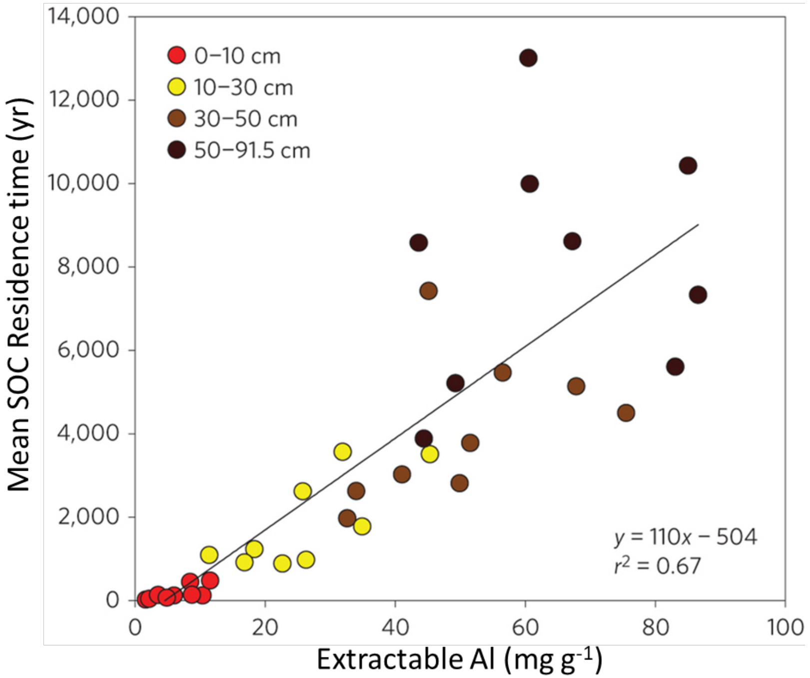
Long residence time (RT)

