Climate Change Mitigation Potential of California's Rangeland Ecosystems

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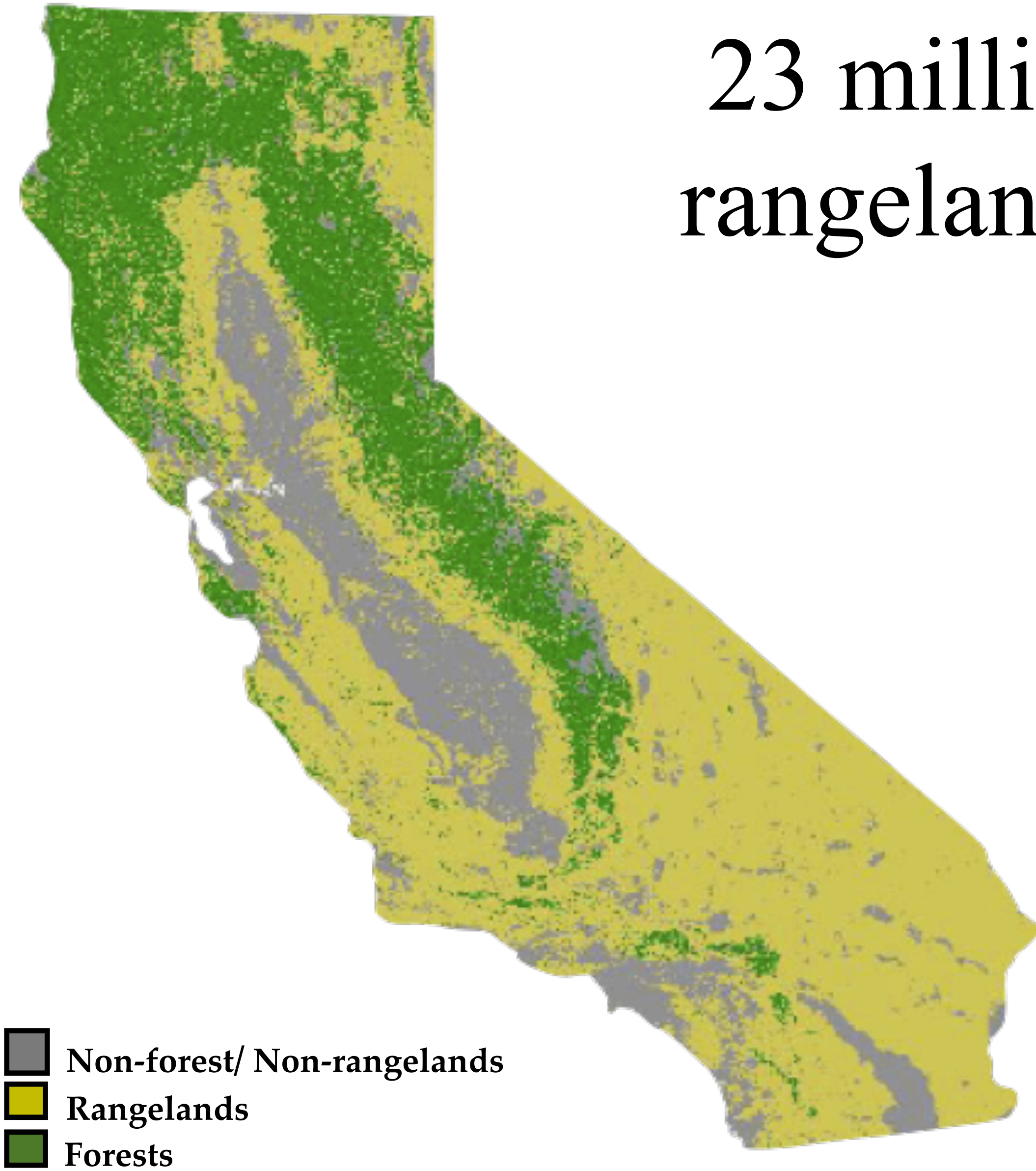
Rangelands are geographically expansive

30 % of global land surface area
30-50 % of US land area
23 million hectares in California

Rangeland systems*: land on which plant cover (climax, sub-climax, or potential) is composed principally of grasses, grass-like plants, forbs or shrubs suitable for grazing and browsing, including both native and introduced plant species (USDA, 2009a).*

LAND COVER SUBCLASSES
MULTI-SOURCE LAND COVER DATA
Compiled for Forest and Range 2002 Assessment
Conifer Forest
Conifer Woodland
Hardwood Woodland
Hardwood Forest
Shrub
Herbaceous
Wetland
Desert Shrub
Desert Woodland
Agriculture
Urban
Barren/Other
Water
PACIFIC OCEAN
NEVADA
ARIZONA
MEXICO
OREGON

There are approximately 23 million hectares of rangeland in California

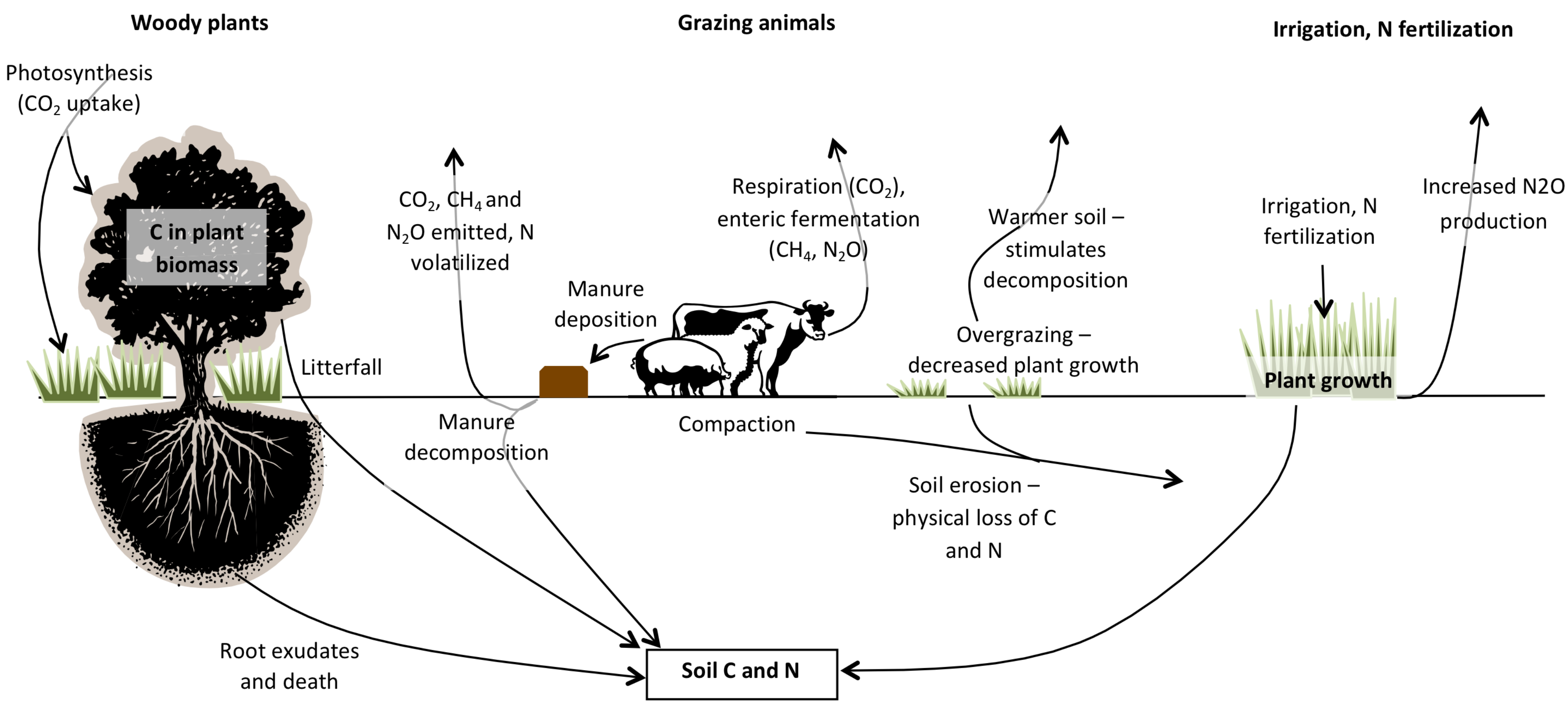


Livestock raised on rangelands are an important contributor to California's agricultural economy

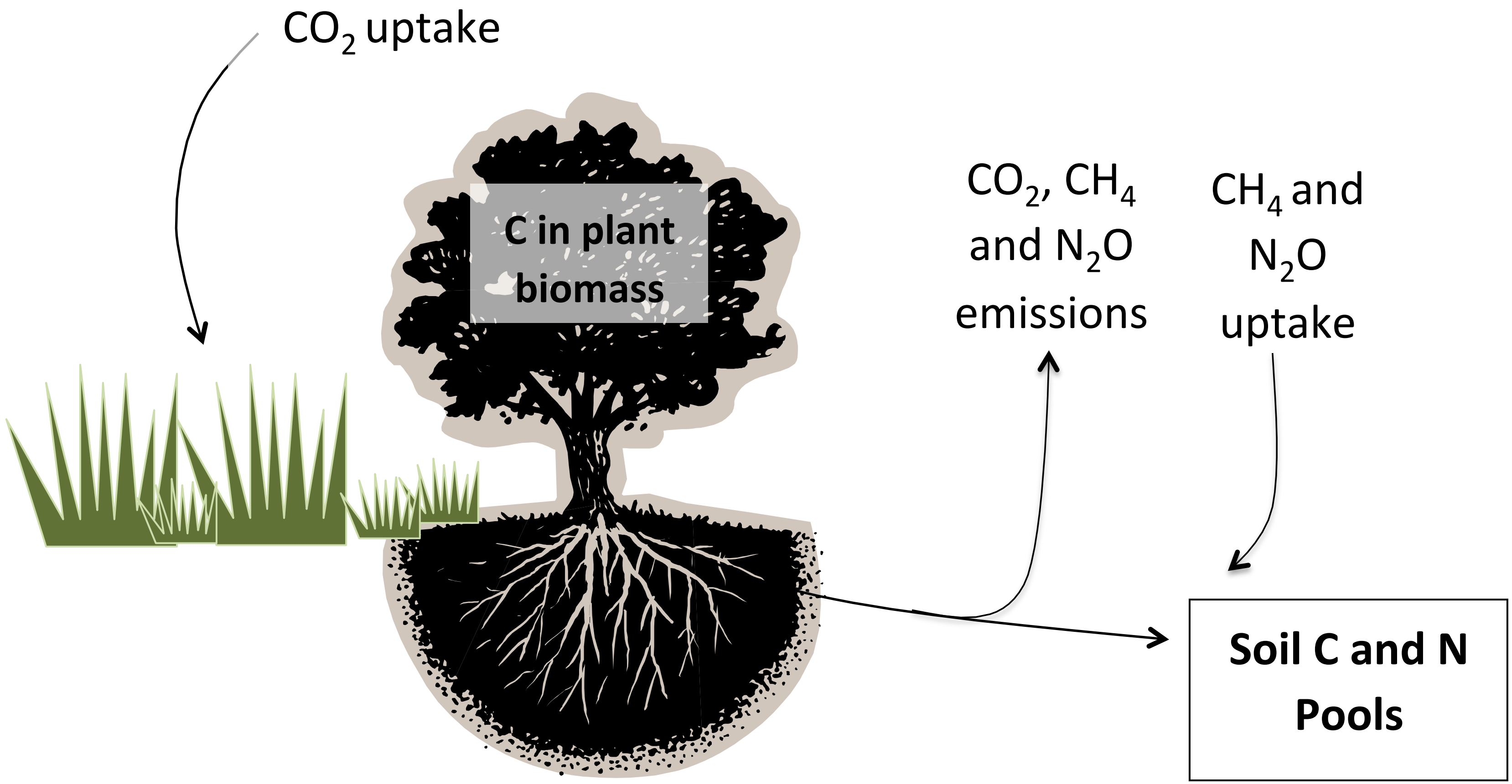
Table 1. ***Economic value of rangeland-supported industries in California (USDA, 2009b).***

