Adaptive rotational grazing and soil carbon sequestration

New data from California rangelands

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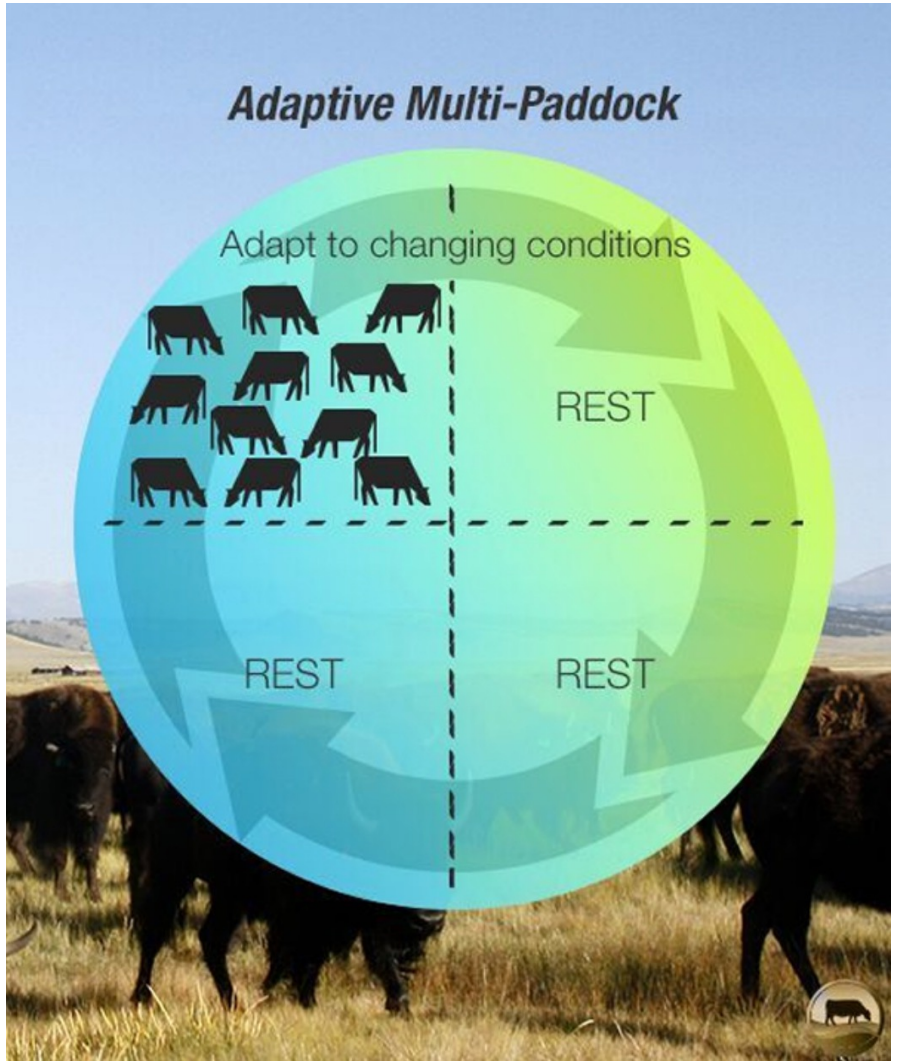
Dissertation work

Adaptive rotational grazing = ARG



- What am I talking about?
  - Adaptive multi-paddock, management intensive grazing, holistic planned grazing
- How I'm defining it:
  - Informed by a grazing plan to premeditate and guide grazing decisions throughout the year
  - Animal movement through smaller paddocks during the grazing season (>10 paddocks) using either mobile electric fencing, range riding, etc
  - Incorporated and targeted pasture rest
  - Moderate-high animal stock densities (either seasonally or year-round) to meet goals
  - Adaptive based on monitoring outcomes
  - Commonly associated with holistic decision-making framework, but not all

Current literature

ALL STUDIES

- Several studies on temperate grasslands in TX, MI, Southeastern US, Alberta [1-4]
- Soil C sequestration rates of ARG range from ~1-3.5 Mg C/ha/yr
- This is higher than most other grazing + soil carbon studies (average = 0.3-0.5 Mg C/ha/yr) [5]

