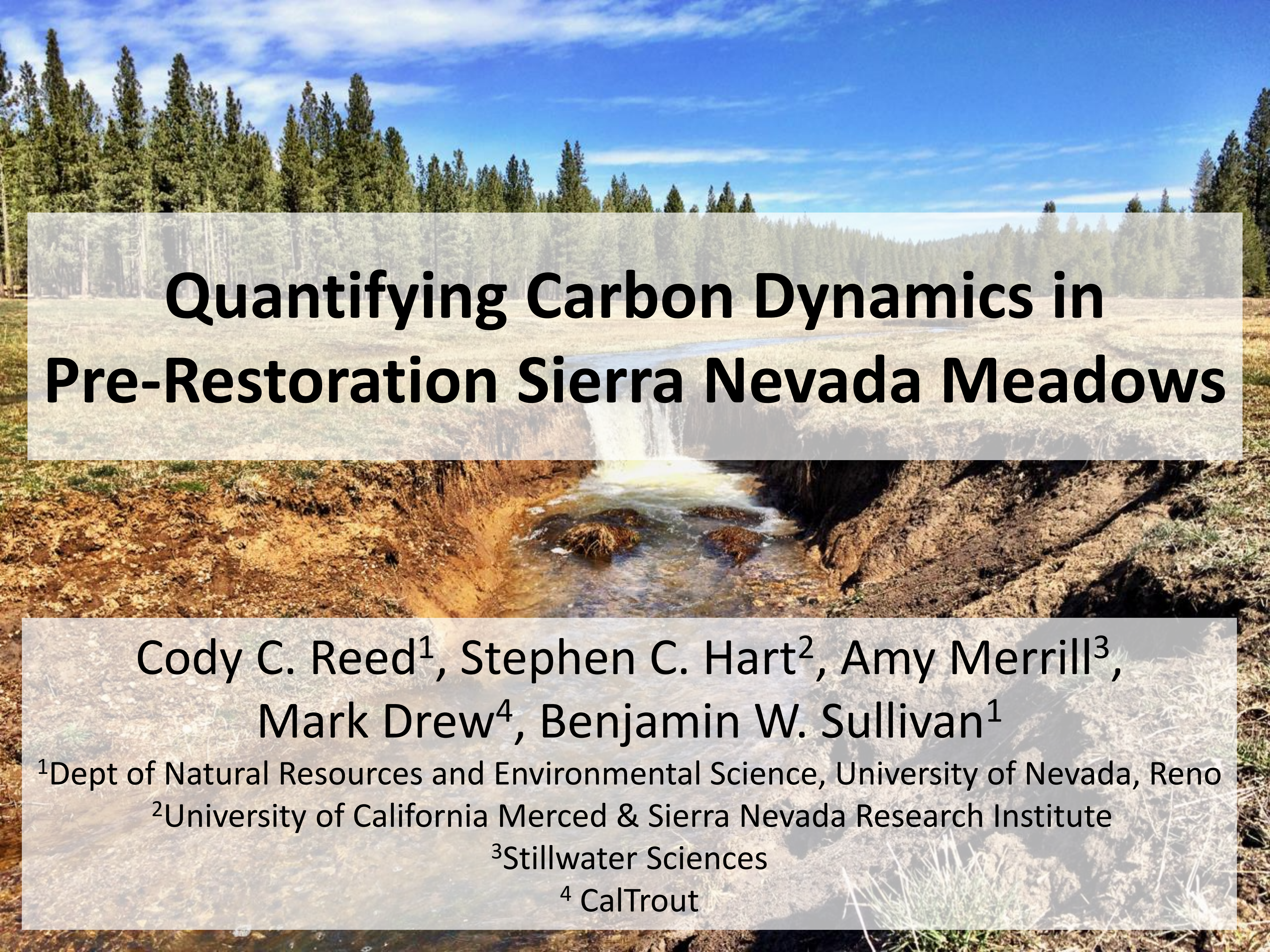


Quantifying Carbon Dynamics in Pre-Restoration Sierra Nevada Meadows

Cody C. Reed[1], Stephen C. Hart[2], Amy Merrill[3], Mark Drew[4], Benjamin W. Sullivan[1]

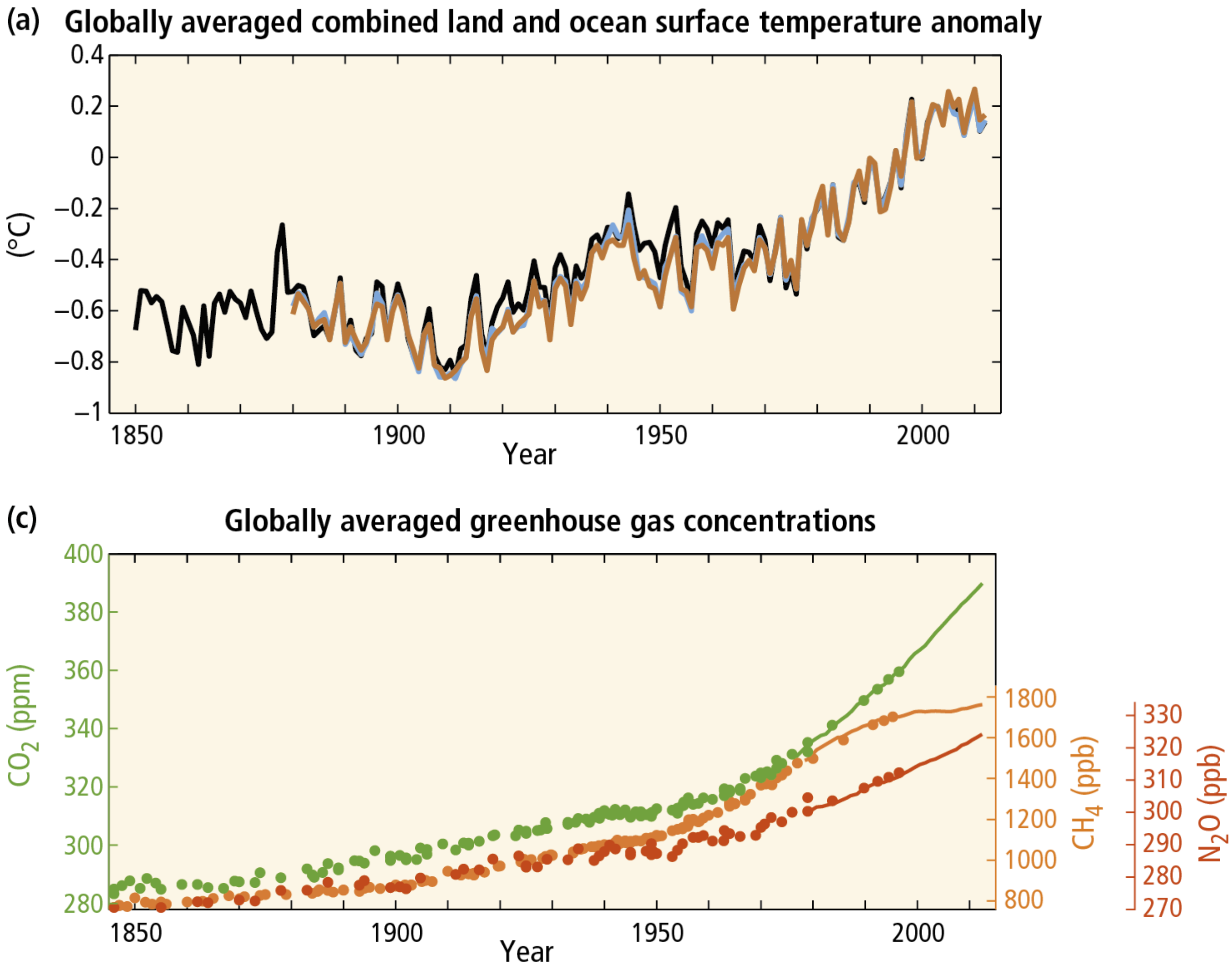
[1]Dept of Natural Resources and Environmental Science, University of Nevada, Reno

[2]University of California Merced & Sierra Nevada Research Institute

[3]Stillwater Sciences

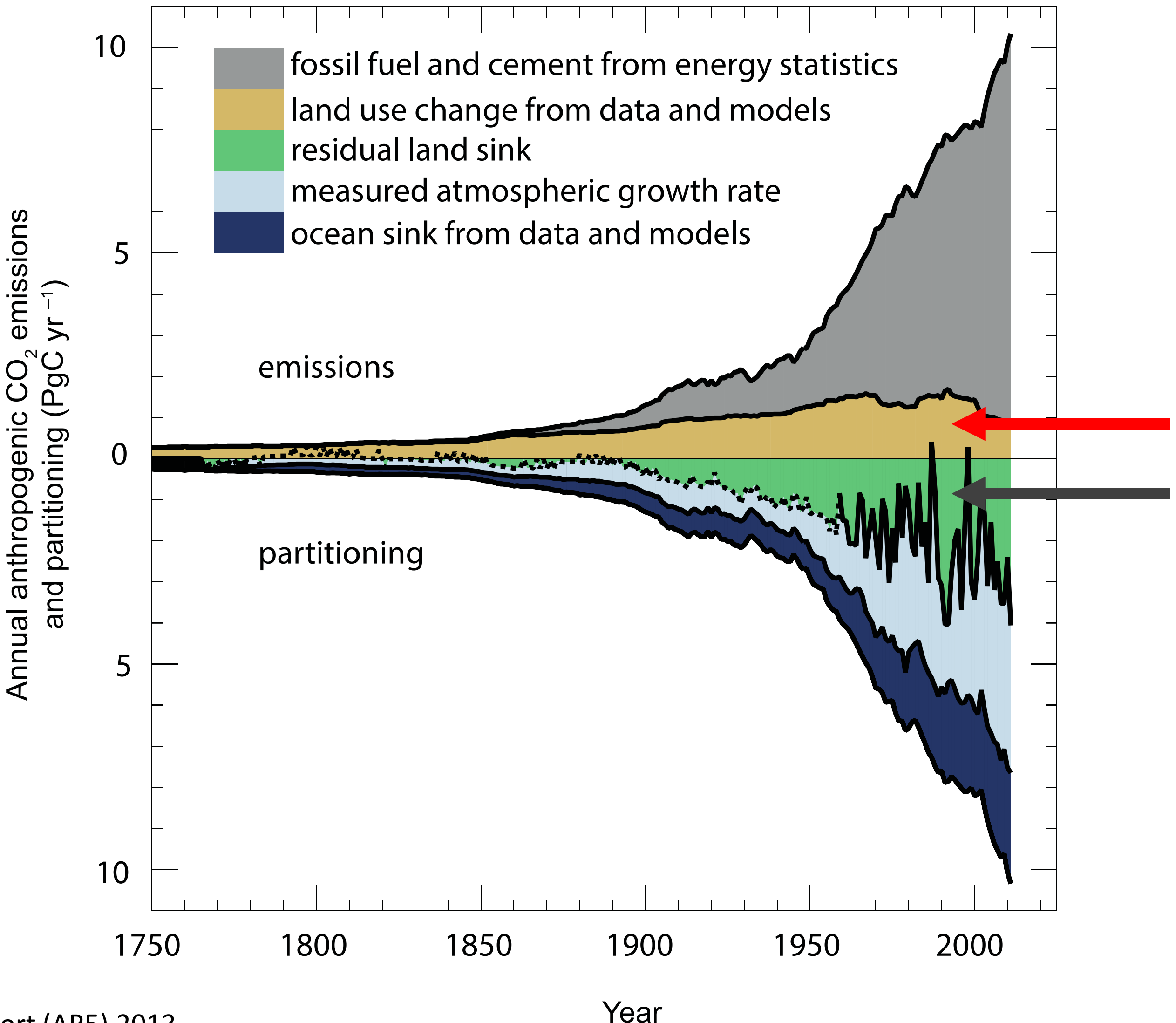
[4] CalTrout

Human-caused greenhouse gases are increasing in the atmosphere and warming the planet



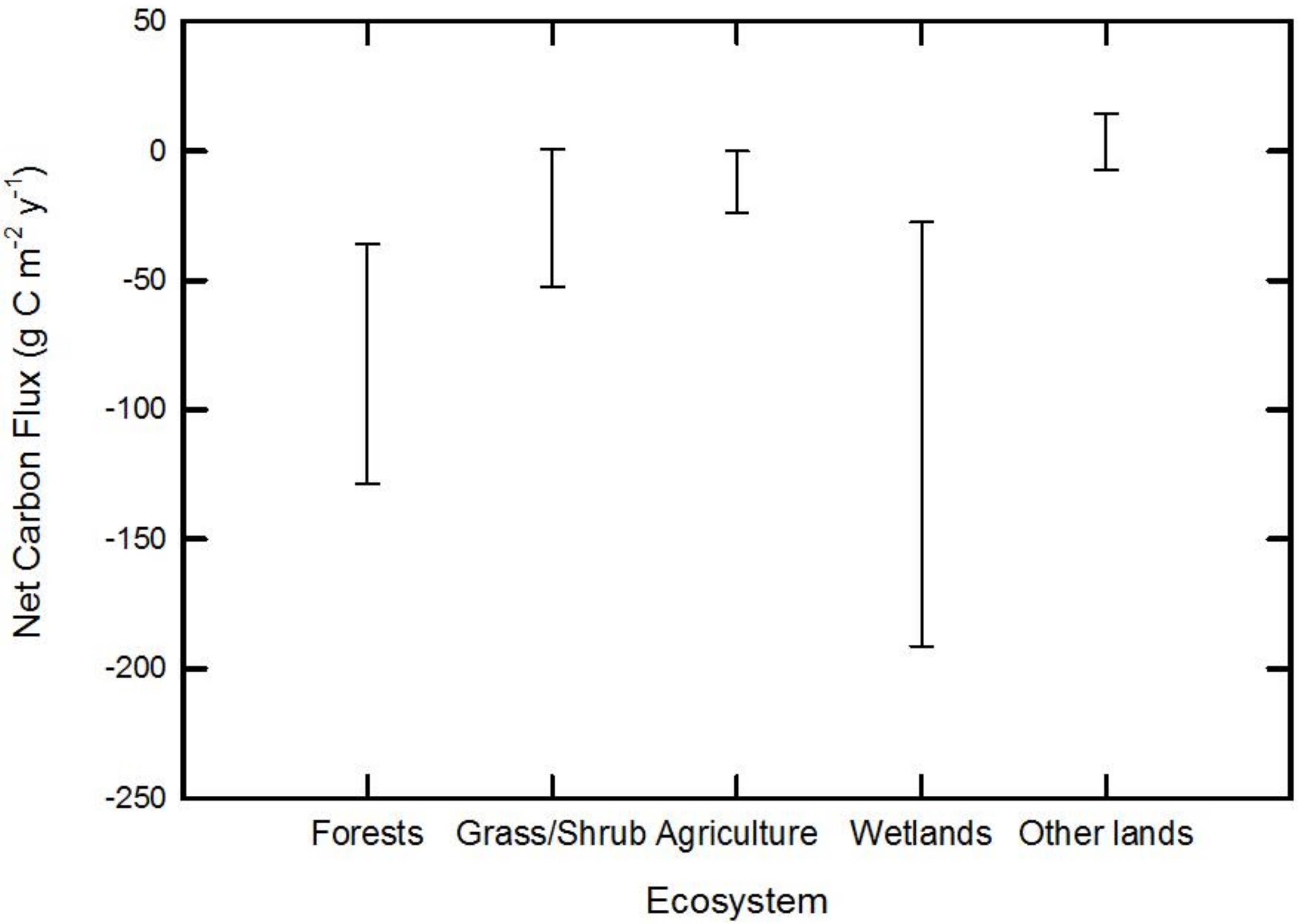
Synthesis Report (SYR) of the IPCC Fifth Assessment Report (AR5) 2014

