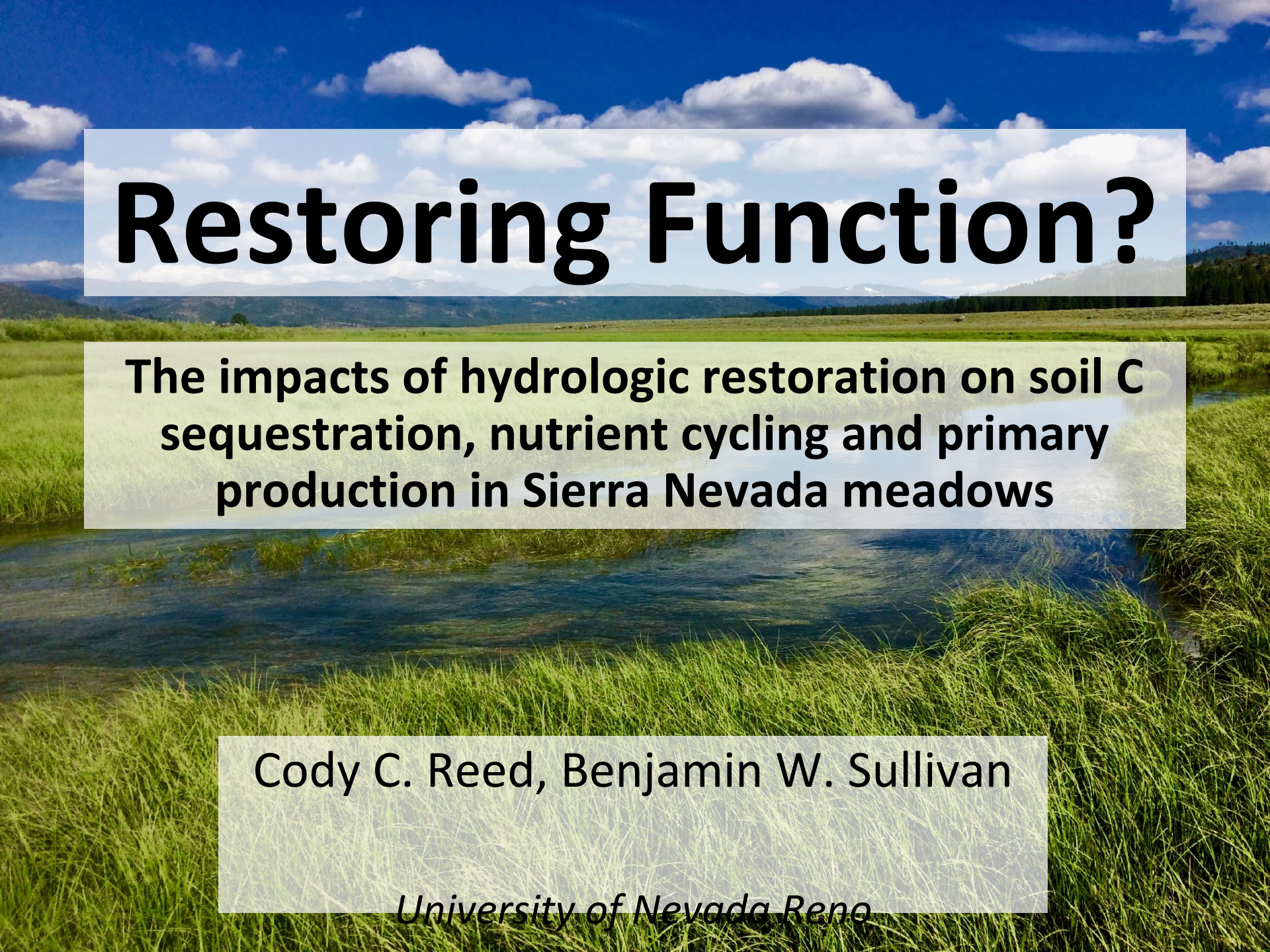

Restoring Function?

The impacts of hydrologic restoration on soil C sequestration, nutrient cycling and primary production in Sierra Nevada meadows

Cody C. Reed, Benjamin W. Sullivan

University of Nevada Reno

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California Environmental Protection Agency

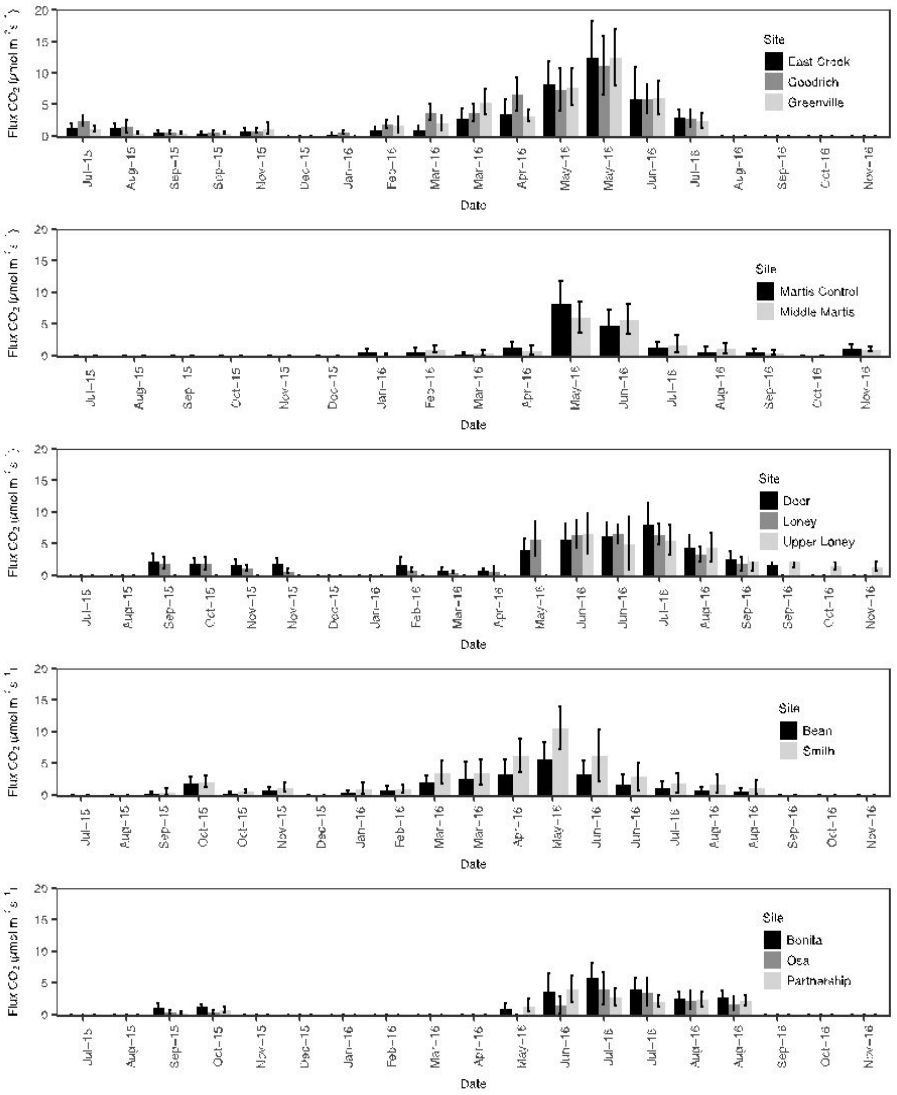
Air Resources Board

CALIFORNIA DEPARTMENT OF FISH & WILDLIFE

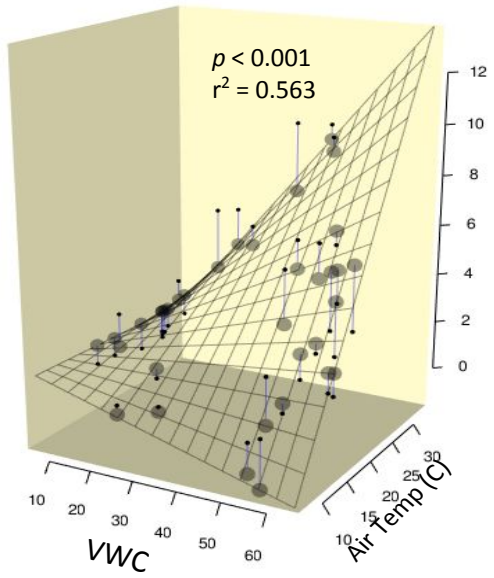
Thank you!