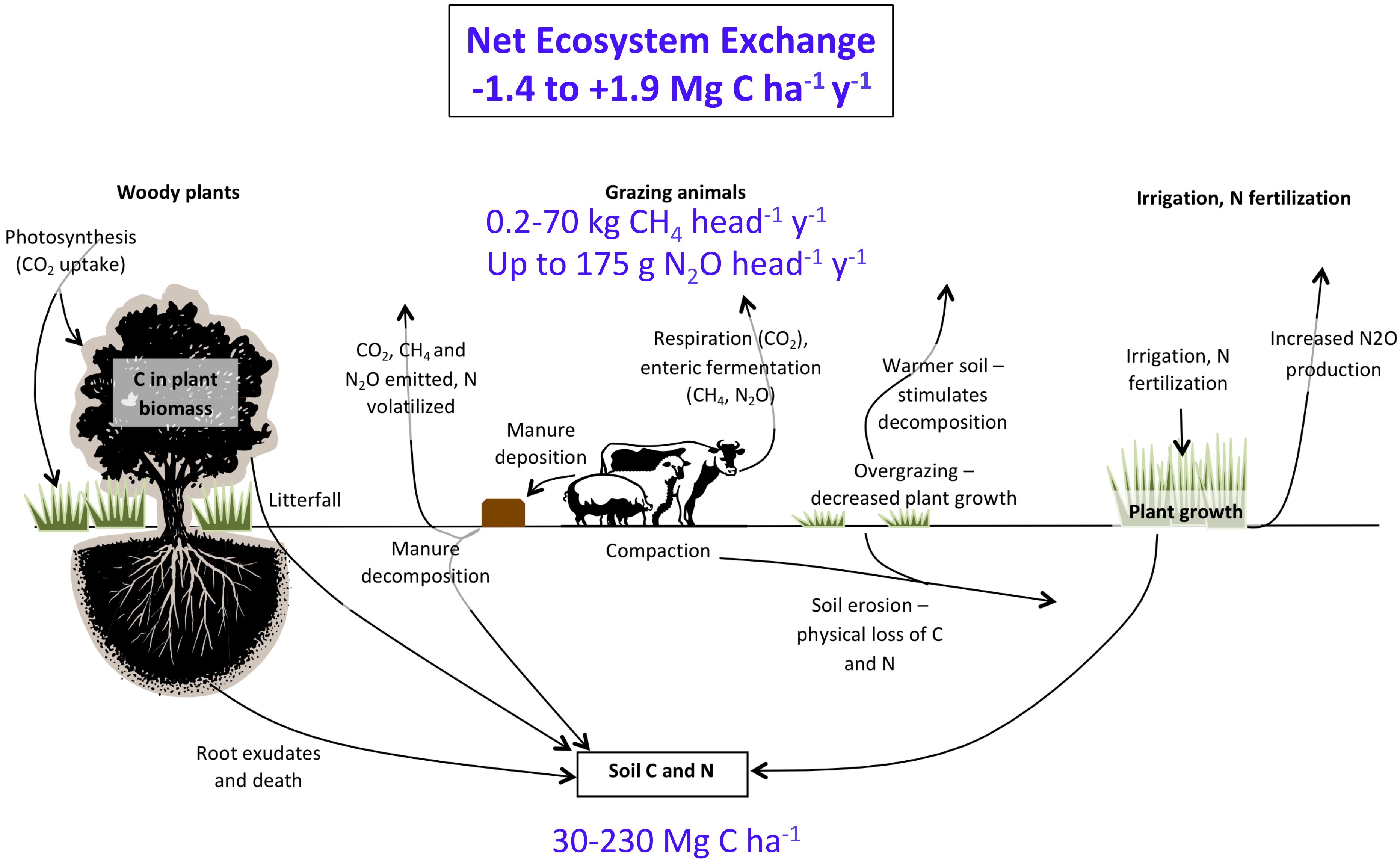
Livestock category	Market value ($1,000)			
	2002	**2007**	**2010**	**2011**
Cattle and calves (excludes dairy products, includes animals on feed)	1,582,334	2,536,571	2,068,412	2,825,125
Sheep, goats, and their products	52,418	71,890		
Horses, ponies, mules, burros, and donkeys	32,397	72,433		

Conceptual model of carbon and greenhouse gas dynamics on California rangelands



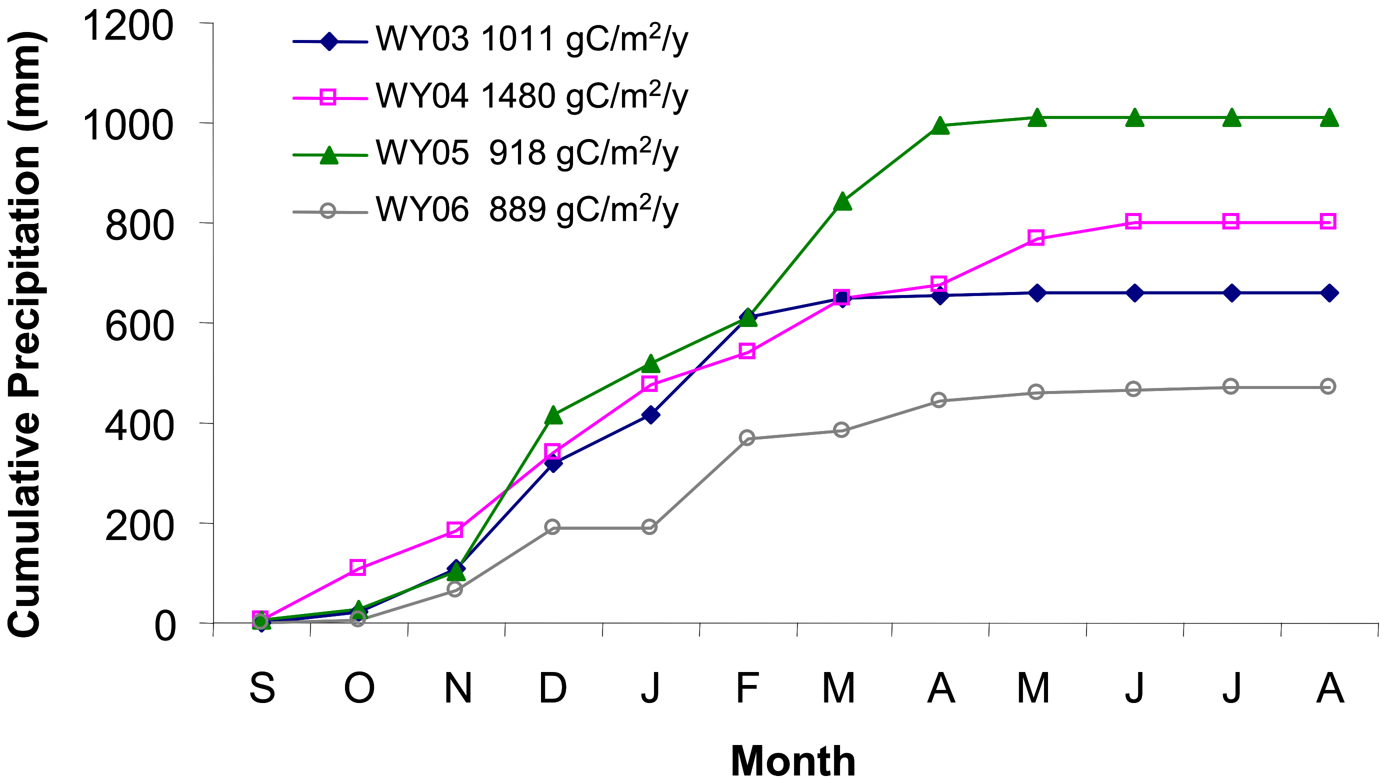
Plant production (a.k.a. forage production) is the primary mechanism for carbon sequestration in rangelands




Net Ecosystem Exchange
-1.4 to +1.9 Mg C ha^{-1} y^{-1}
Woody plants
Photosynthesis (CO_2 uptake)
C in plant biomass
Litterfall
Root exudates and death
Grazing animals
0.2-70 kg CH_4 head^{-1} y^{-1}
Up to 175 g N_2O head^{-1} y^{-1}
CO_2, CH_4 and N_2O emitted, N volatilized
Manure deposition
Manure decomposition
Respiration (CO_2), enteric fermentation (CH_4, N_2O)
Compaction
Warmer soil – stimulates decomposition
Overgrazing – decreased plant growth
Soil erosion – physical loss of C and N
Irrigation, N fertilization
Irrigation, N fertilization
Increased N2O production
Plant growth
Soil C and N
30-230 Mg C ha^{-1}

Annual grasses and sensitive to climate

Rainfall in California is naturally highly variable and is likely to get more variable in the future.

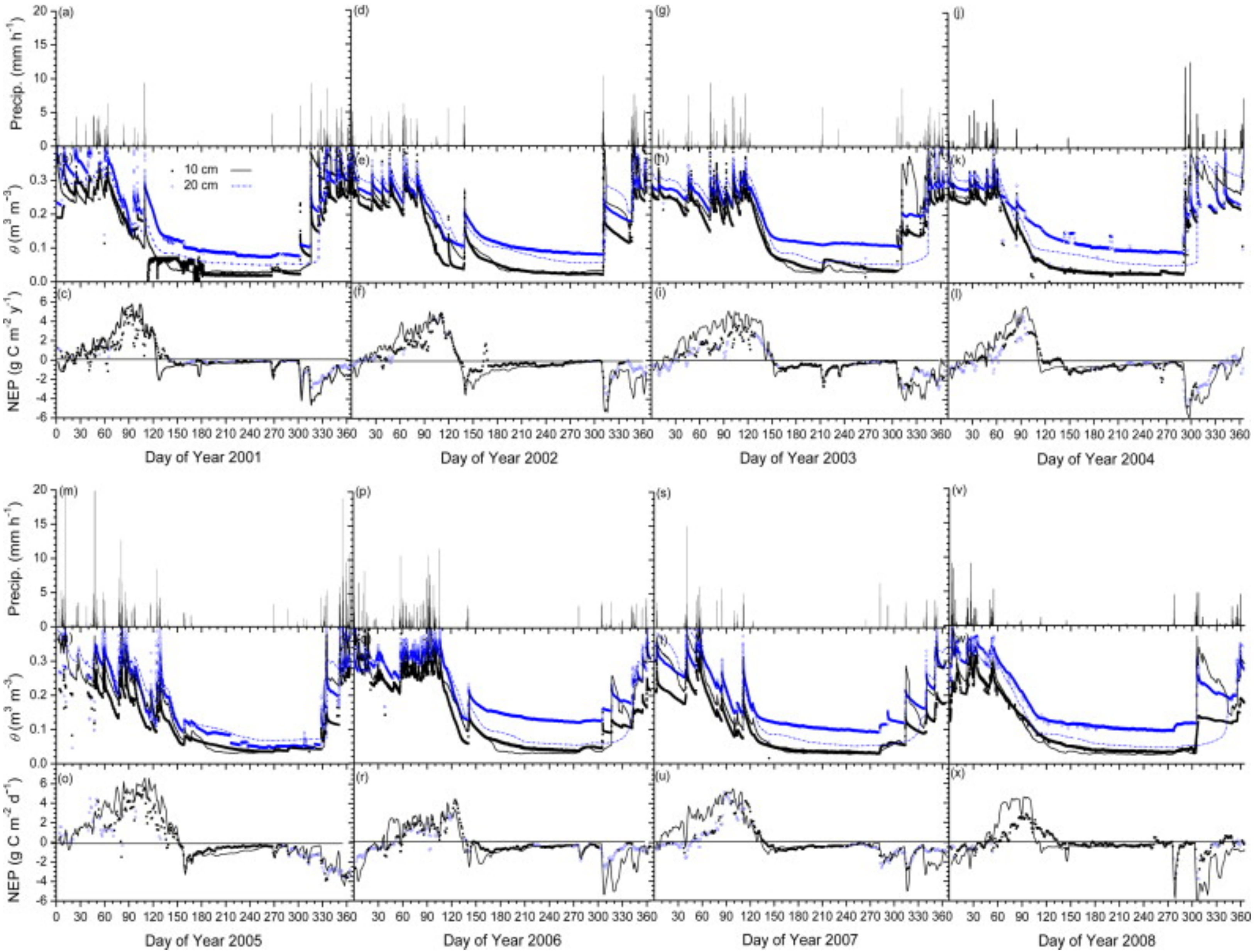


Chou et al. 2008

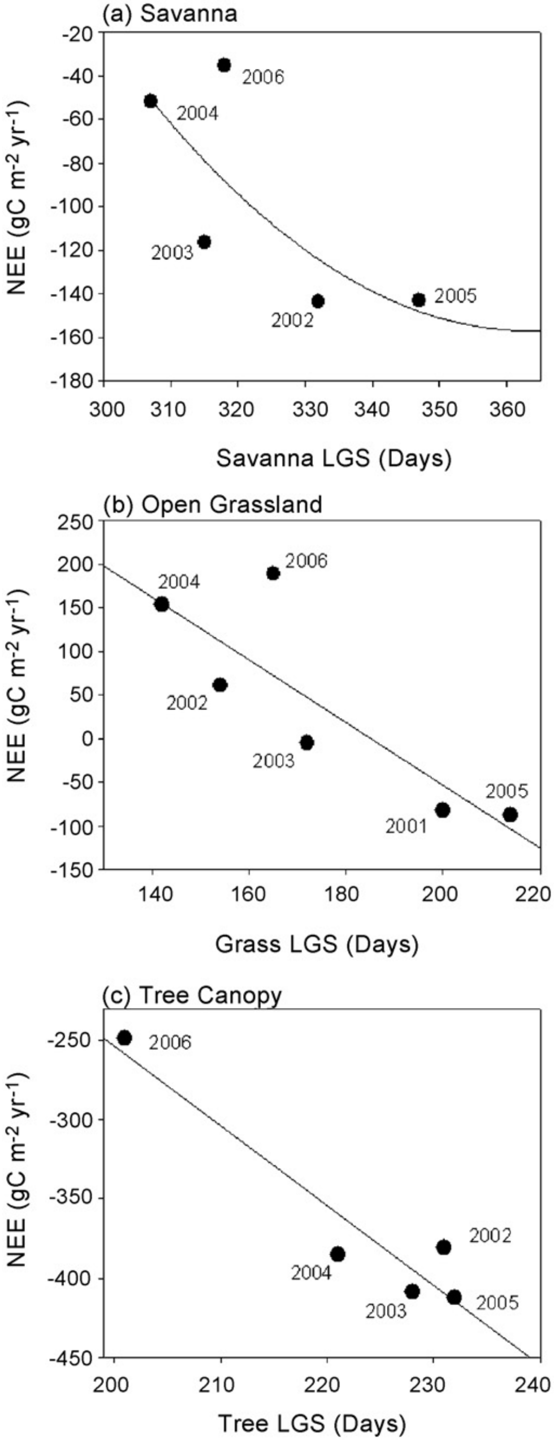
Eddy covariance provides an estimate of net ecosystem exchange of CO_2