Land management can be both a source and sink of GHGs

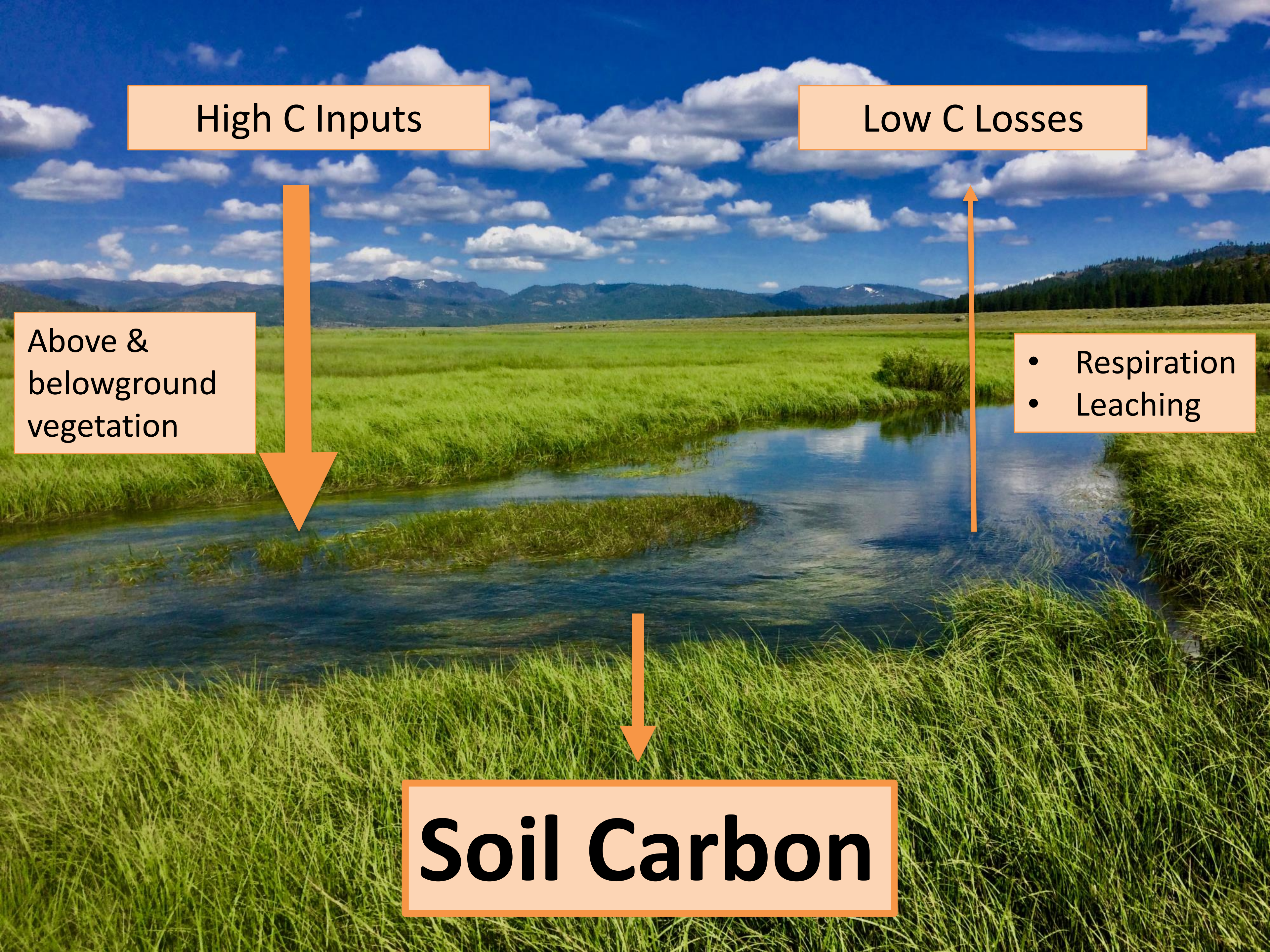


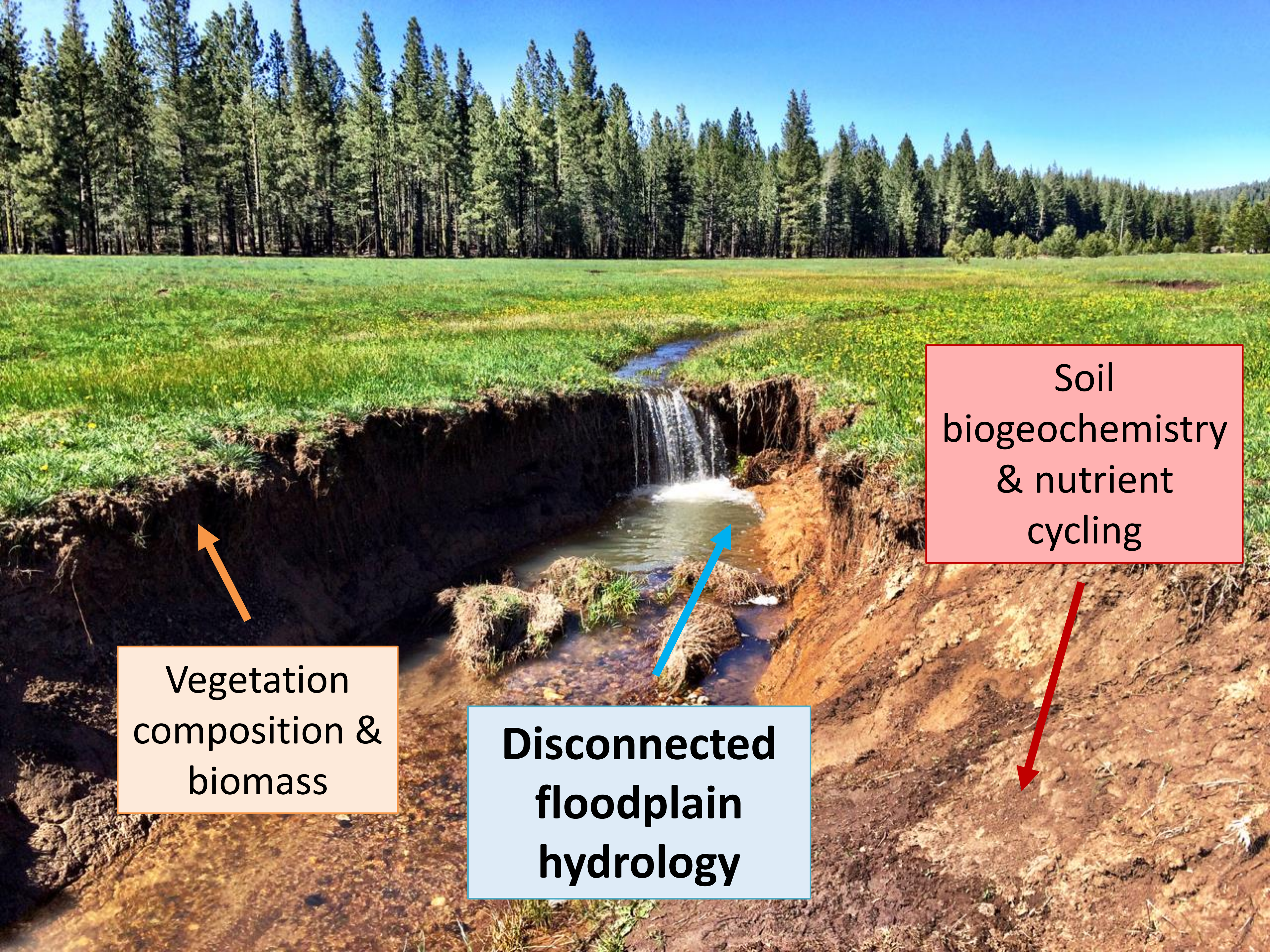
IPCC Fifth Assessment Report (AR5) 2013

C sequestration potential varies by ecosystem



Calculated from data for Western Cordillera, USA, reported in Chapter 5, Zhu, Zhiliang, and Reed, B.C., eds., 2012, Baseline and projected future carbon storage and greenhouse-gas fluxes in ecosystems of the Western United States: U.S. Geological Survey Professional Paper 1797, 192 p.


High C Inputs
Low C Losses
Above & belowground vegetation
• Respiration
• Leaching
Soil Carbon


Soil biogeochemistry & nutrient cycling
Vegetation composition & biomass
Disconnected floodplain hydrology

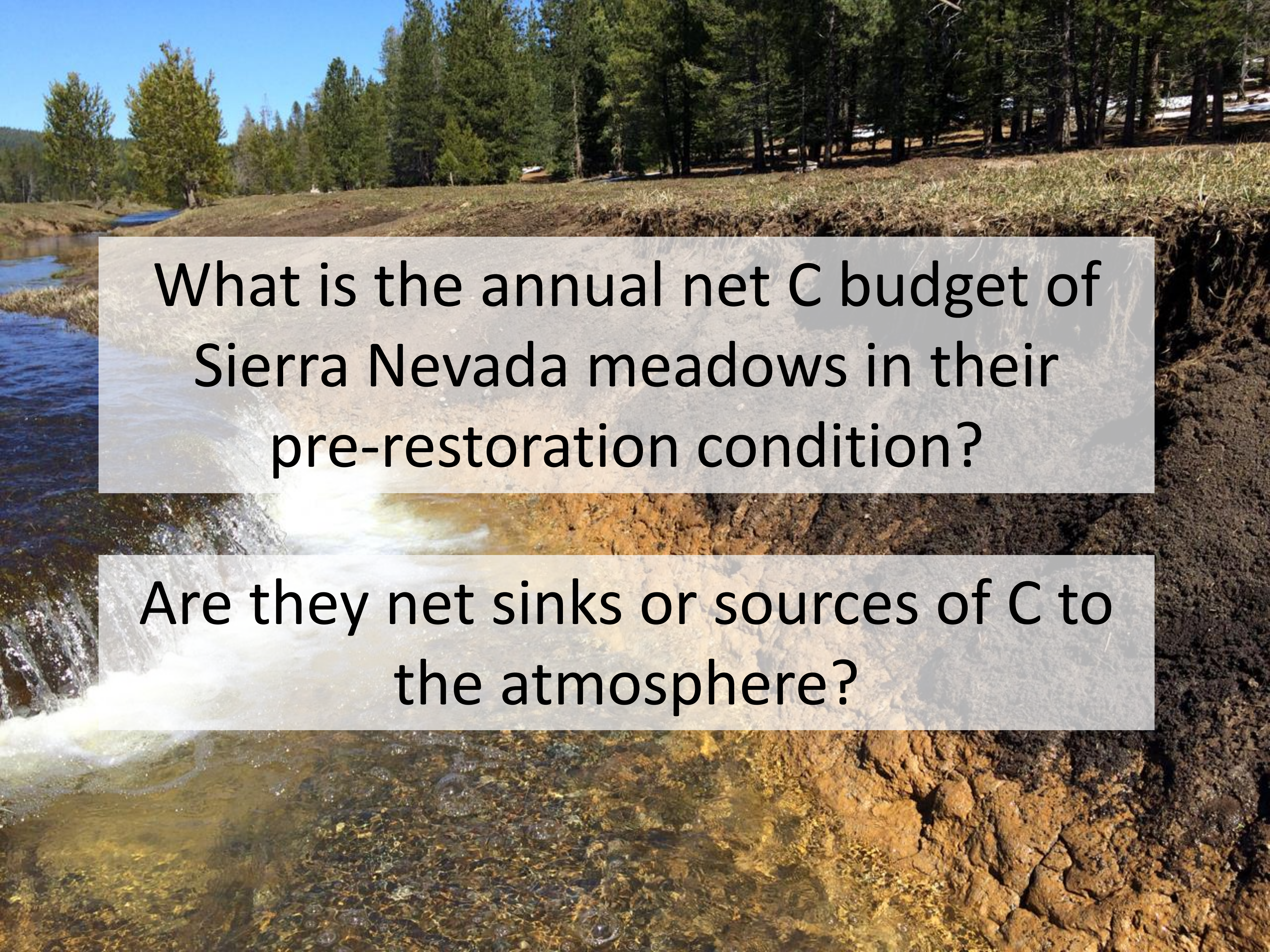

How does restoration of floodplain hydrology alter C sequestration in mountain meadows?

General Research Design

- Comparison of pre- and post-restoration C stocks and fluxes
- Mass balance approach to estimate total belowground C allocation
- Total C sequestered as a result of restoration

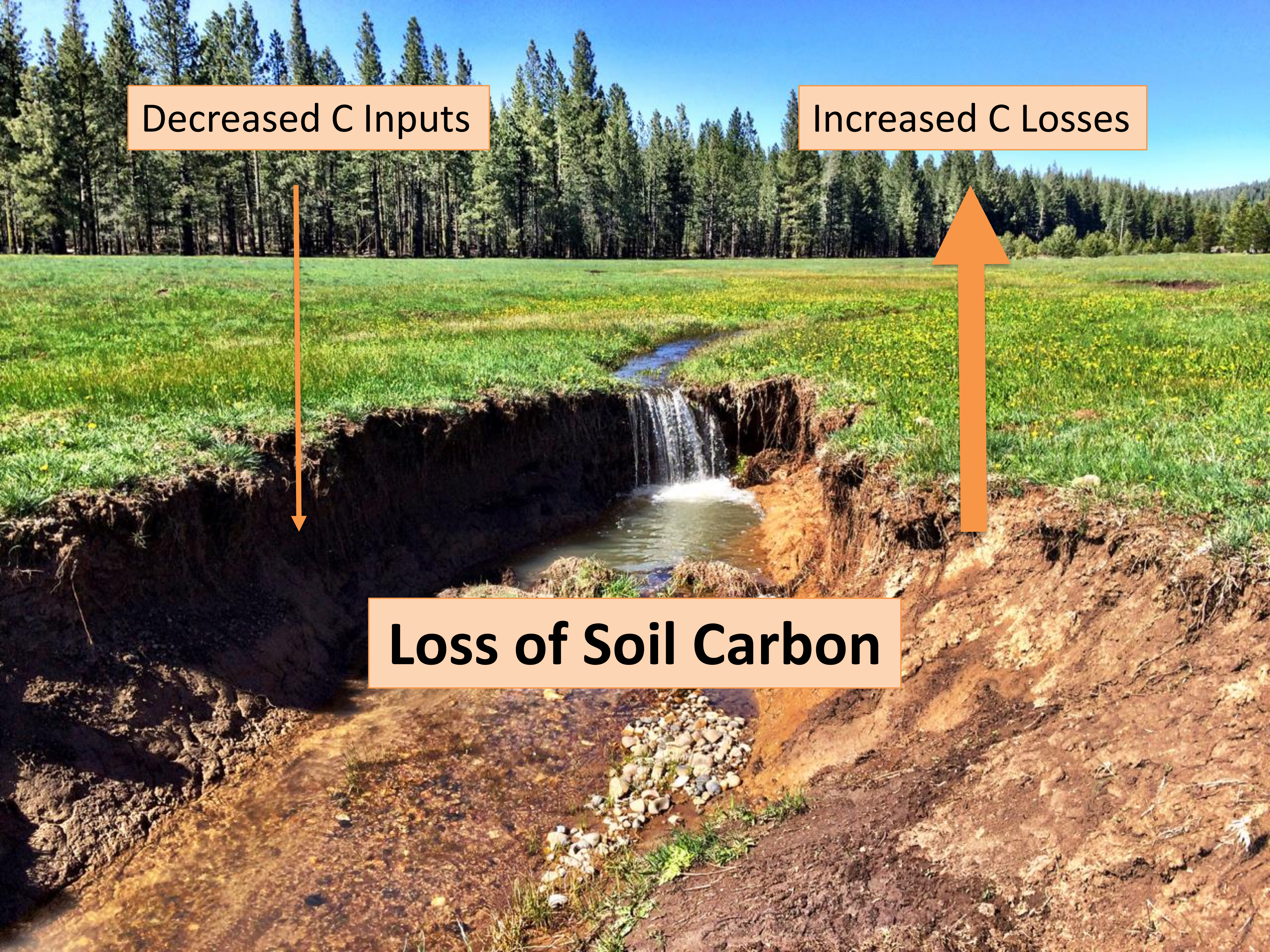
BUT to measure the impact of restoration,

