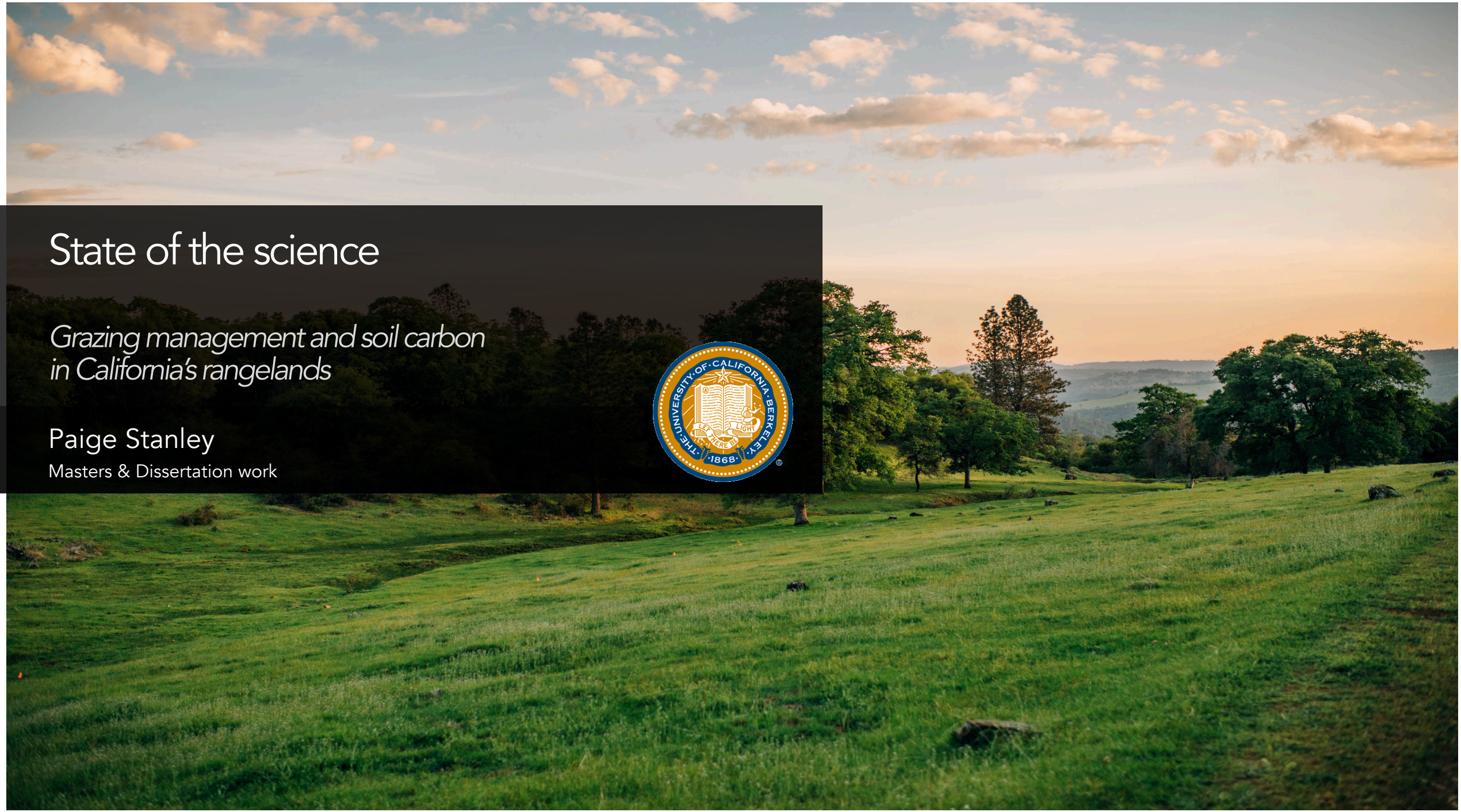


State of the science

Grazing management and soil carbon in California's rangelands

Paige Stanley

Masters & Dissertation work

Goals of this talk

50 years of science in 20 mins, grab some coffee!