Photo credit: D. Baldocchi Lab

These data highlight the sensitivity of rangeland C fluxes to rainfall



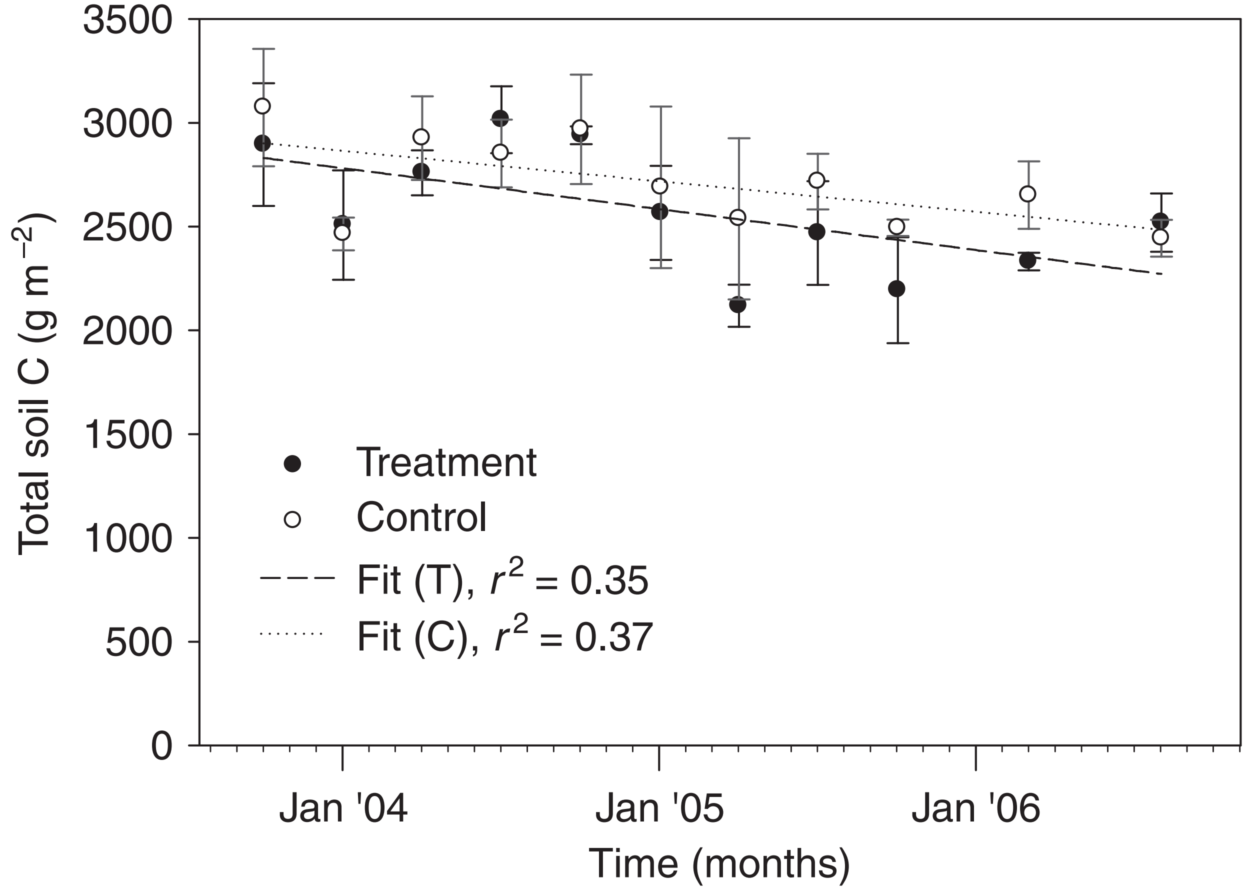
Grant et al. 2012



The more rainfall, the more likely these ecosystems will be a carbon sink.

Ma et al. 2007

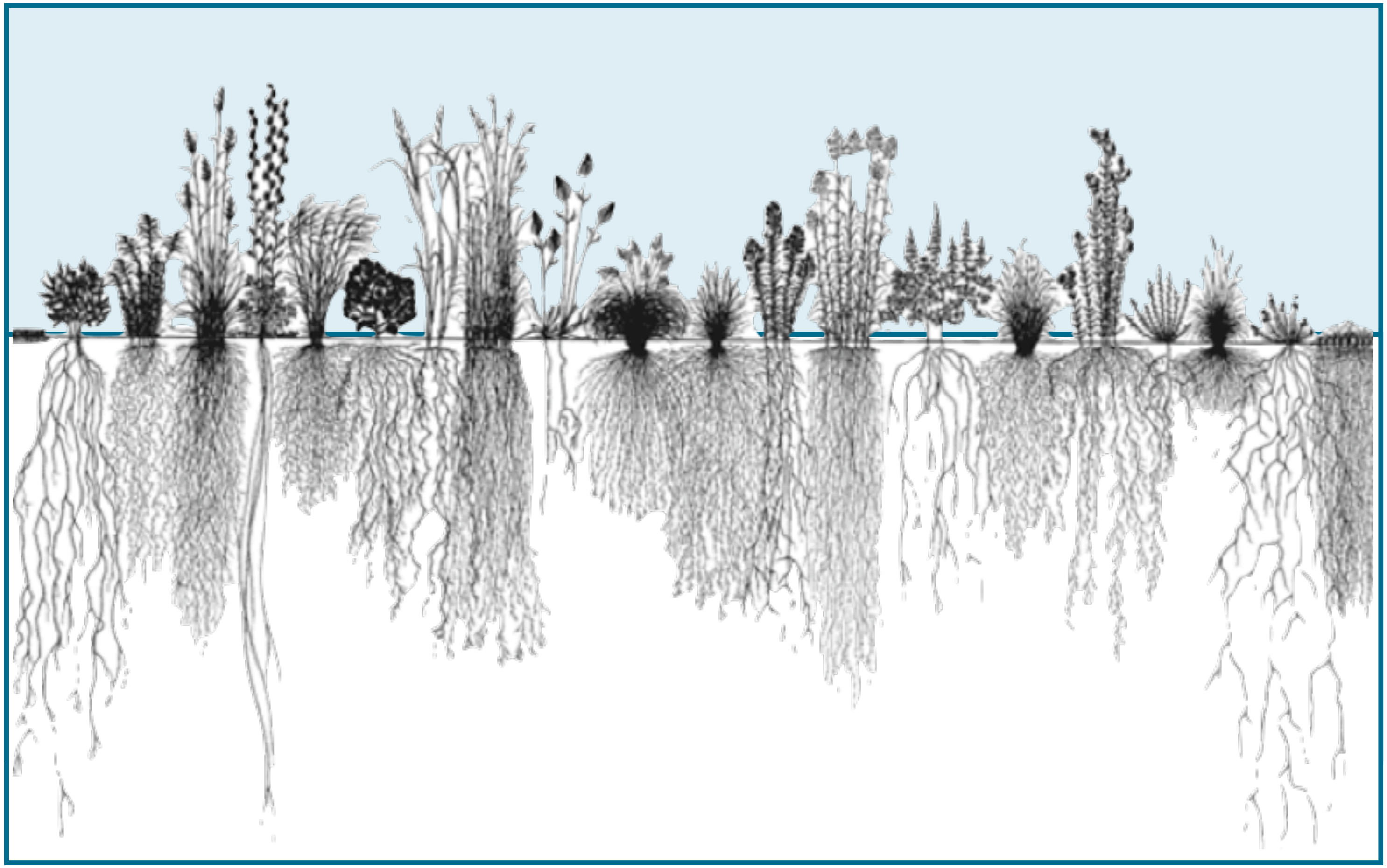
Annual grasslands may be losing carbon under current management and conditions



Chou et al. 2008

Can rangeland management help mitigate climate change?

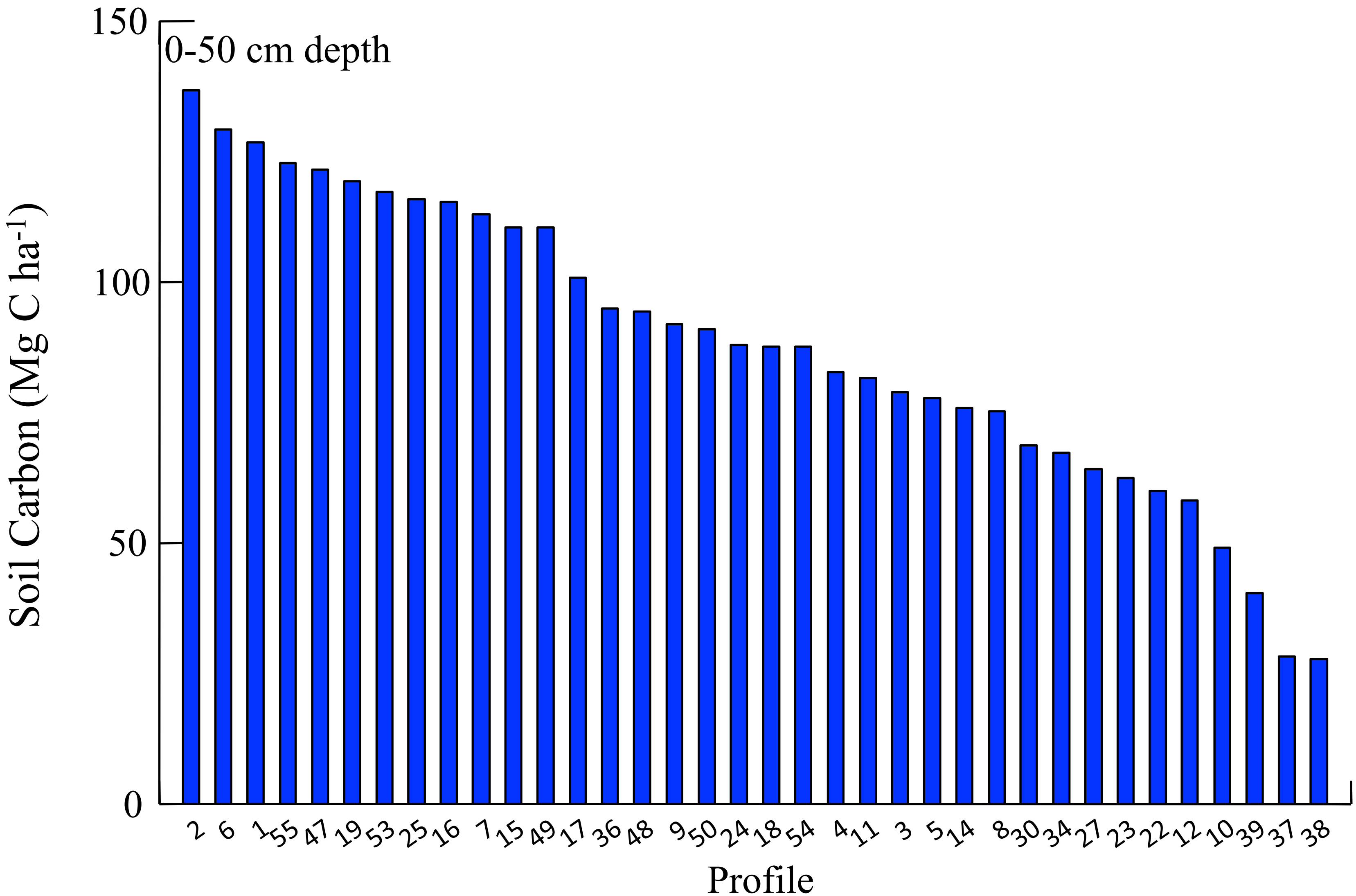
Grasslands store one-third of the world's soil carbon



Grasses allocate a large portion of photosynthate belowground to roots

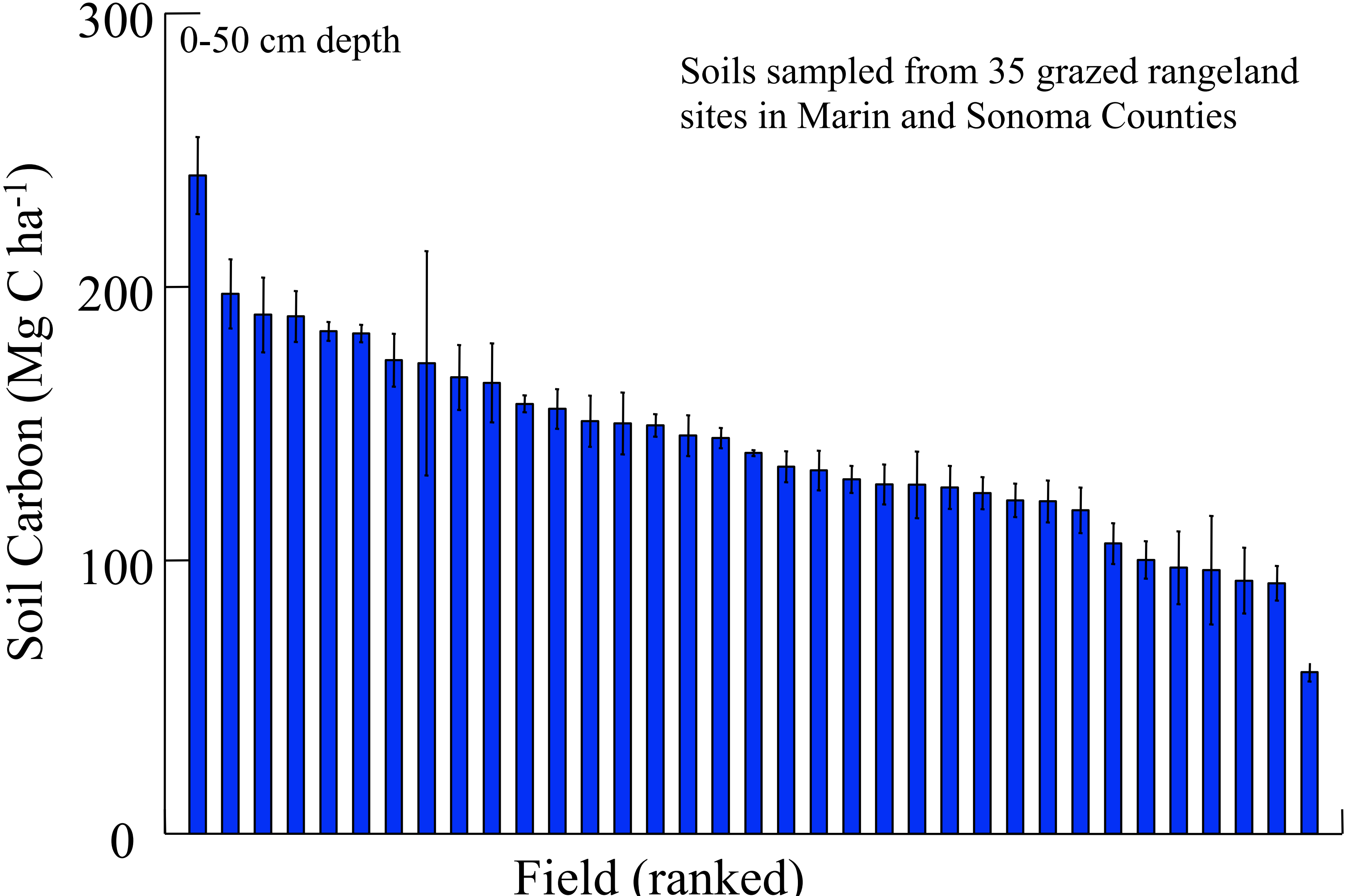
California Rangelands:

Wide range in soil carbon pool size
High soil carbon storage capacity



From Silver et al. 2010

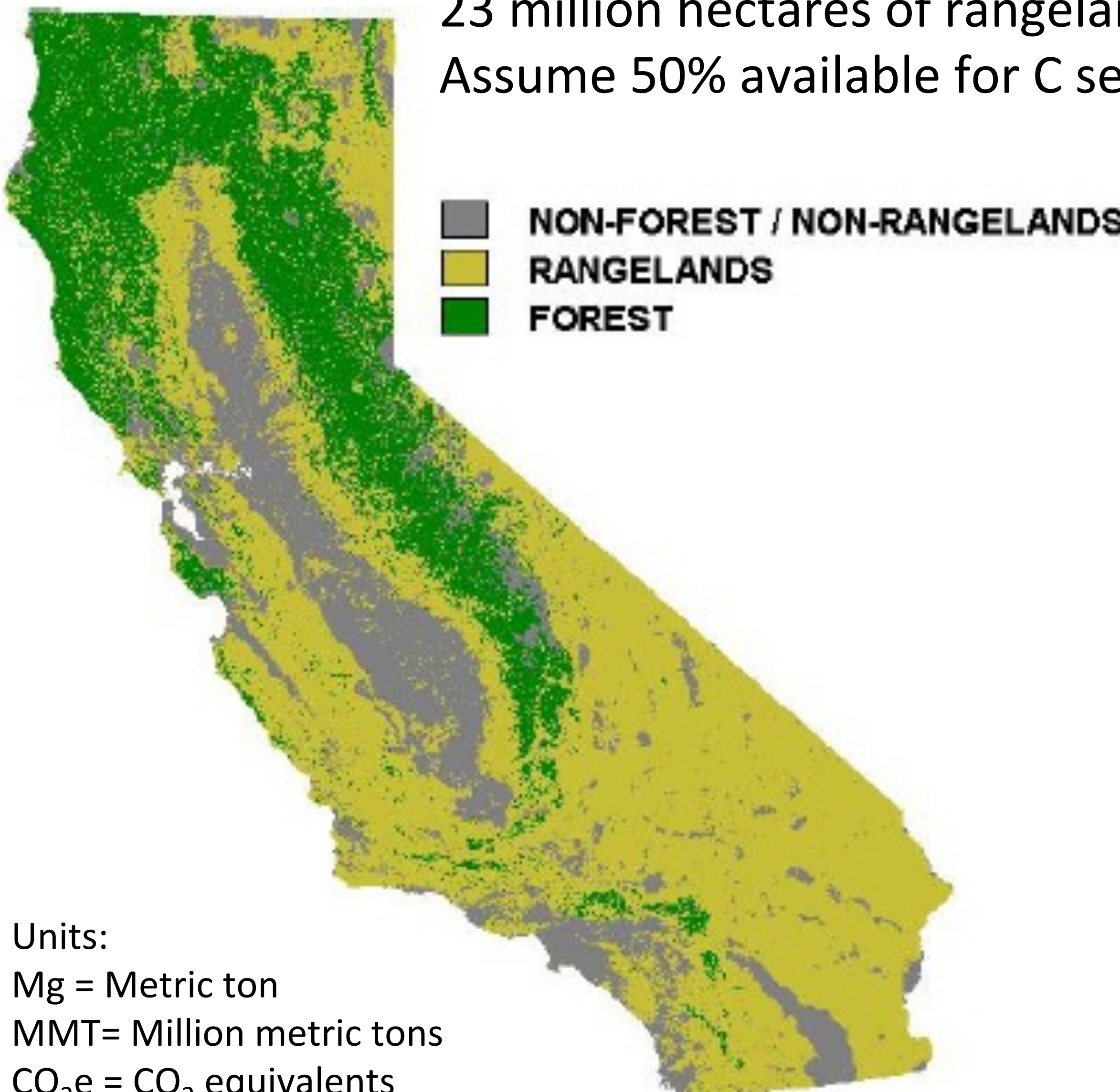
We can detect changes in rangeland soil carbon pools with management



From Silver et al. In prep

California Rangelands and Carbon Sequestration

23 million hectares of rangeland statewide
Assume 50% available for C sequestration projects



Units:
Mg = Metric ton
MMT= Million metric tons
CO_2e = CO_2 equivalents

Emissions data: CA GHG Inventory 2010

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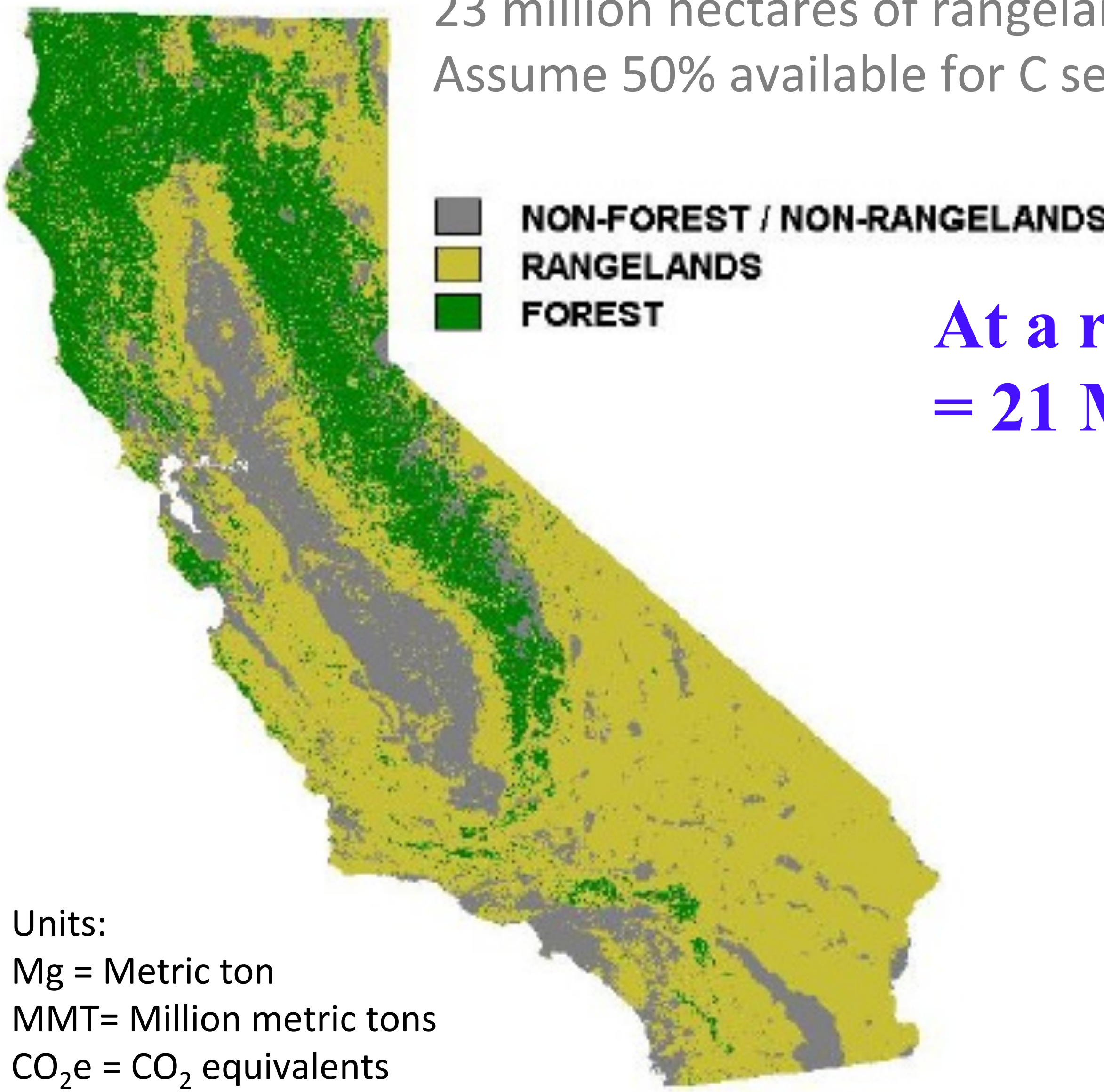

At a rate of 0.5 Mg C ha^{-1} y^{-1} = 21 MMT CO_2e/y

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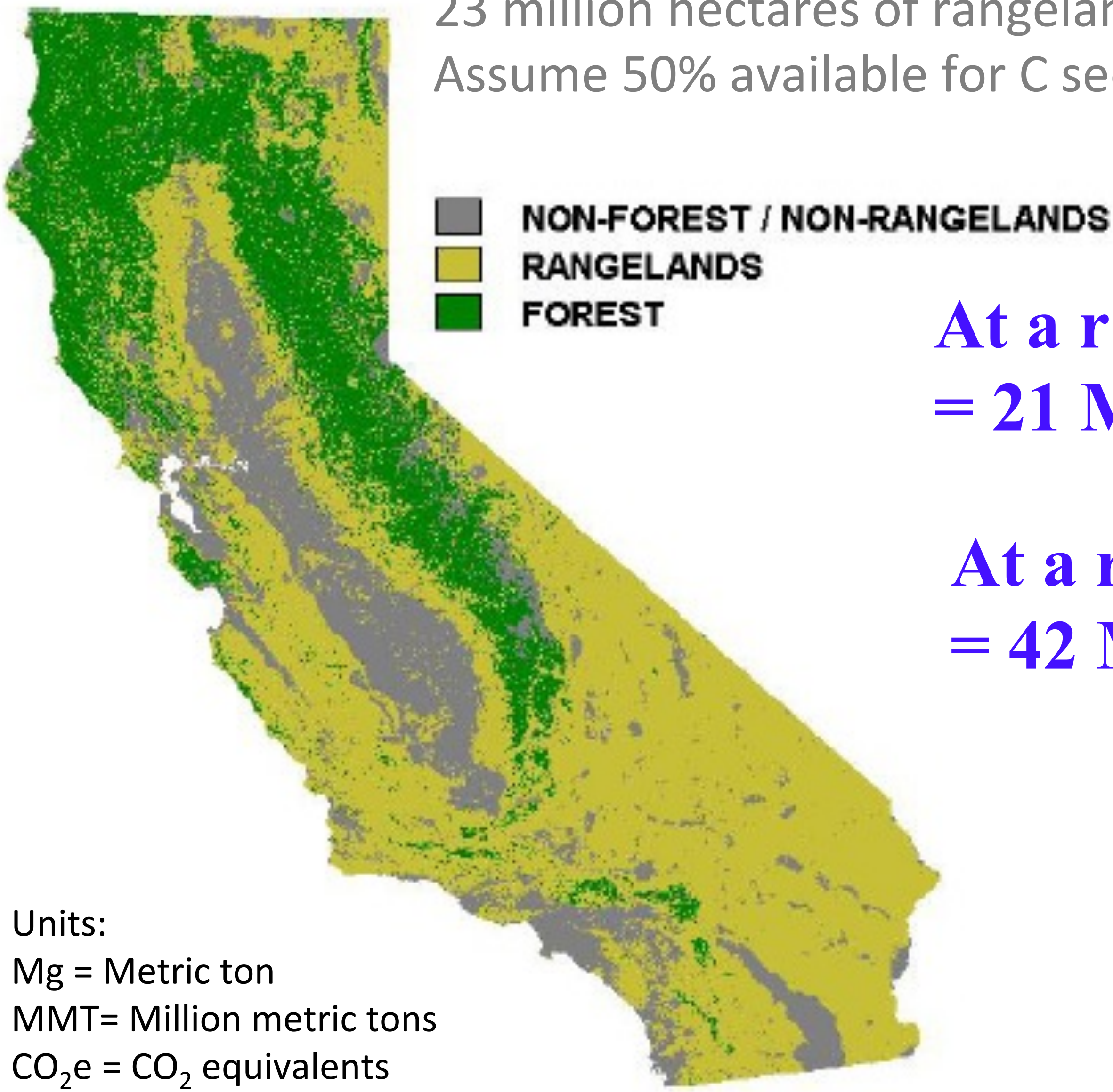