Fine soil textures = high SOM

Long RT

Sandy textures = low SOM

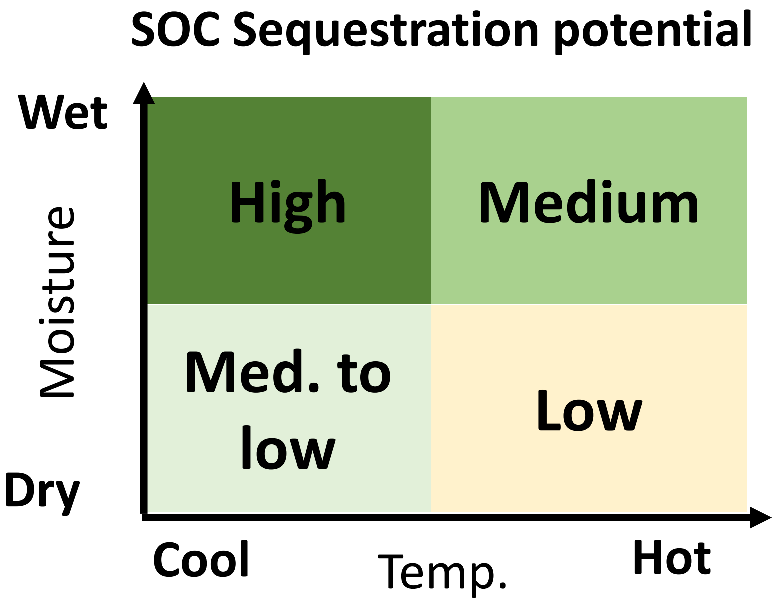
Short RT

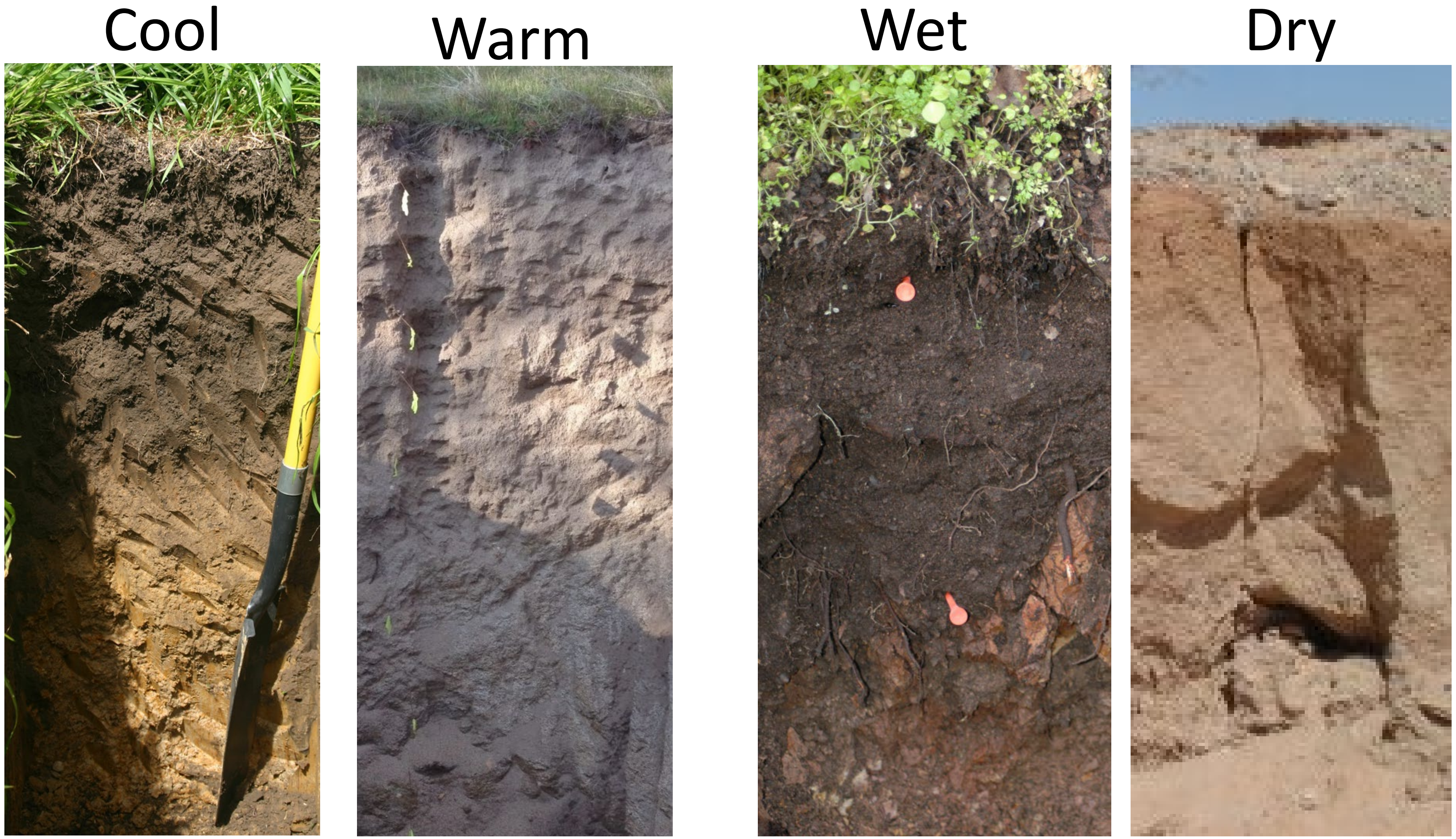


Giardina et al., 2014 Nature Climate Change

How much organic carbon can a soil store?

- Climate
- Vegetation
- Topography
- Type of organic matter
- Soil properties
- Management





Possibilities for increasing C in rangelands: CDFA-Healthy Soils Program incentives

What are the tradeoffs?

Are the soils capable of stabilizing C?

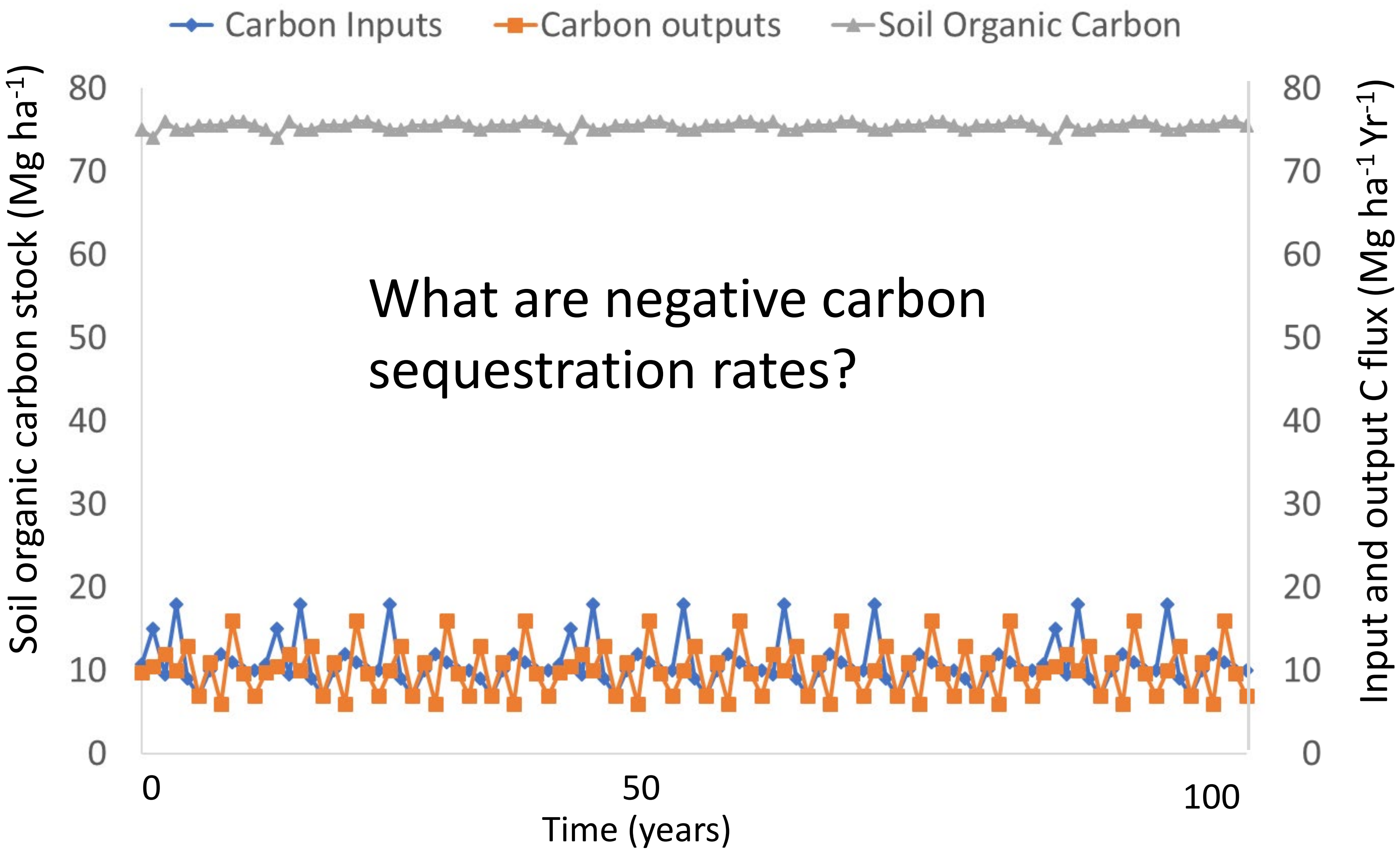
Does the practice target MAOM?

Can it maintain long-term increases in C stock?

Is the climate conducive to sequestration?