US RANGELANDS

- There are only TWO studies of ARG in the Western US
- ONLY ONE measured soil C
  - South Dakota prairie
  - Showed increased soil C vs heavy continuous but not low continuous grazing [6]
- The other didn't measure soil C, but showed ARG only improved forage conditions in above average precipitation years [7]

SEMI-ARID RANGE

- Few global studies of impact of ARG on soil C in arid + semi-arid rangelands
- Some studies on other ecosystem impacts:
  - Water infiltration [6,8]
  - Soil water content [9]
  - Soil GHG fluxes [10-11]
- *IN SHORT: the impact of ARG on soil C in semi-arid rangelands is largely unknown*

Why is the research so limited?

1. Classic agronomic experiments are **non-adaptive** by design
    1. Set stocking densities
    2. Set rest, recovery, and rotation schedules
2. Short duration research may not pick up on long-term changes
3. Scientists aren't ranchers!
4. "Natural" on-ranch studies = more representative, but scientifically limited

Other important soil science considerations

Not all carbon cycles the same way [12-13]

- Particulate organic matter
  - Soil carbon "checking account"
- Mineral associated organic matter
  - Soil carbon "savings account"

Digging deeper: the importance of deep soil samples [14-15]

- Most soil C studies only sample down to 30 cm
- More than 50% of all grass and rangeland soil C is contained below 30cm [16]
- Deep sampling is necessary to get the full soil C story

Spatial heterogeneity and sample density [17-18]

- Detecting small soil C changes on variable rangelands = finding a needle in a haystack!
- Need lots of samples for reliable estimates (*Stanley et al. in review)*

Central questions of my study

Impact of ARG on soil carbon?

How does ARG affect soil carbon versus more conventional grazing management in CA?

Different forms of soil carbon?

How does soil C change in different pools under different grazing management?

Vegetation?

How does vegetation change under ARG vs conventional grazing management?

Methods

What I did and how I did it

RANCH SELECTION CRITERIA

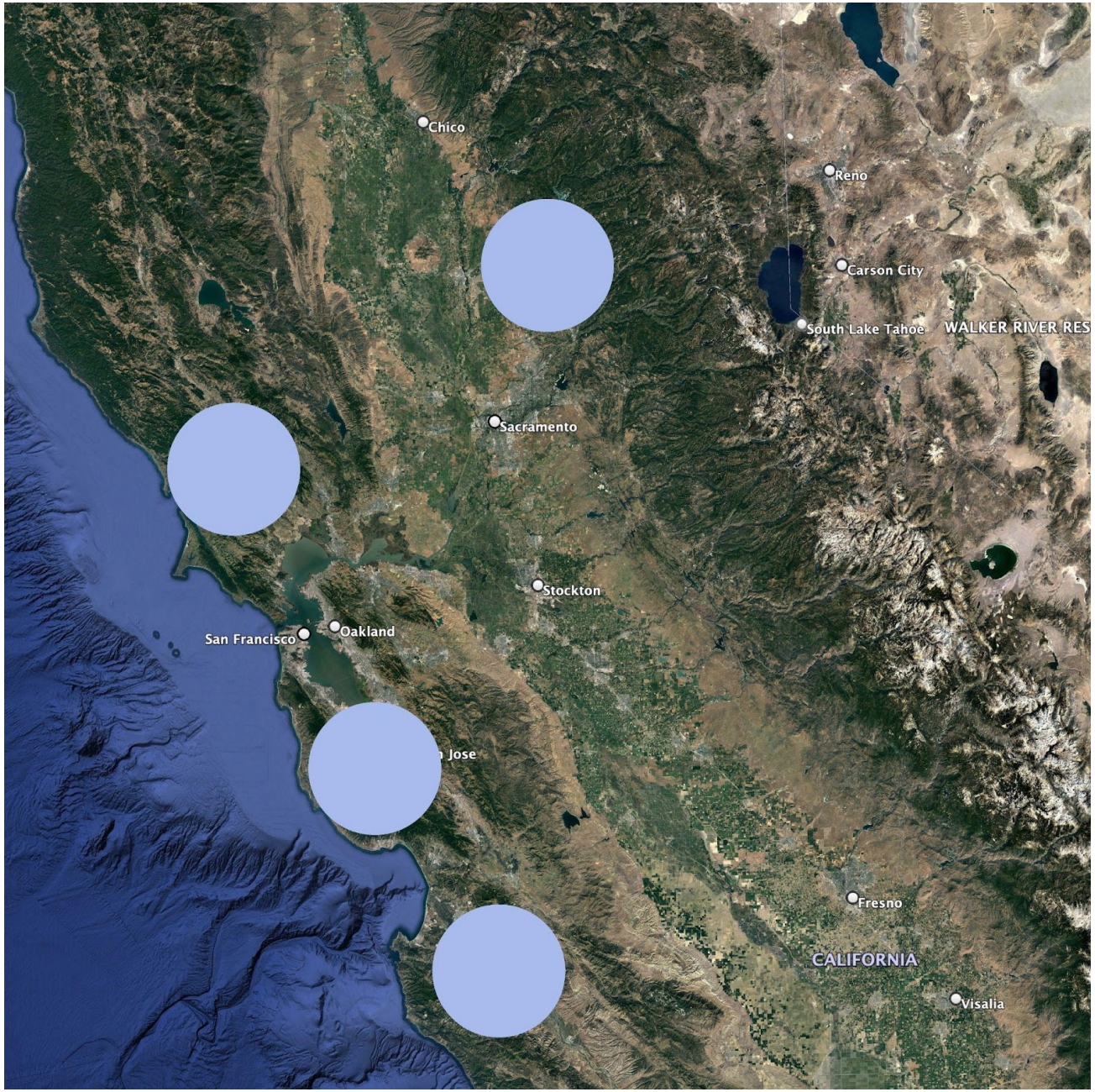
- Developed grazing management and ranch ecological criteria
- Phone calls, rancher interviews, and site visits June 2019 – Jan 2020
- 4 paired ARG/CONV ranch pairs across northern CA
- All grazed beef cattle, non-irrigated rangelands, no other management interventions