At a rate of 0.5 Mg C ha^{-1} y^{-1}
= 21 MMT CO_2e/y

At a rate of 1 Mg C ha^{-1} y^{-1}
= 42 MMT CO_2e/y

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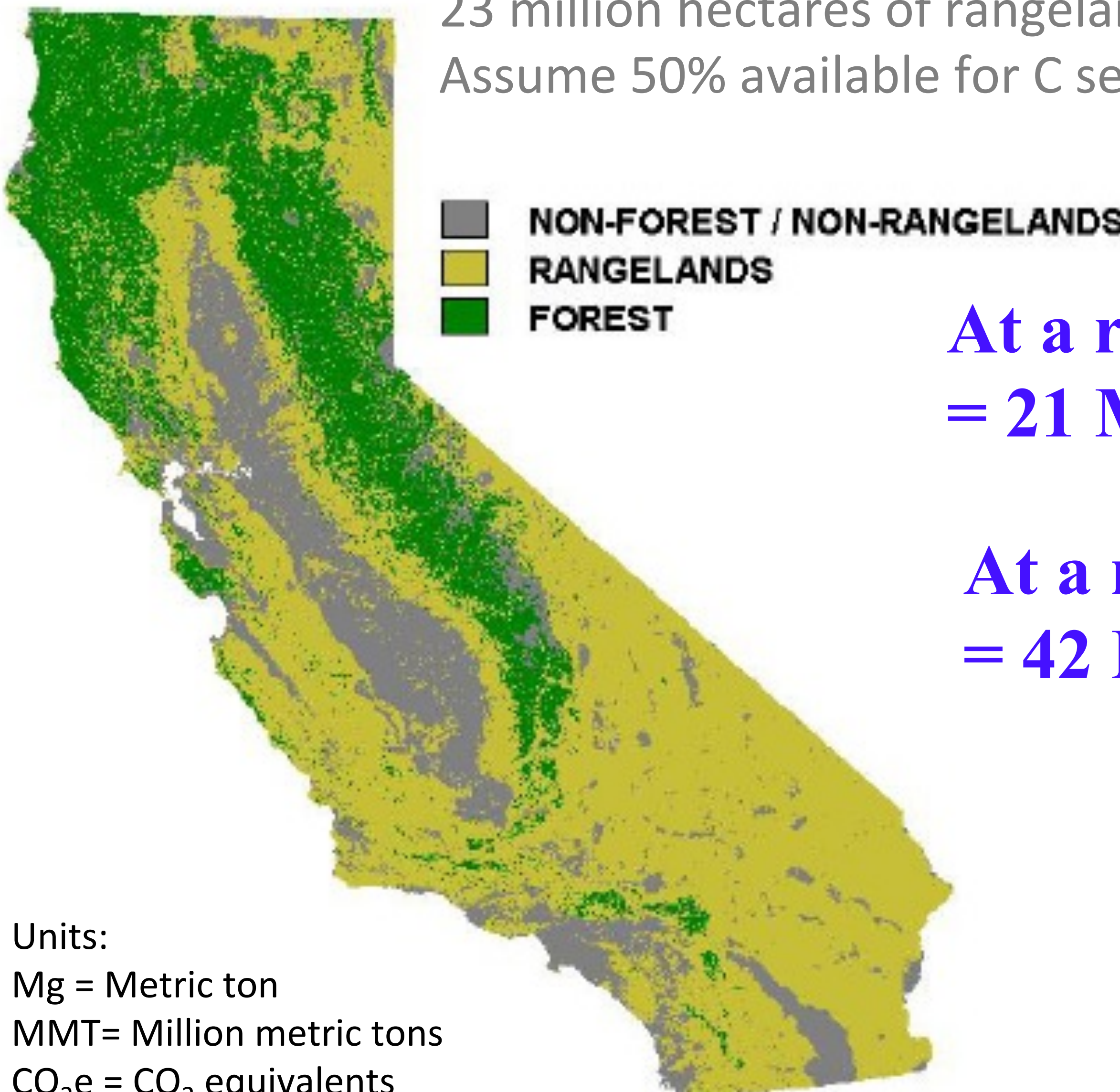

At a rate of 0.5 Mg C ha^{-1} y^{-1} = 21 MMT CO_2e y^{-1}

At a rate of 1 Mg C ha^{-1} y^{-1} = 42 MMT CO_2e y^{-1}

- Livestock
  ~ 15 MMT CO_2e y^{-1}
- Commercial/residential
  ~ 42 MMT CO_2e y^{-1}
- Electrical generation
  ~112 MMT CO_2e y^{-1}

Emissions data: CA GHG Inventory 2010

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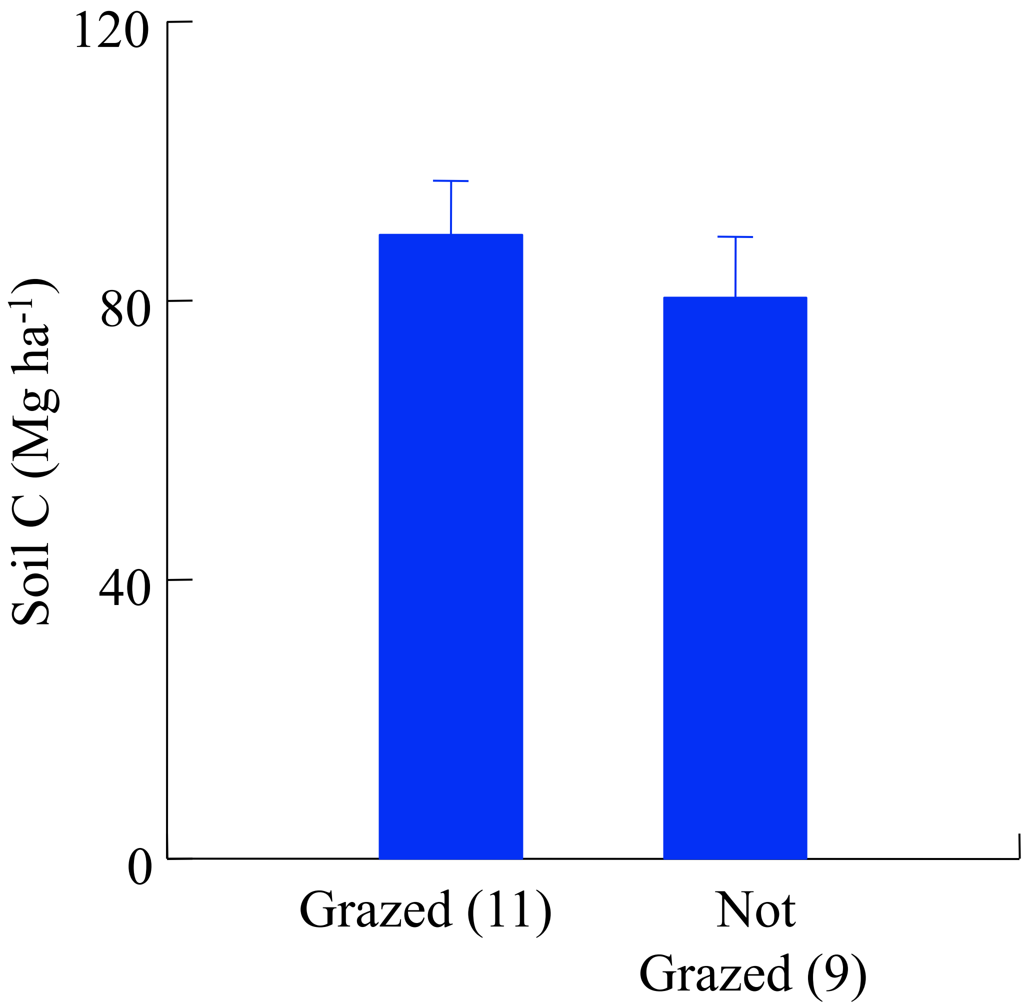
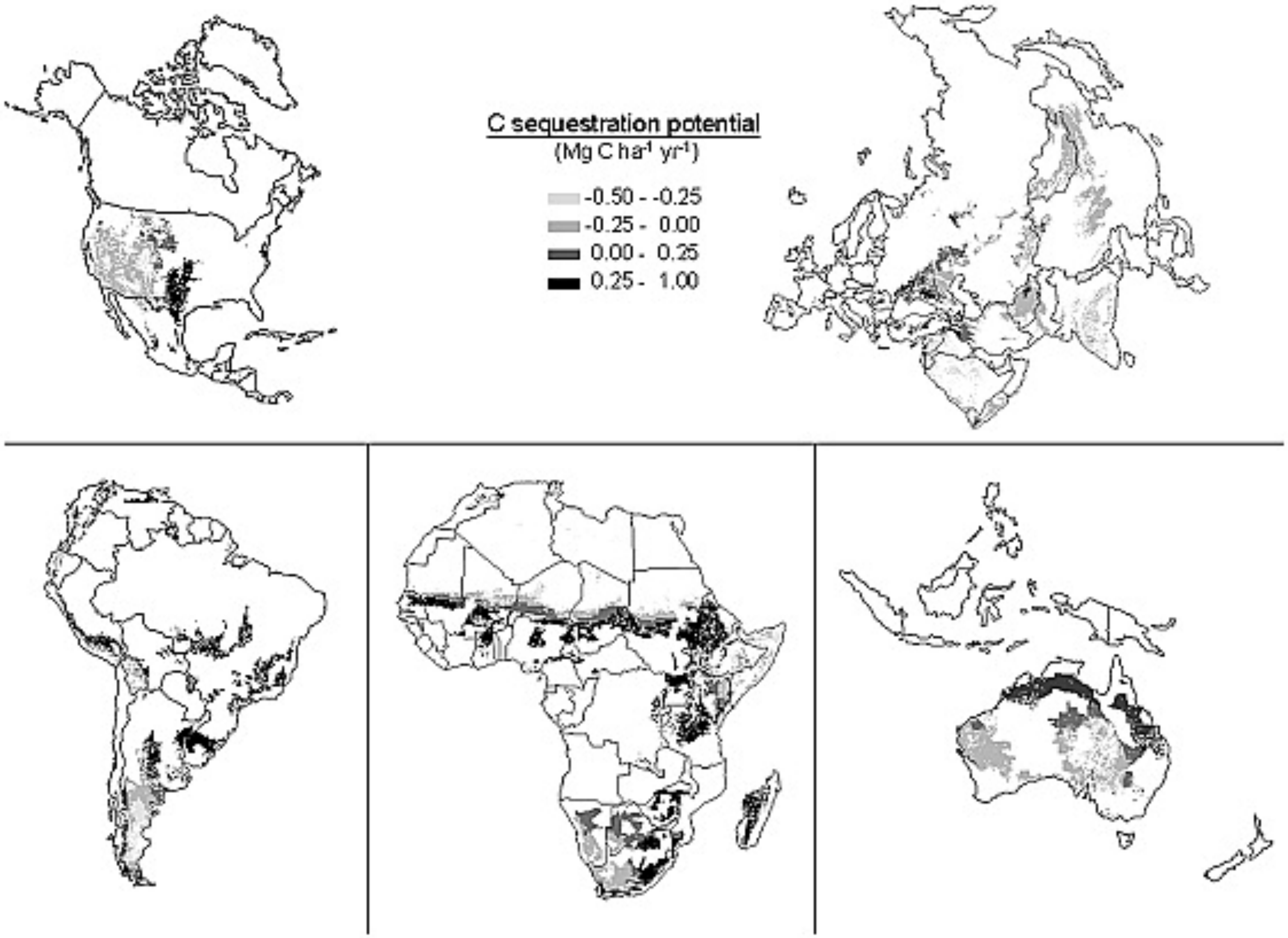
The potential for grazing to increase carbon sequestration

Rangeland soils appear to be adapted to grazing (not overgrazing)



Silver et al 2010

Improved grazing practices can sequester soil carbon



Conant and Paustian 2002

Carbon sequestration potential from improved grazing practices:

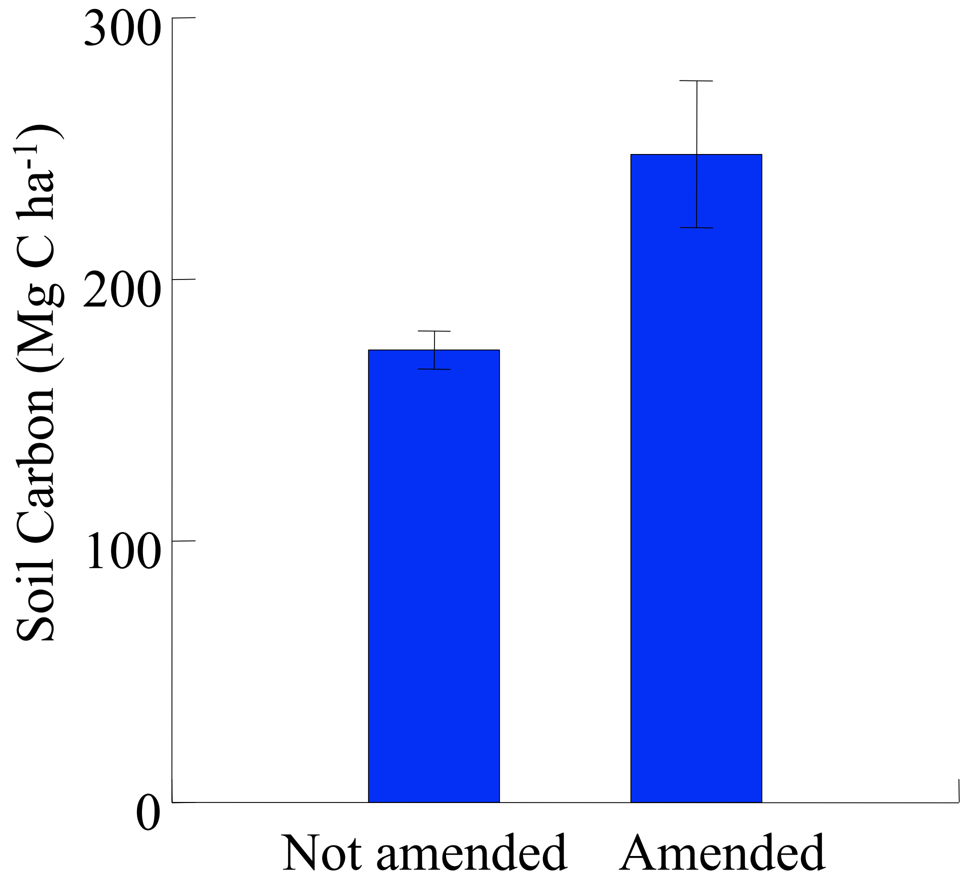
1.3 to 3.2 Mg CO_2e ha^{-1} y^{-1} (Eagle et al. 2011)

Scaled to 50% of California rangelands: 15-37 Tg CO_2e y^{-1}

1 Mg C ha^{-1} y^{-1} (Conant et al. 2001)

S***caled to 50% of California rangelands: 42 Tg CO_2e y^{-1}***

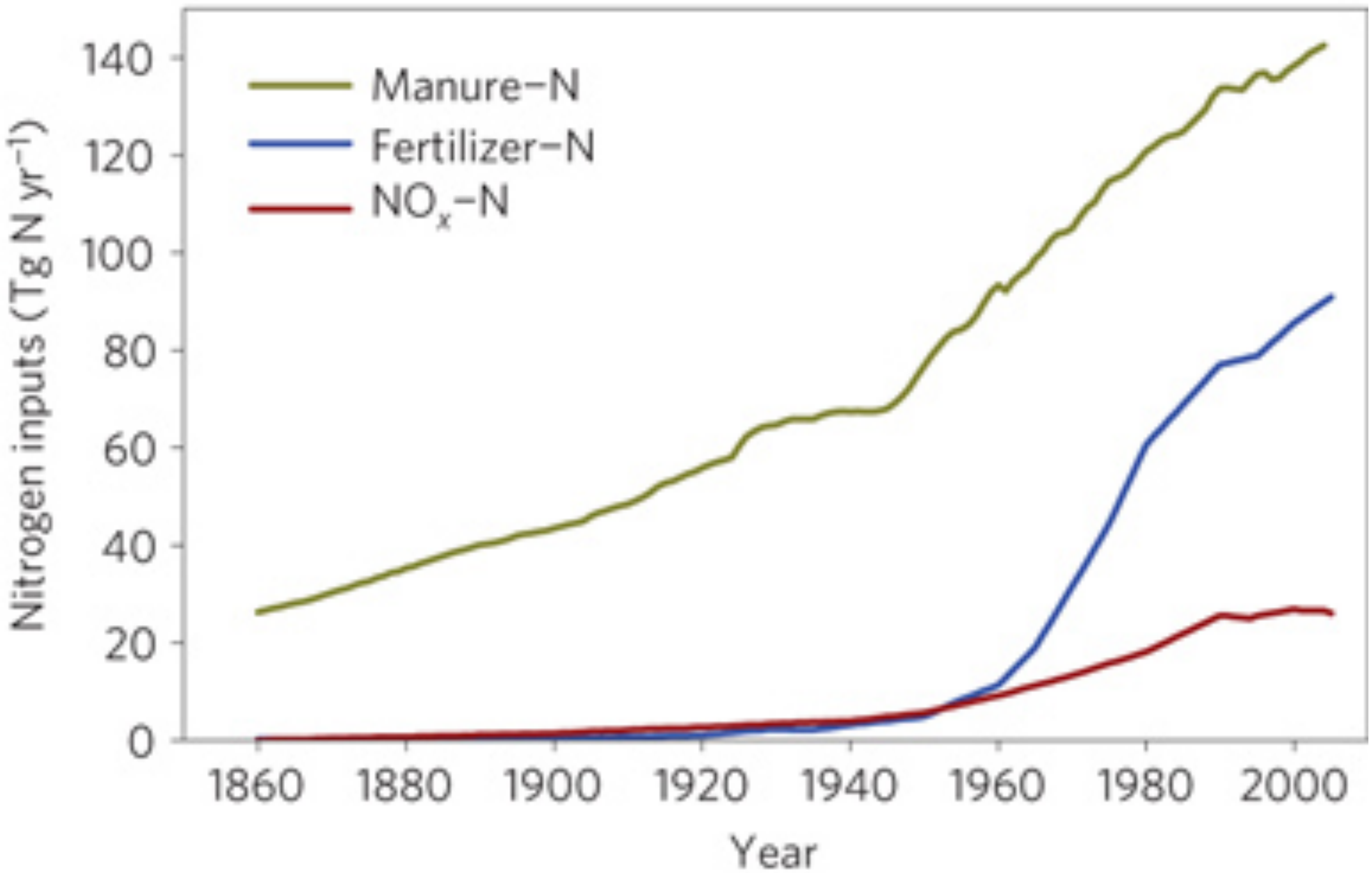
Organic matter amendments increased soil carbon by 50 Mg C ha^{-1} in the top meter of soil



Analysis of 35 fields (1050 samples) from Marin and Sonoma Counties

From Silver et al. In prep

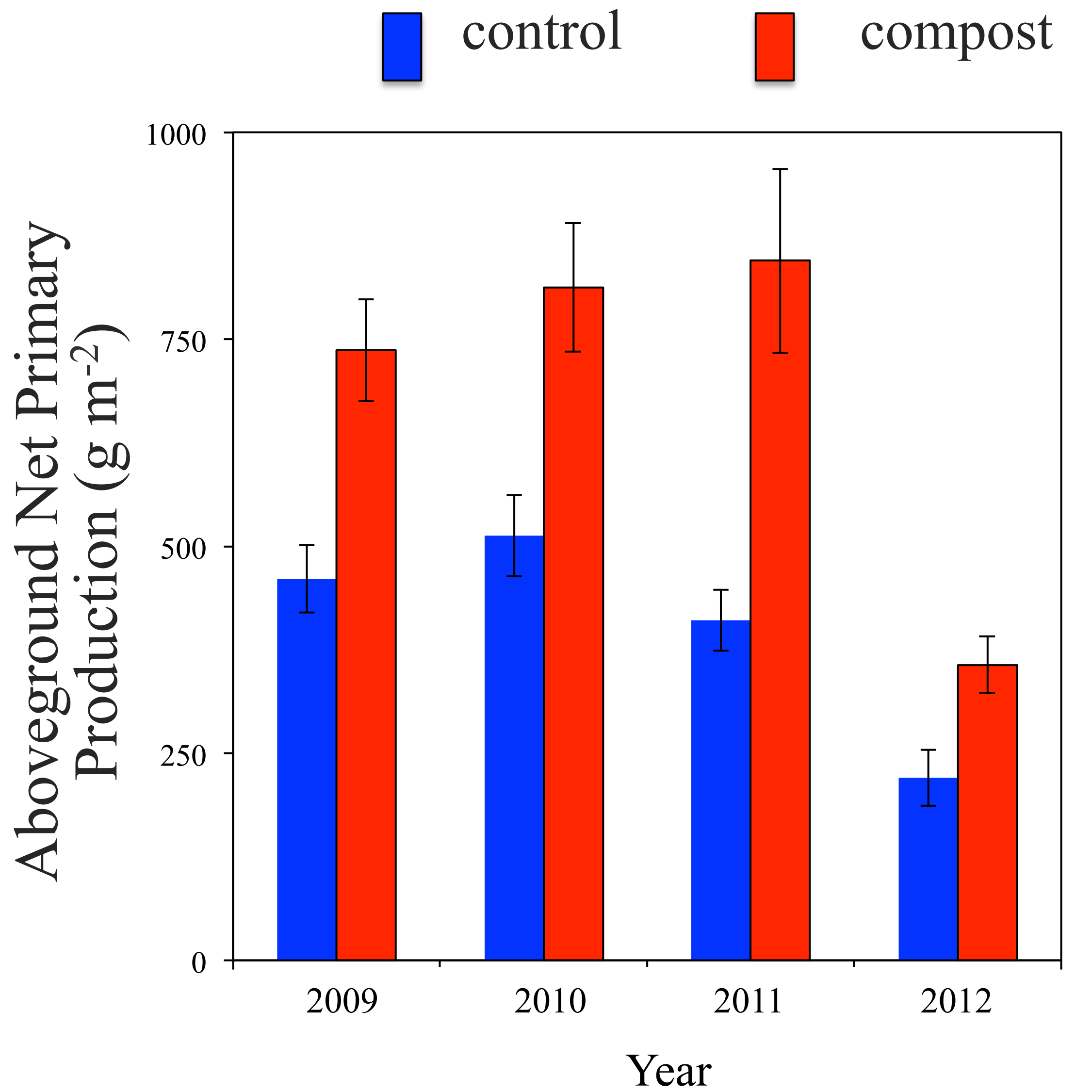
Manure applications have the potential to increase nitrous oxide emissions



Davidson 2009

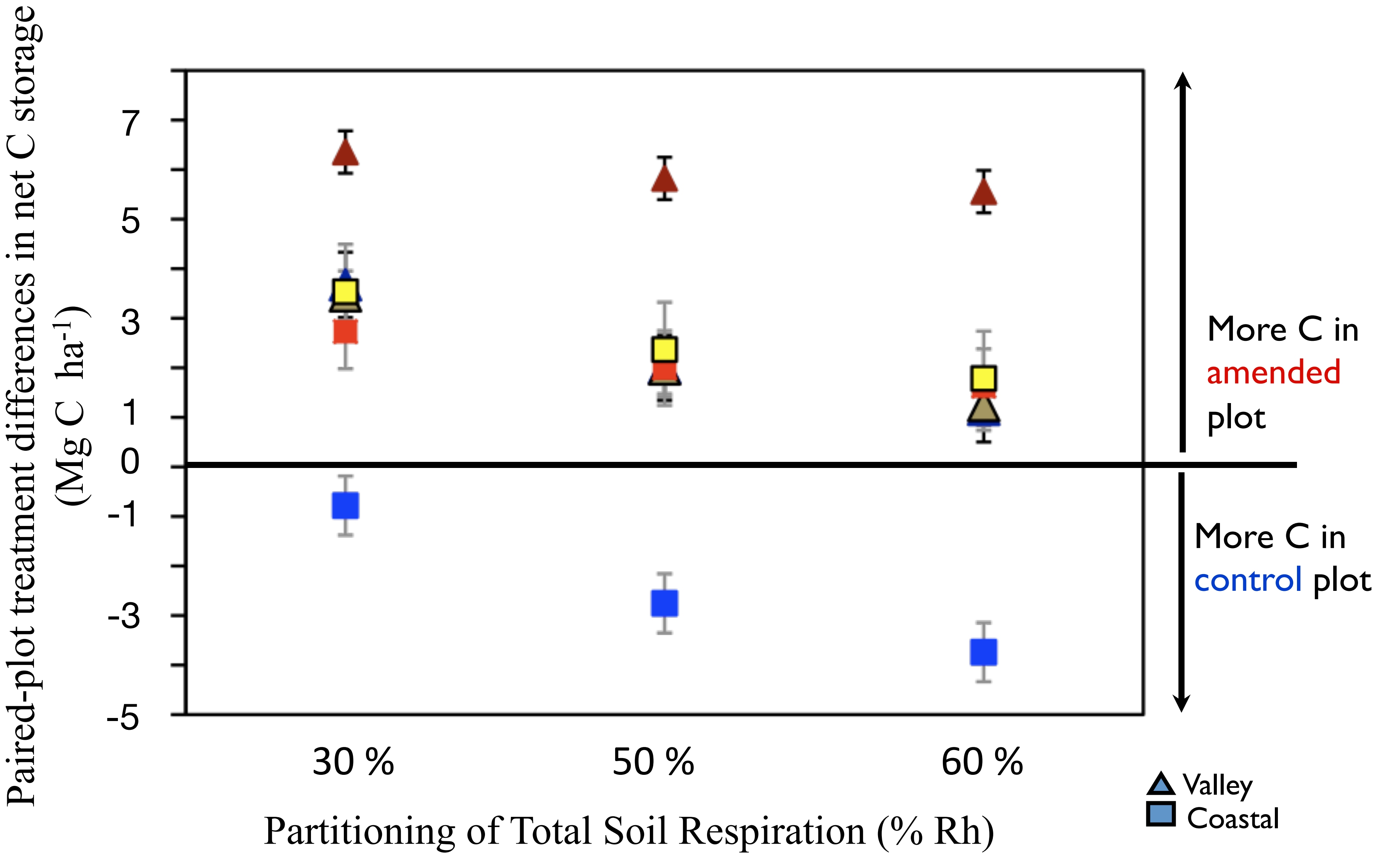
Organic matter amendments to rangelands can increase carbon sequestration

Plant production (aka forage) has increased every year following a one time compost application