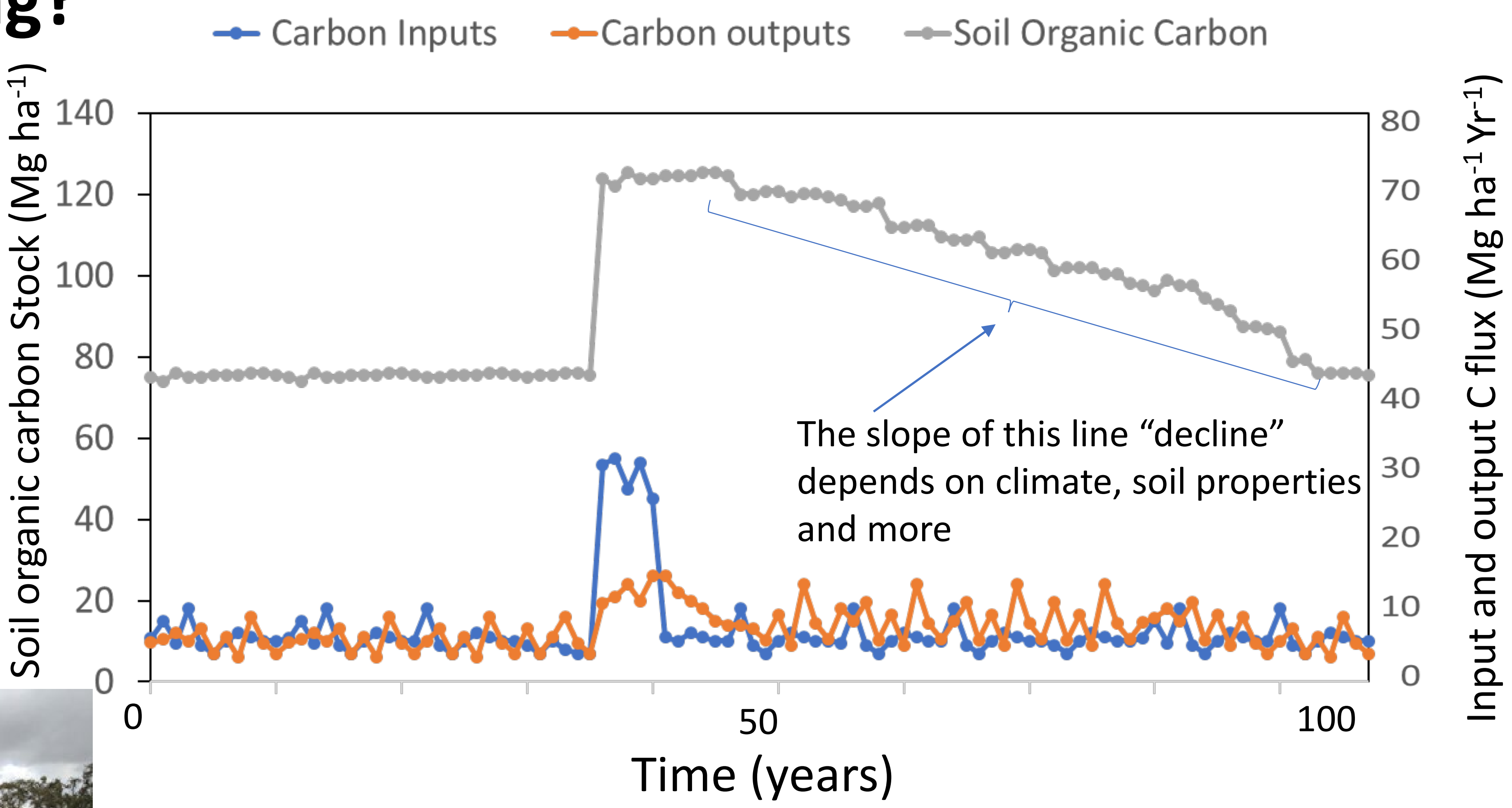
Is the C stock responsive to the change in practice?

Scenario 1. Carbon stocks and fluxes in a normal annual range condition



What are negative carbon sequestration rates?

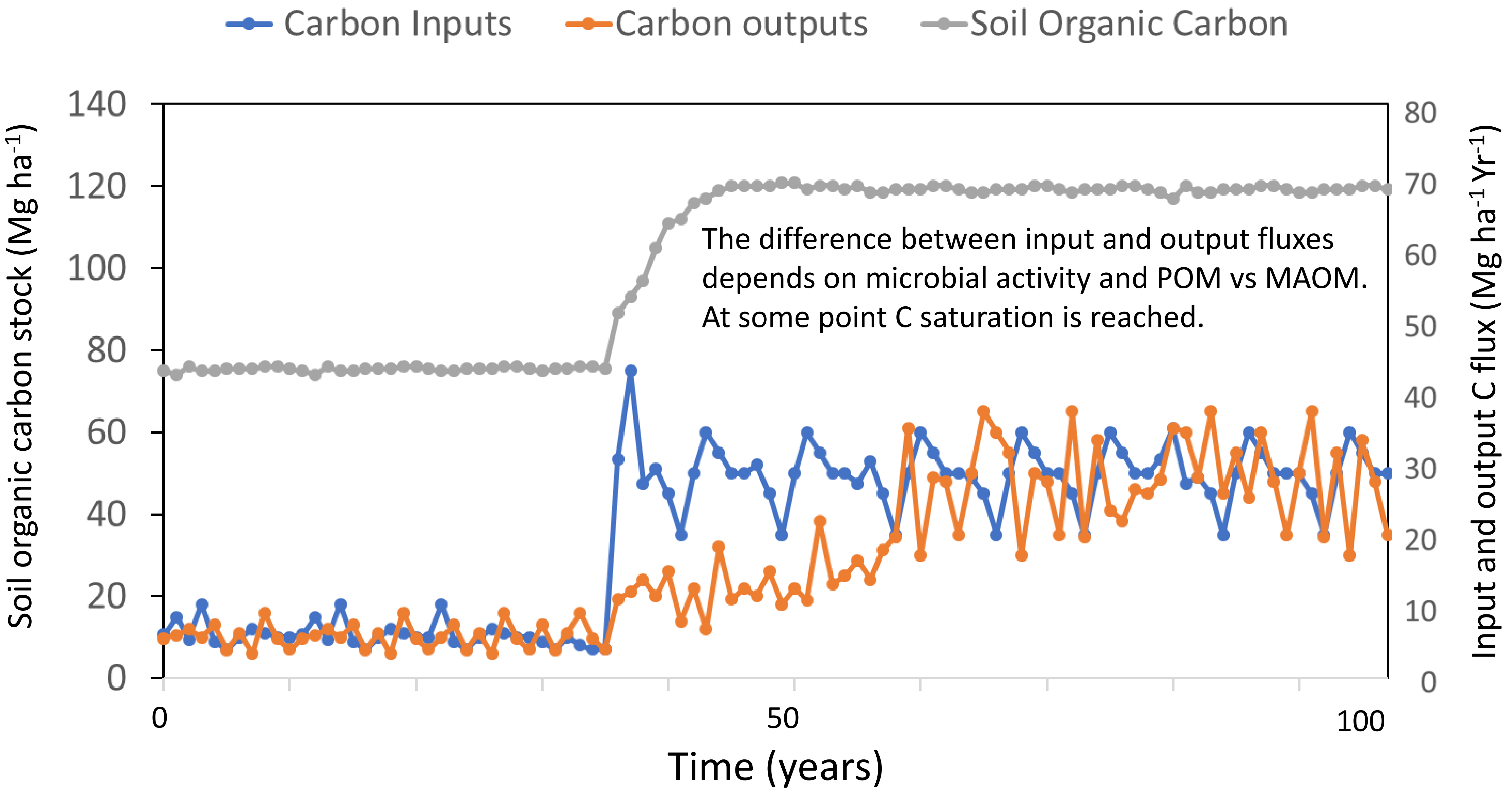
Scenario 2. Are temporary increases in inputs (e.g. compost) lasting?