- Plumas Corp
- Ryan Kasten, Kelsey Smith, Darden Mueller

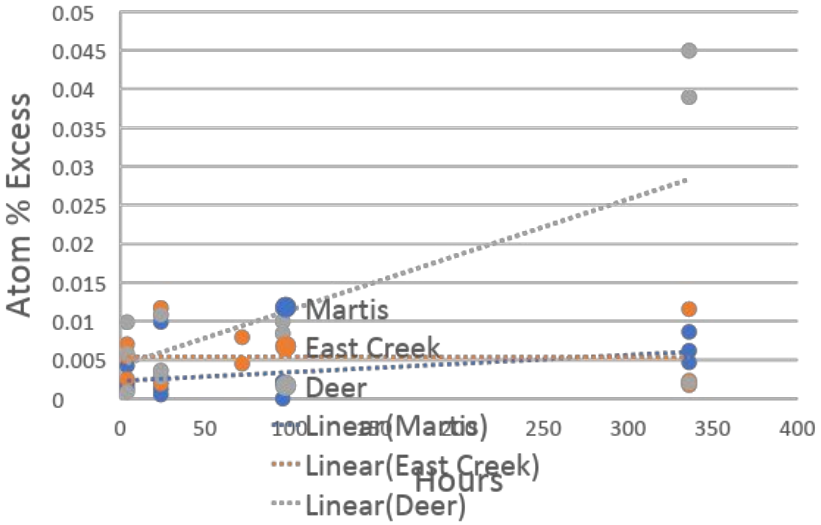
Annual variation in CO_2 Flux

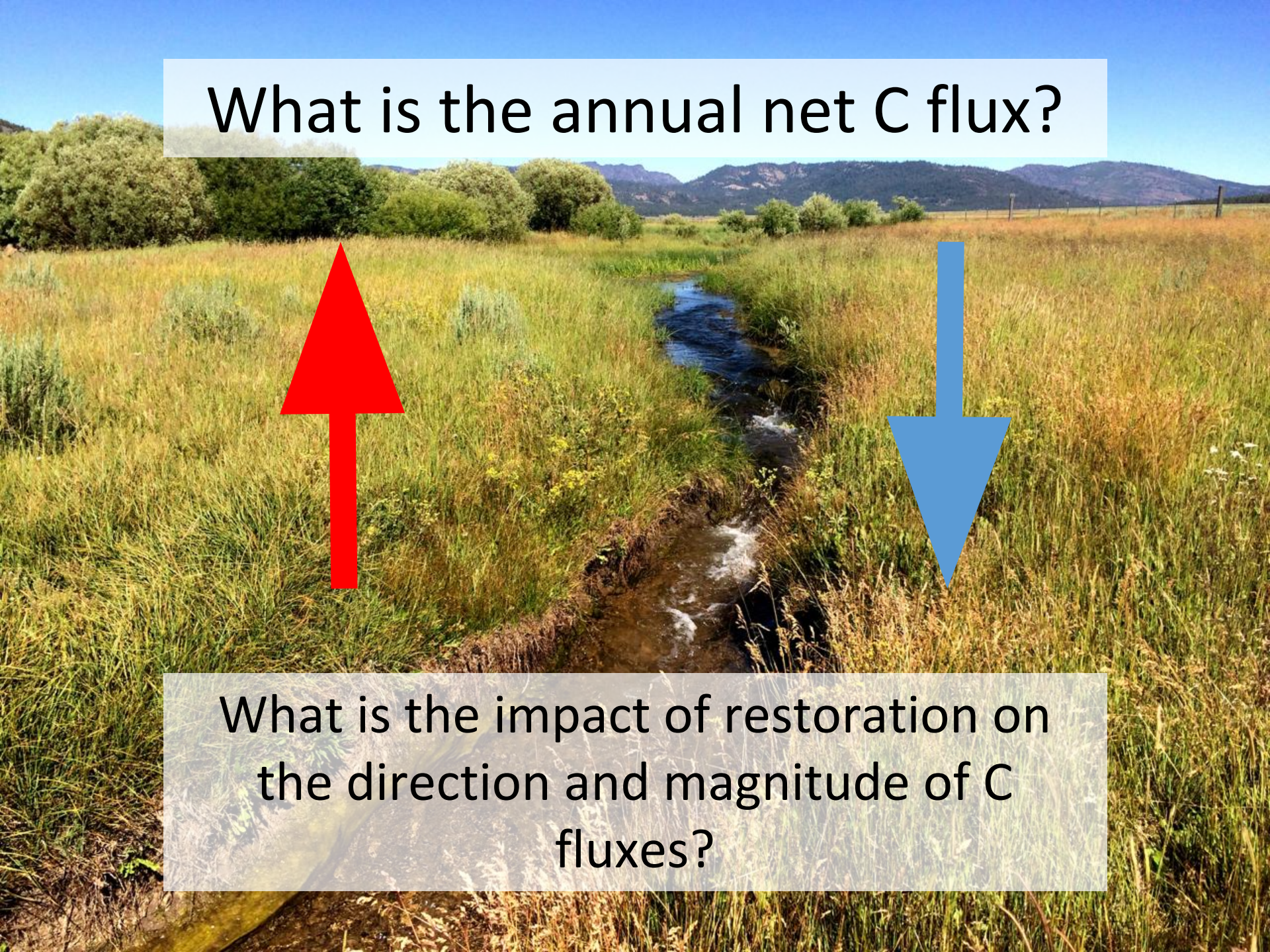


Relationship with soil moisture and temperature

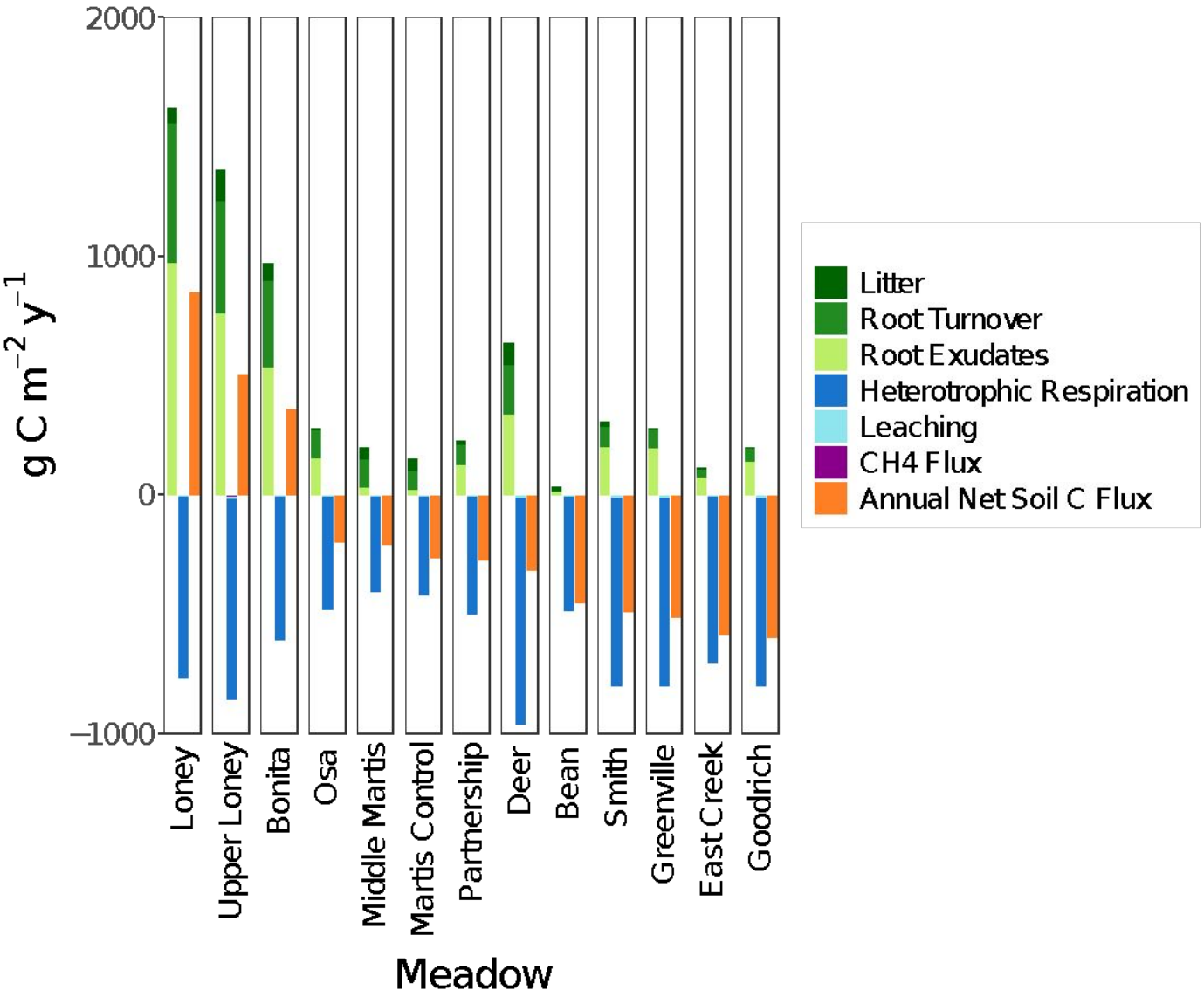


13C in Roots

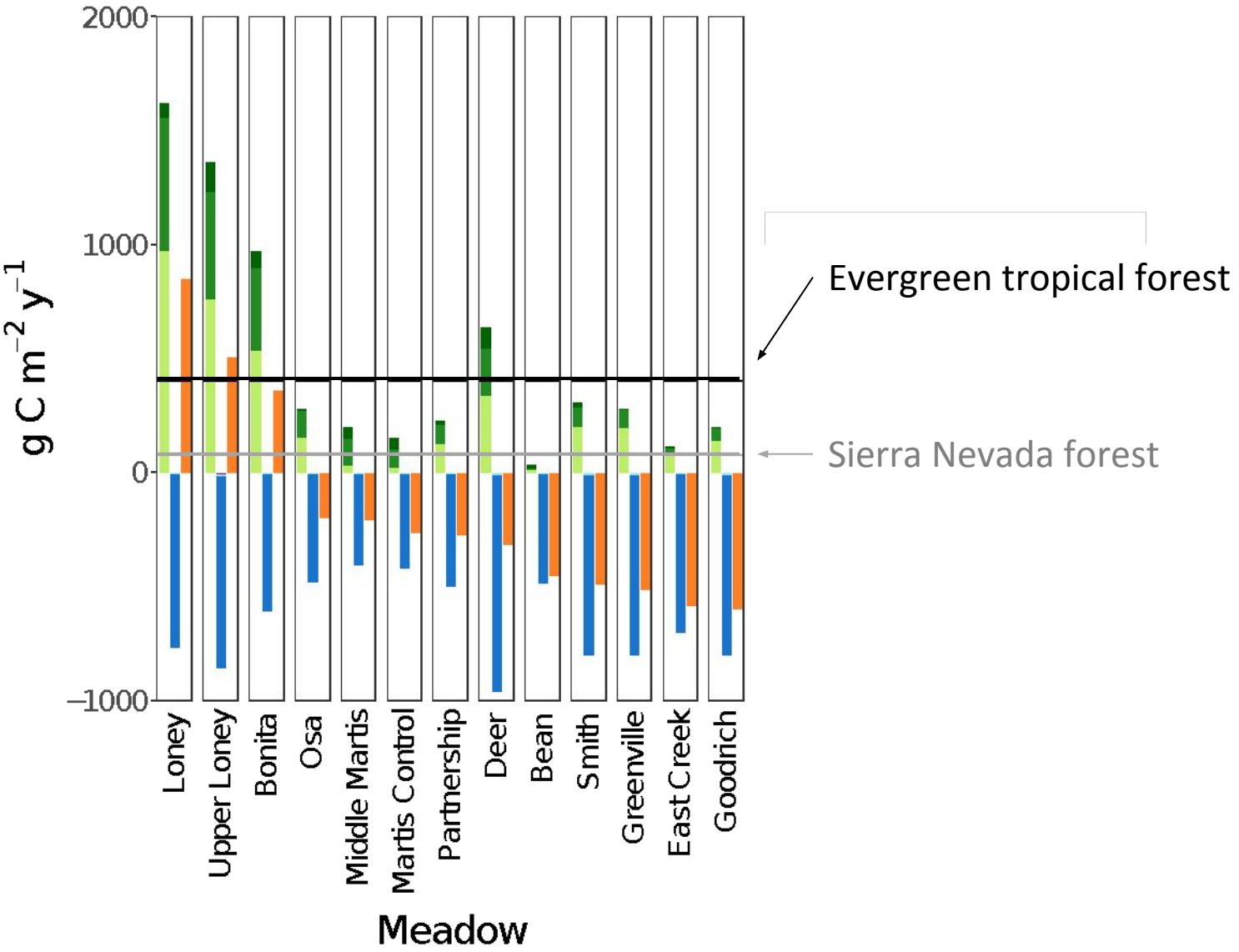



What is the annual net C flux?
What is the impact of restoration on the direction and magnitude of C fluxes?