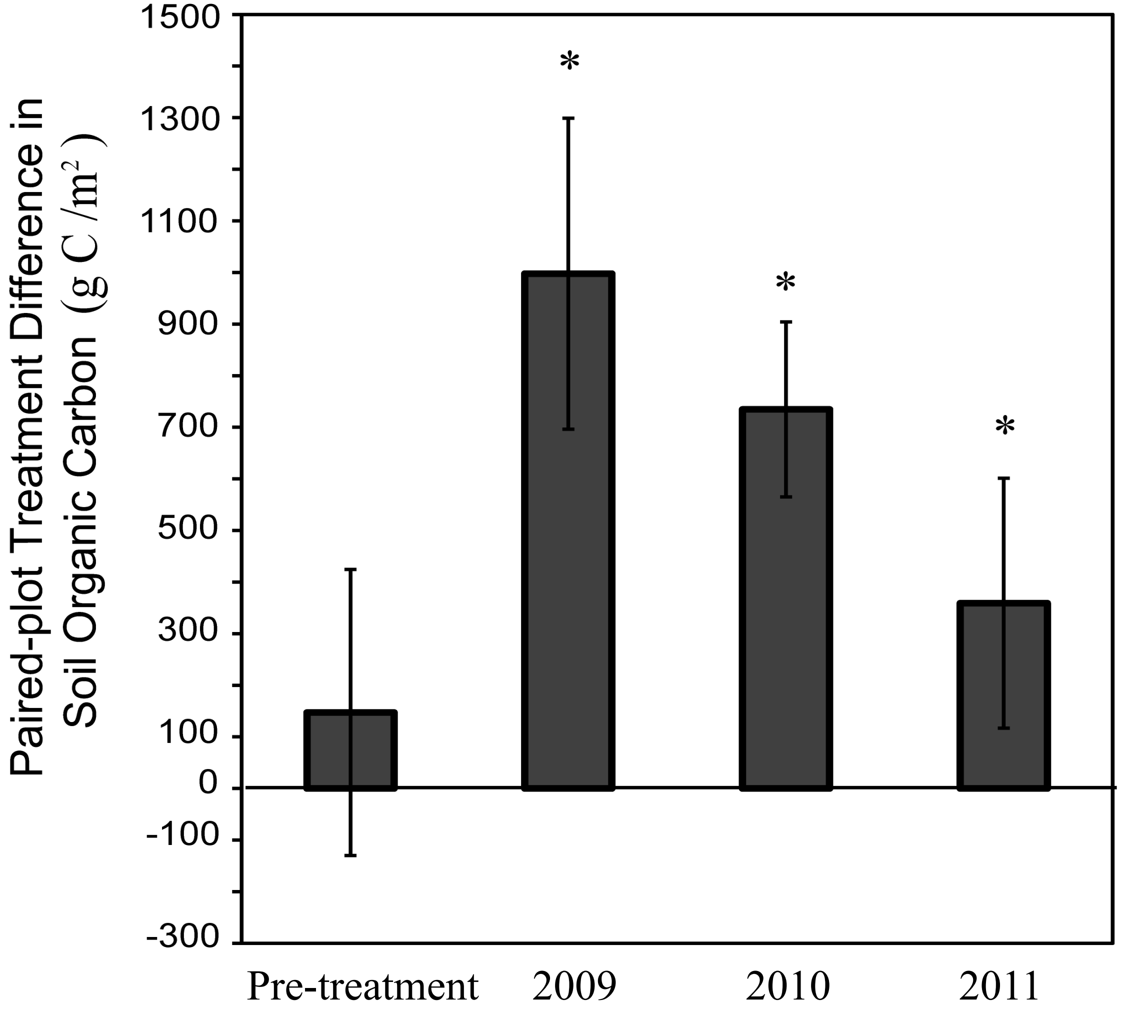
Ryals and Silver 2012, Ryals and Silver in prep.

Net Ecosystem Production
Compost increase net C storage by 0.5 to 1.2 Mg C ha^{-1} y^{-1}



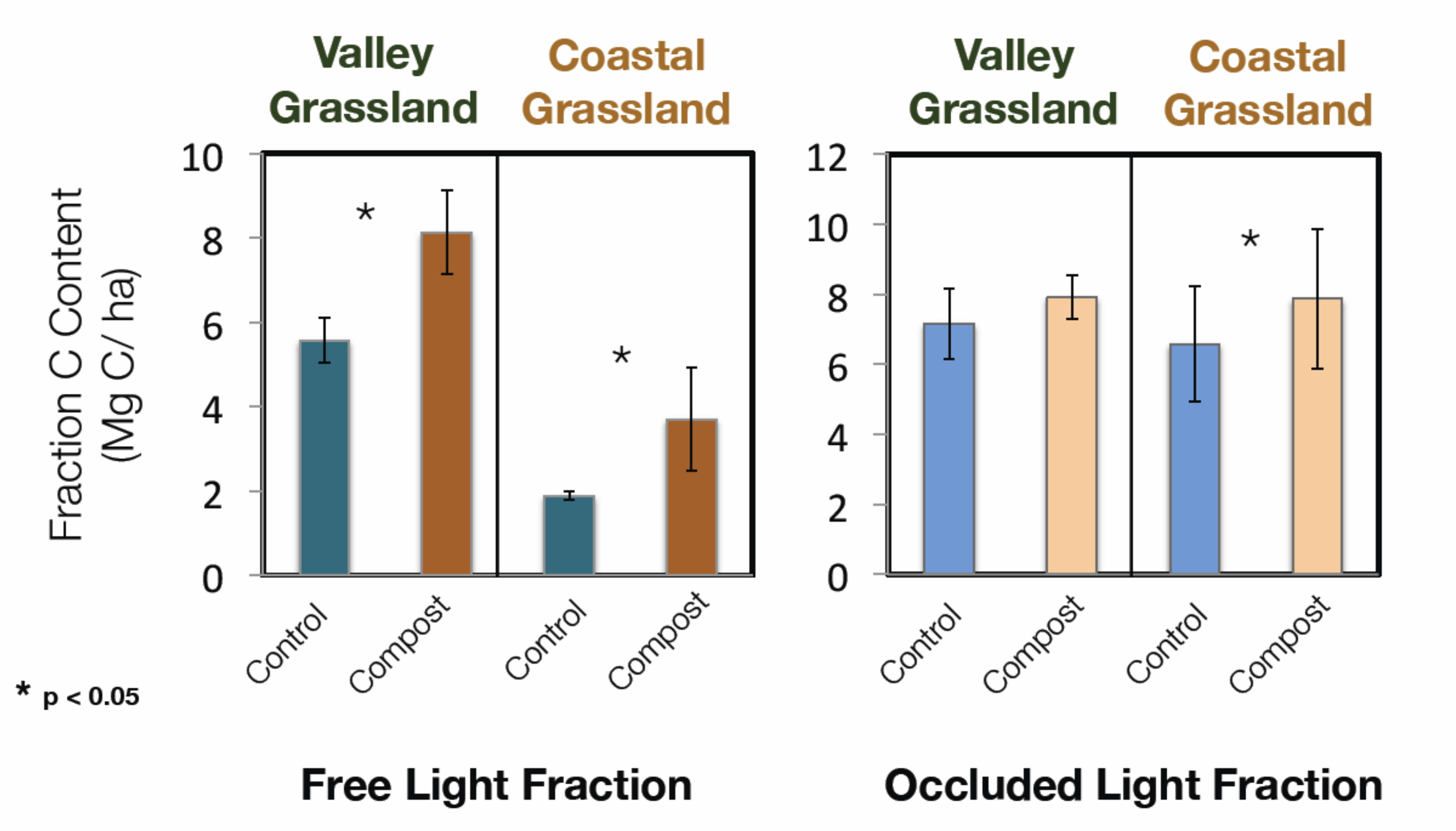
Ryals and Silver 2012 Ecological Application

Organic matter amendments increase soil C pools



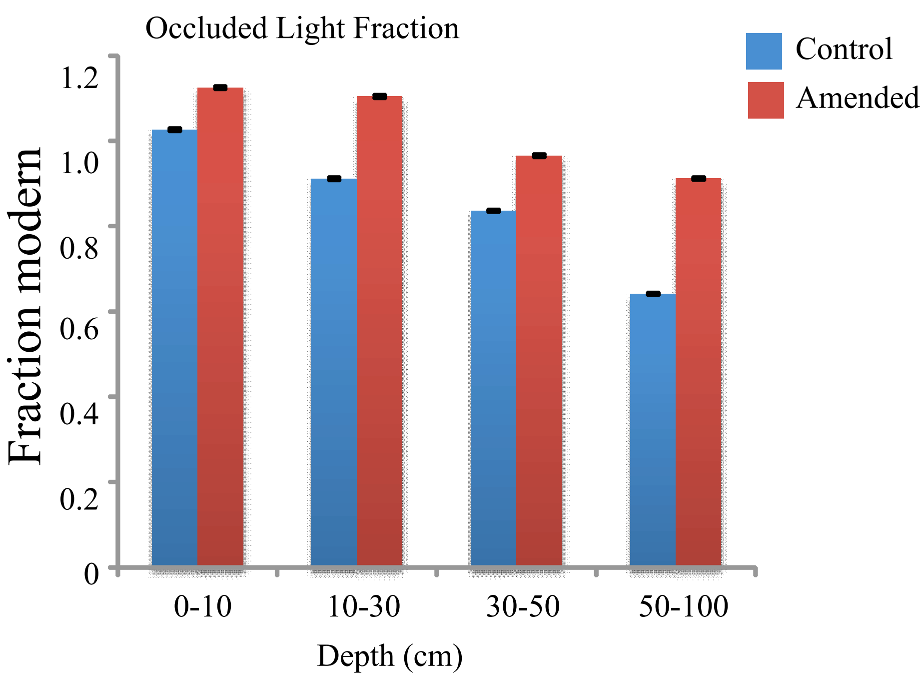
Ryals et al. in review

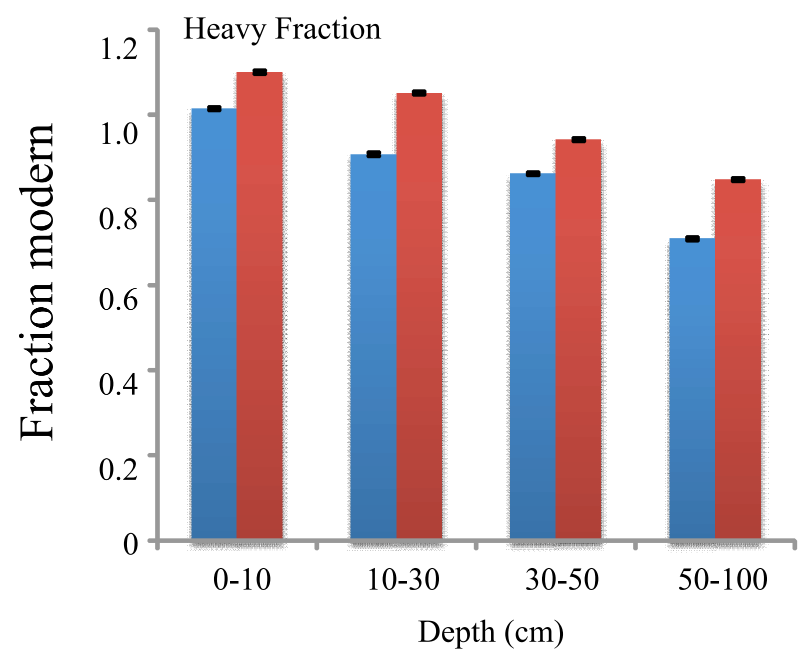
Compost added an average of 3 Mg C/ha to the soil over three years