Increased inputs must be maintained to sequester C in most CA soils

Nobody knows how long one-time applications will last

Scenario 3. What happens if inputs are increased permanently?



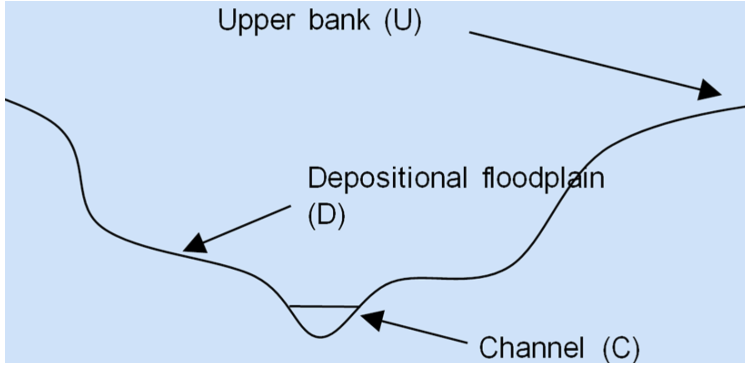
Long term practices: Riparian restoration increases soil organic carbon sequestration in rangelands

Time = 0 years → **Time = 45 years**

42 restoration projects

Practices include:

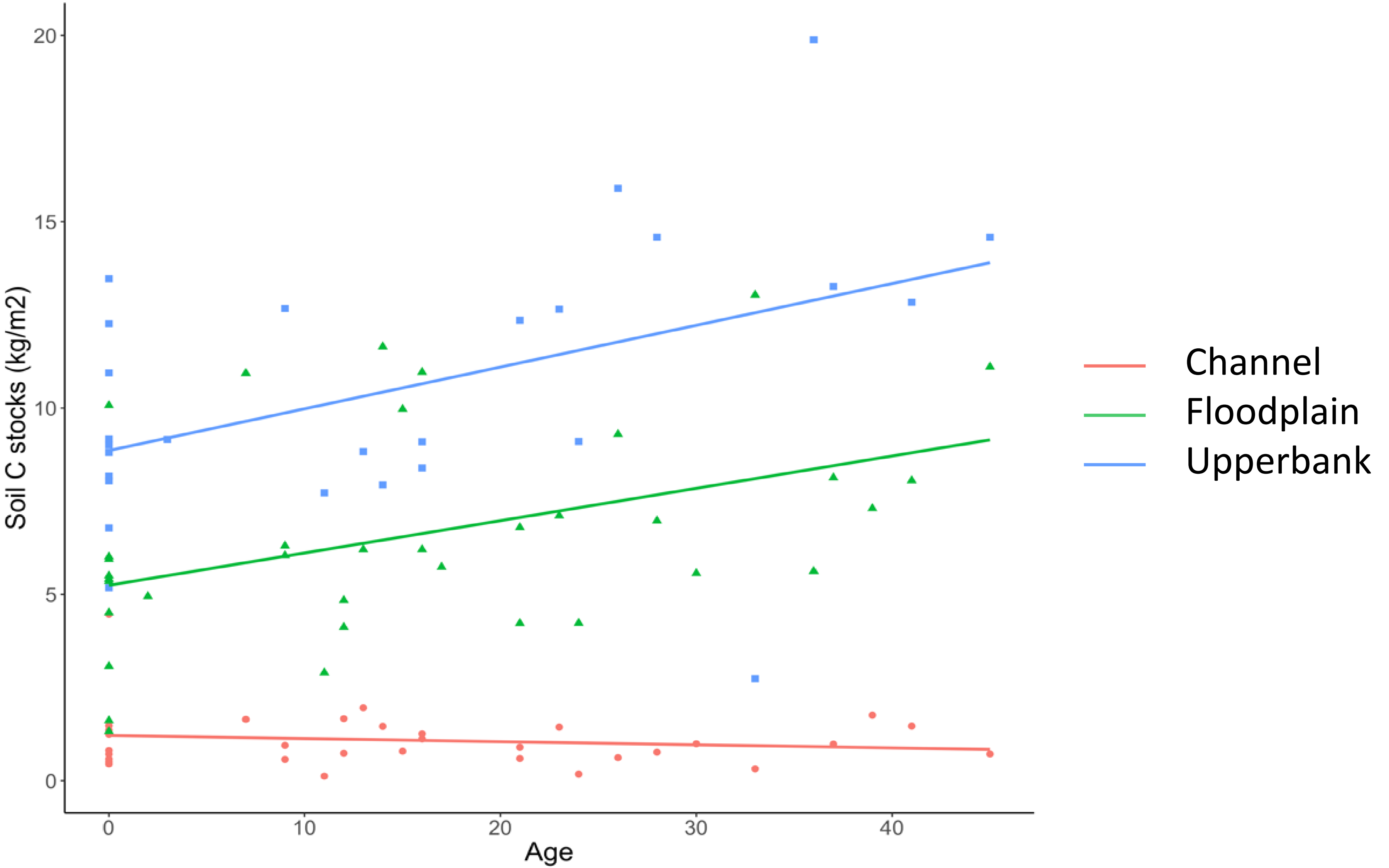
- **Tree planting**
- **Bio technical bank stabilization**
- **Grazing management (removal or reduced stocking rates)**