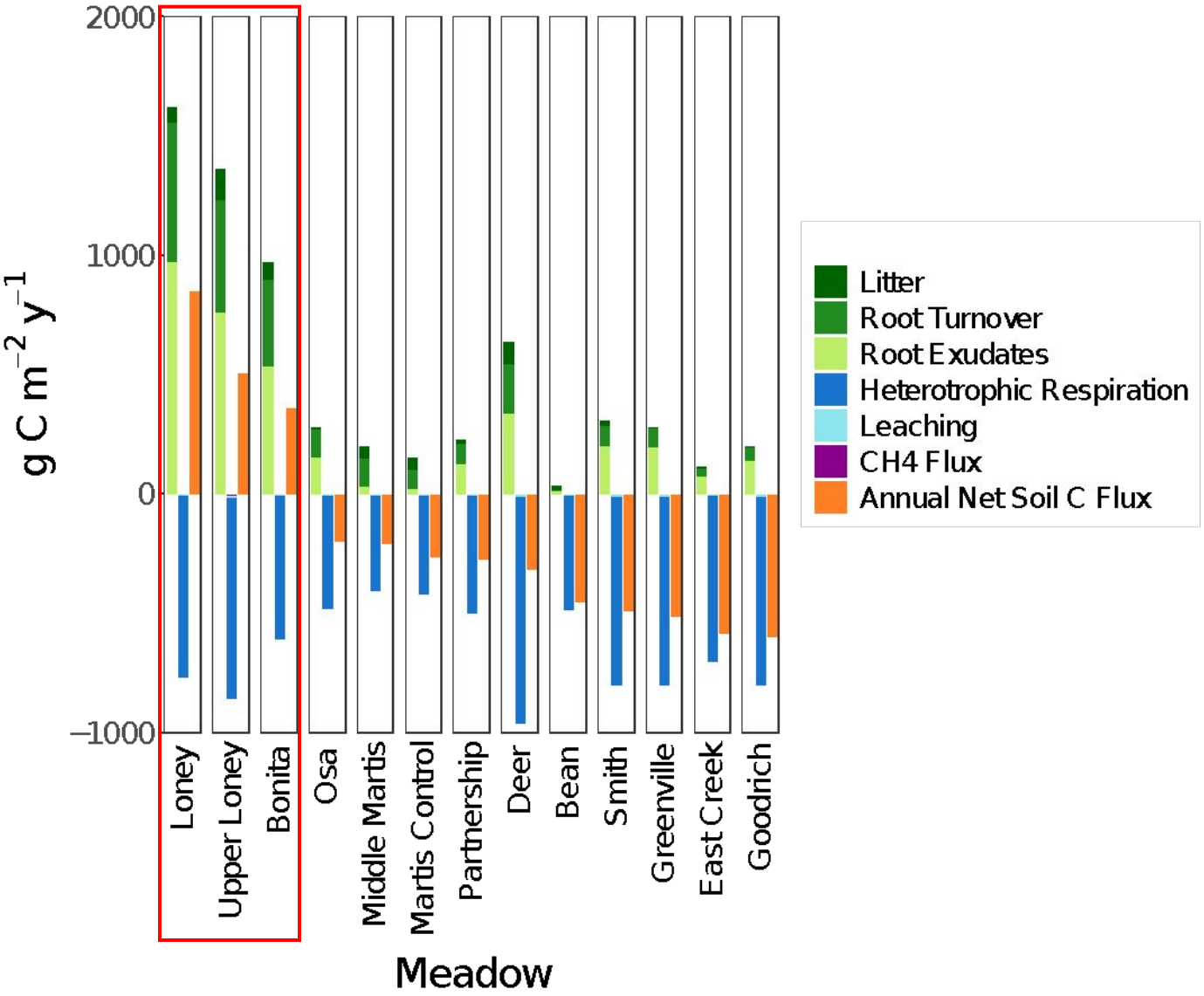
Meadows have large annual net soil C fluxes

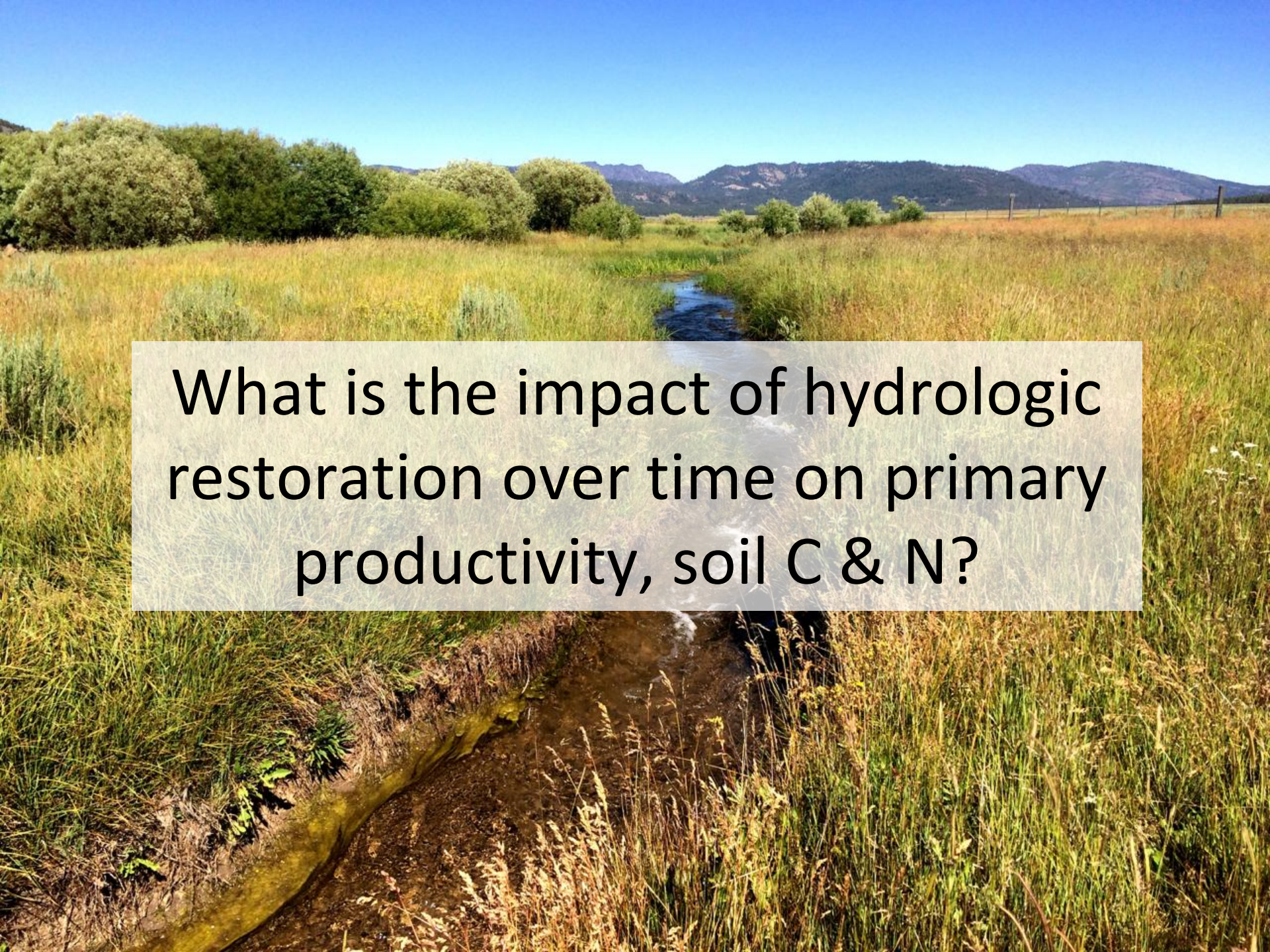


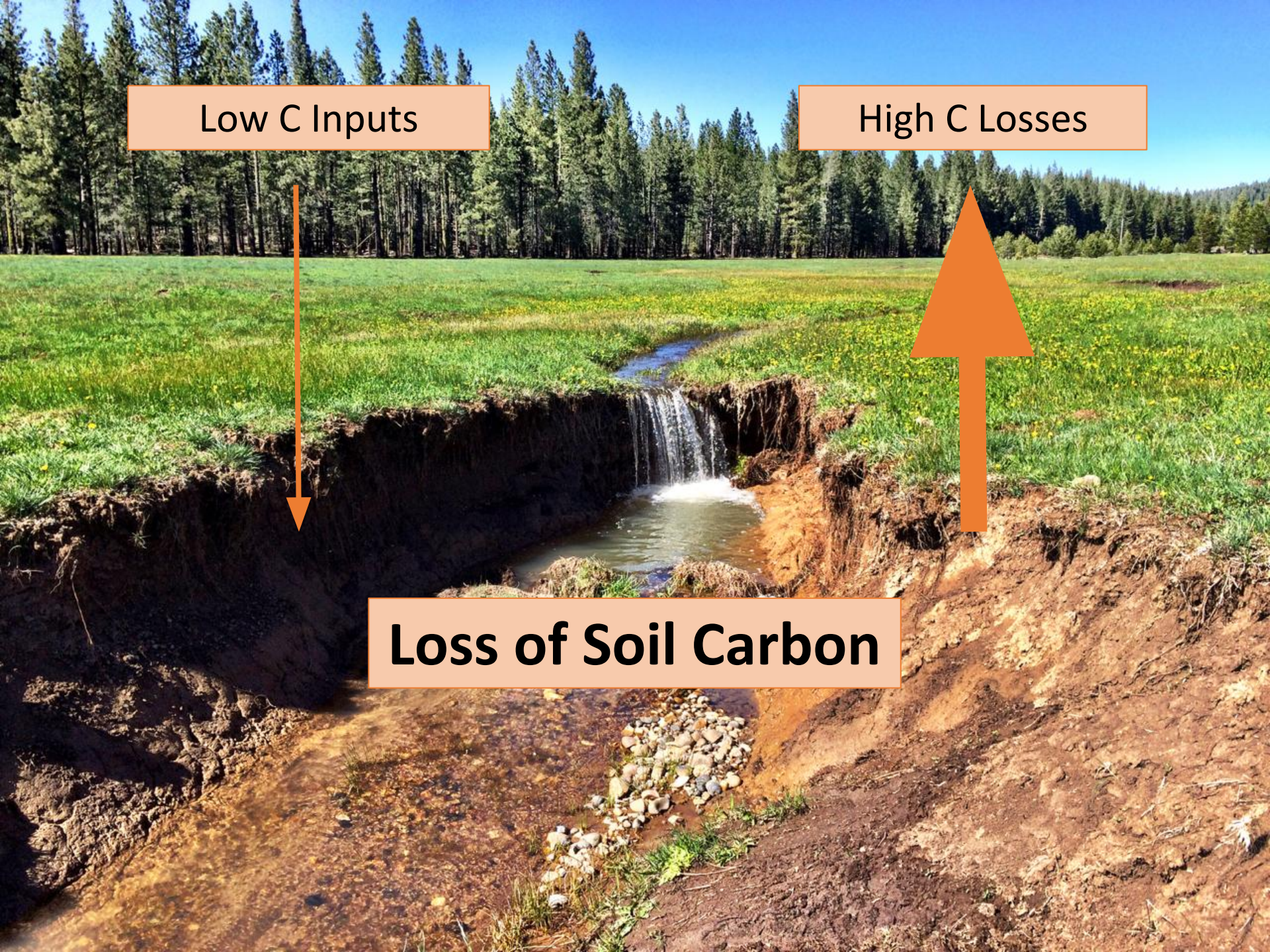
Meadows have large annual net soil C fluxes