Ryals et al. in review

Organic matter amendments can be stored in pools with long turnover times

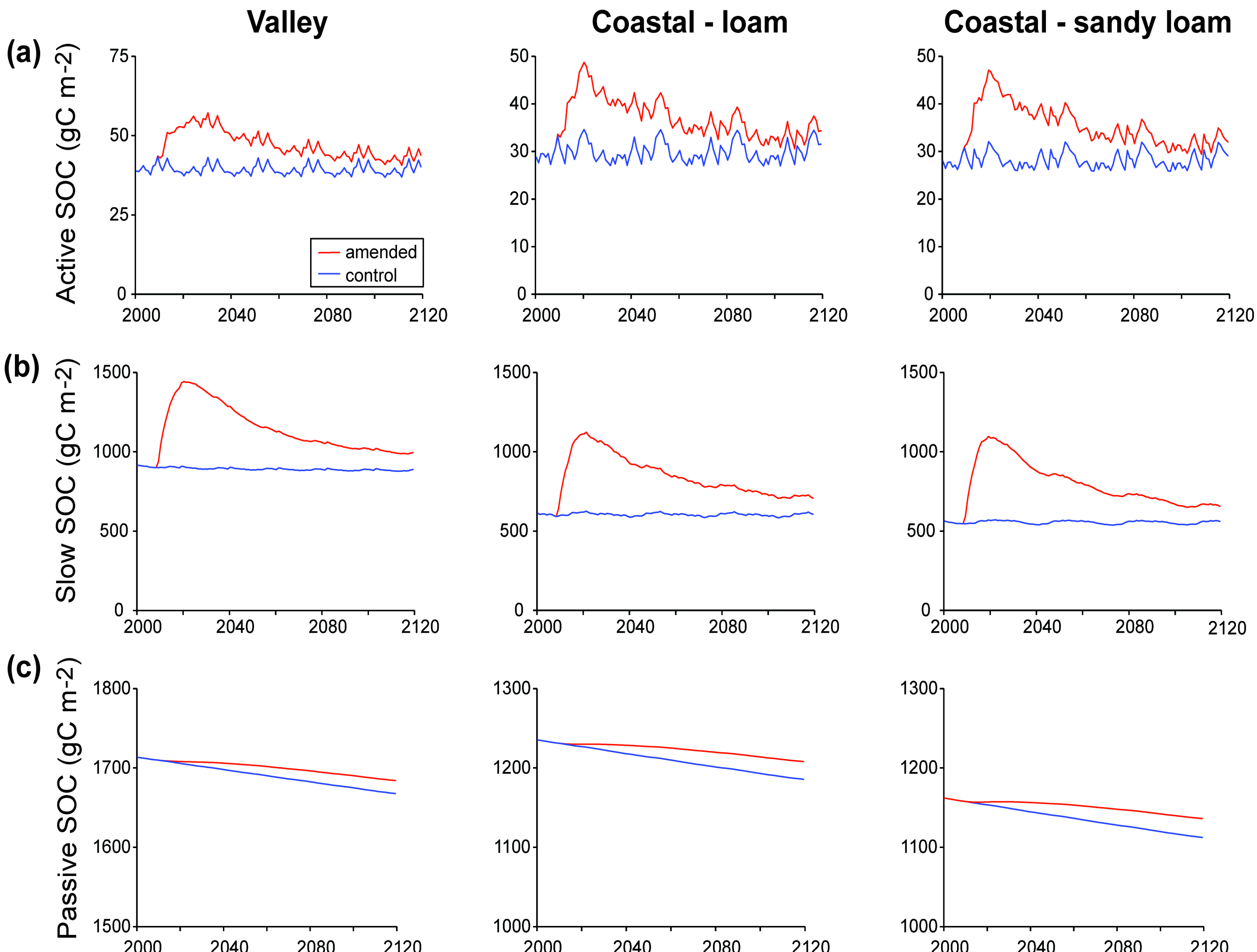




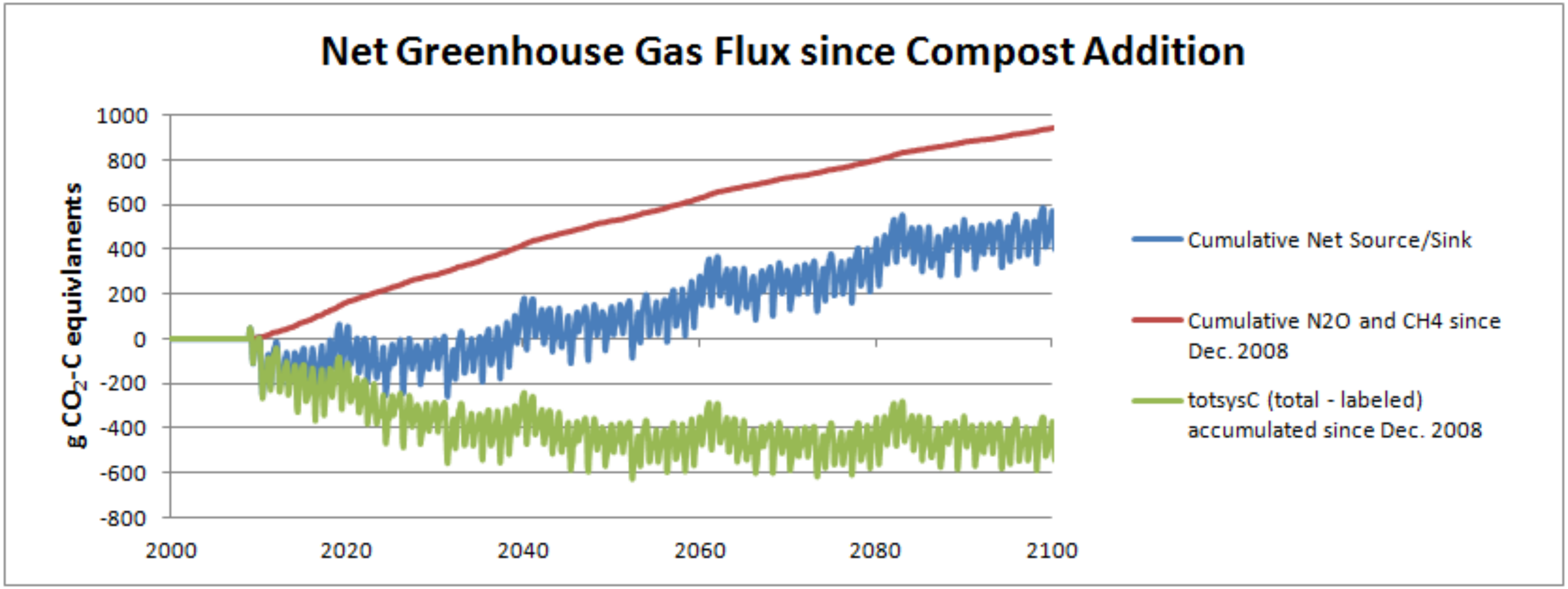
Analysis of ^{14}C in soil carbon fractions

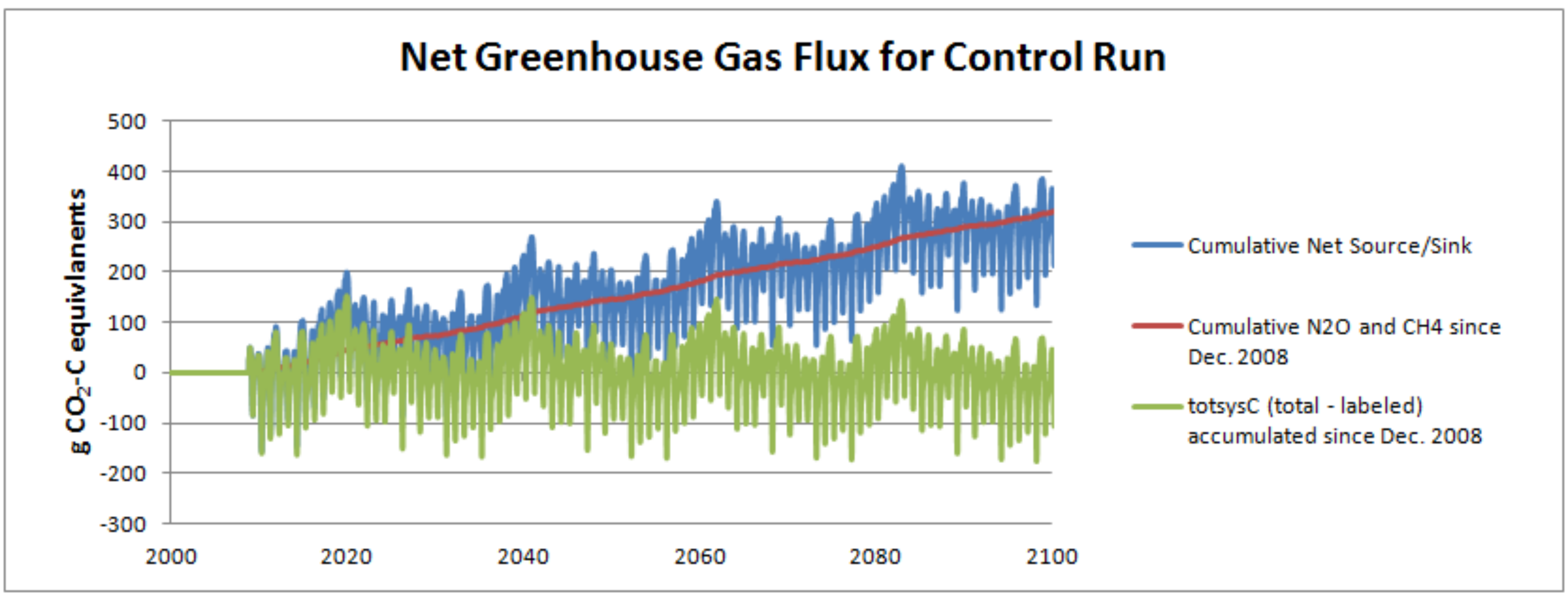
Silver et al. in prep.

Model results suggest that C persists in soil for > 100 years



Ryals et al. in prep





Ryals et al. in prep

Scalability

Photo credit: John Wick

Scalability

One quarter of the rangeland area in California:

= 23 Tg of CO_2e y^{-1} (without including compost C)

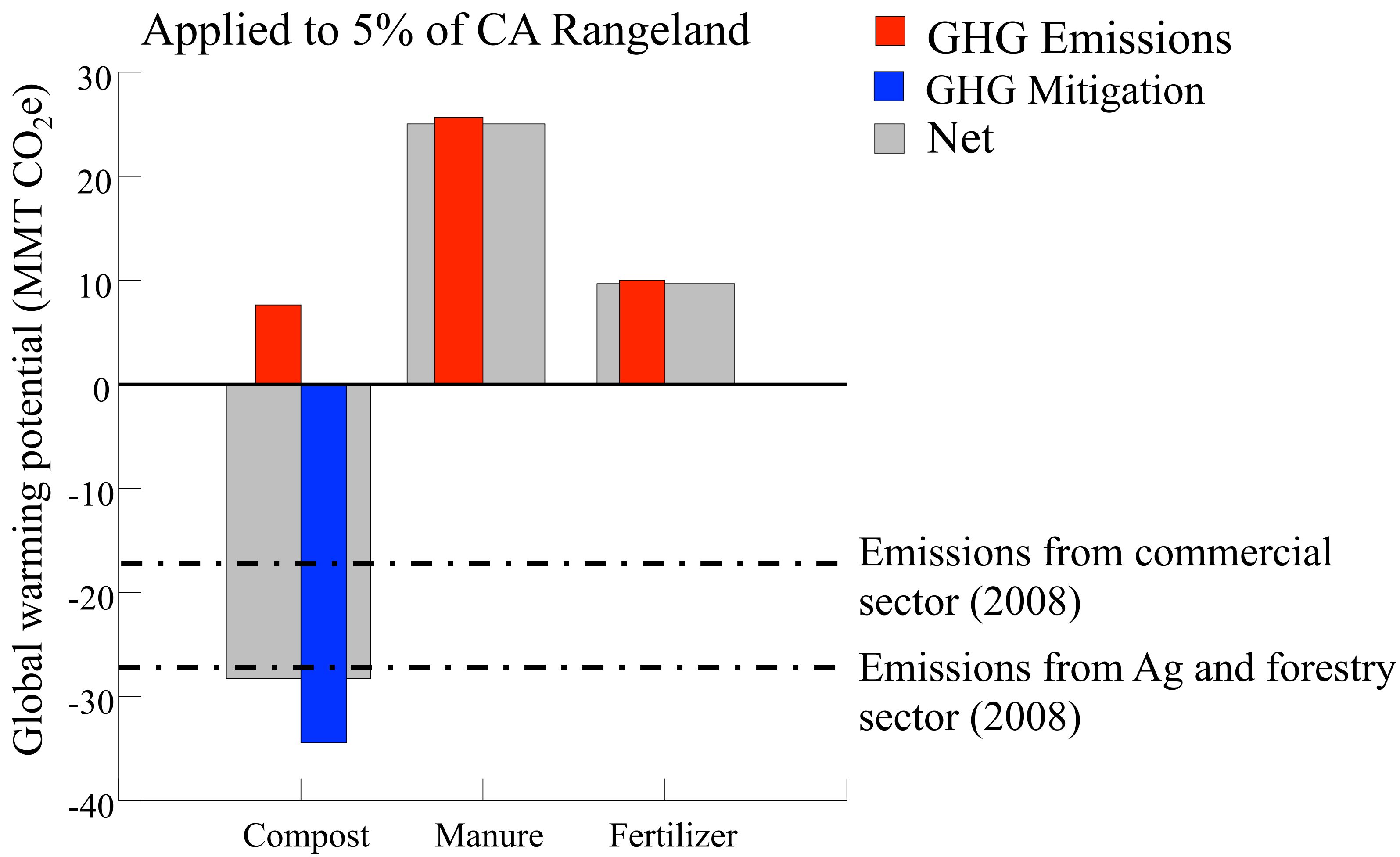
= 337 Tg of CO_2e y^{-1} (with compost C additions)

Availability of compost

Potential compost production: 27 to 33 MMT y^{-1}

Enough to reapply to 25% of California's rangelands every 17-40 years

Life cycle assessment suggests much higher climate change mitigation potential



Redrawn from DeLonge et al. 2013

Gaps in knowledge

Compost quality and greenhouse gas emissions

Arid and semi-arid systems

Key Findings:

California's rangelands are extensive and diverse. Even small rates of C sequestration and emissions reduction across these landscapes have the potential to make significant contributions to the State's climate change mitigation goals.

Differences in the life history strategy of annual grasslands compared to perennial systems are likely to lead to significant differences in management outcomes for climate change mitigation.

A large proportion of California's rangelands are likely to be degraded with regard to soil C pools, and thus have significant potential for increased C sequestration in soils through management.

Organic mater amendments, and particularly composted organic wastes, are a viable strategy for C sequestration on rangelands in California's Mediterranean climate. This management approach has the added benefit of greenhouse mitigation in other sectors (i.e. waste management, confined livestock operations).

Well managed, rotational grazing is not likely to decrease soil C pools on rangelands, and could increase C storage. Identification and testing of sustainable grazing practices will be particularly important to meeting growing demands for meat and dairy products with population growth in the State.

Climate change is posing new challenges to rangeland management in California.

Research Priorities

- Carbon and greenhouse gas dynamics of California's diverse rangelands
- Grazing management to reduce greenhouse gas emissions and increase C storage.
- The use of organic matter amendments for climate change mitigation
- The interactions of grazing and fire management
- Modeling the effects of management alternatives (including those outlined above) under changing climate