1. Why does soil carbon matter?
2. Why is restoring soil carbon important?
3. What is soil carbon sequestration, and how does it work?
4. Challenges of soil carbon sequestration on rangelands
5. What options are there for sequestering soil carbon on rangelands?
    1. Existing practices
    2. State of the science
    3. Unknowns, gaps, and future research
    4. Adaptive rotational grazing

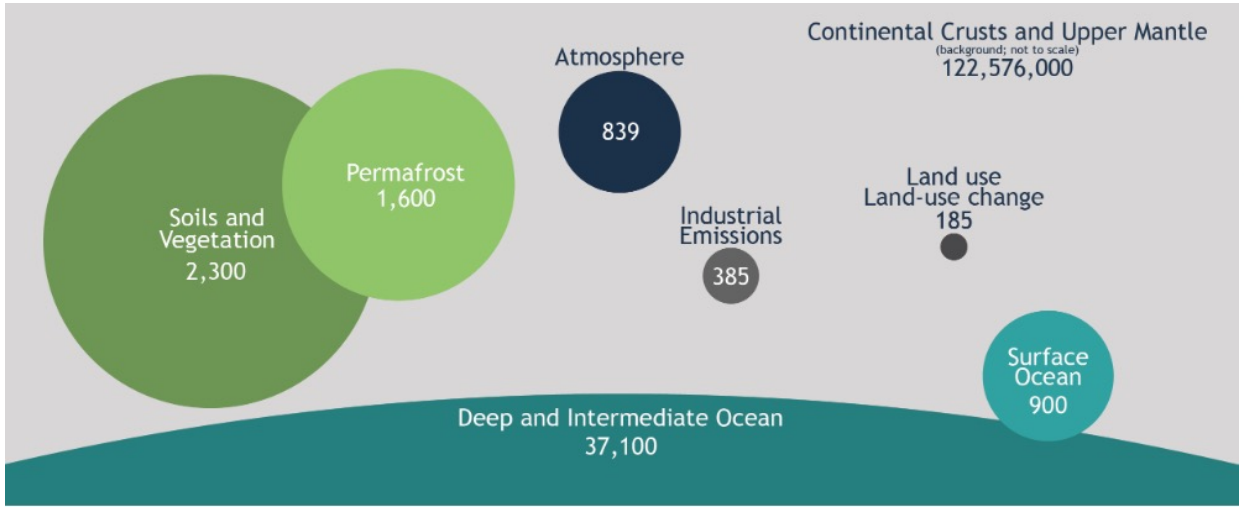
Why does carbon in soils matter?

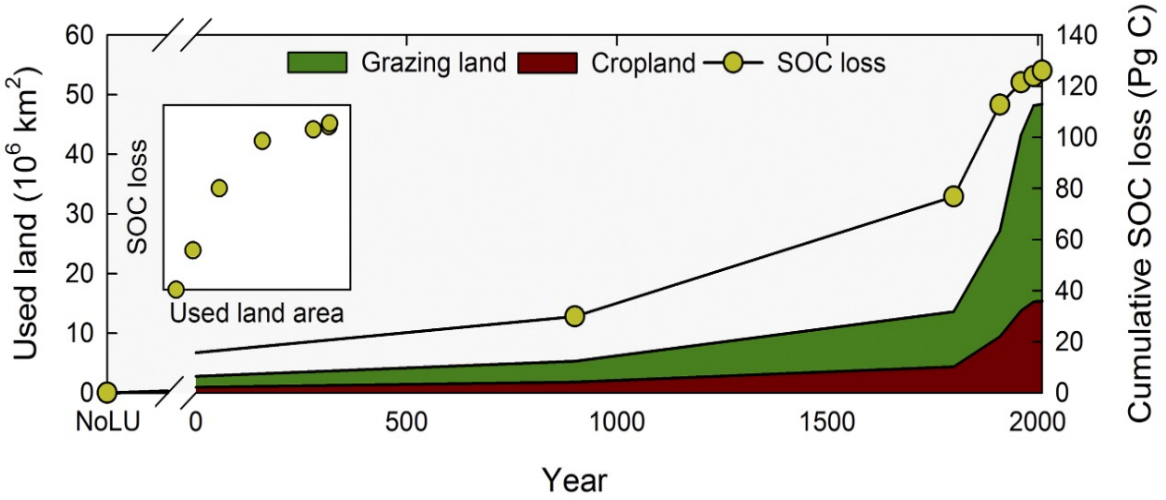
Soils contain a lot of carbon

- Next to the ocean, soils are the largest reservoir of carbon on Earth
- Soils contain 3x more carbon than the atmosphere, and >2x the carbon in all vegetation and the atmosphere combined!