FIELD SAMPLING

- On-ranch data collection
- Soils
  - Collected 360 samples from each ranch pair, totaling 1440 samples
  - Sampled in 0-10, 10-30, 30-50, and 50-100cm depths
- Vegetation
  - Line point-intercept and nested quadrat data
- Water
  - Full water retention curves

LAB AND DATA ANALYSIS

- Analyzed all soils for C + N using elemental analysis by dry combustion
- Texture
- Soil C fractions
  - DOM, fPOM, oPOM, MAOM
- Equivalent soil mass
- Analyzed data with mixed models, significance level = 0.05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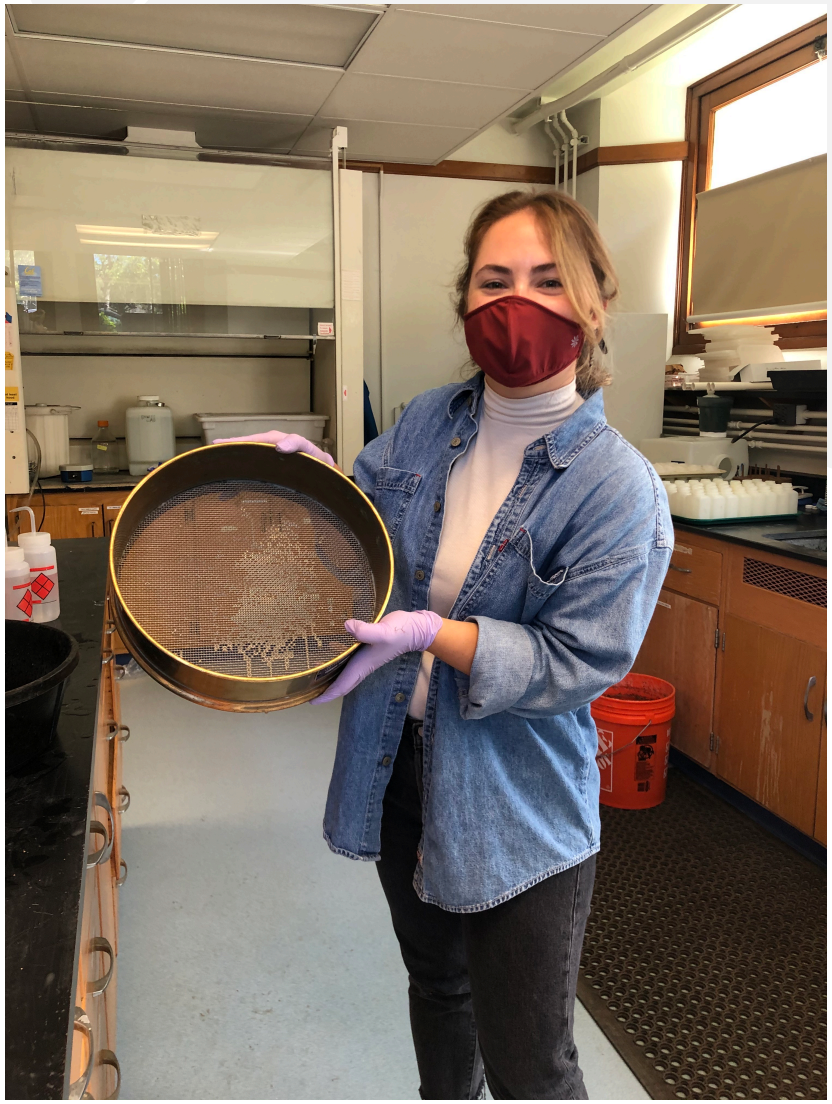
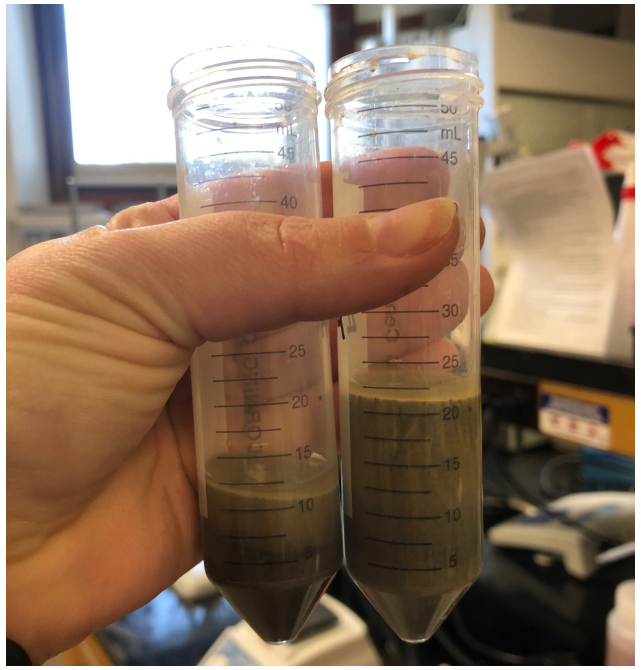
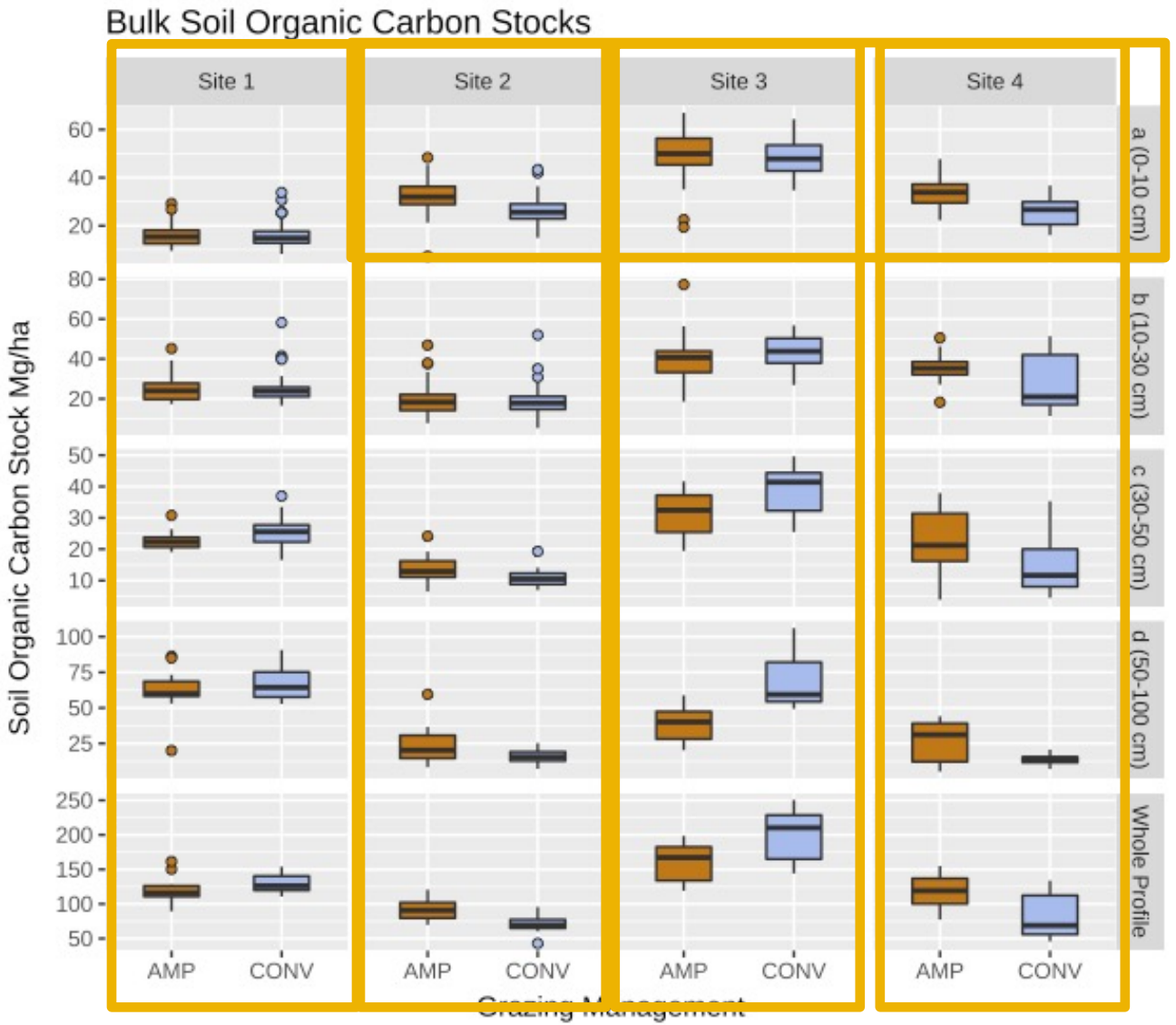