we need to understand and quantify C dynamics in degraded meadows

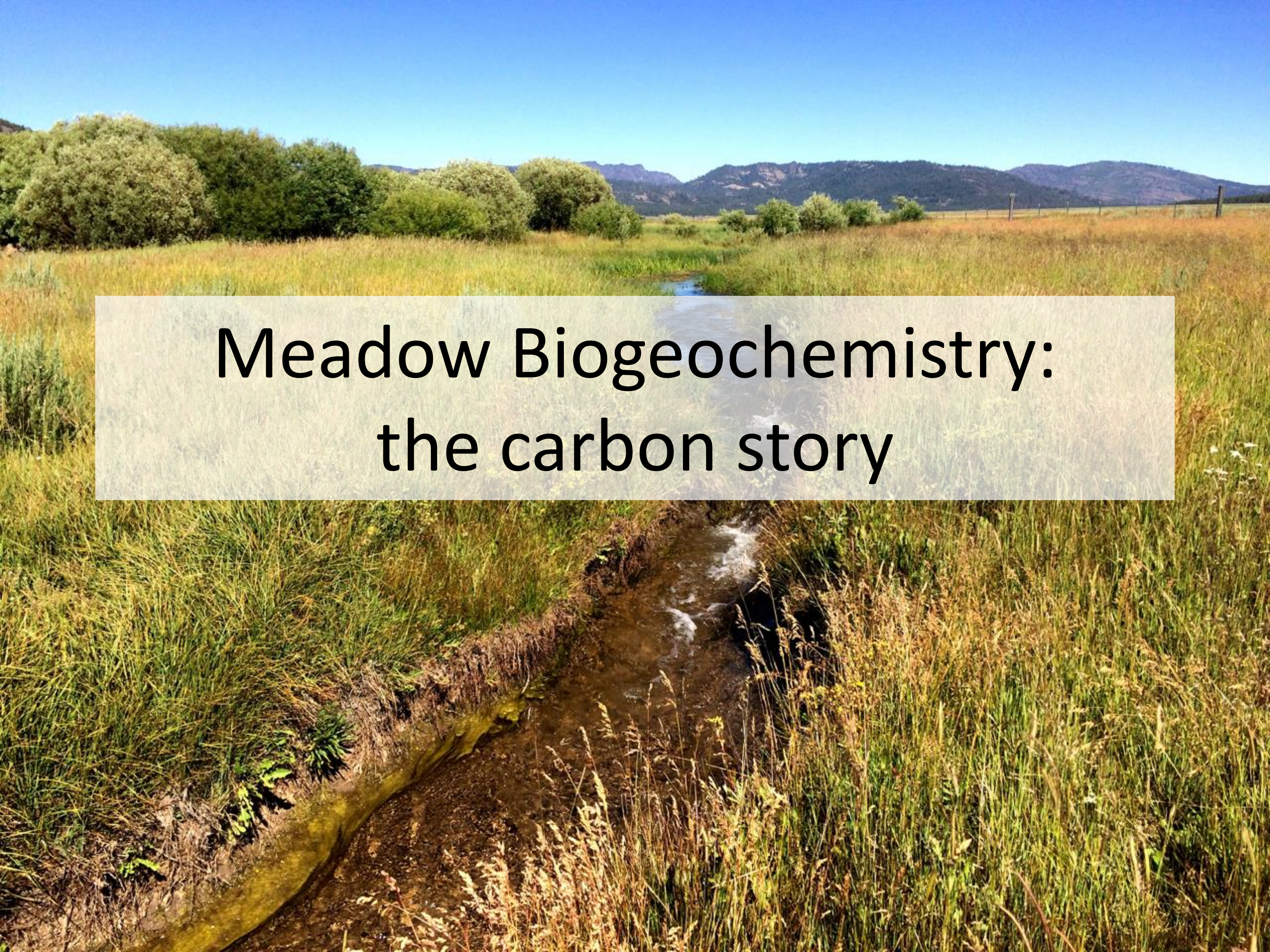


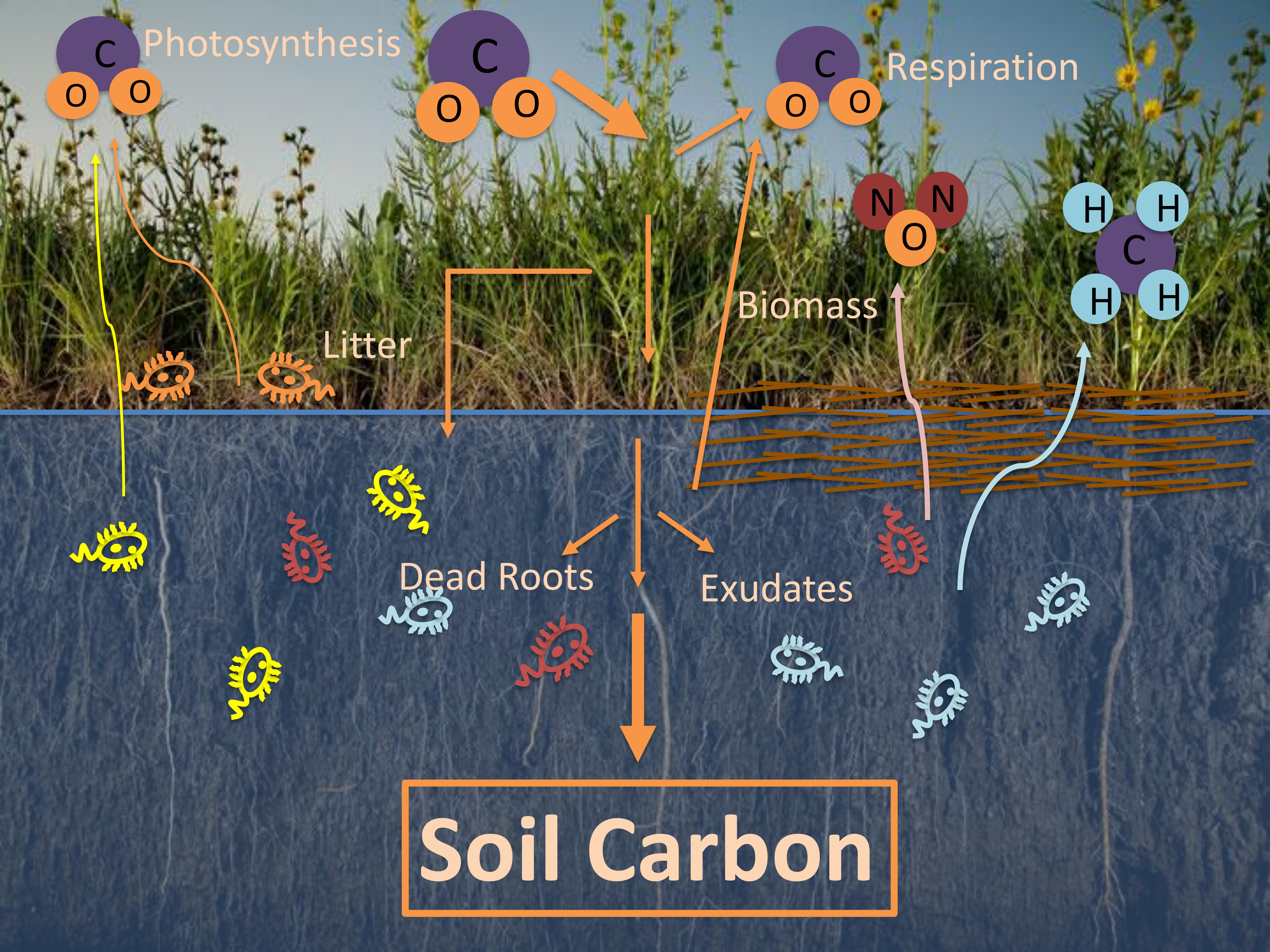
What is the annual net C budget of Sierra Nevada meadows in their pre-restoration condition?

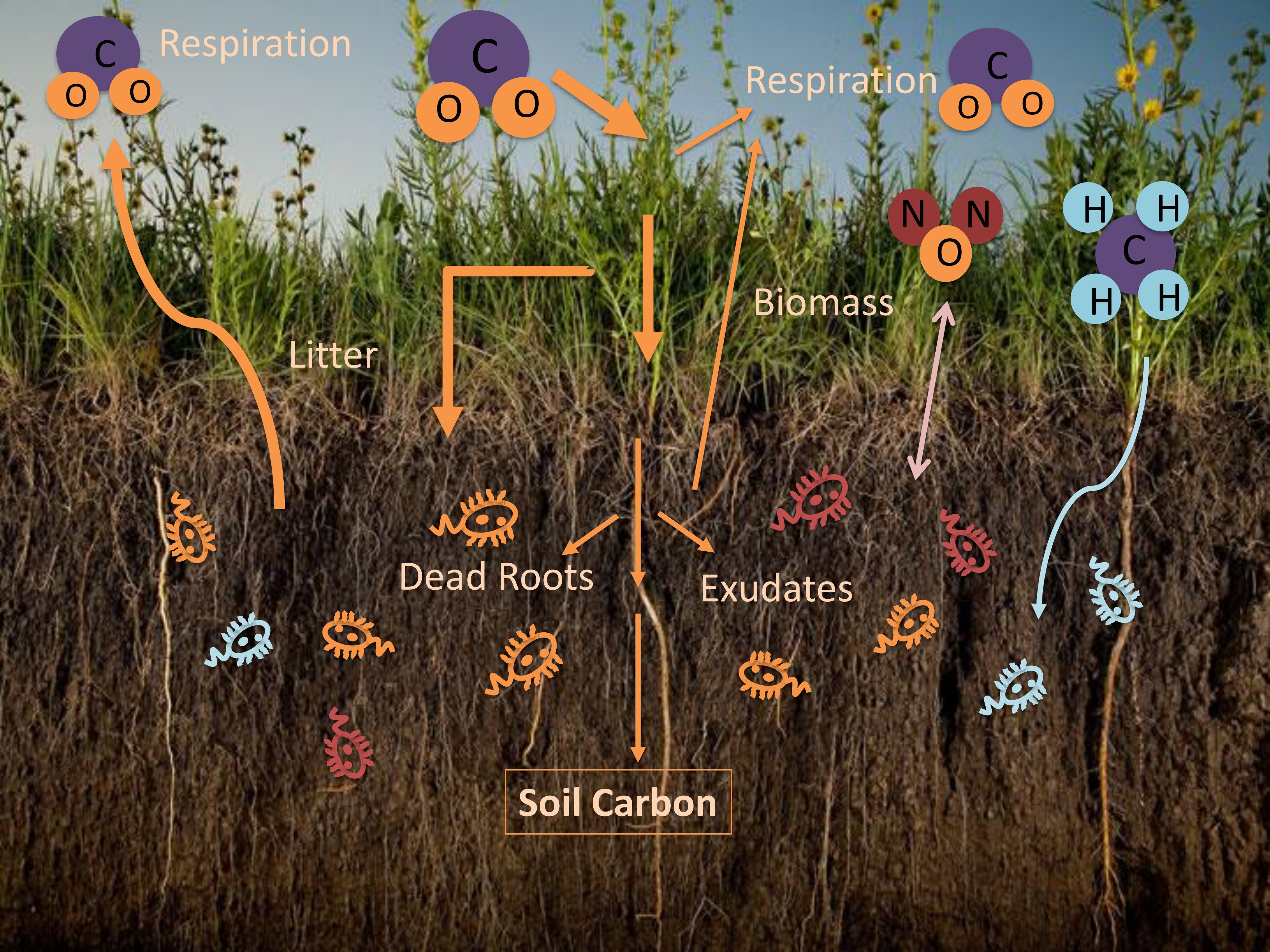
Are they net sinks or sources of C to the atmosphere?


Decreased C Inputs
Increased C Losses
Loss of Soil Carbon

Meadow Biogeochemistry: the carbon story



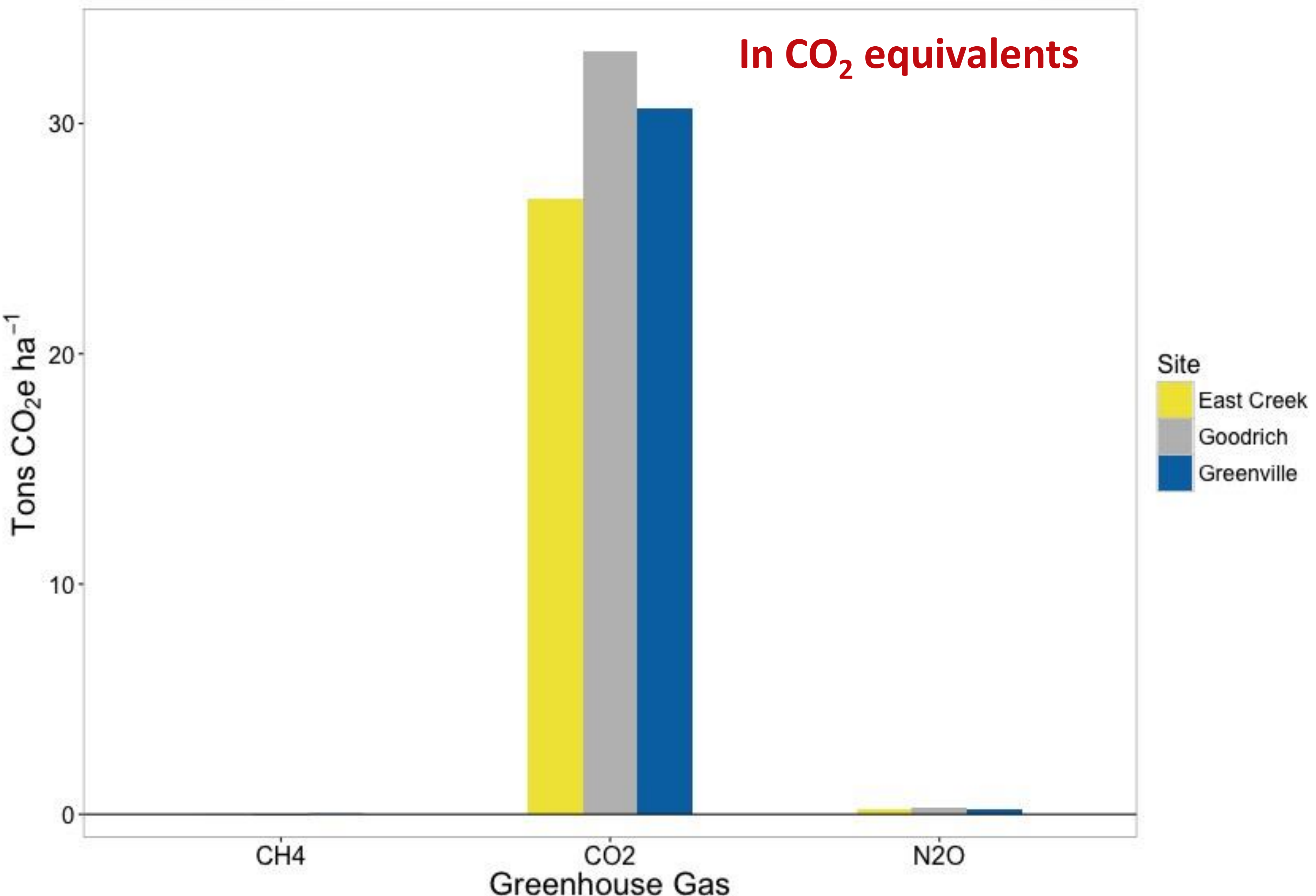

Photosynthesis
Respiration
Biomass
Litter
Dead Roots
Exudates
Soil Carbon
C
O
O
N
N
O
H
H
C
H
H


Respiration
Respiration
Biomass
Litter
Dead Roots
Exudates
Soil Carbon
C O O
C O O
C O O
N N O
H H C H H

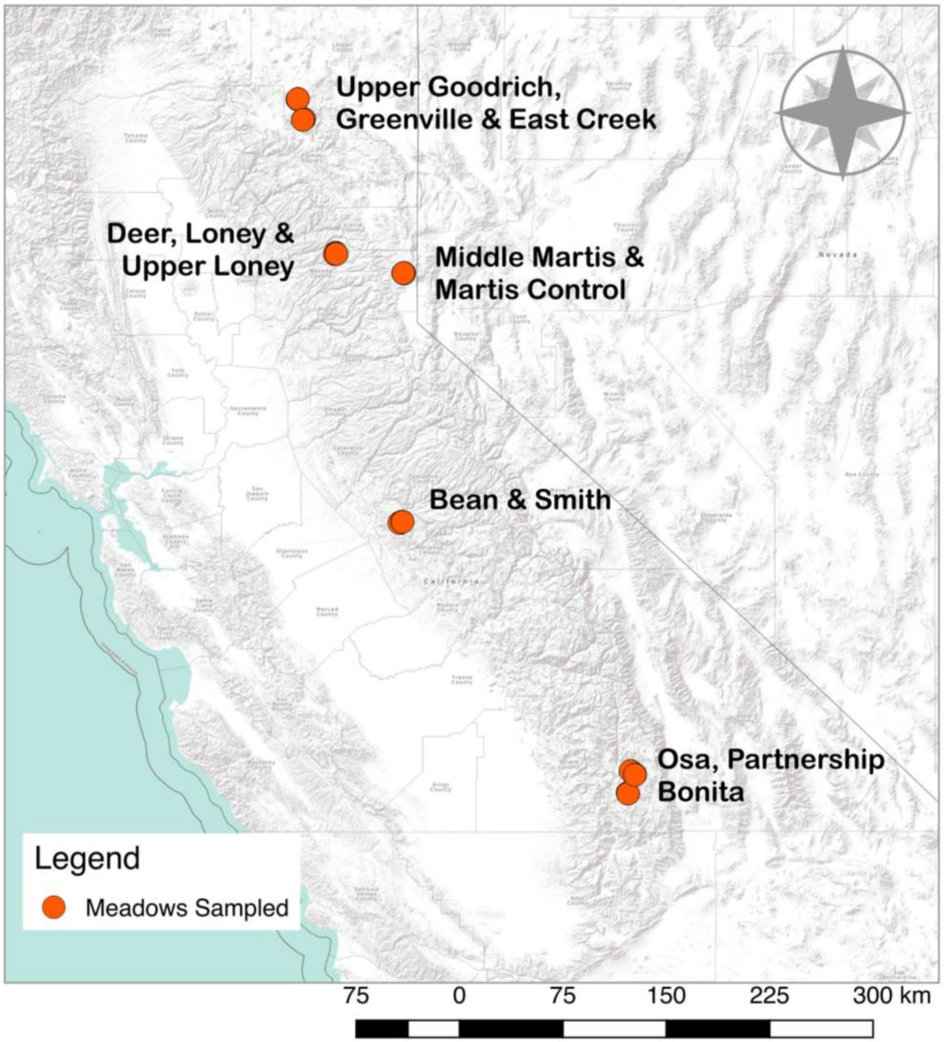
Meadows are not farmland or wetlands

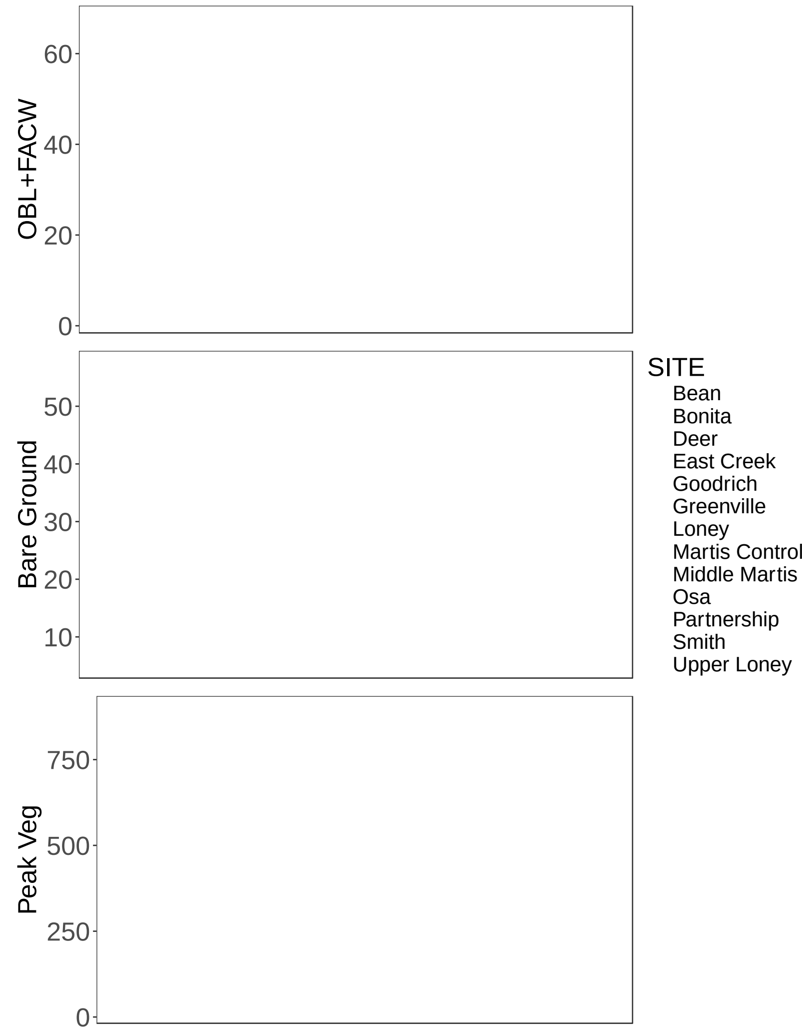
- Seasonally dynamic hydrology & low temps
  - Temperature and redox controls on microbial activity
  - Plant community composition & productivity
- Dominance of herbaceous OBL + FACW species
  - Large root biomass and belowground C inputs
- High mineral soil content
  - Increase C stability through absorption and adsorption processes
  - Alternative electron acceptors impact rates of C mineralization under changing redox conditions