….But they've lost a lot of carbon

- Soils have lost up to 50% of their carbon due to human activity
- Much of the loss has been on grazing lands [1]





P. Stanley, CCRC Spring 2022

Why is restoring soil carbon important?

Climate change mitigation

Pulling carbon from the atmosphere into soils can help reduce greenhouse gas emissions [2-3]

Plant productivity

Soil carbon is important for plant growth and productivity: more soil carbon often = higher productivity [4]

Water infiltration

Increasing soil carbon improves soil's ability to hold, absorb, and infiltrate water [5]

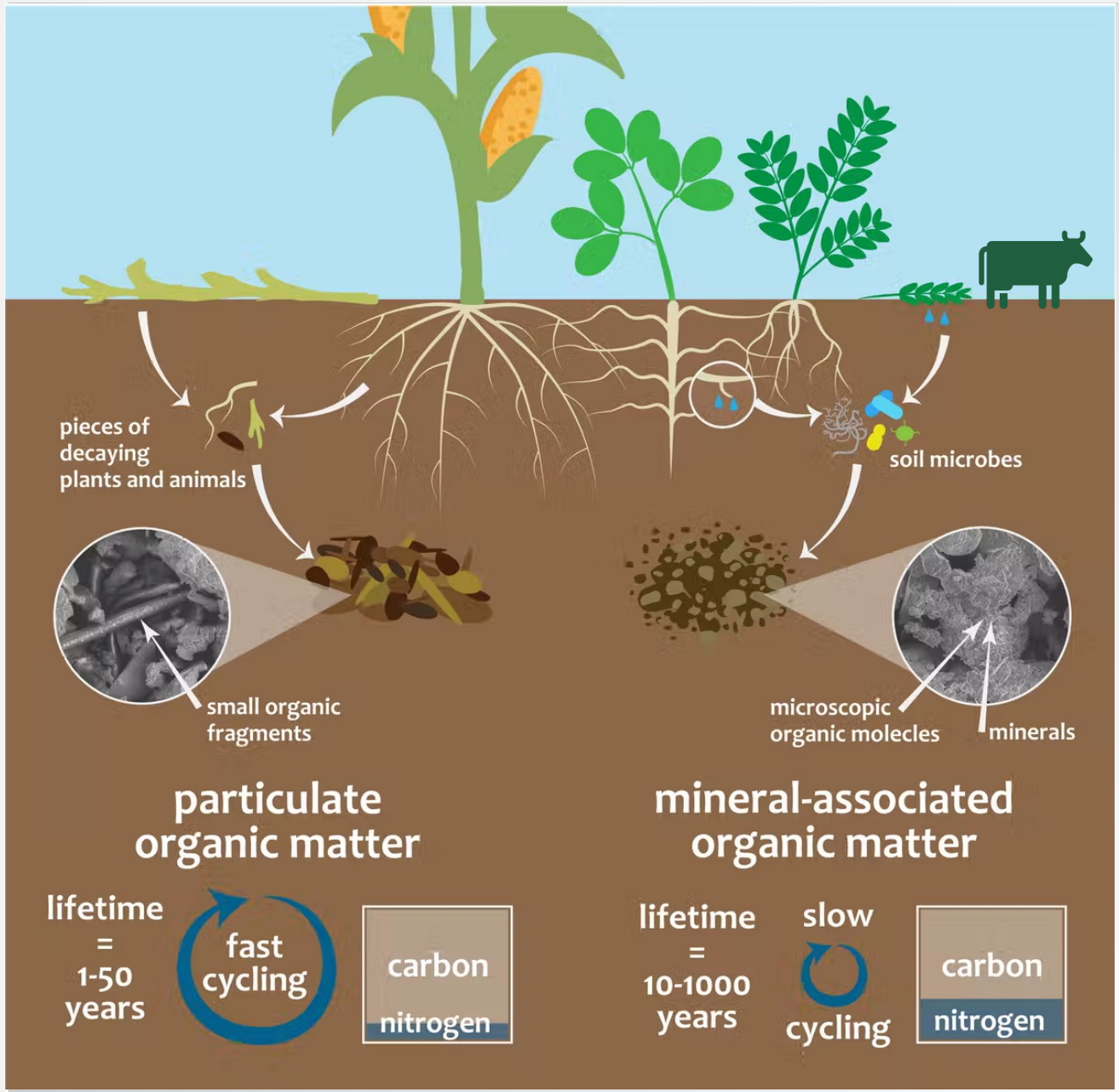
Reduced input needs

Improved ecosystem services through soil carbon can reduce the need for inputs like irrigation and fertilizers

Climate change adaptation

Healthier soils can better adapt to climate change [6], and soil C is more stable than other types of C [7]

What is soil C sequestration – how does it work?



Plants!

Plants, and largely roots, die + decompose and eventually become soil C

Microbes + organisms

Microbes transform plant and soil inputs to form soil C, and eventually die and decompose too

Other inputs

Additions like fertilizer, compost, and animal manure also contain C and can add/change soil C

Cotrufo, M. F., & Lavallee, J. M. (2021). Soil organic matter formation, persistence, and functioning: A synthesis of current understanding to inform its conservation and regeneration.

Where do rangelands fit into this equation?

What are the challenges of soil carbon sequestration on rangelands?

Rangelands cover ~50% of Earth's terrestrial surface

- Rangelands cover approximately 50% of Earth's terrestrial surface [8-9]
- Large land area = large potential for soil carbon sequestration! [10-11]