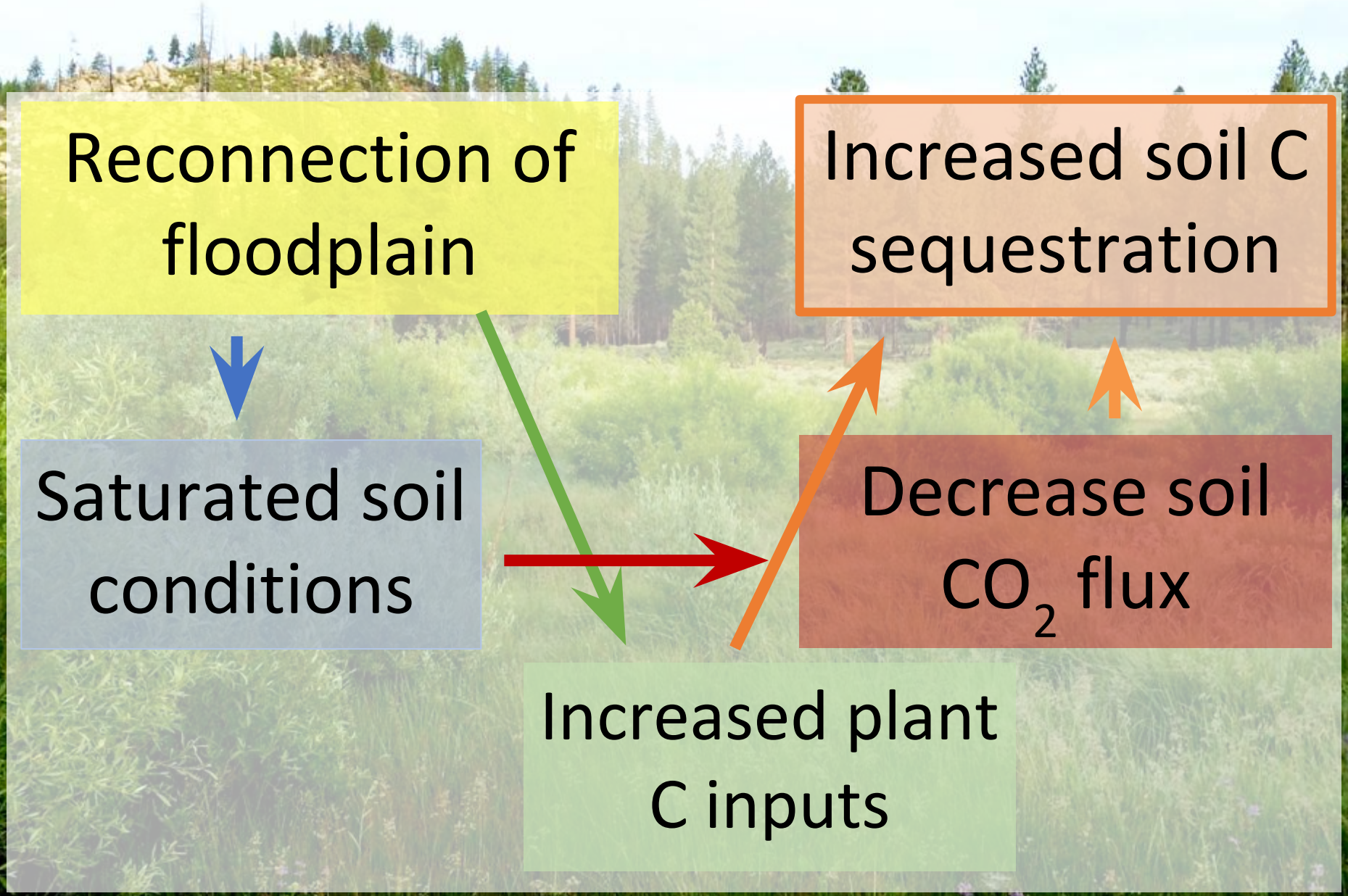


Difference between sinks and sources driven by inputs not outputs



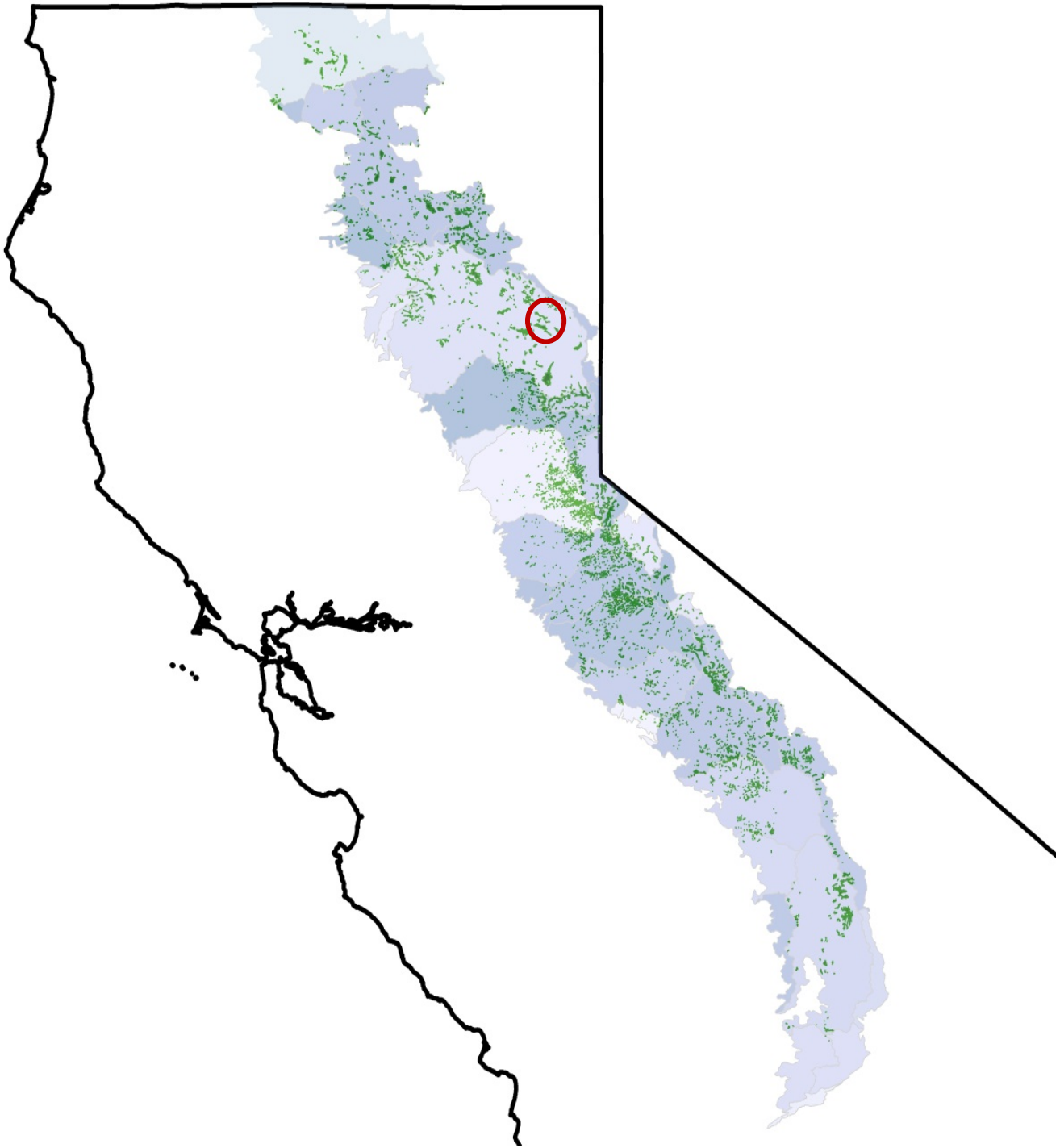

What is the impact of hydrologic restoration over time on primary productivity, soil C & N?