Annual Soil GHG Budget

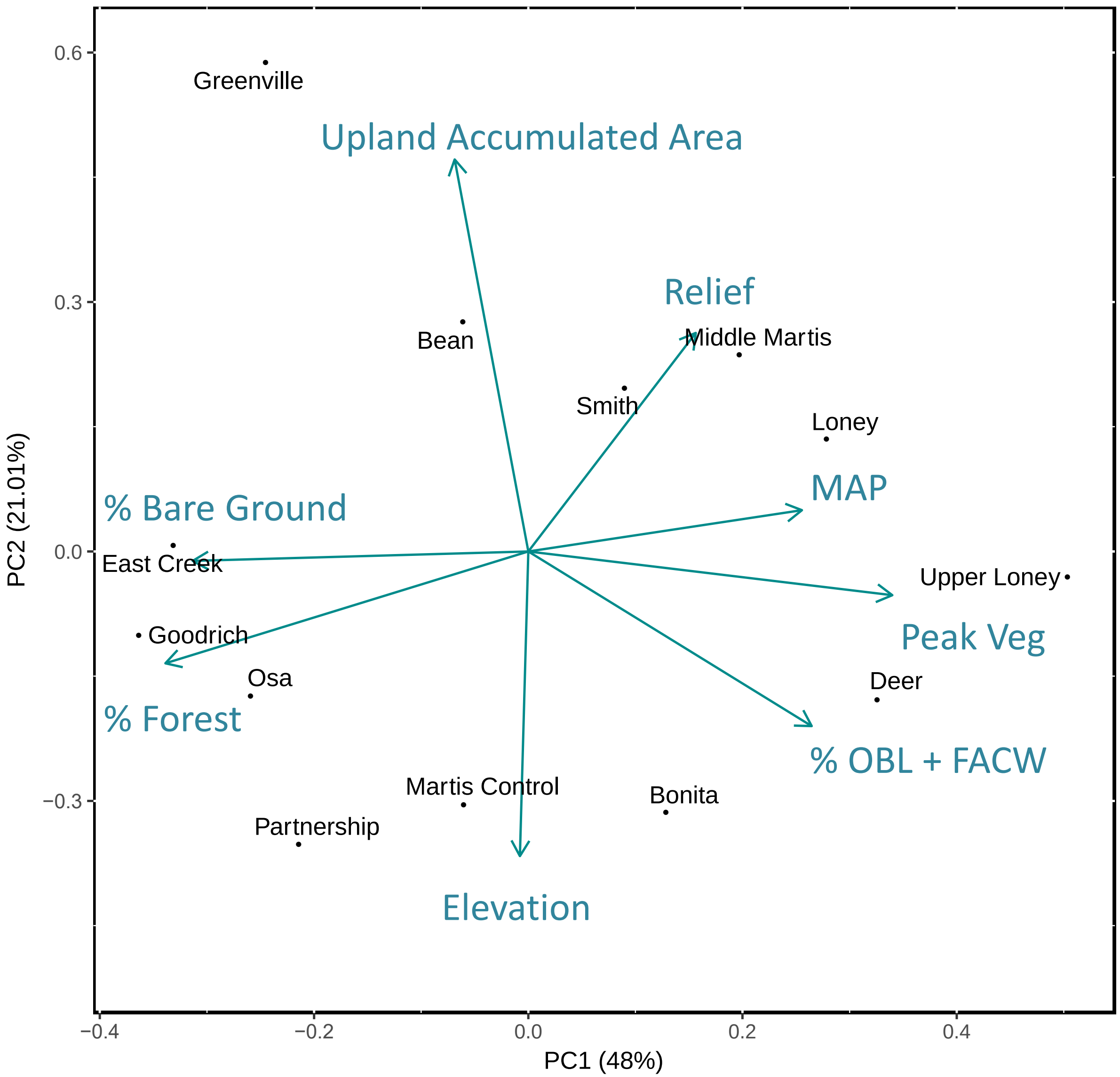


13 meadows across Sierra Nevada
Continuous levels of degradation



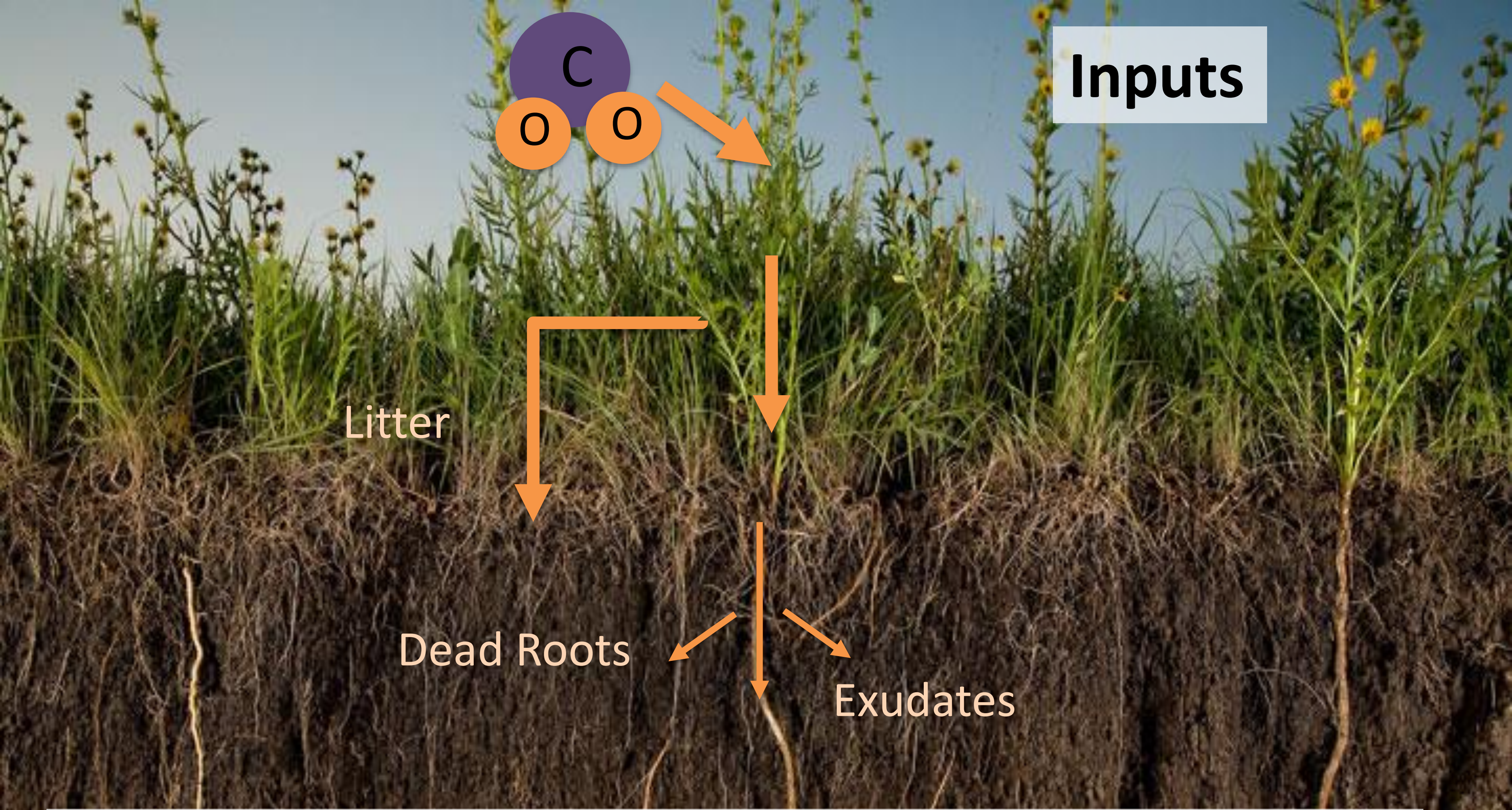


Sites don't cluster based on climate, watershed characteristics or level of degradation




Annual Net △ Soil C
= Gross C Inputs – Gross C Outputs

Inputs



Gross Inputs = C inputs from litter + C inputs from roots

C inputs from litter = Senescent biomass x %C x k

C inputs from roots =

(Root biomass x Root turnover rate x %C x k) +

Root Exudates

Litter

Root Biomass

Problem

- BUT roots are not just passive stocks
- Actively release root exudates
- Important for ecosystem function
- Just measuring litter and root biomass ignores root exudates
- Changes in soil C pool size hard to capture with short-term experiments

Solution

- δ^{13}C pulse-labeling experiment
- Track flow of labeled C through plants, into the soil and back to the atmosphere
- Quantitative measure of rate of root exudation
- Separate microbial respiration from root and shoot respiration

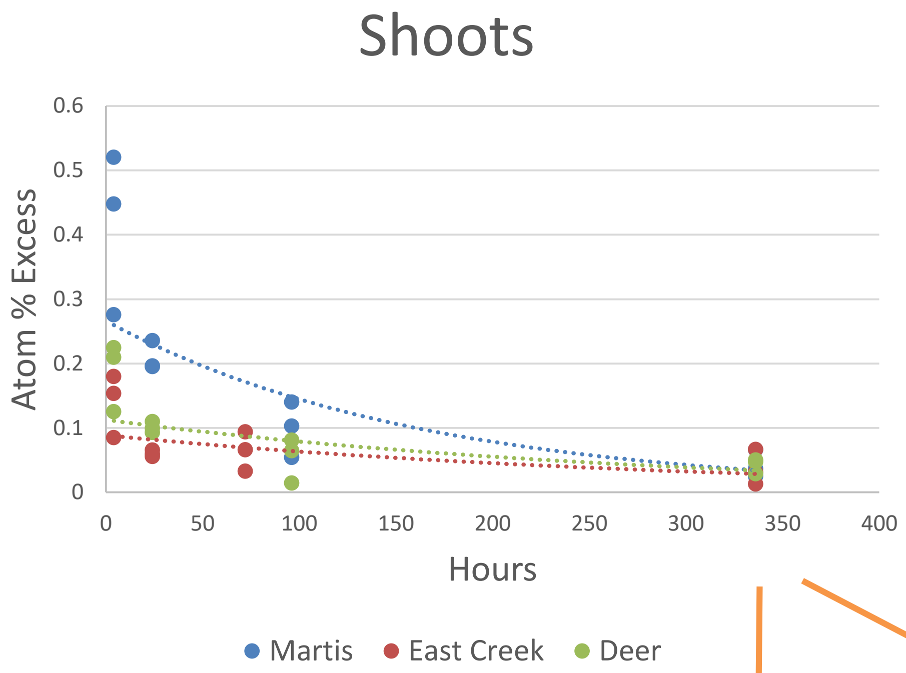
δ^{13}C Pulse-chase Experiment

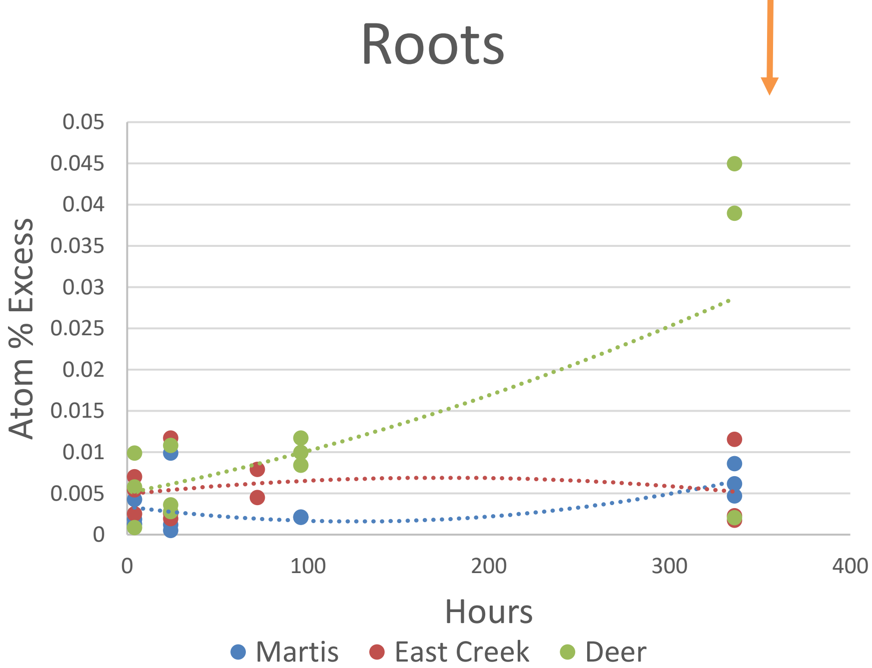
3 meadows
5 plots
- 3 labeled
- 2 natural abundance

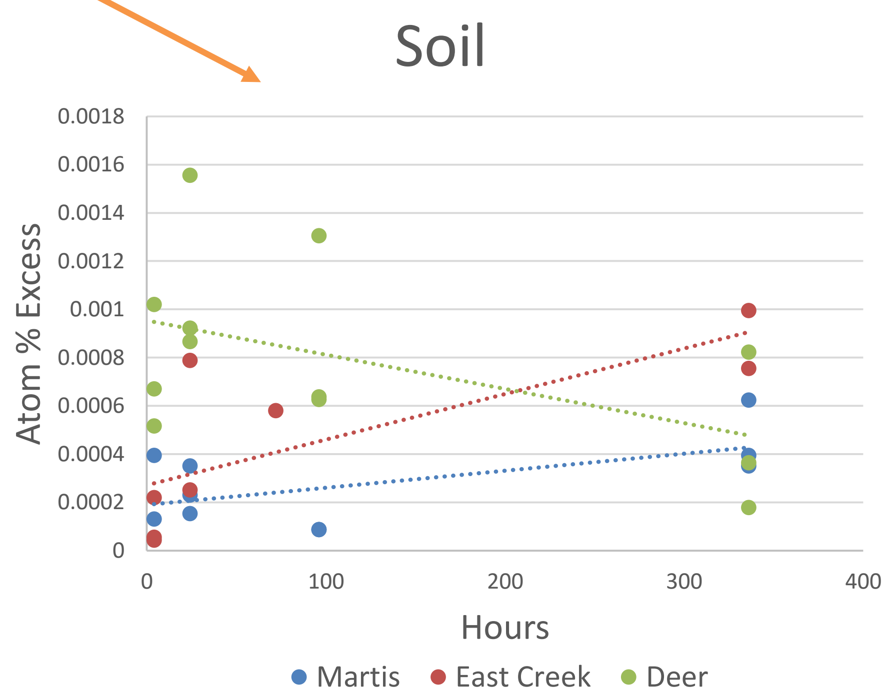
300 mL 95 atom% $^{13}C - CO_2$
Sampled 4, 24, 96, 336h after labeling
- Vegetation biomass
- Root biomass
- Soil
- CO_2 flux

Analyzed for %C and $^{12}C/^{13}C$

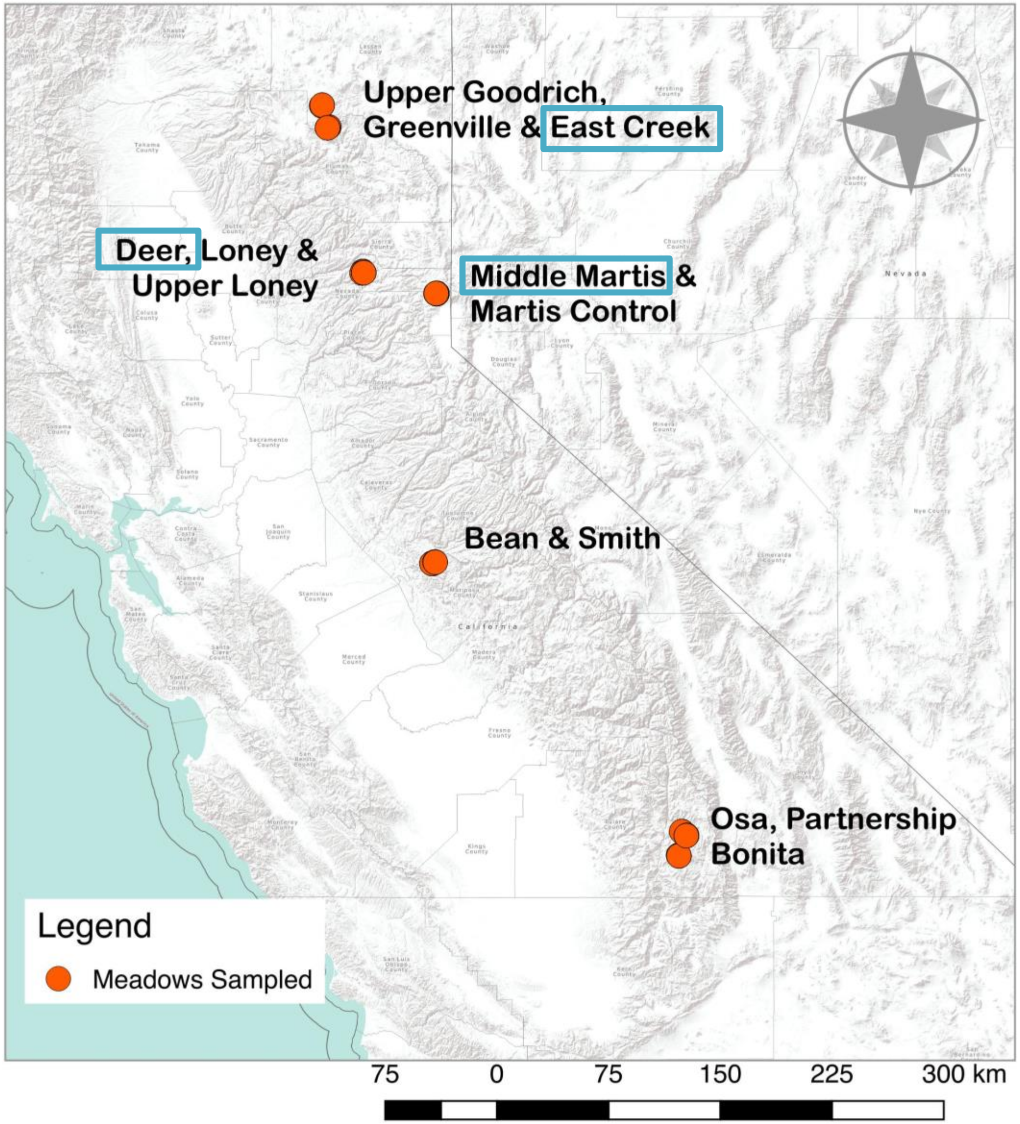
Labeled C transferred from shoots into roots and soil over time