Landforms Sampled

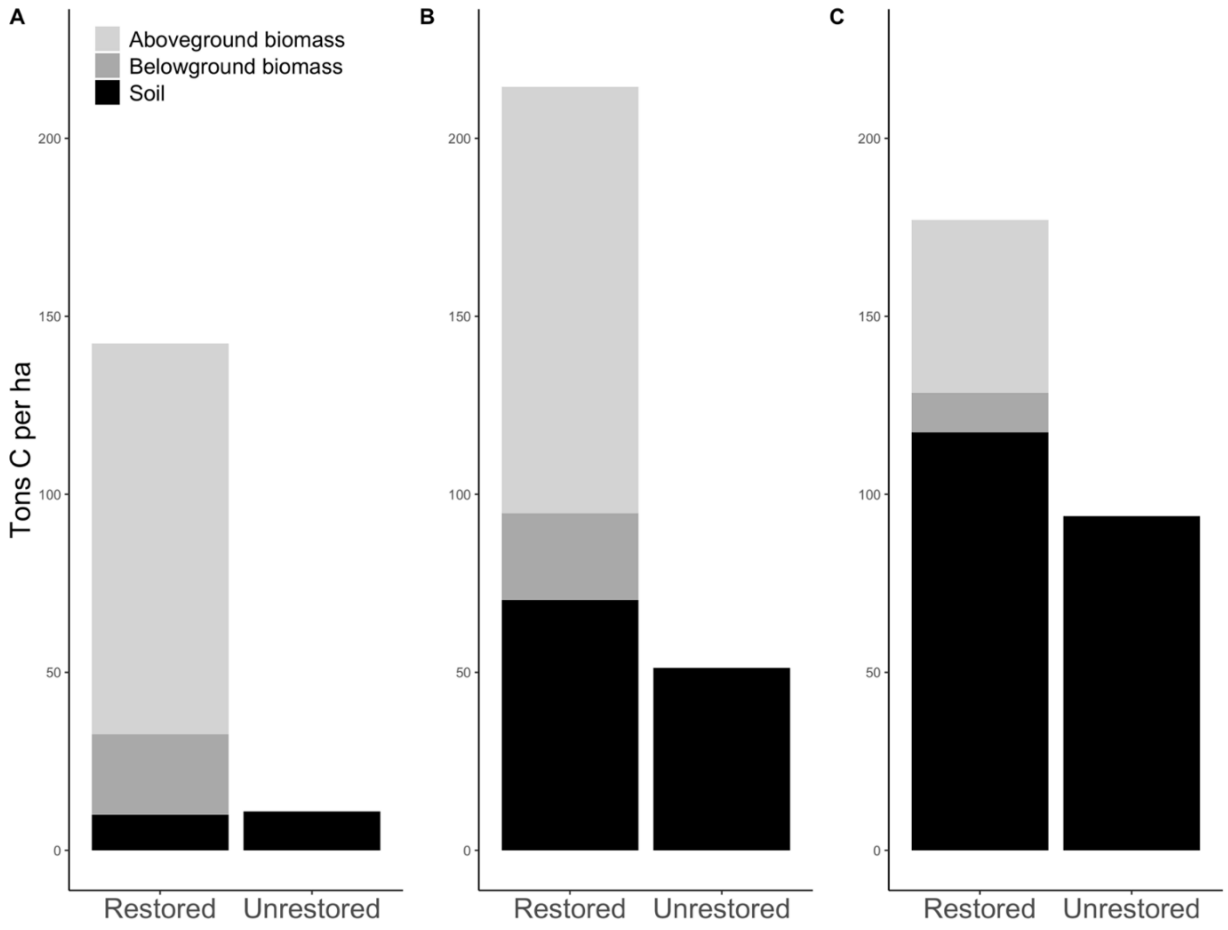
Matzek, Lewis, O'Geen et al., 2020

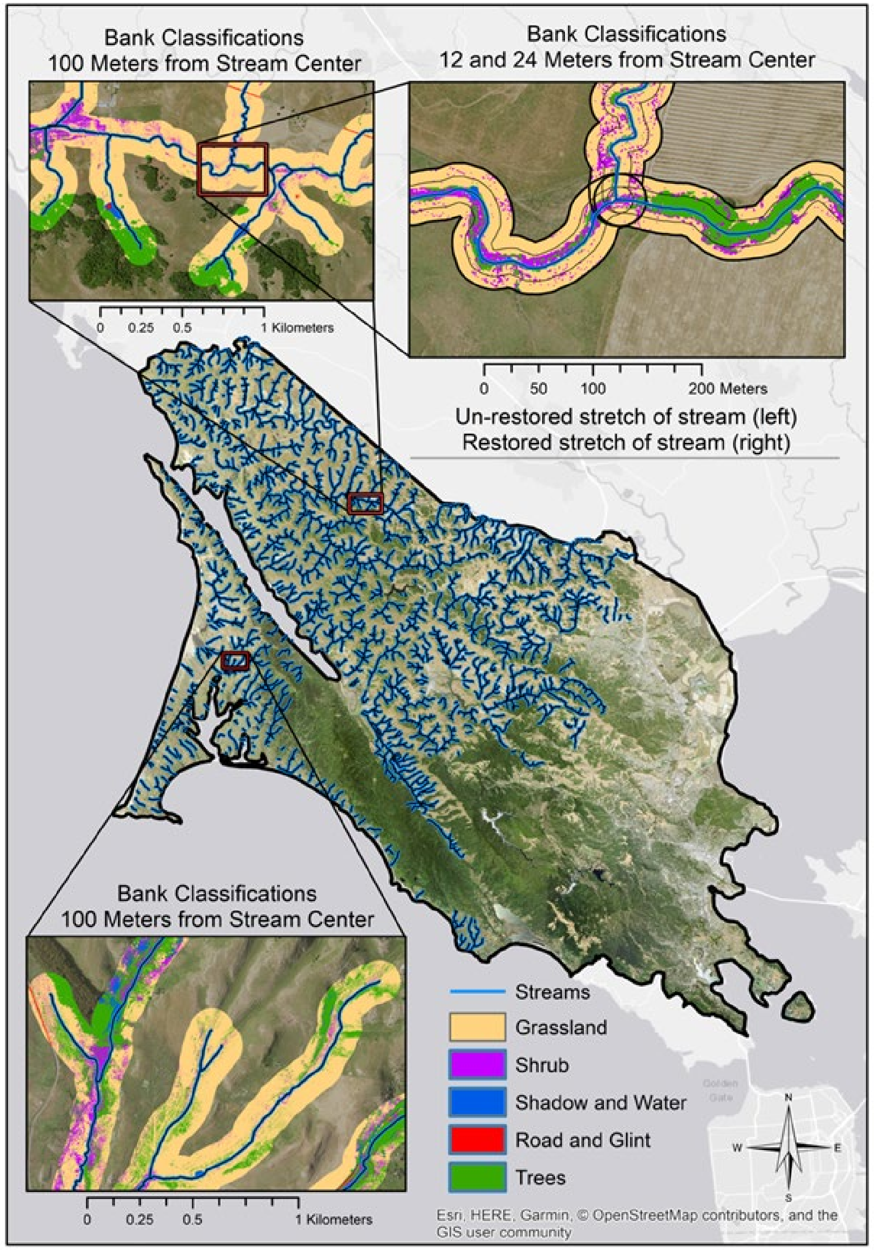
SOC stock increases with time since restoration