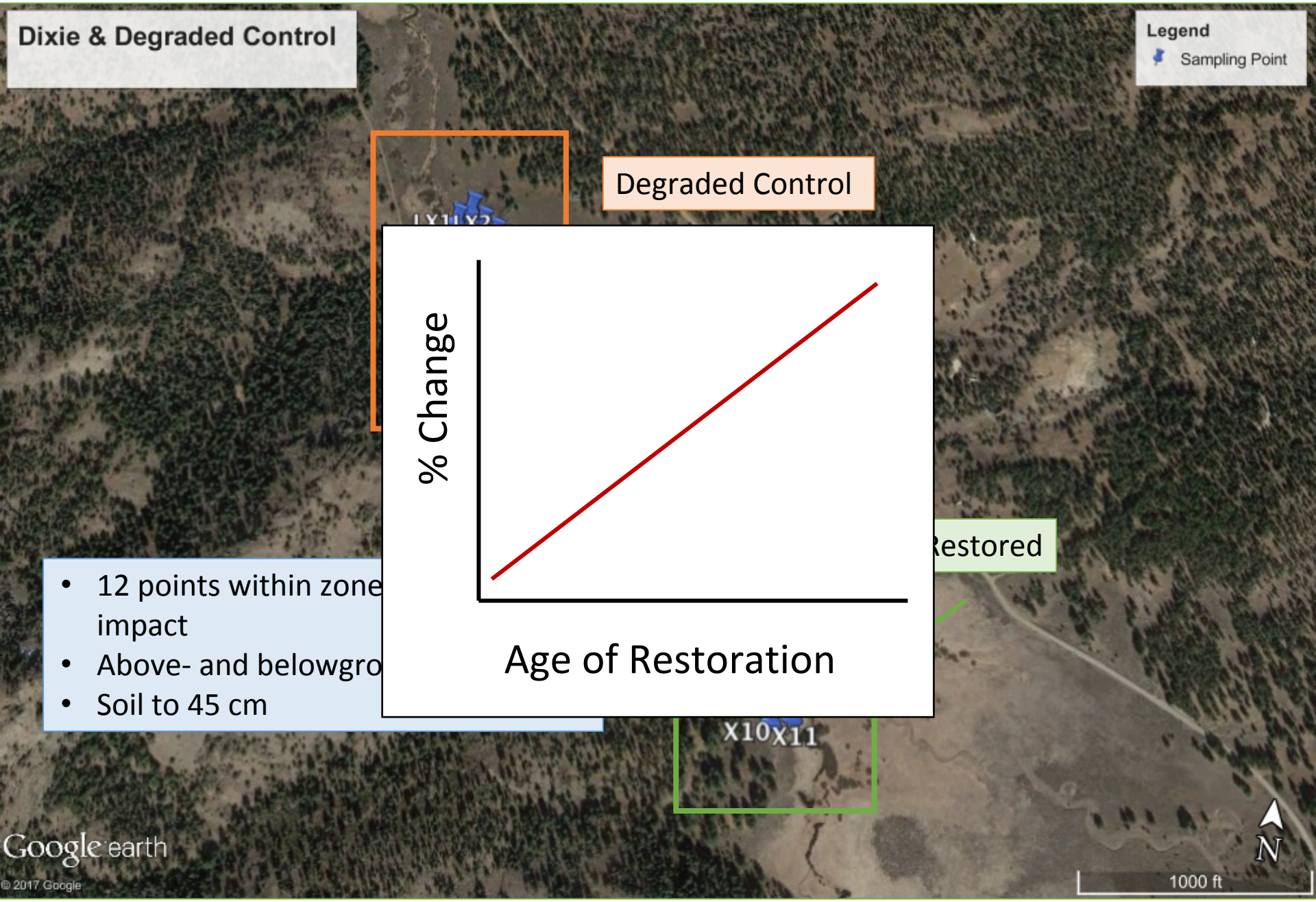

Low C Inputs
High C Losses
Loss of Soil Carbon

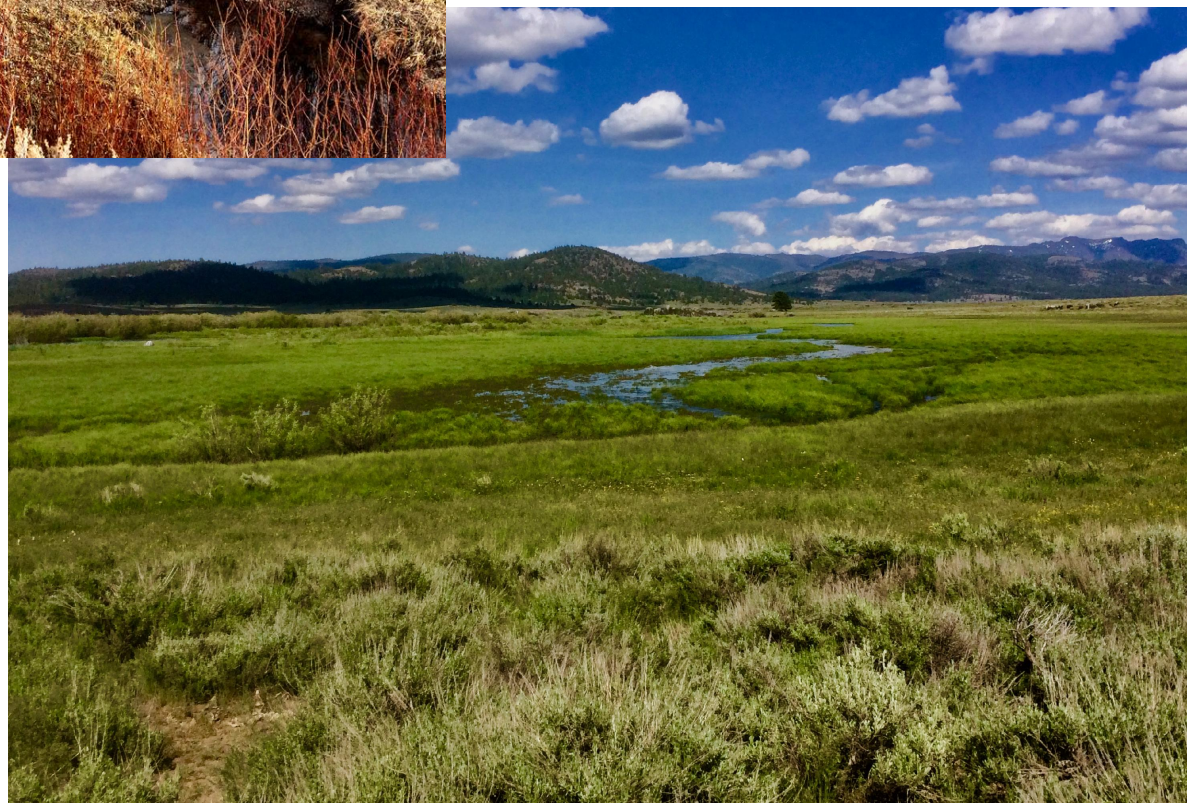

Reconnection of floodplain
Increased soil C sequestration
Saturated soil conditions
Decrease soil CO_2 flux
Increased plant C inputs

Restoration Chronosequence

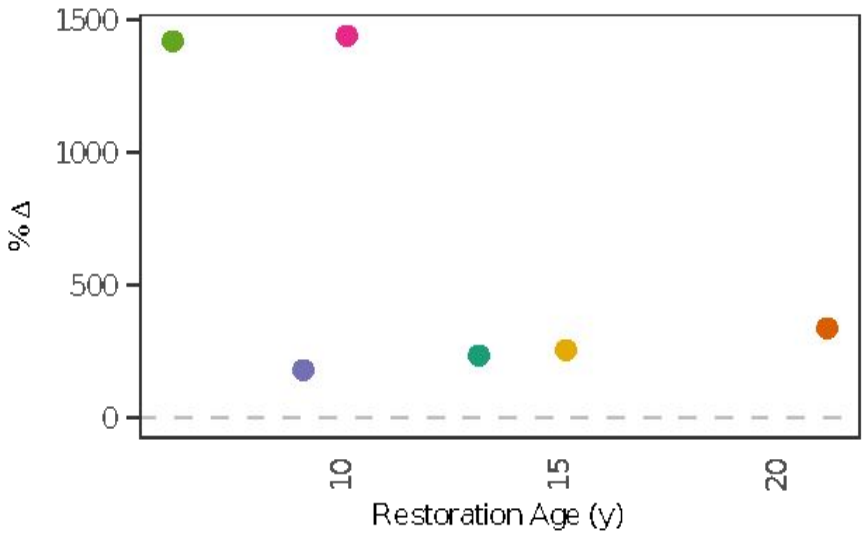
- 22-year restoration chronosequence
  - Constrained by climate, parent material, vegetation, restoration type
- 6 restored meadows & unrestored pairs
  - Relative changes at each site over time
  - Allow us to control for
    - Microclimate
    - Watershed size
    - Management
    - Climate history
    - Level of degradation & soil C prior to restoration




Dixie & Degraded Control
Legend
Sampling Point
Degraded Control
% Change
Age of Restoration
Restored
• 12 points within zone
impact
• Above- and belowgro
• Soil to 45 cm
X10X11
Google earth
© 2017 Google
N
1000 ft



Aboveground Biomass

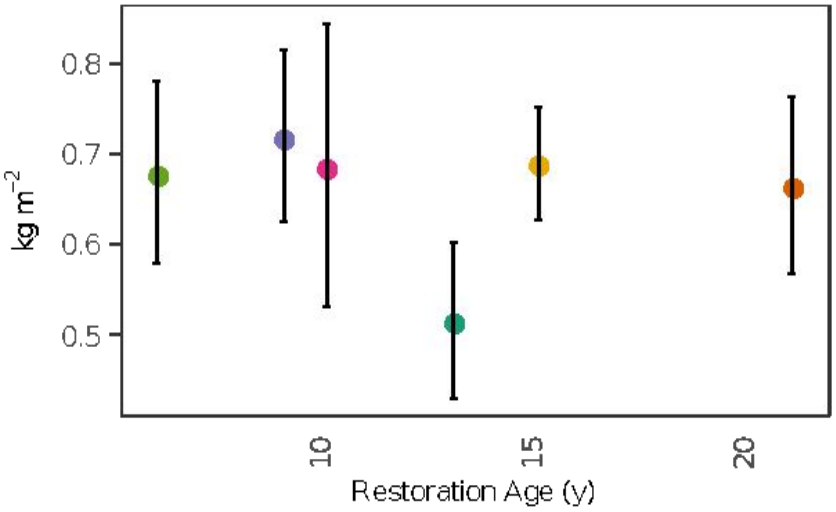


Restoration effect but no time effect

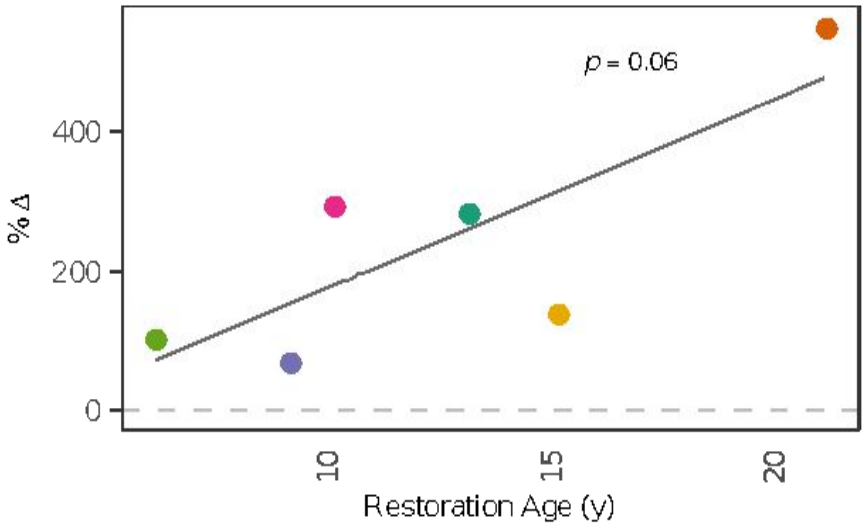
185 – 1514% increase

No significant difference among restored sites (p = 0.33, F = 1.2)

Max aboveground biomass achieved soon after restoration



Belowground Biomass

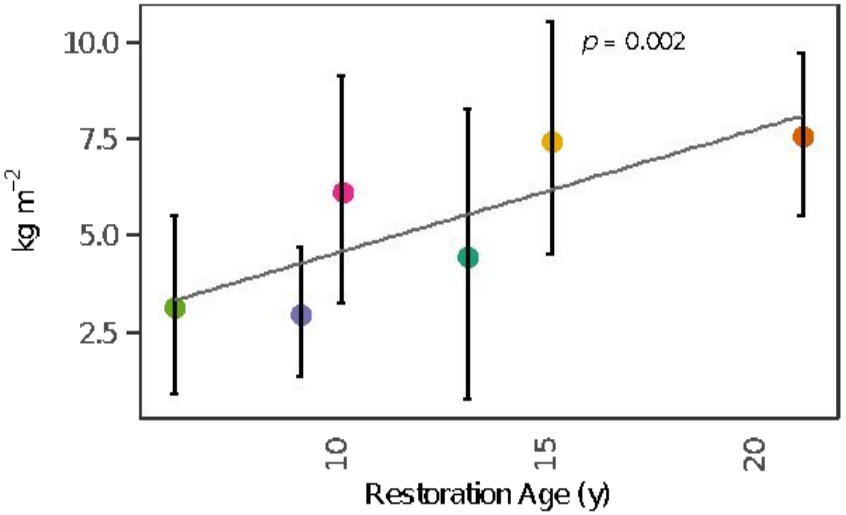


Restoration & Time Effect

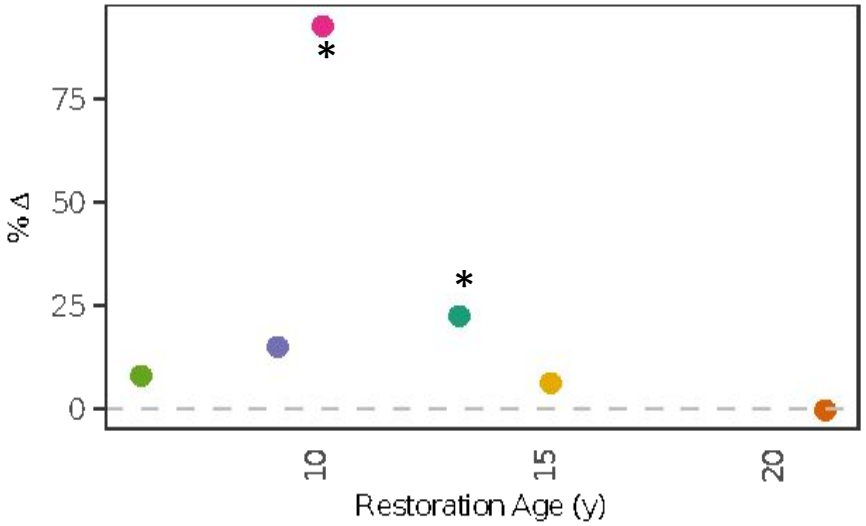
41 - 432% increase

Max belowground biomass achieved after aboveground

Significant increase through time
(p = 0.02, r^2 = 0.84)