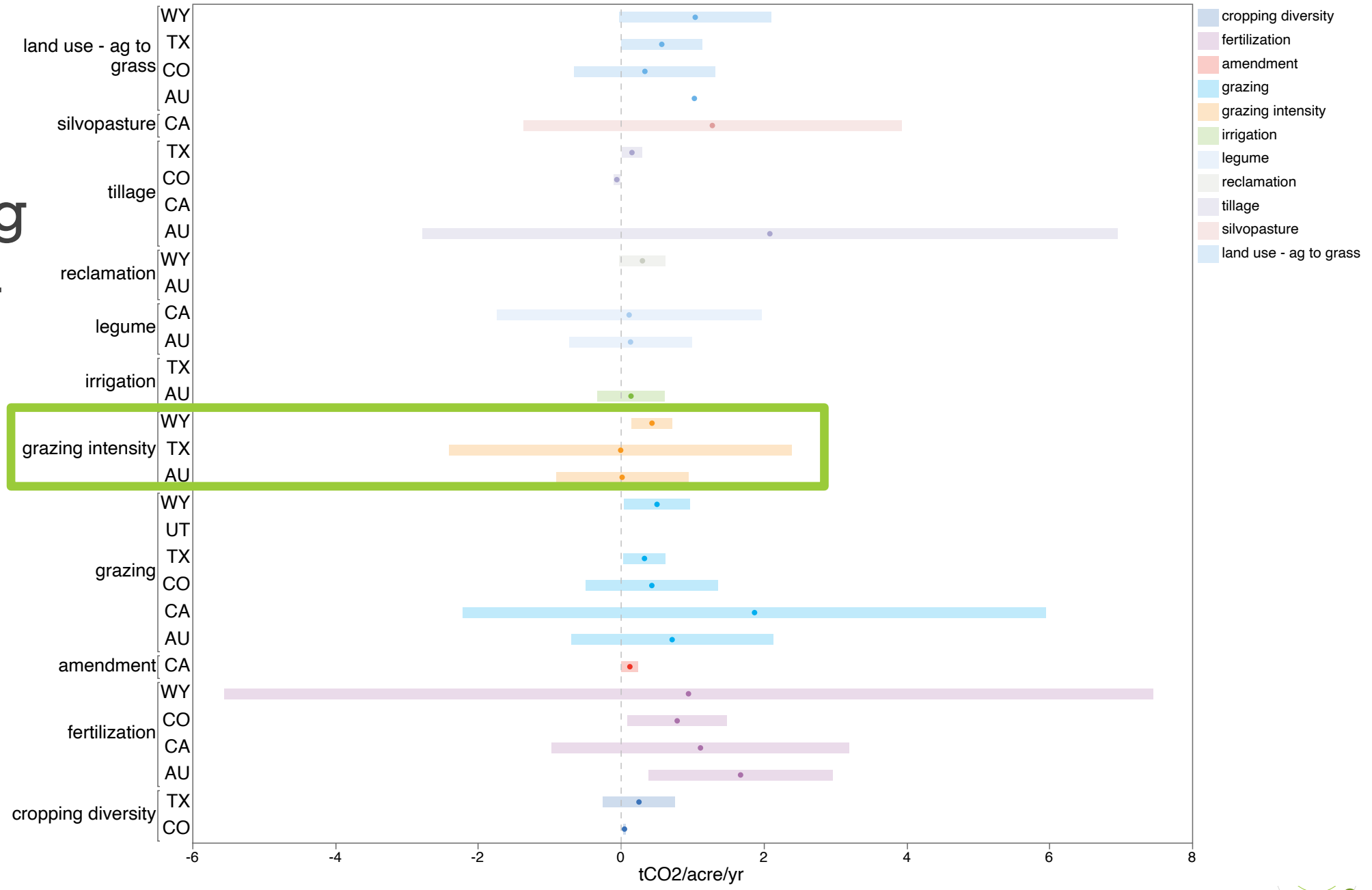
There are biogeophysical limitations

- Compared to other lands like croplands, there are constraints to soil C sequestration on rangelands[12], including:
  - Marginality
  - Variable precipitation
  - Rocky soils
  - Remoteness and difficulty of managing

Research challenges constrain understanding

- In addition, research of soil carbon sequestration on rangelands is ***very limited***
- Small and short-term experiments are not representative [13]
- Heterogeneity of rangelands require lots of soil samples [14]

Possible C-sequestering practices on rangelands



Megan Machmuller (2022). *Unpublished data*

Possible C-sequestering practices on rangelands

Compost application

Marin Carbon Project results showed an 18% average soil C increase after 3 years of compost on valley rangelands [15]

Perennialization

Perennials have deeper roots and longer life-spans, which increase soil carbon [16]

Grazing management?

Can changes to grazing management help sequester carbon, since cattle are already ranchers' primary tool?