Some, not all, ARG ranches have higher soil carbon

1. 3/4 ARG ranches (sites 2,3,4) had significantly higher surface soil C than their neighboring conventional ranches
2. 2 (sites 2 & 4) ARG ranches had significantly greater soil C all the way down to 1m deep
3. ARG ranch at site 3 had been previously tilled, but showed soil C accumulation in the surface
4. Site 1 showed no differences in soil C between different grazing management strategies



Average ⬆
5.3 Mg C/ha
or
16%

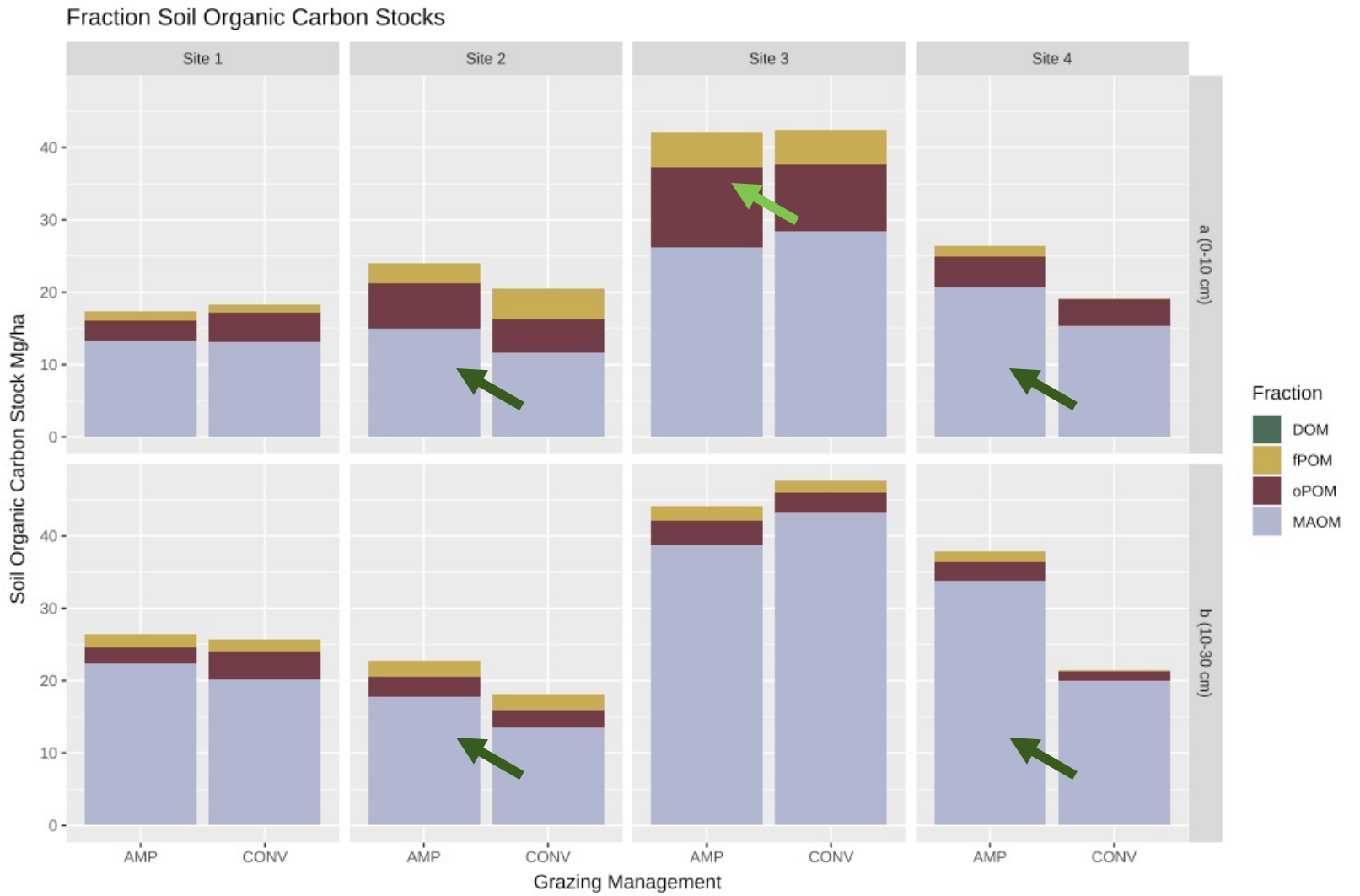
Adaptive rotational grazing mainly increased soil C in the mineral pool

- The biggest differences in soil C between ARG and conventional grazing was in the mineral pool:

  MAOM

- But at site 3, the difference was in the soil aggregate pool:

  oPOM



Some things to chew on…

- How does plant community composition play a role?
  - Does it predispose some sites toward soil C sequestration under ARG?
  - Or does ARG change soil C by way of shifting plant community composition and cover?
- Are there any measurable impacts on soil water?
  - Is this tied to soil C change under ARG?
  - Are there non soil C water benefits?
- I measured all this – more data to come!

What does all this mean?

Key Takeaways