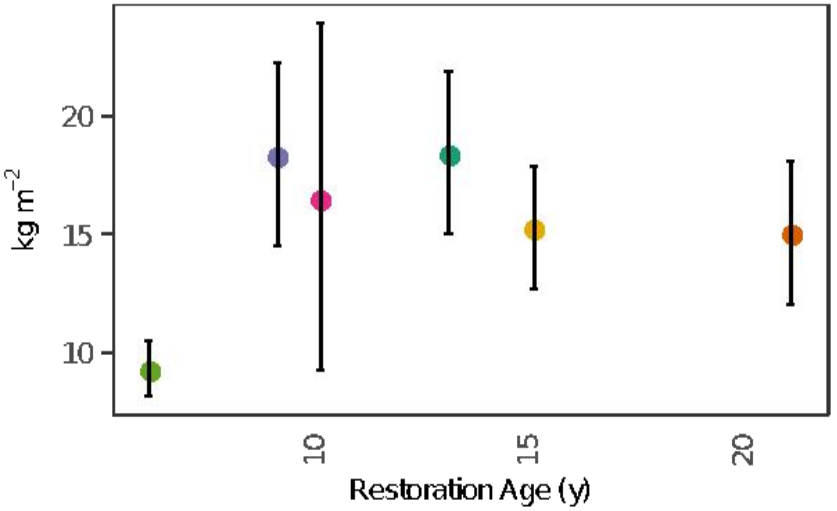
Soil Carbon Stocks



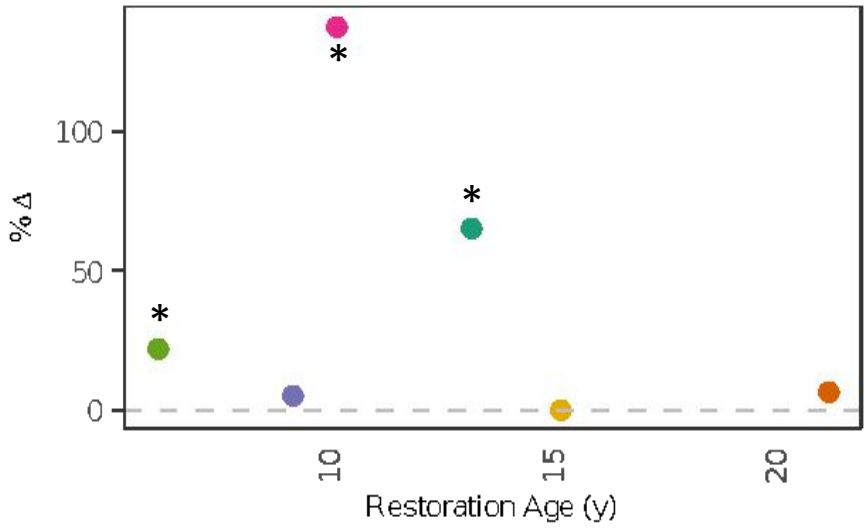
Restoration effect at some sites

0.5 - 93% increase

Significant difference among restored sites only if youngest site included
(p = 0.06, F = 2.1)



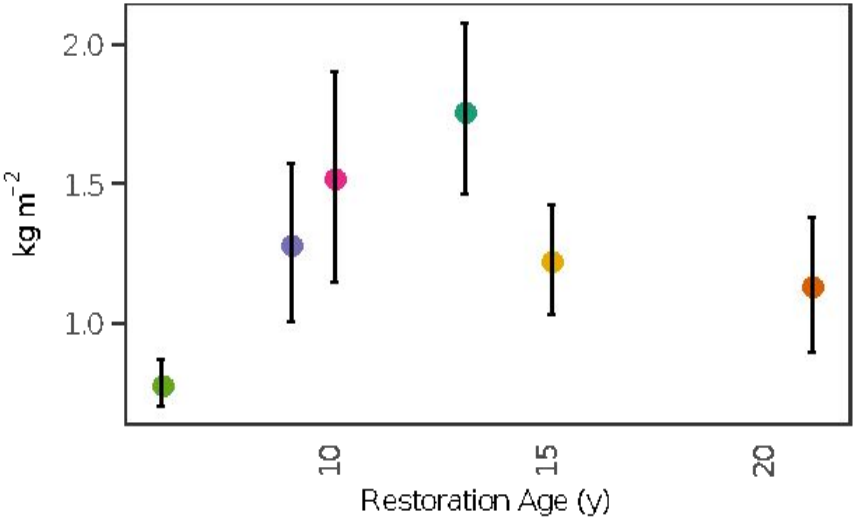
Soil Nitrogen Stocks



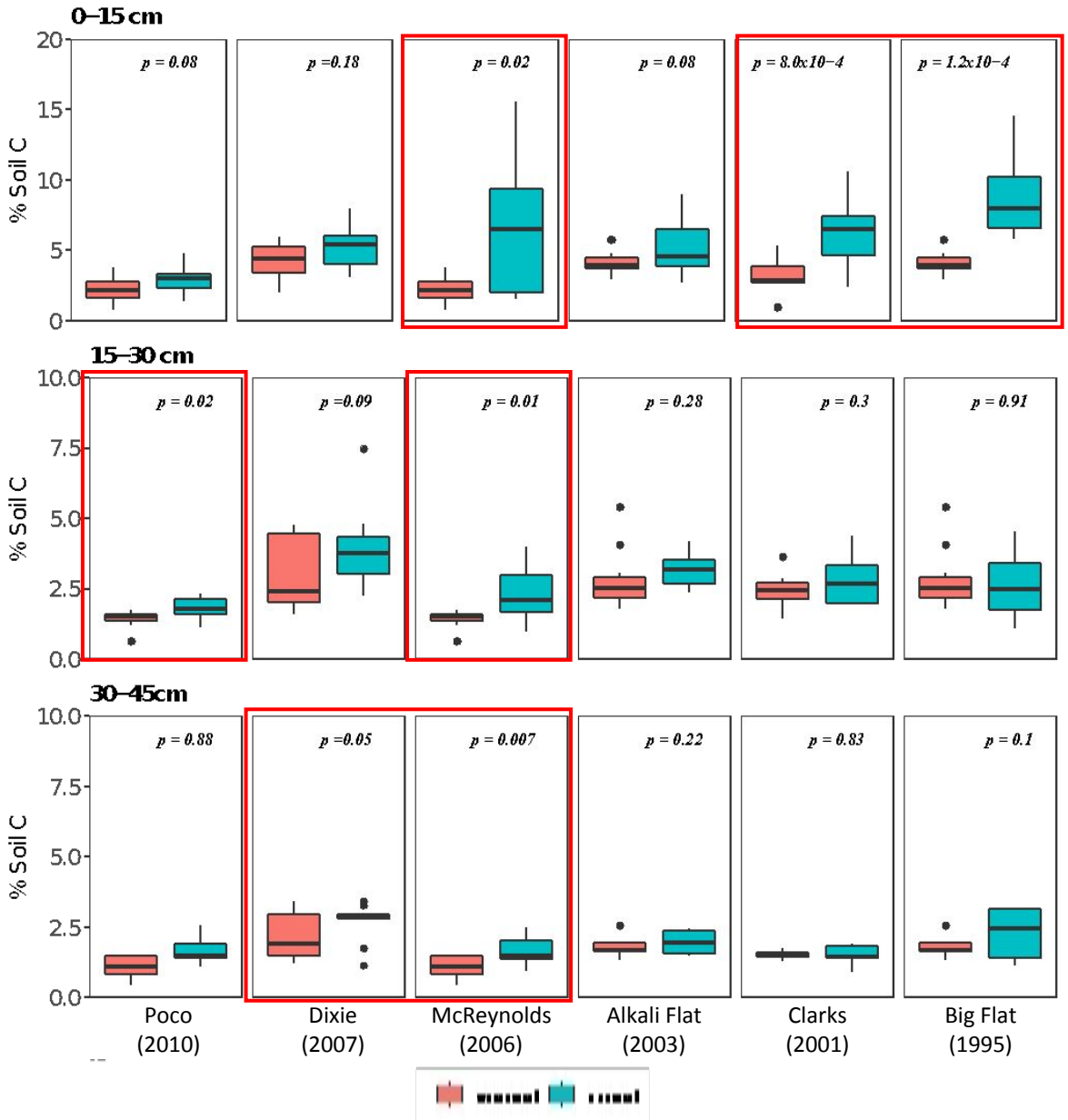
Restoration effect at some sites

1.1 - 138% increase

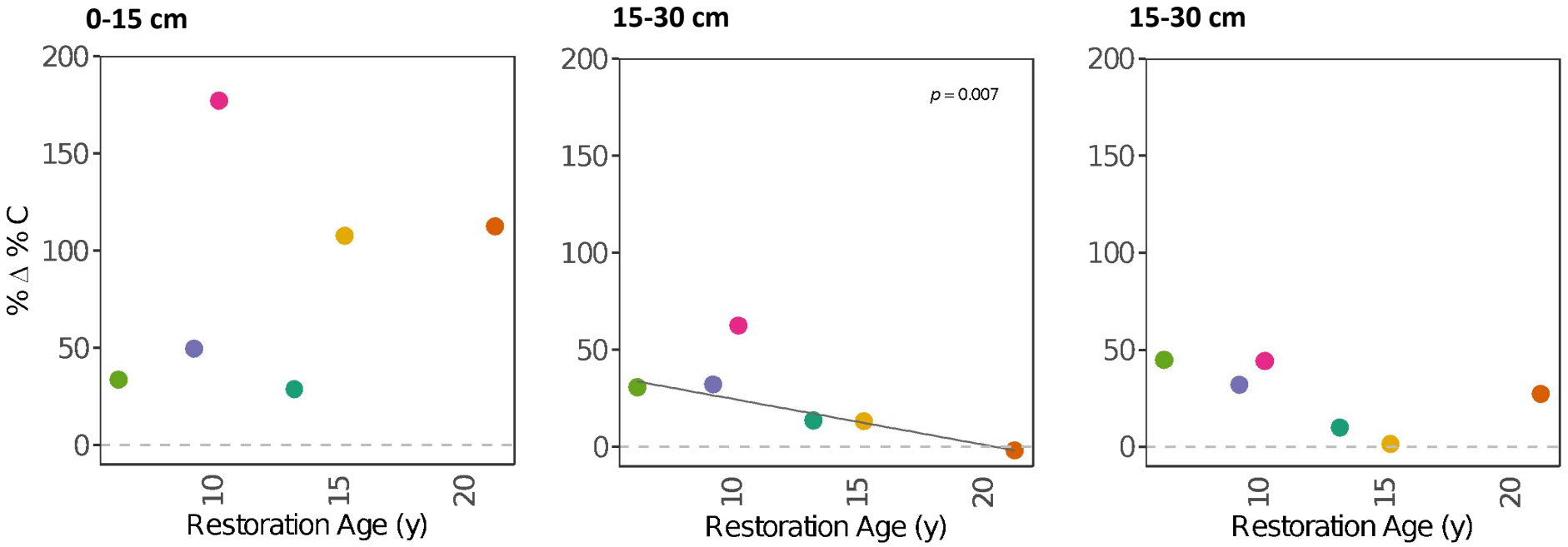
Significant difference among restored sites
(p = 2.2 x 10^{-12}, F = 12.6)