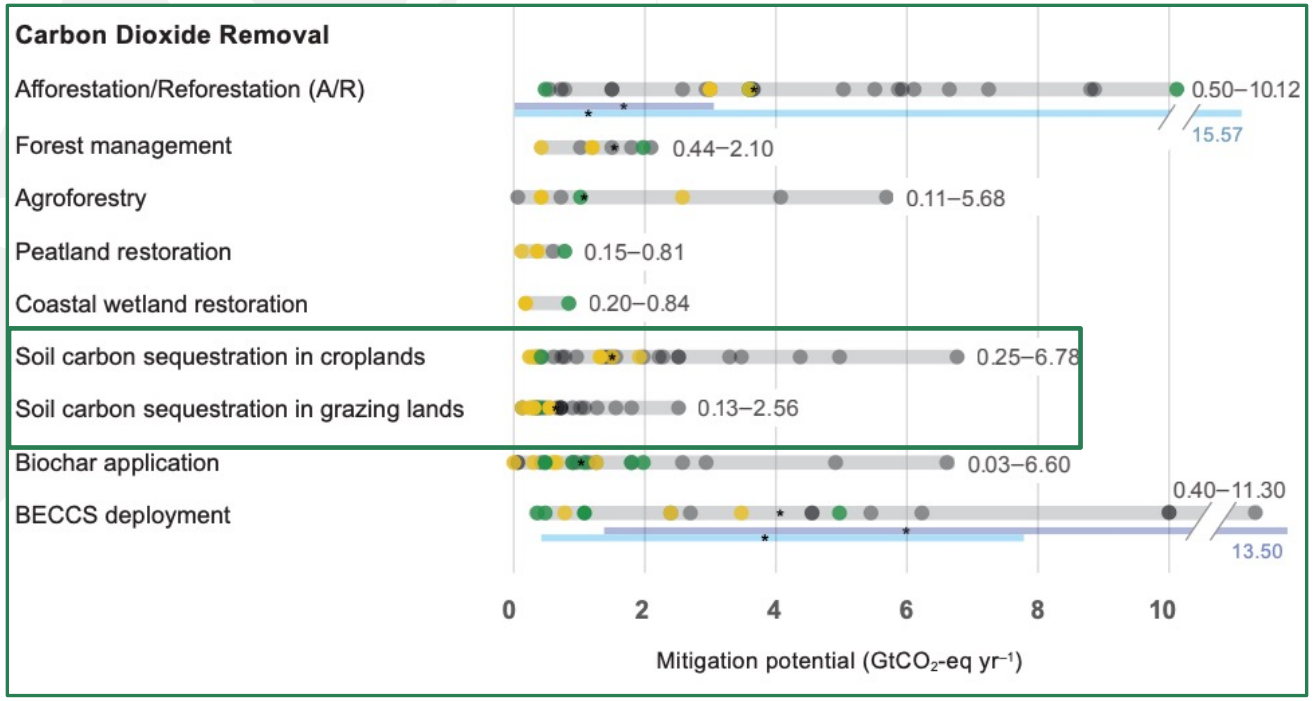
Soil carbon sequestration potential of grazing management

4-5 $GtCO_2\ yr^{-1}$