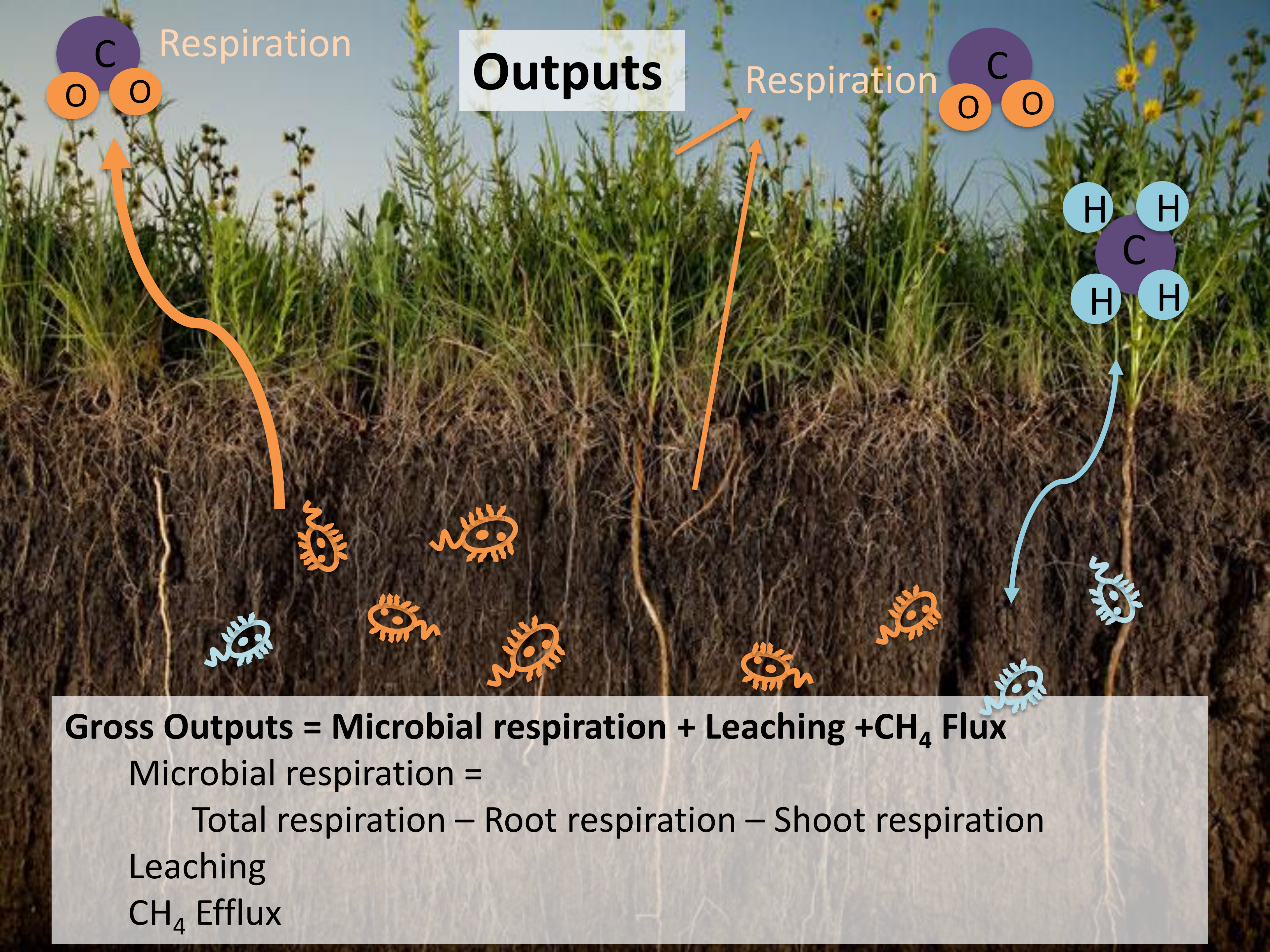


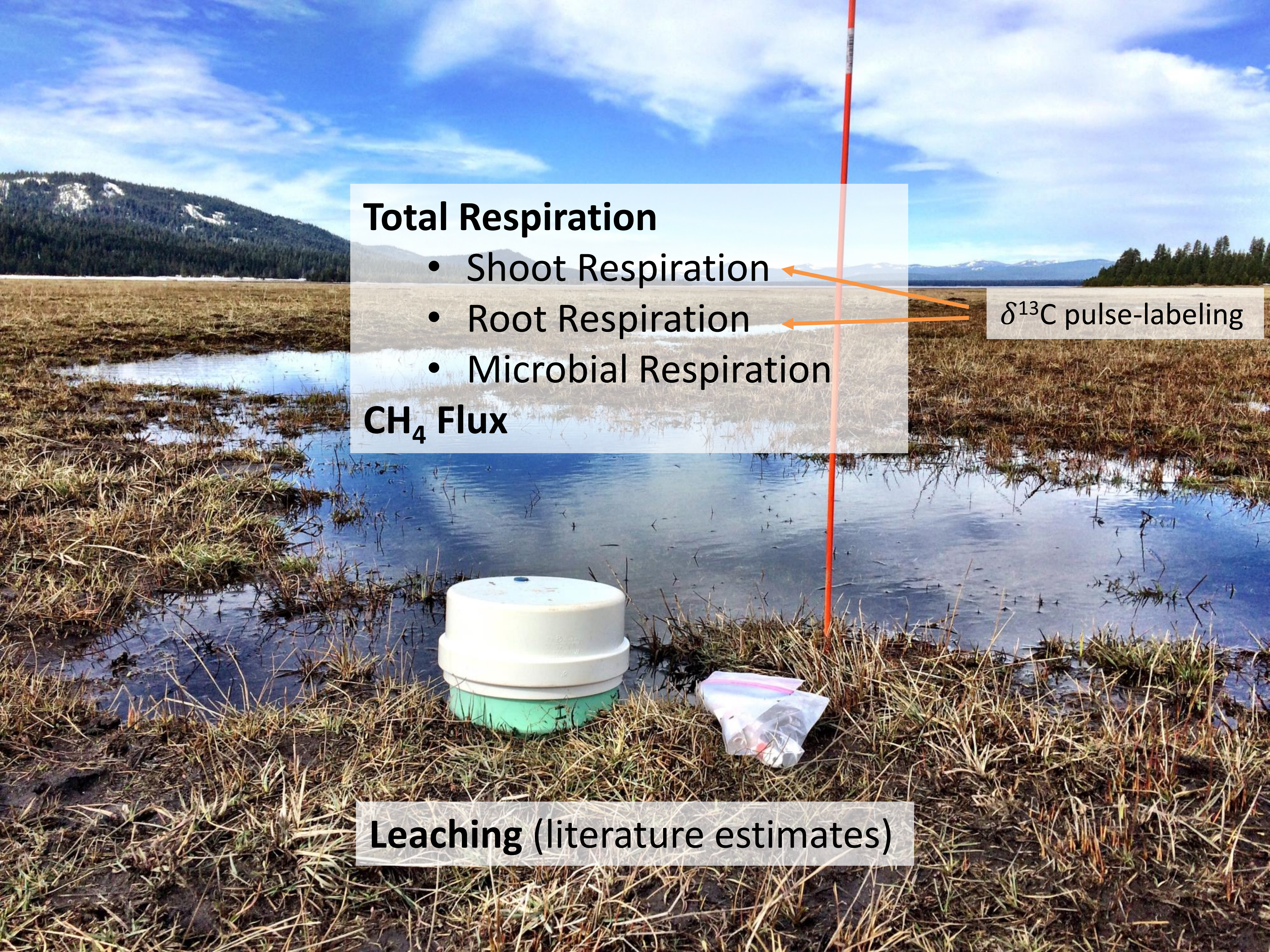


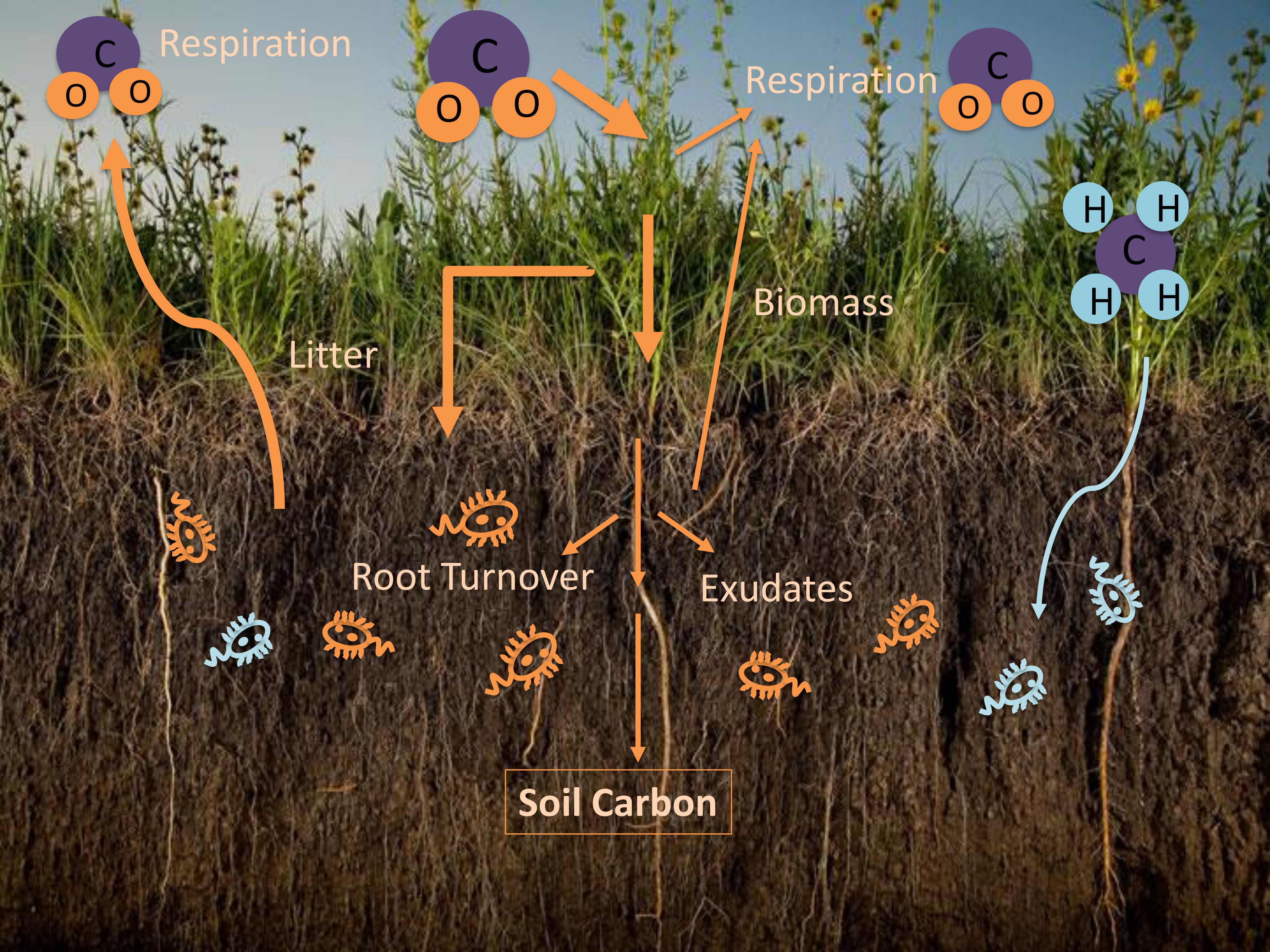


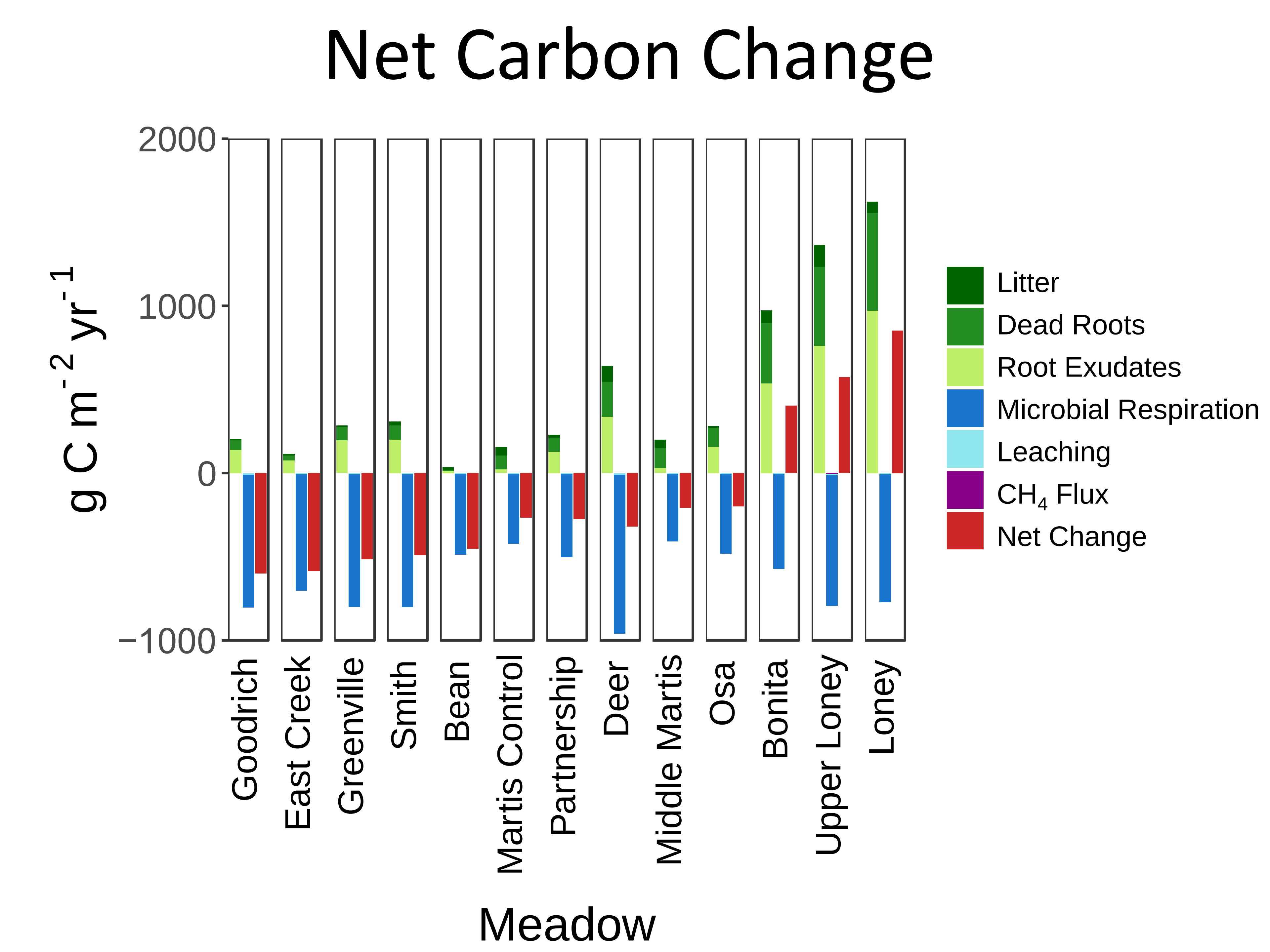
Sites stratified by elevation & representatives of each sampled




Outputs
Respiration
Respiration
C
O
O
C
O
O
H
H
C
H
H
Gross Outputs = Microbial respiration + Leaching +CH_4 Flux
Microbial respiration =
Total respiration – Root respiration – Shoot respiration
Leaching
CH_4 Efflux

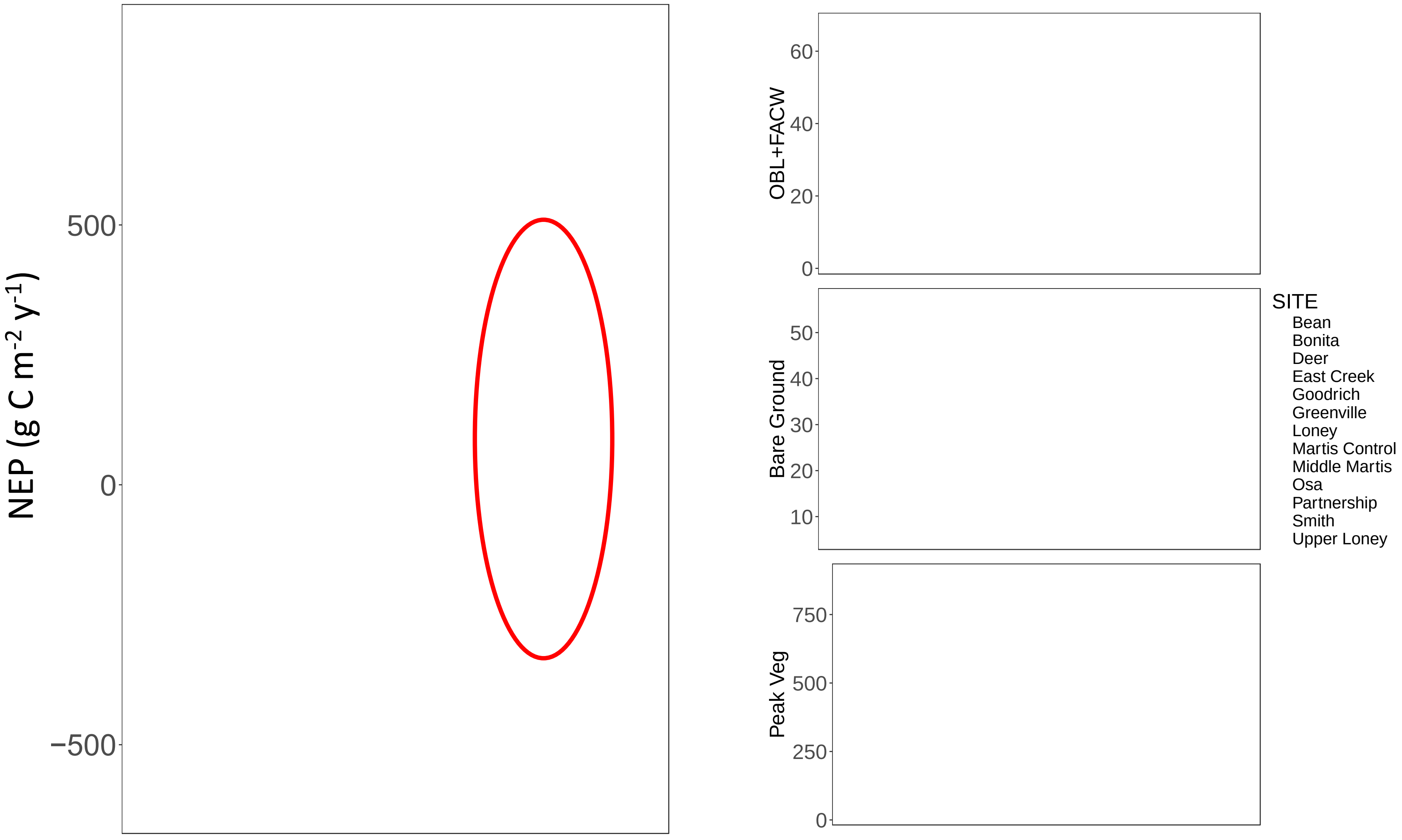

Total Respiration
• Shoot Respiration
• Root Respiration
• Microbial Respiration
CH_4 Flux
δ^{13}C pulse-labeling
Leaching (literature estimates)