1. This study shows some evidence that ARG *can* increase soil carbon on CA rangelands compared to conventional grazing management
2. However, not all sites seem to be responsive to ARG
3. Land use history, edaphic factors, plant communities interact with and potentially moderate grazing management's impacts on soil C
4. Soil C under ARG was largely added to the mineral associated C pool

Implications

1. Grazing management is not a lost cause for soil C sequestration on CA rangelands!
2. But outcomes aren't universal or guaranteed
3. Persistent soil C from ARG is good news for climate change mitigation

Unknowns: a call for future research

This is the first study to analyze the impact of ARG on soil C outcomes on California Rangelands

Further research is needed to better understand where, when and how ARG impacts soil carbon in California

Research on drivers of soil C sequestration under ARG is a clear next step

Acknowledgements

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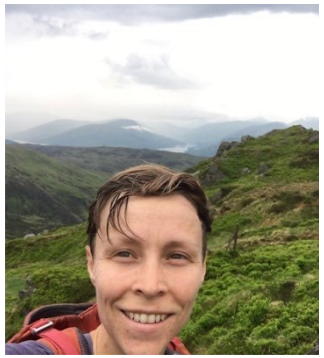
NCBA National Cattlemen's Beef Association

Central Coast Rangeland Coalition

University of California Agriculture and Natural Resources

My village



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Thank you

Happy to answer questions!