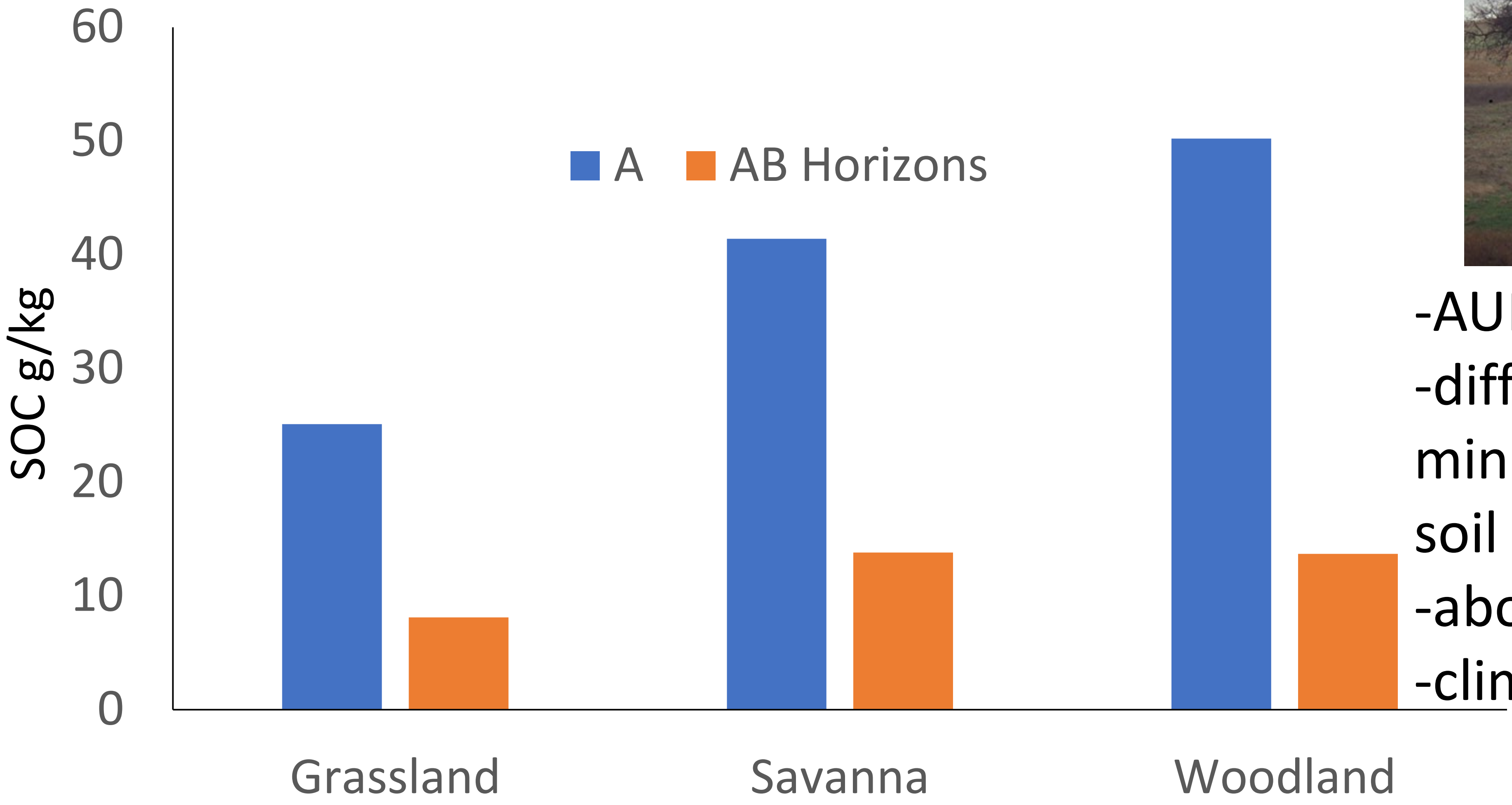
Additional C in soil and biomass 20-yr after restoration in Marin Co. equates to 1,044,399 Mg of CO_2e. Enough to offset emissions from electricity usage of 9,106 homes over 20 yrs.

Channel Floodplain Upperbank





Oak restoration (Silvopasture) may increase SOC



6.8 AUM ha^{-1} 4.2 AUM ha^{-1} 2.8 AUM ha^{-1}

-AUM tradeoff
-difference in C stock is minimal considering whole soil
-above ground C counts
-climate limited