Respiration
C
O O
C
O O
Respiration
C
O O
H H
C
H H
Biomass
Litter
Root Turnover
Exudates
Soil Carbon

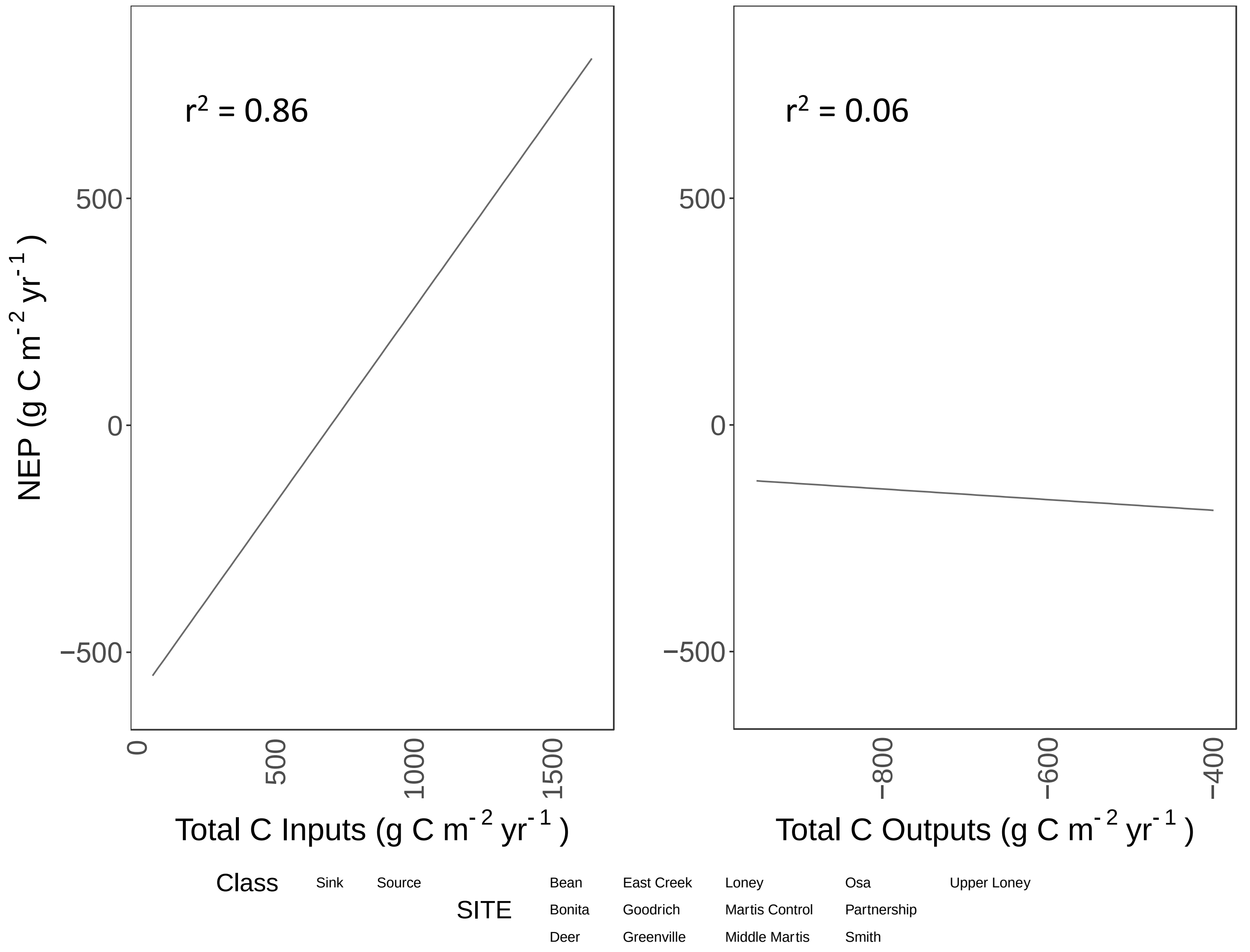


Net Carbon Change
g C m-2 yr-1
2000
1000
0
−1000
Goodrich
East Creek
Greenville
Smith
Bean
Martis Control
Partnership
Deer
Middle Martis
Osa
Bonita
Upper Loney
Loney
Meadow
Litter
Dead Roots
Root Exudates
Microbial Respiration
Leaching
CH_4 Flux
Net Change

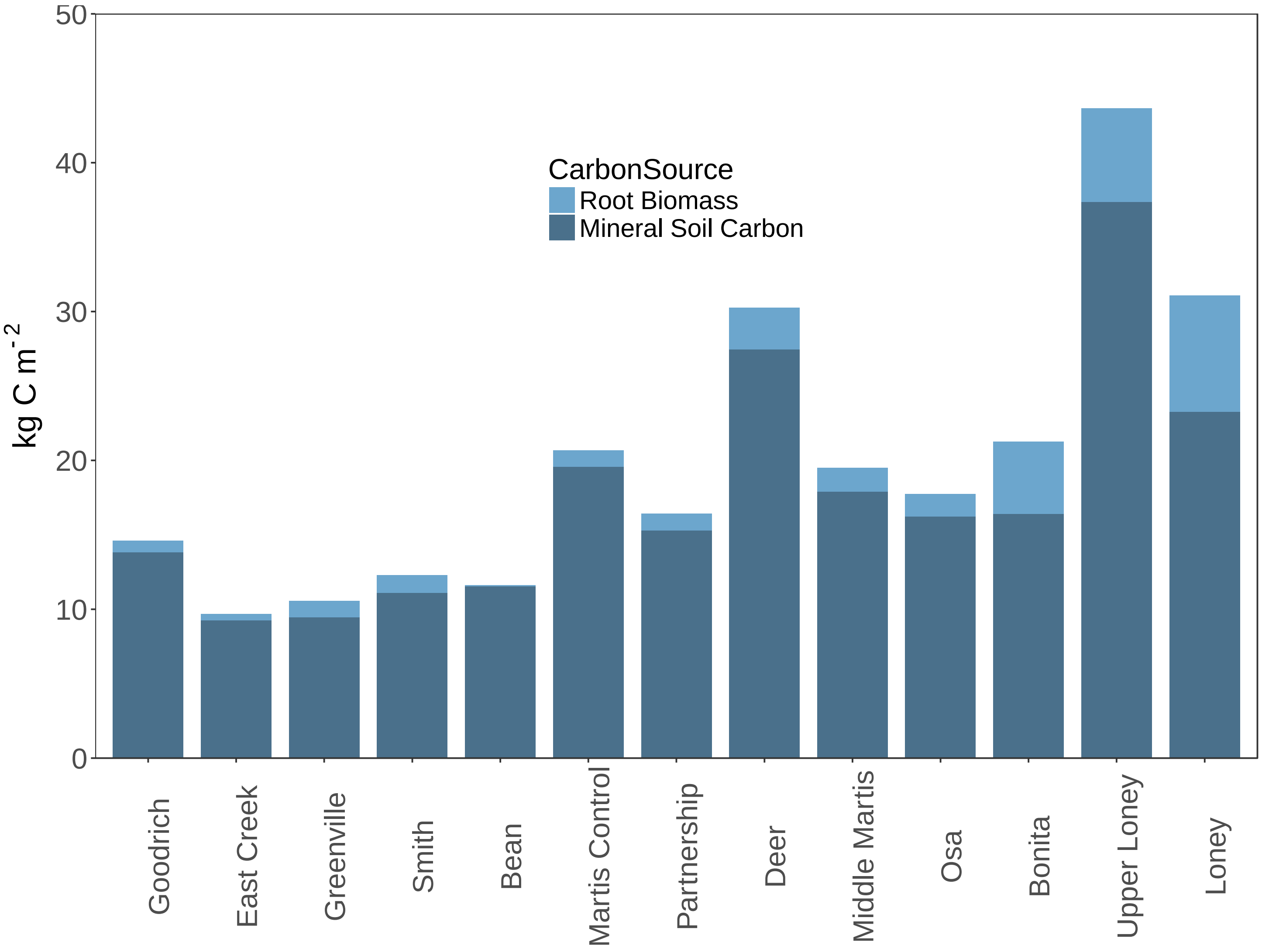
Carbon dynamics exhibit non-linear response to disturbance



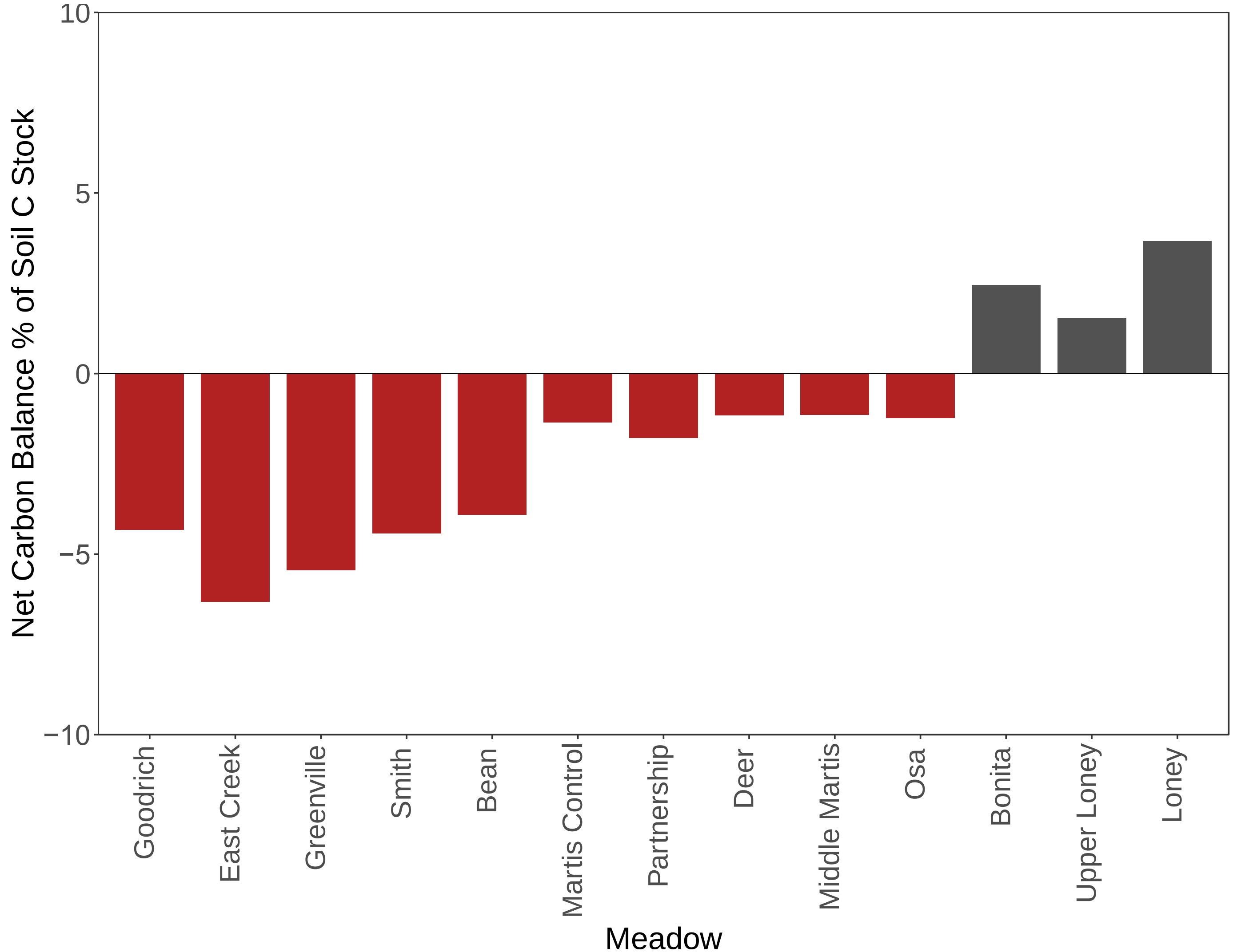
Switch from C sink to source driven by C inputs not outputs

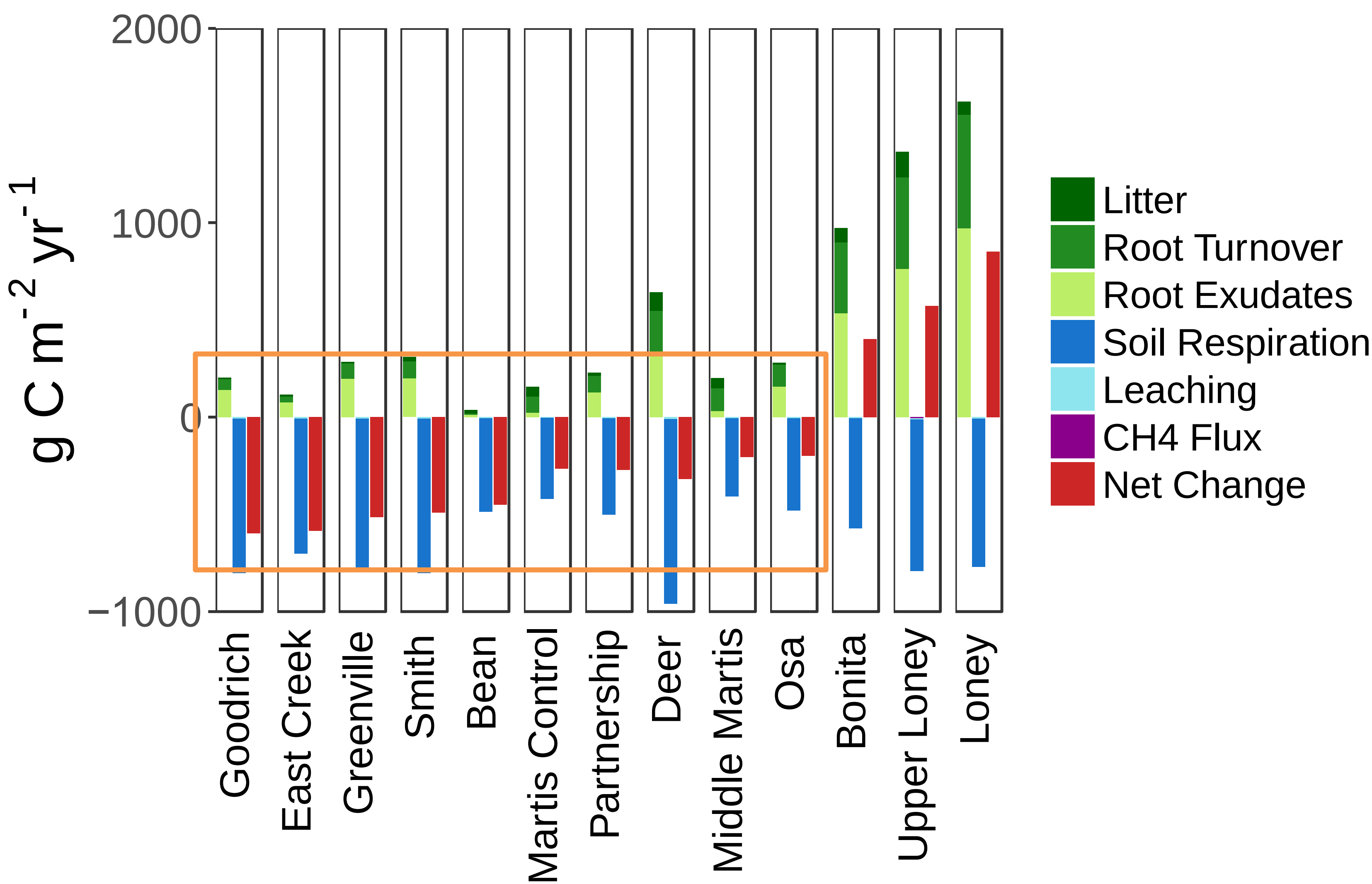


Degraded meadows still have a lot of belowground C



Annual C gains/losses substantial fraction of belowground C stocks





What explains variation in the magnitude of C losses from degraded meadows?