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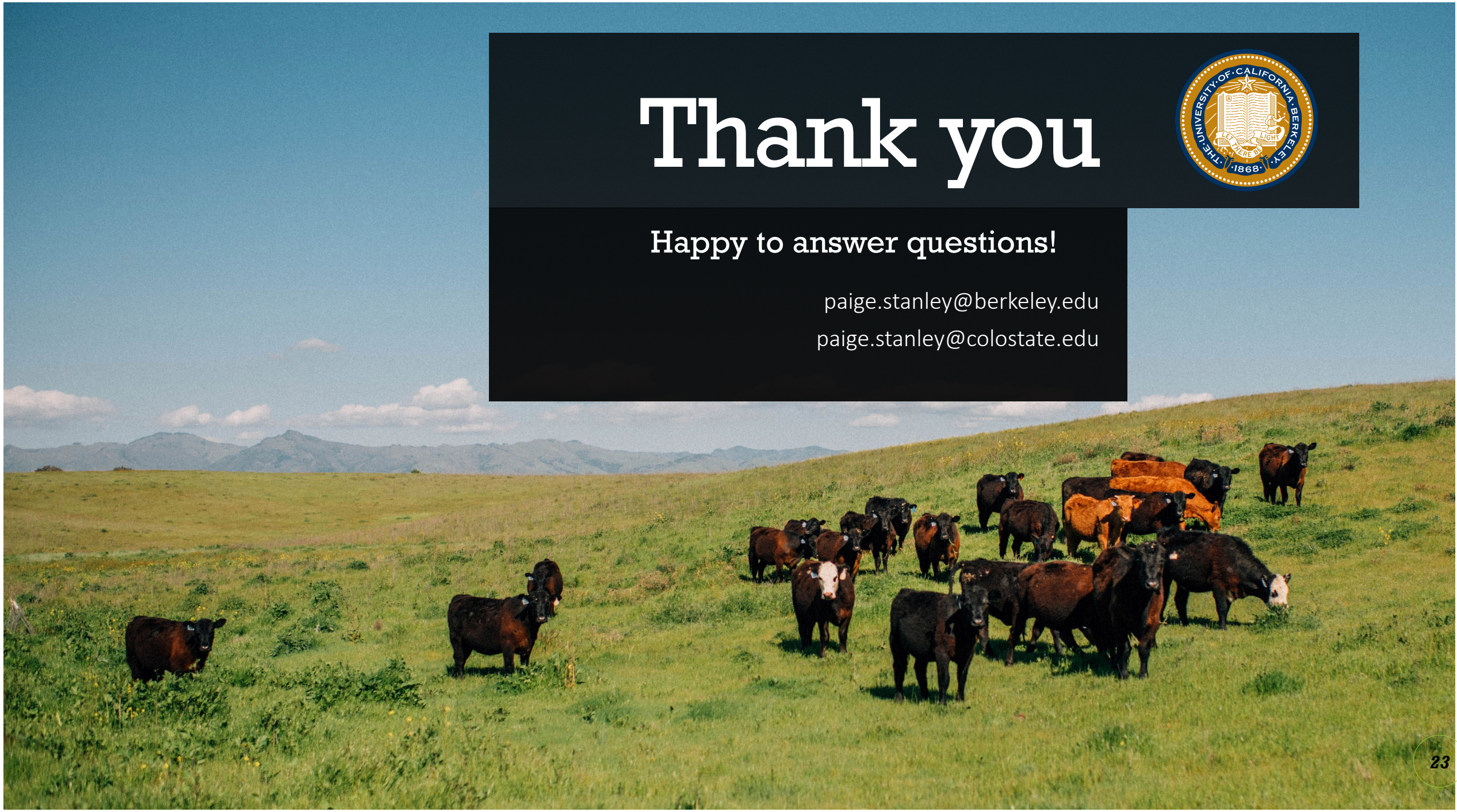

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