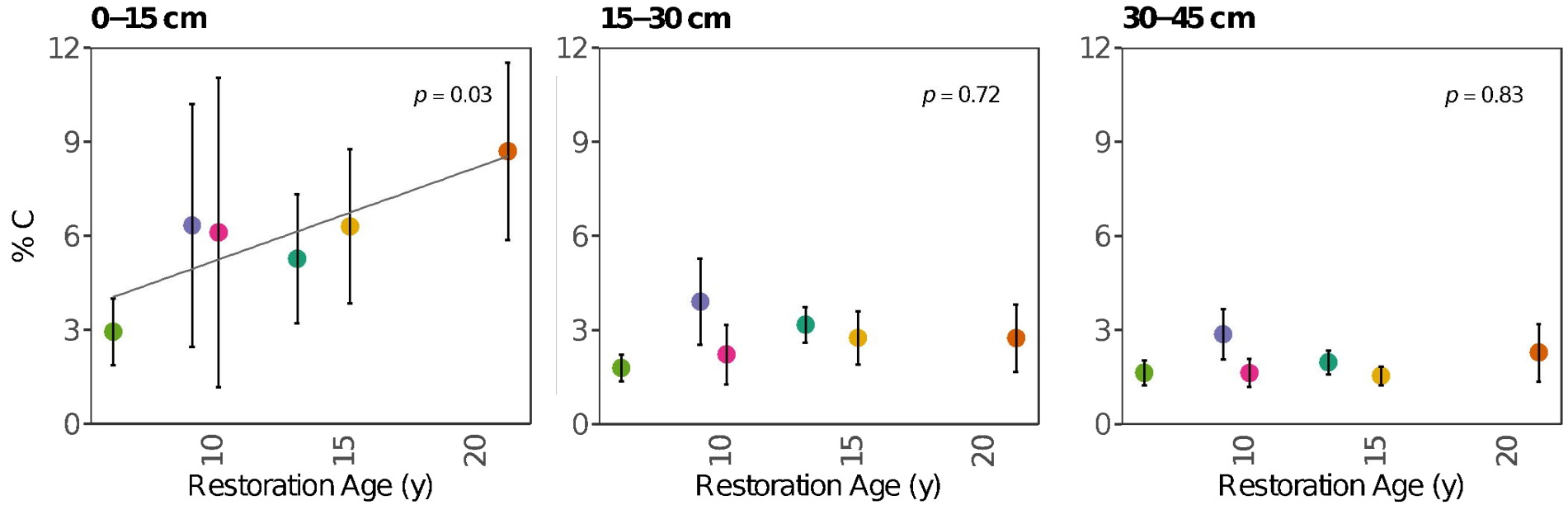
% Soil Carbon


0–15 cm
15–30 cm
30–45cm
% Soil C
p = 0.08
p =0.18
p = 0.02
p = 0.08
p = 8.0x10−4
p = 1.2x10−4
p = 0.02
p =0.09
p = 0.01
p = 0.28
p = 0.3
p = 0.91
p = 0.88
p =0.05
p = 0.007
p = 0.22
p = 0.83
p = 0.1
Poco (2010)
Dixie (2007)
McReynolds (2006)
Alkali Flat (2003)
Clarks (2001)
Big Flat (1995)

% Soil Carbon


0-15 cm
15-30 cm
15-30 cm
% Δ % C
200
150
100
50
0
10
15
20
Restoration Age (y)
p = 0.007
Site
Alkali Flat
Dixie
Poco
Big Flat
McReynolds
Upper Clarks

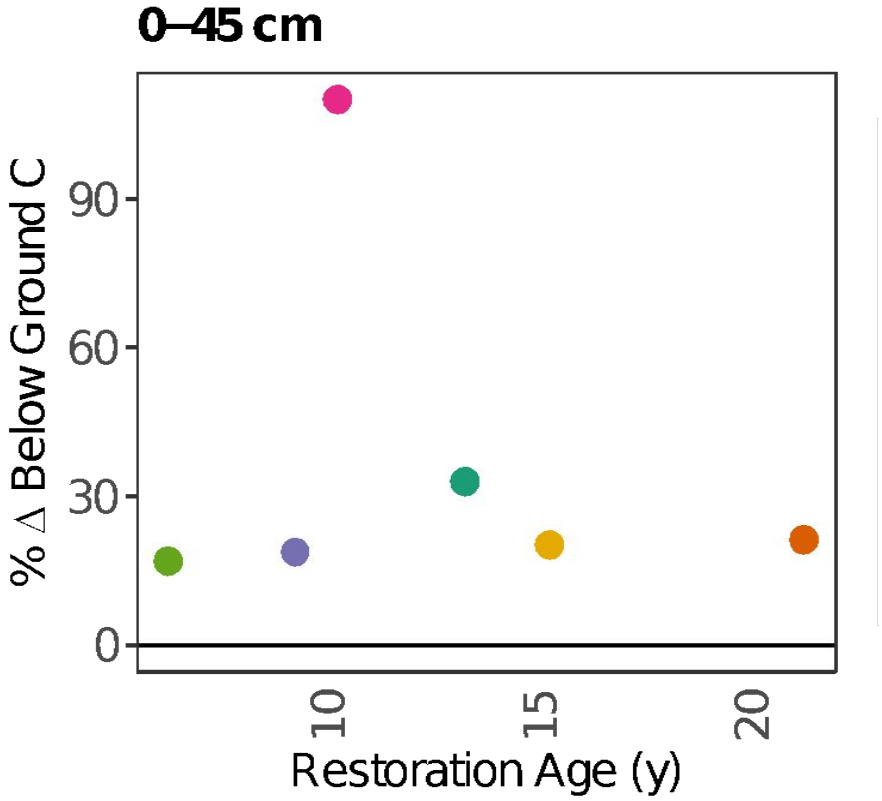
% Soil Carbon

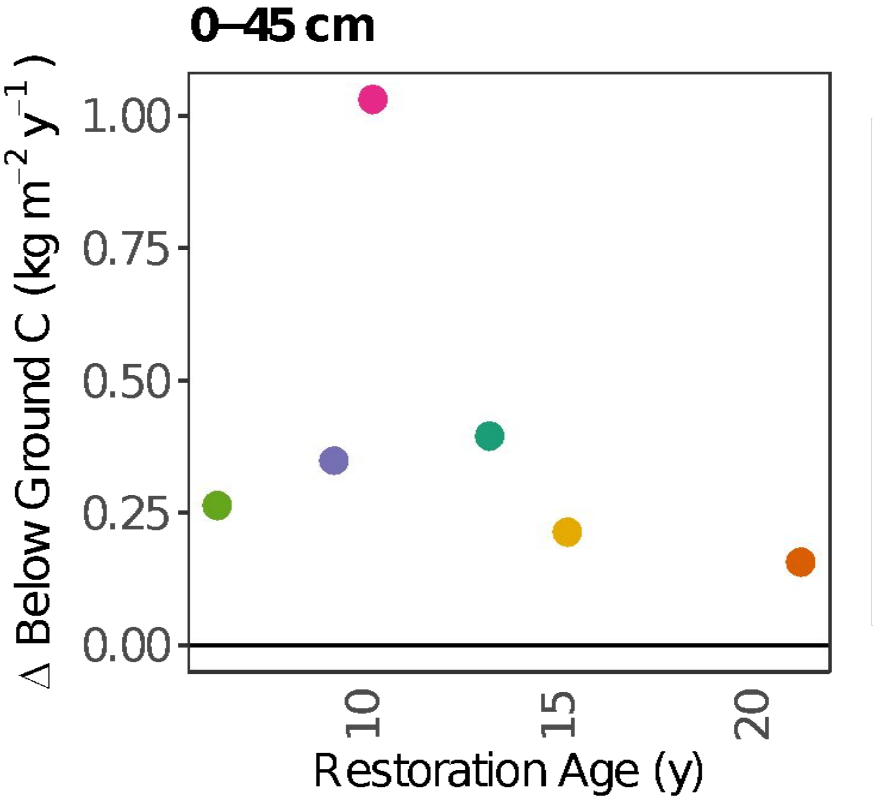

0–15 cm
15–30 cm
30–45 cm
p = 0.03
p = 0.72
p = 0.83
% C
Restoration Age (y)
0
3
6
9
12
10
15
20
Site
Alkali Flat
Dixie
Poco
Big Flat
McReynolds
Upper Clarks

The Upshot

- Hydrologic restoration of degraded meadows leads to rapid and significant increases in above- and belowground biomass
- Max vegetation biomass may be achieved <10 y following restoration
- Root biomass may continue to show increases over a longer time period
- Soil C & N increase as a result of restoration but patterns do not emerge through time
    - Other biogeochemical processes or landscape characteristics may influence rates of C sequestration