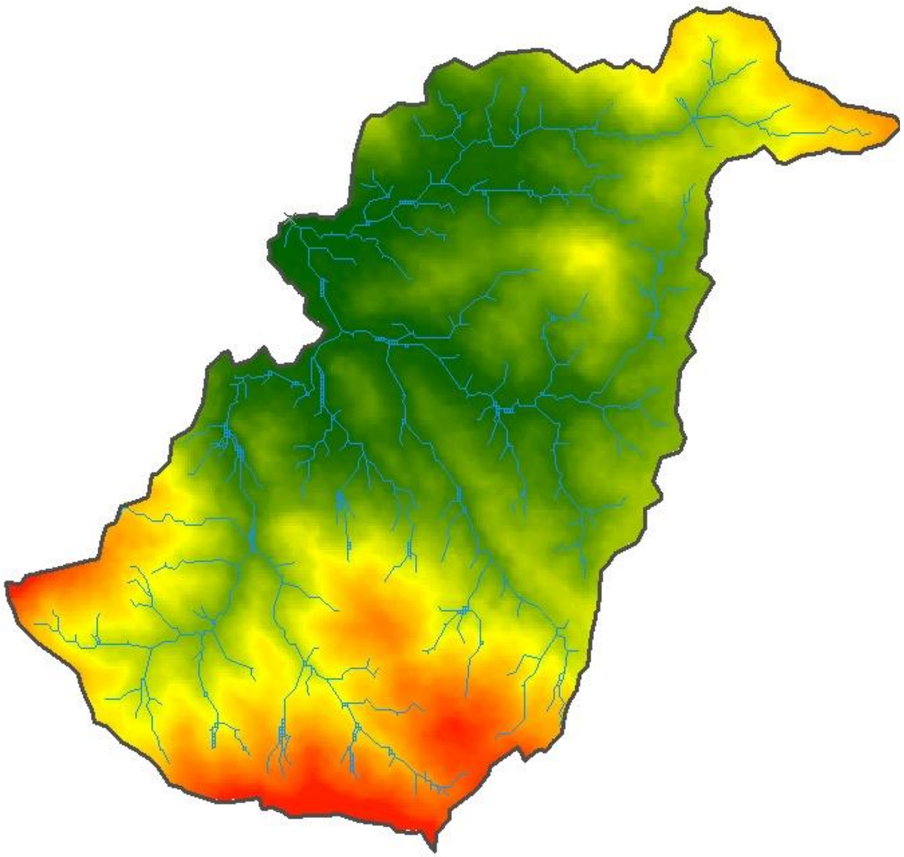
Level of Degradation?

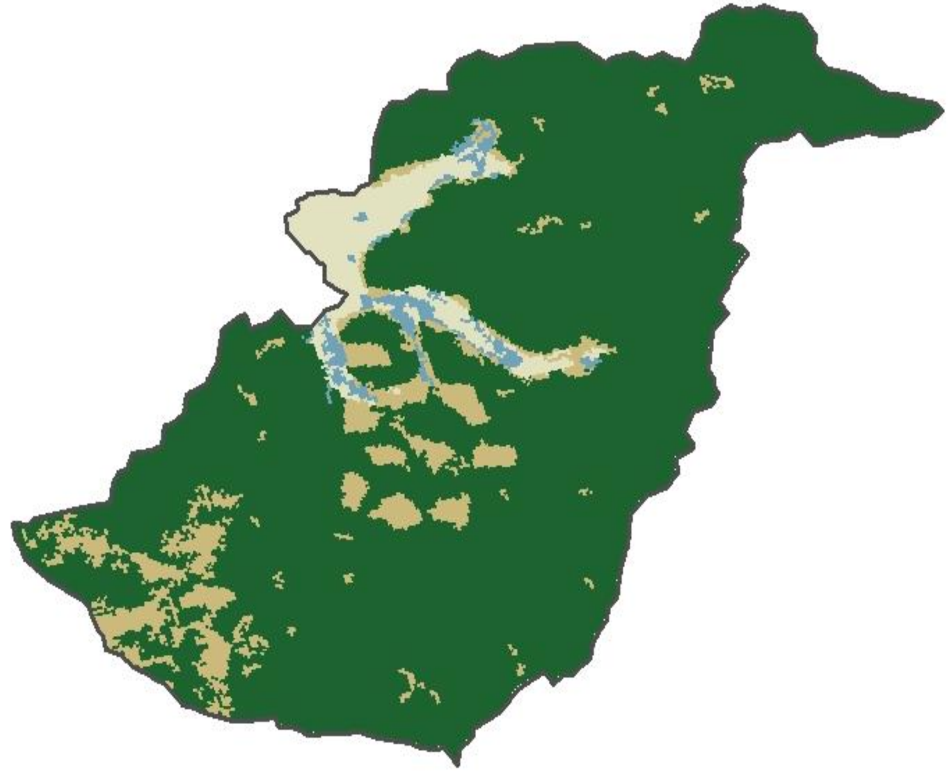
% cover OBL + FACW species
% cover bare ground

Climate?

Mean annual temperature
Mean annual precipitation

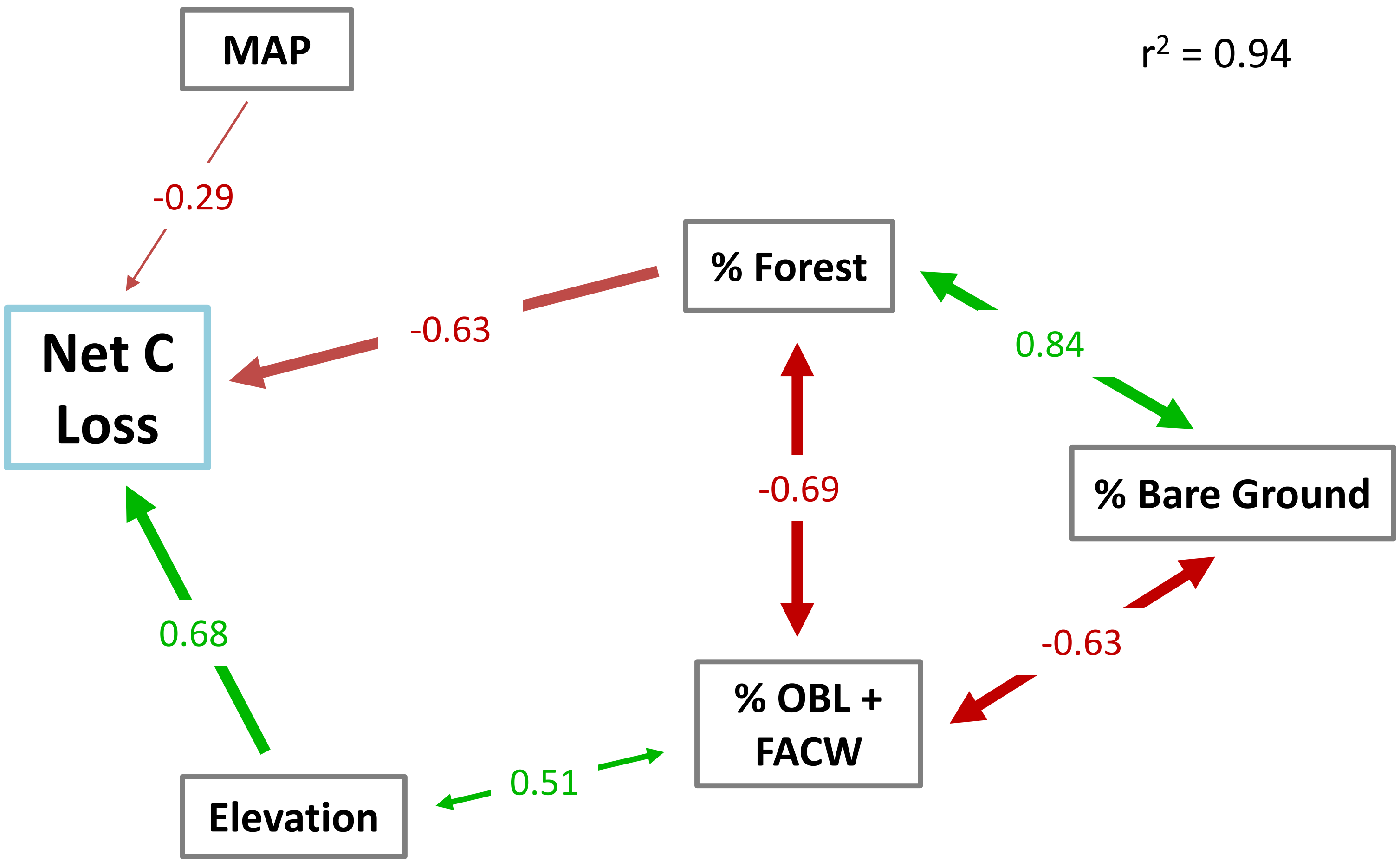
Watershed Characteristics?





Upland accumulated area
Watershed relief
% forest in uplands

Climate and levels of degradation drive variation in NEP in degraded meadows



Functioning meadows sequester C

Net soil C gains

(mean 3 Sierra Nevada meadows)

6.1 Mg C ha^{-1} y^{-1}

=

Carbon sequestered by

10.8 ha temperate forest y^{-1}

Degraded meadows are losing C

Net soil C losses

(mean 9 Sierra Nevada meadows)

-3.9 Mg C ha^{-1} y^{-1}

=

Carbon sequestered by

6.9 ha temperate forest y^{-1}

Pre-disturbance condition across the Sierra Nevada

Scaled across entire Sierra Nevada

(~130,000 ha)

=

814 Gg C y^{-1}

=

Carbon sequestered by

1.4 M ha temperate forest y^{-1}

Current Condition

Scaled across all degraded meadows in Sierra Nevada (~90,000 ha)

=

351 Gg C y^{-1}

=

Carbon sequestered by

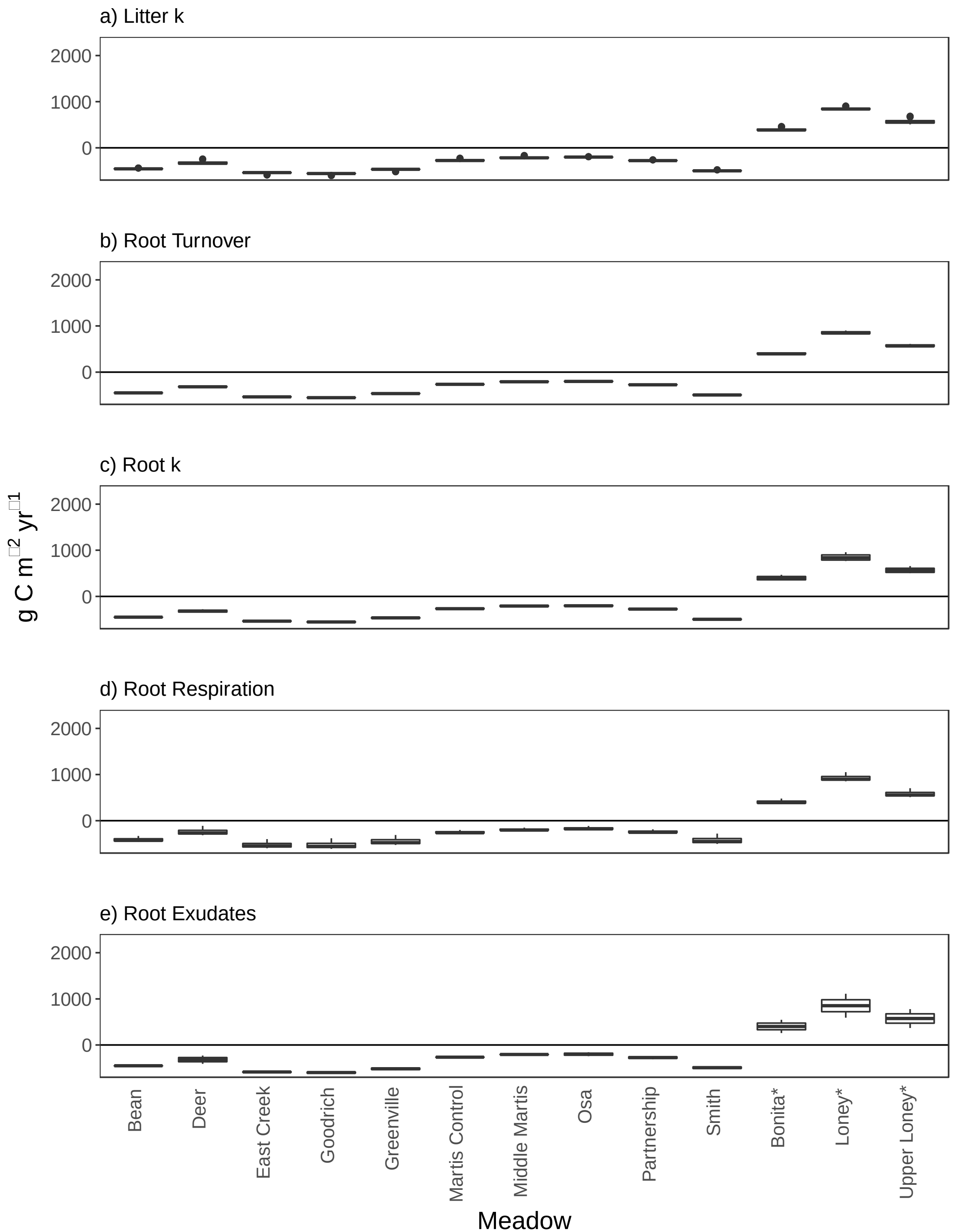
607,000 ha temperate forest y^{-1}

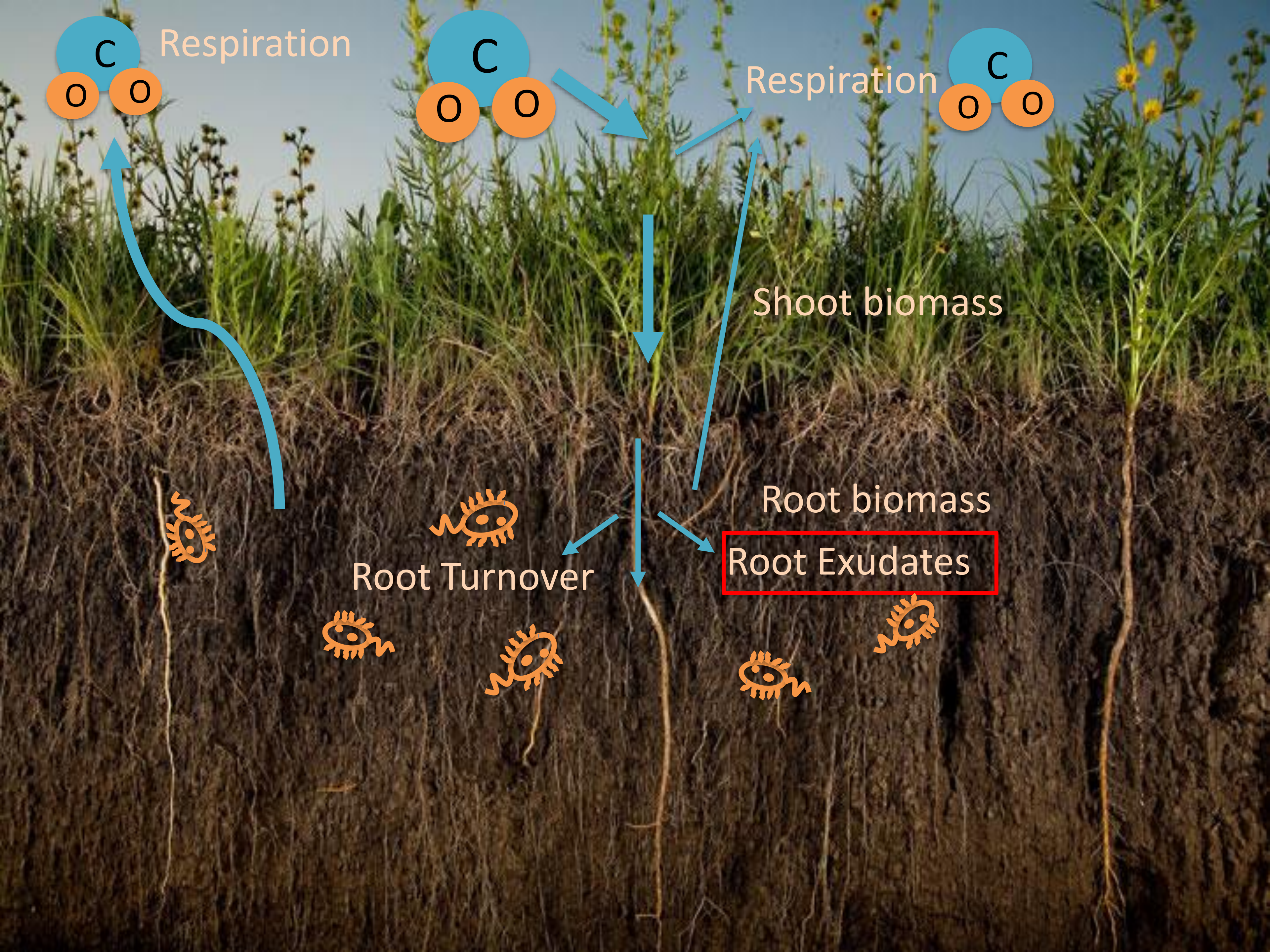
Take Home Messages

- Stemming C losses from degraded meadows may be as important as sequestering new C
- Restoring ”at-risk” meadows may prevent them from crossing the threshold
- Identifying and preserving functioning meadows should be a priority