AUM- animal unit month; one 454 kg cow for 30 days

Eastburn et al., 2017

Grazing management does not increase SOC in most CA soils

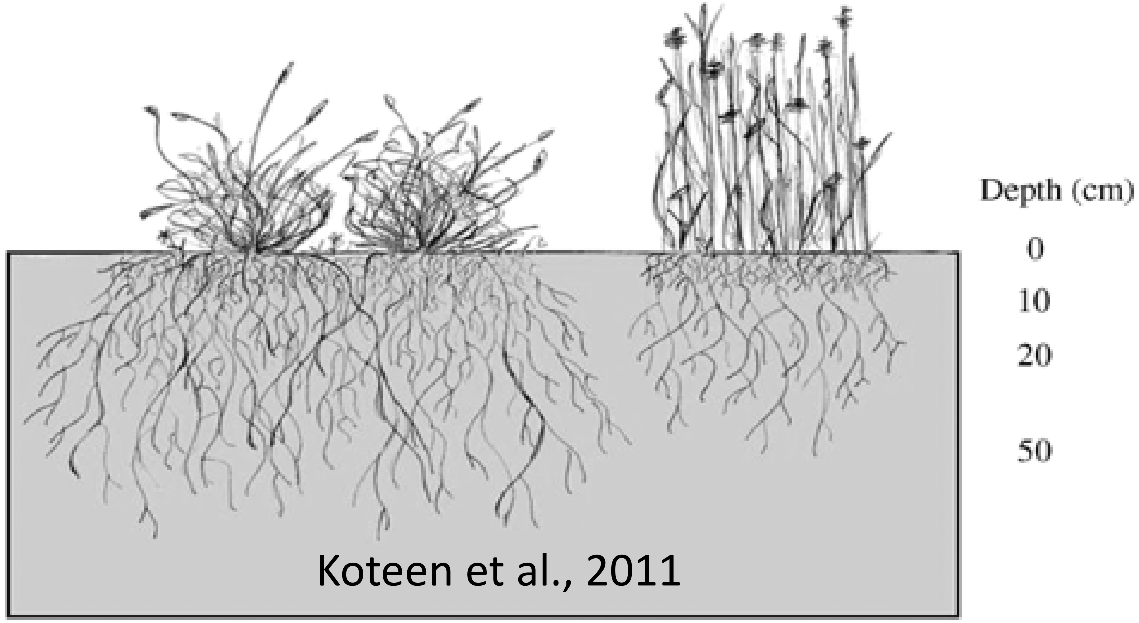
-Most SOM comes from roots

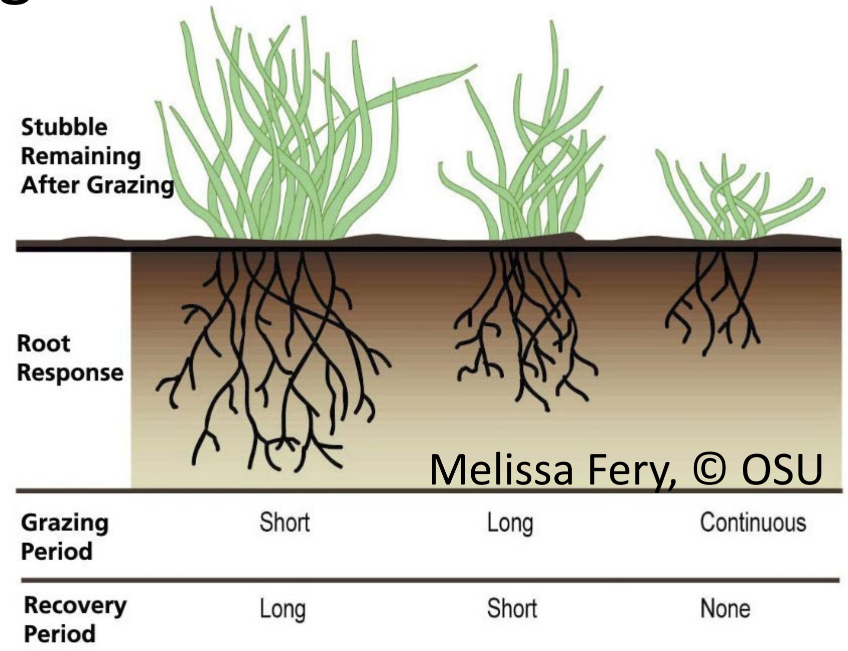
-Annual grass roots are less responsive to grazing

-Prescribed grazing improves productivity of perennial and annual grasses

-Excessive grazing causes erosion, decreases productivity and SOC

-Little evidence exists to indicate grazing management improves SOC in CA, but it can sustain conditions and possibly help restore degraded land.





Alternatives to rangeland exacerbate GHG emissions and decrease SOC stocks

K.W. Tate

Summary:
Can management increase SOC stocks in rangeland soils?

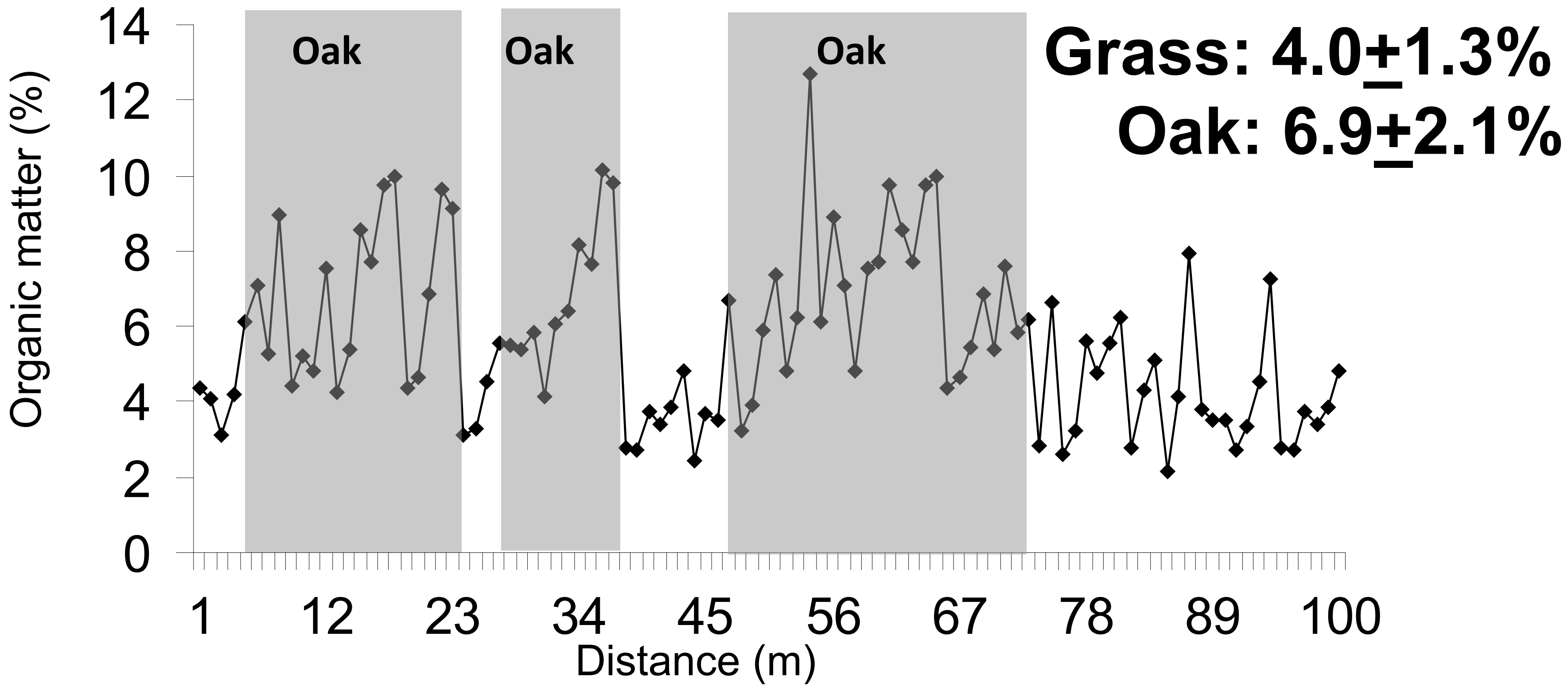
HSP Practice	C Sequestration	Comments
Prescribed Grazing	Probably not	Difficult to study; Very important to protect the existing stock, including soil health & ecosystem.
Riparian Restoration	Yes	Demonstrated SOC increase, but limited extent
Compost	Maybe	No long term studies, only modeling shows positive outcomes; POM not MAOM.
Range planting	Maybe	Difficult to establish, significant soil disturbance; Long term?; More conceivable in pasture.
Tree/shrub/silvopasture	Maybe	Forage production tradeoff; Spatial impact?; Constrained to certain climates; Whole soil?