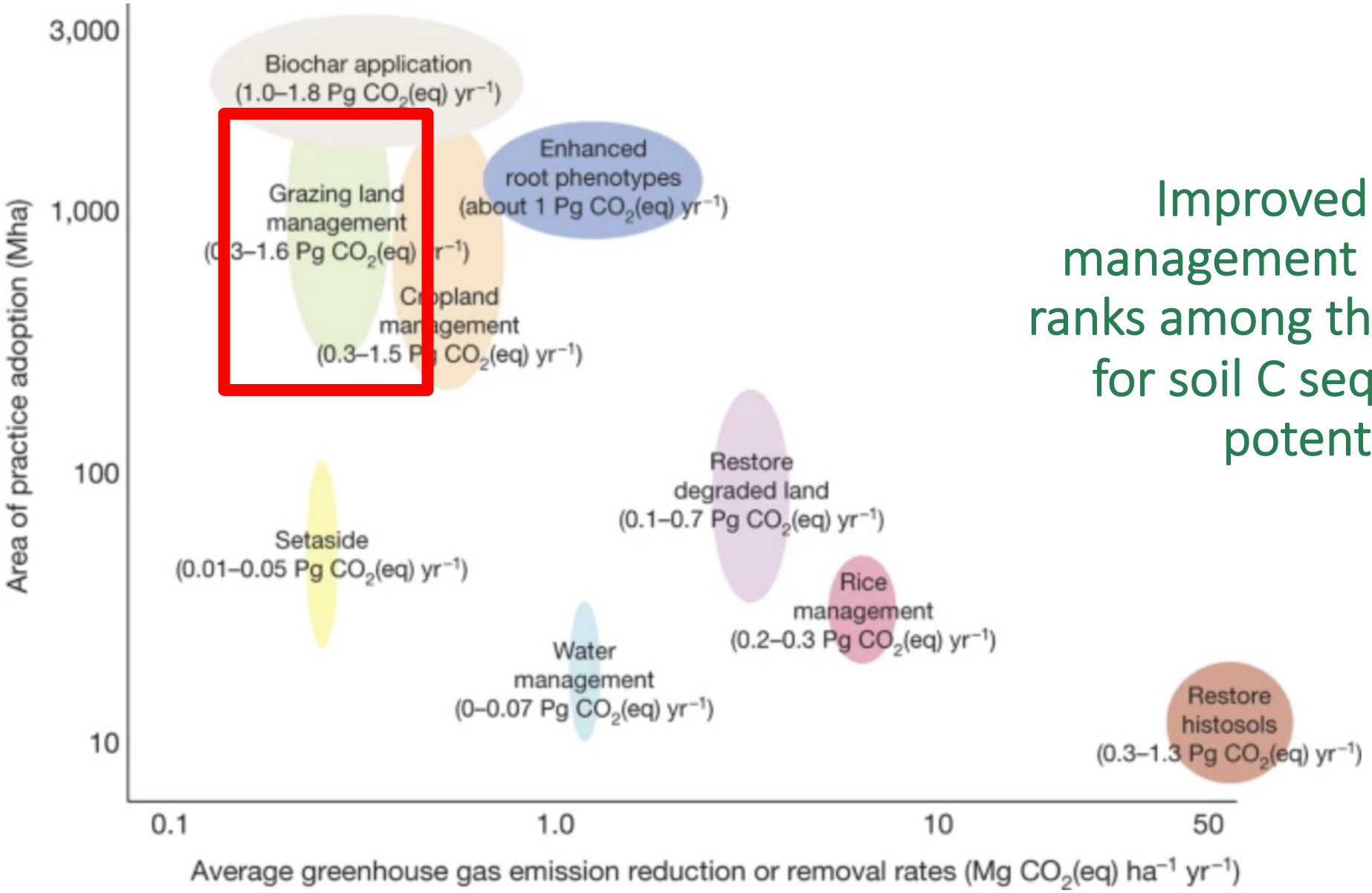
- Total sequestration potential on crop and grazing lands [17]