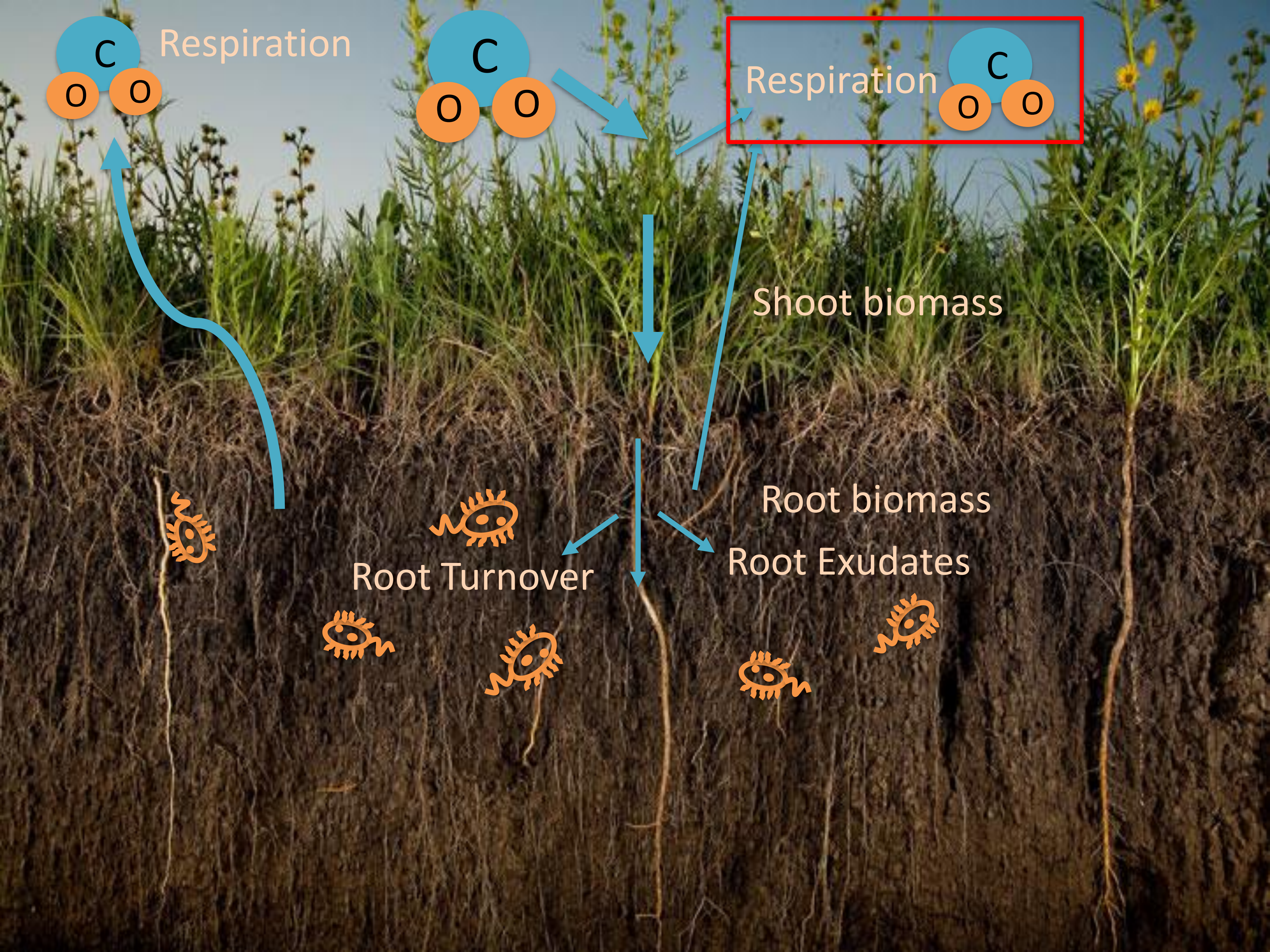
Questions?

Contact Info: creed@cabnr.unr.edu

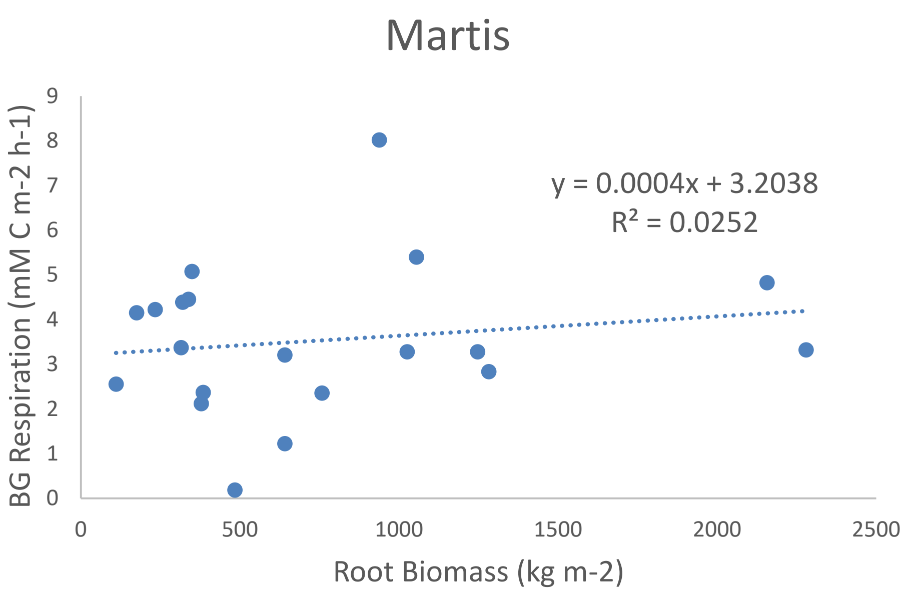

a) Litter k
b) Root Turnover
c) Root k
d) Root Respiration
e) Root Exudates
2000
1000
0
g C m□2 yr□1
Bean
Deer
East Creek
Goodrich
Greenville
Martis Control
Middle Martis
Osa
Partnership
Smith
Bonita*
Loney*
Upper Loney*
Meadow

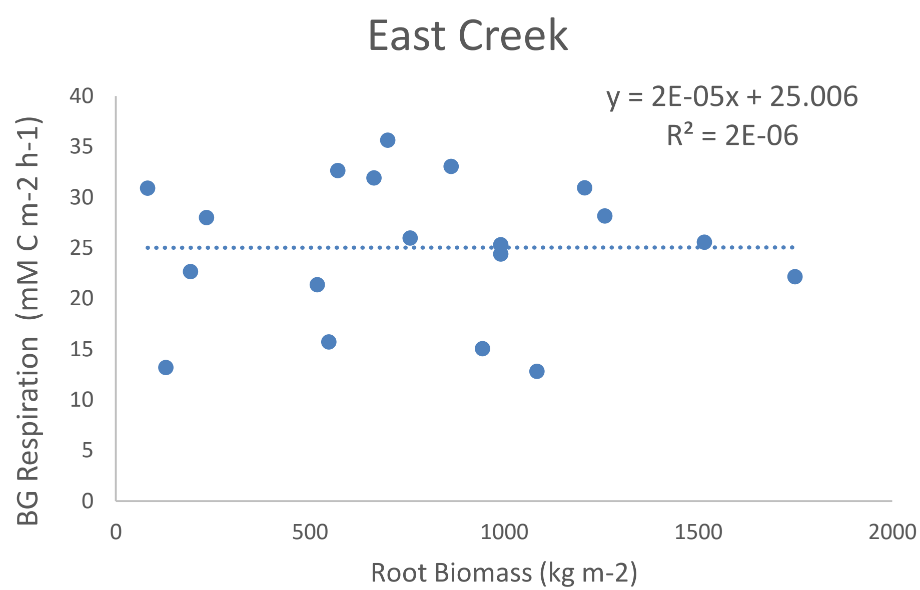


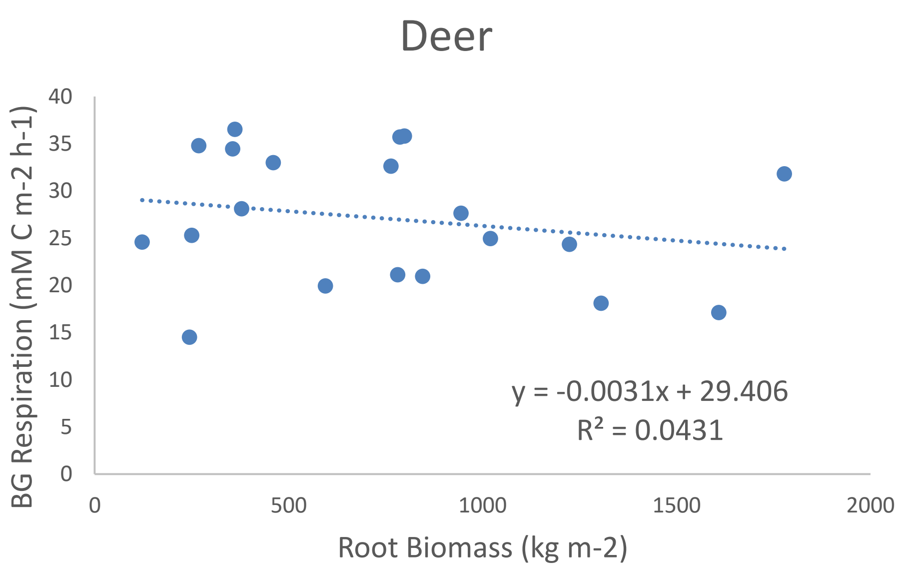
C
O O
Respiration
C
O O
Respiration
C
O O
Shoot biomass
Root biomass
Root Turnover
Root Exudates


Respiration
C
O O
C
O O
Respiration
C
O O
Shoot biomass
Root biomass
Root Turnover
Root Exudates

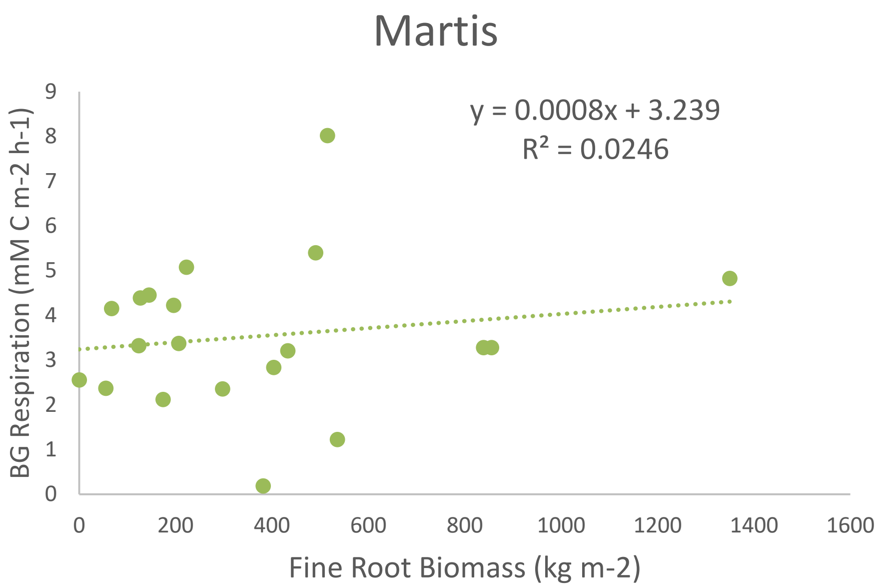
Root contribution to CO_2 flux

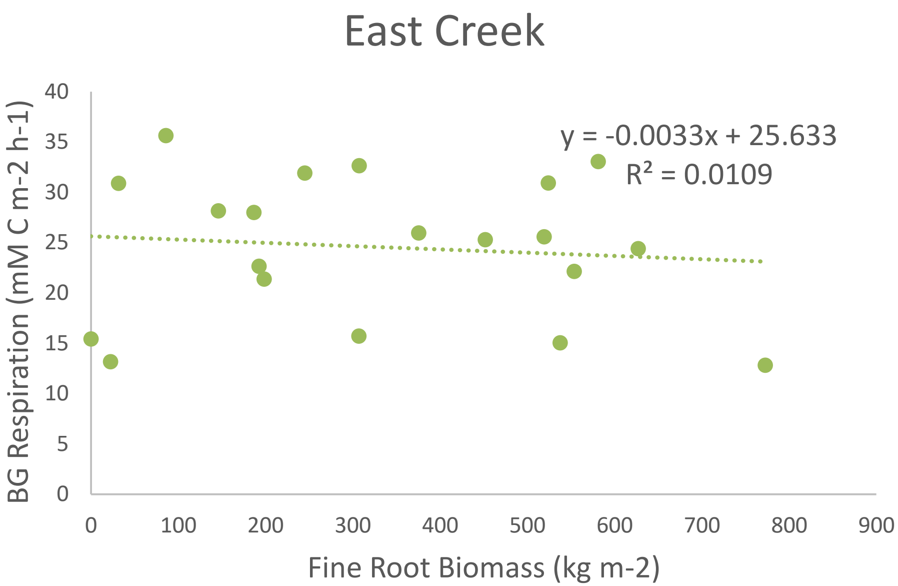


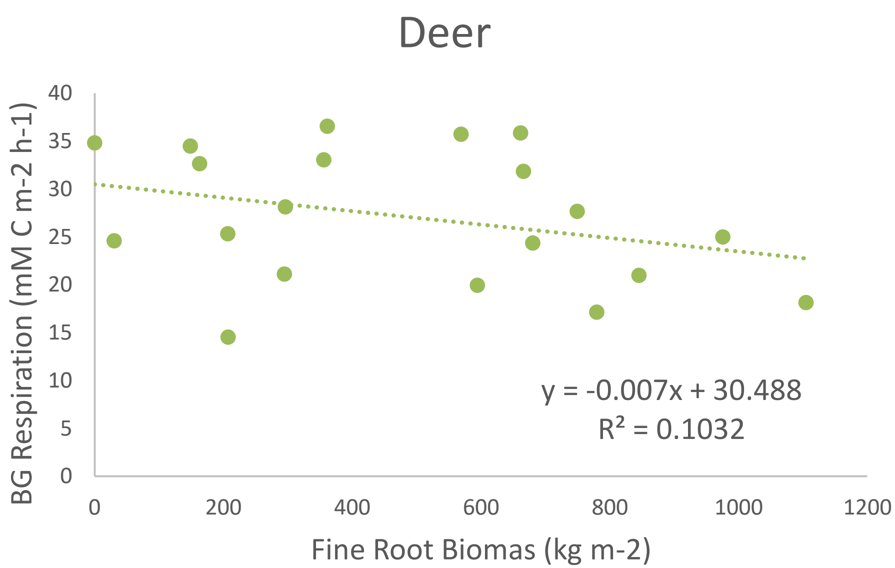


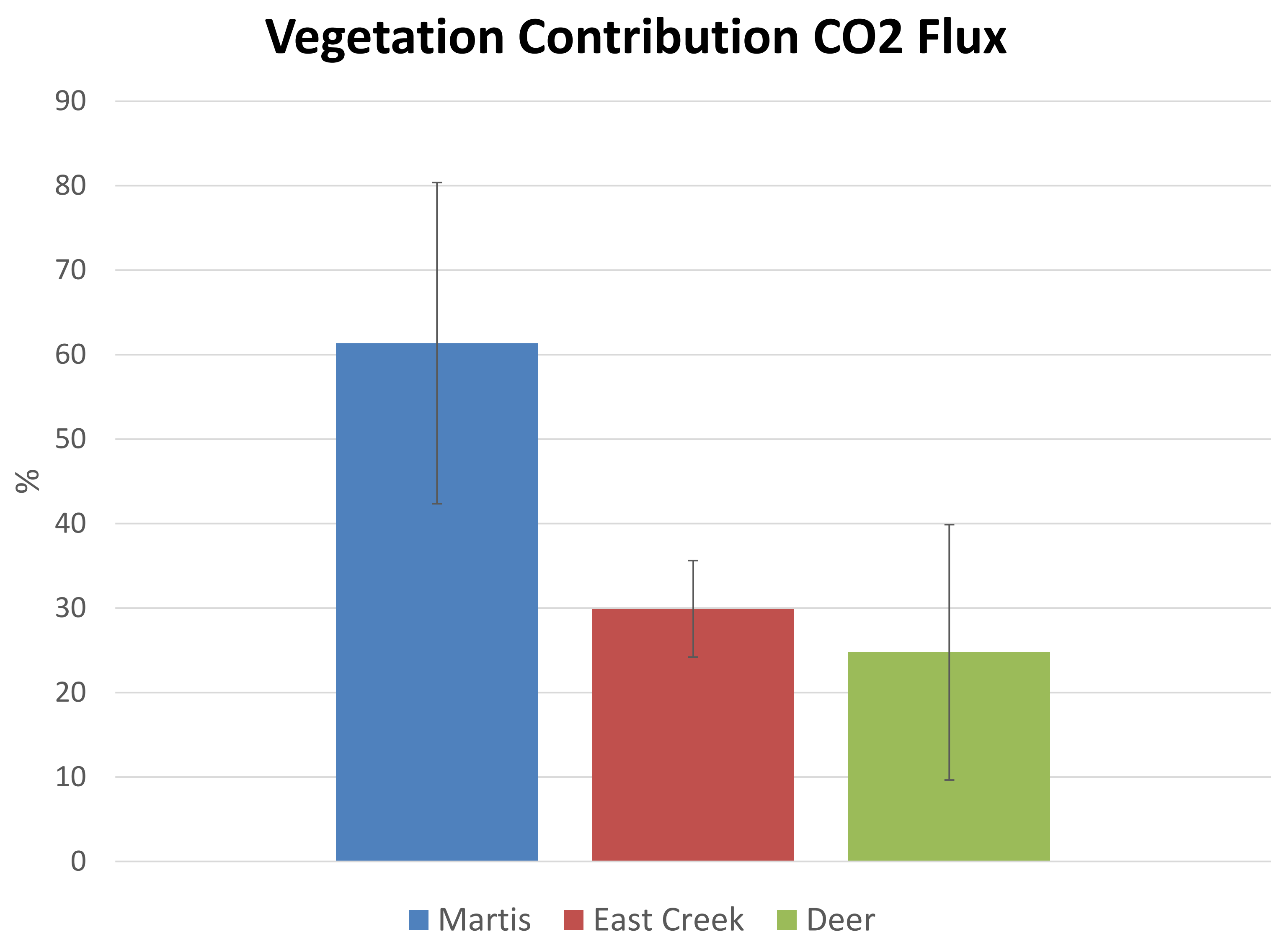


FINE Root contribution to CO_2 flux









$$\text{Veg Contribution } CO_2 \text{ Flux} = (CO_{2\ (\text{with veg})} - CO_{2\ (\text{no veg})})/CO_{2\ (\text{with veg})} * 100$$