Delivering multiple ecosystem services with prescribed grazing across the ranch mosaic: stable carbon stocks, food production, biodiversity, clean water, healthy soil

Thank You

Extra slides

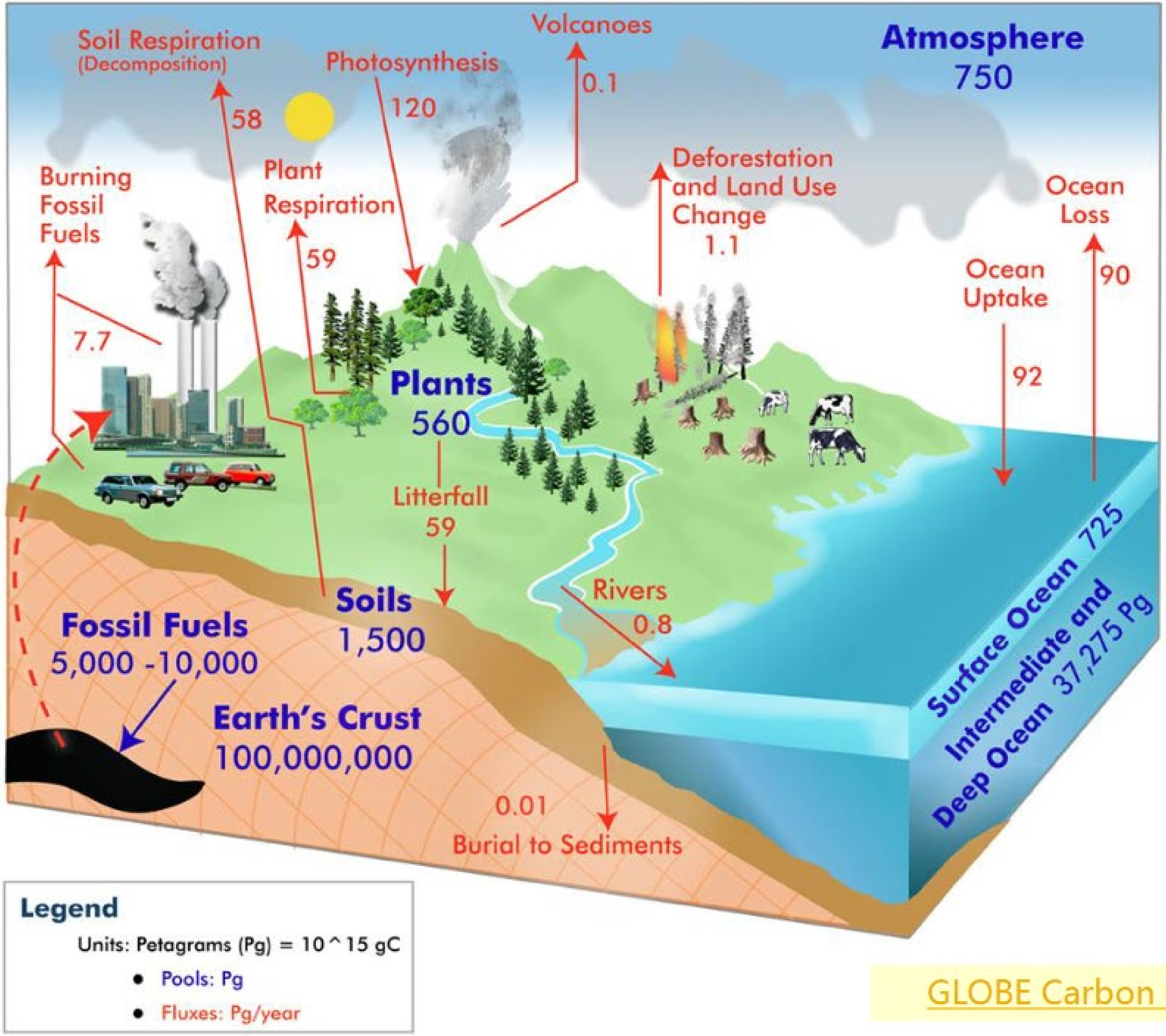
Soil organic carbon (top 5 cm) along a 100-m transect of an oak woodland/annual grassland.



Shaded regions indicate soils under oak canopy, un-shaded = open grassland

IPCC 2013 Carbon Stock Estimates

	Area	Global Carbon Stocks (Gt C)		
Biome	**(10^9 ha)**	**Vegetation**	**Soil**	**Total**
Tropical forests	1.76	212	216	428
Temperate forests	1.04	59	100	159
Boreal forests	1.37	88	471	559
Tropical savannas	2.25	66	264	330
Temperate grasslands	1.25	9	295	304
Deserts and semideserts	4.55	8	191	199
Tundra	0.95	6	121	127
Wetlands	0.35	15	225	240
Croplands	1.6	3	128	131
Total	**15.12**	**466**	**2011**	**2477**



GLOBE Carbon Cycle Project (2010)

Köppen climate types of California