1.4-1.8 $GtCO_2\ yr^{-1}$

- Mitigation potential via soil C sequestration via grazing management [18-19]



Soil carbon sequestration potential of grazing management



Improved grazing management consistently ranks among the top options for soil C sequestration potential [17]

How can grazing management impact soil carbon?

Many of the same strategies are recommended as drought adaptation strategies [20]

Practices like:

- Animal movement/rotation[21]
- Pasture rest [21]
- Changes in stocking density and "intensity" [21]

Can influence soil C dynamics:

- Reducing C outputs
- Increasing C inputs
- Changing internal C transformation

By:

- Preventing overuse or overgrazing
- Changing forage utilization
- Changing amount or distribution of manure
- Building adaptability/flexibility to meet these goals

State of the science: grazing and soil carbon on rangelands

What do we know about when, where, and how grazing affects soil carbon on rangelands?

GLOBAL
all grazing lands

- Globally, there are many studies on grazing and soil carbon
- *Most studies are on non-arid grasslands*
- They have shown changes in grazing management can increase soil carbon
- Carbon sequestration rates range from 0.1-3.5 Mg C/ha/yr depending on the place and practice [22]

SEMI-ARID
rangelands

- *Studies on semi-arid rangelands are limited*
- Generally, grazing ↑ soil C compared to no grazing, and heavy grazing ↓ soil C [23]
- Evidence of "rotational" grazing on soil C on semi-arid rangelands is mixed [24]
- Recent meta-analysis shows that "rotational grazing" can improve soil C on semi-arid rangelands by ~0.3x [25]

CALIFORNIA
rangelands

- In California, studies of grazing management + soil carbon are even more limited
- Current studies show only the ***presence or absence of grazing*** on soil carbon, but do not study grazing management systems
- The effect of different grazing management regimes on soil carbon is unknown in California! [26-28]

State of the science: grazing and soil carbon on rangelands

OTHER SCIENTIFIC GAPS

1. What does it take to measure soil carbon *accurately* on rangelands?
   - Not enough samples = unreliable estimates! [29]
2. Differentiating between grazing management types, moving beyond "rotational" grazing

NEED FOR FUTURE RESEARCH

1. Clear need for more research on grazing management and soil carbon, especially in semi-arid rangelands!
2. California specific studies
3. *Studies on adaptive rotational grazing as one form of grazing management!* [26]

What about adaptive rotational grazing?

... Stick around for the next talk!!

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