Below ground C may be more ecologically relevant





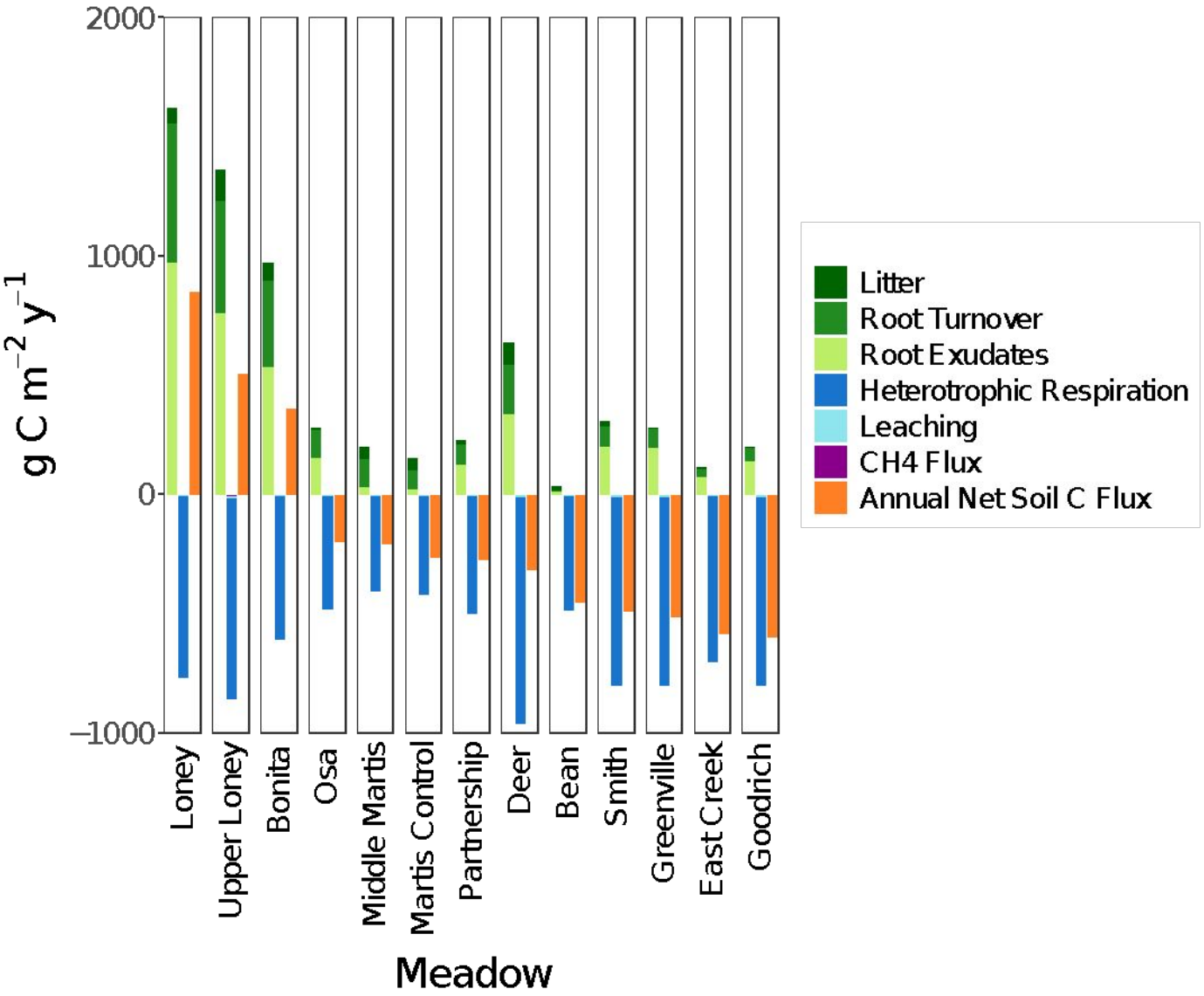
Potential Annual Restoration Gains

Net belowground C gains

0.16 to 1.03 kg C m^{-2} y^{-1}

or if all ~90,000 ha of degraded meadows were restored

144,000 to 927,000 MT C y^{-1}


2000
1000
0
−1000
g C m^{-2} y^{-1}
Loney
Upper Loney
Bonita
Osa
Middle Martis
Martis Control
Partnership
Deer
Bean
Smith
Greenville
East Creek
Goodrich
Meadow
Litter
Root Turnover
Root Exudates
Heterotrophic Respiration
Leaching
CH4 Flux
Annual Net Soil C Flux

Potential Annual Restoration Gains

0.39 kg C m^{-2} y^{-1} (Prevented Losses)

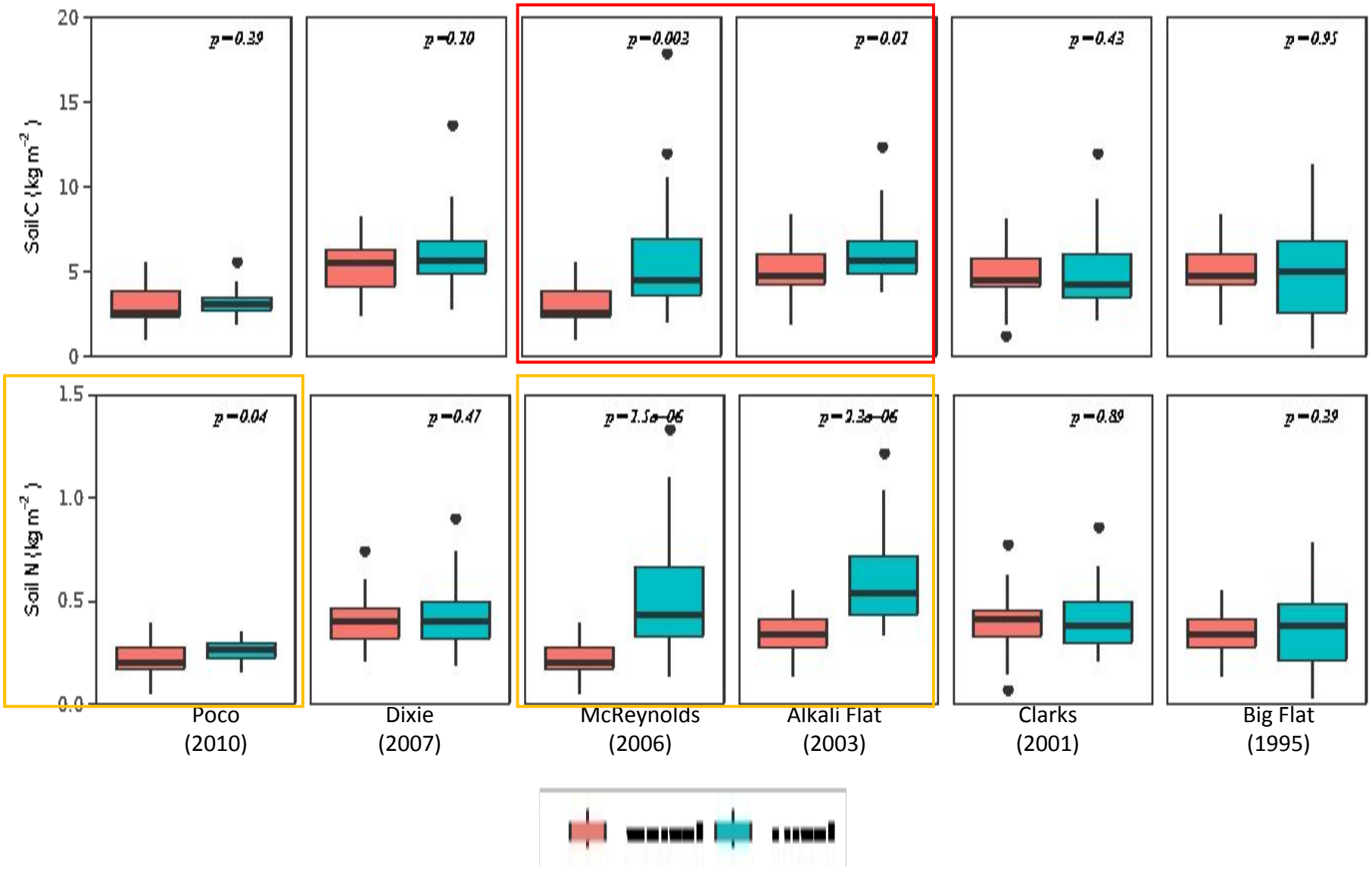
0.16 to 1.03 kg C m^{-2} y^{-1} (Gains)

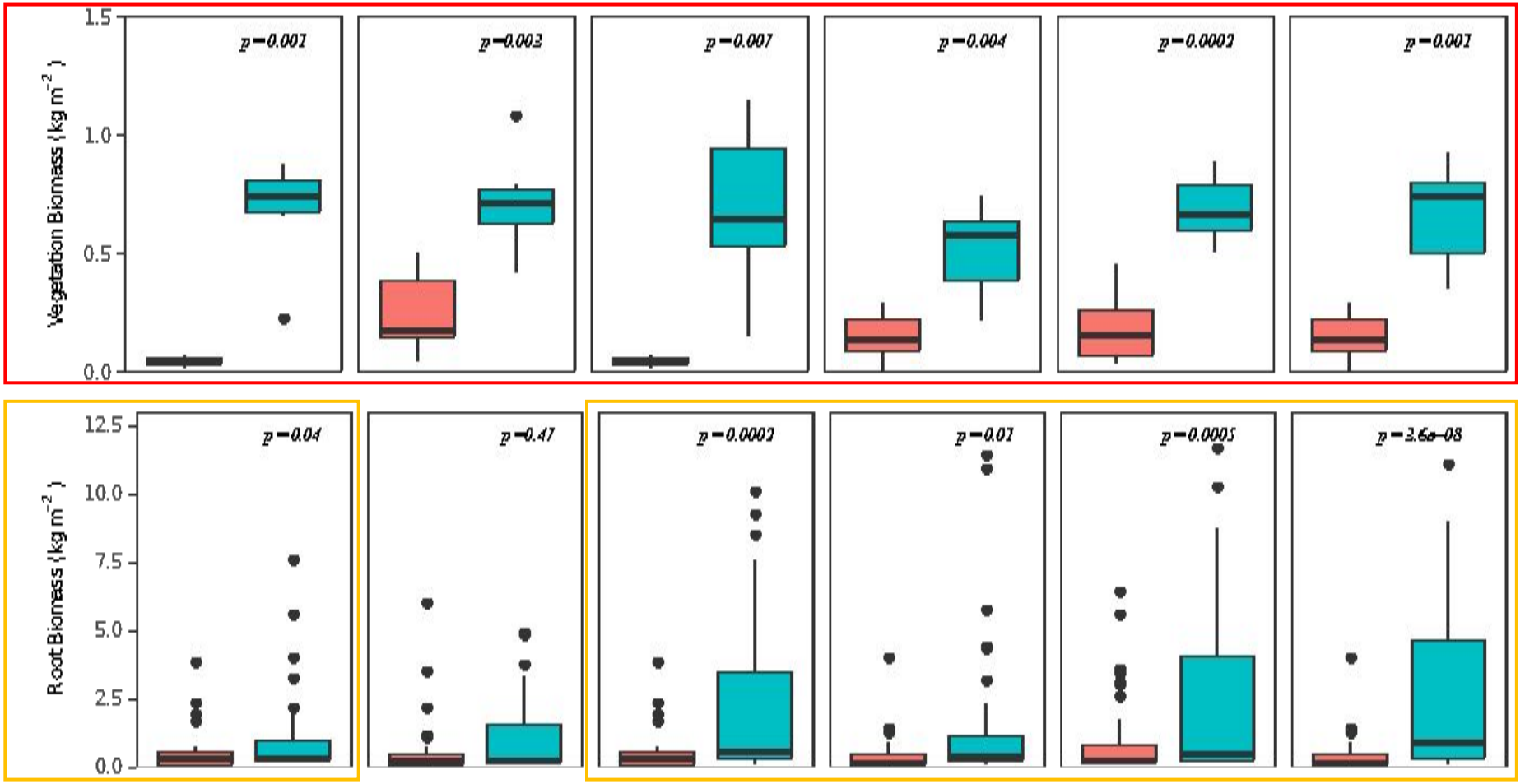
0.55 to 1.42 kg C m^{-2} y^{-1} (Net Impact)

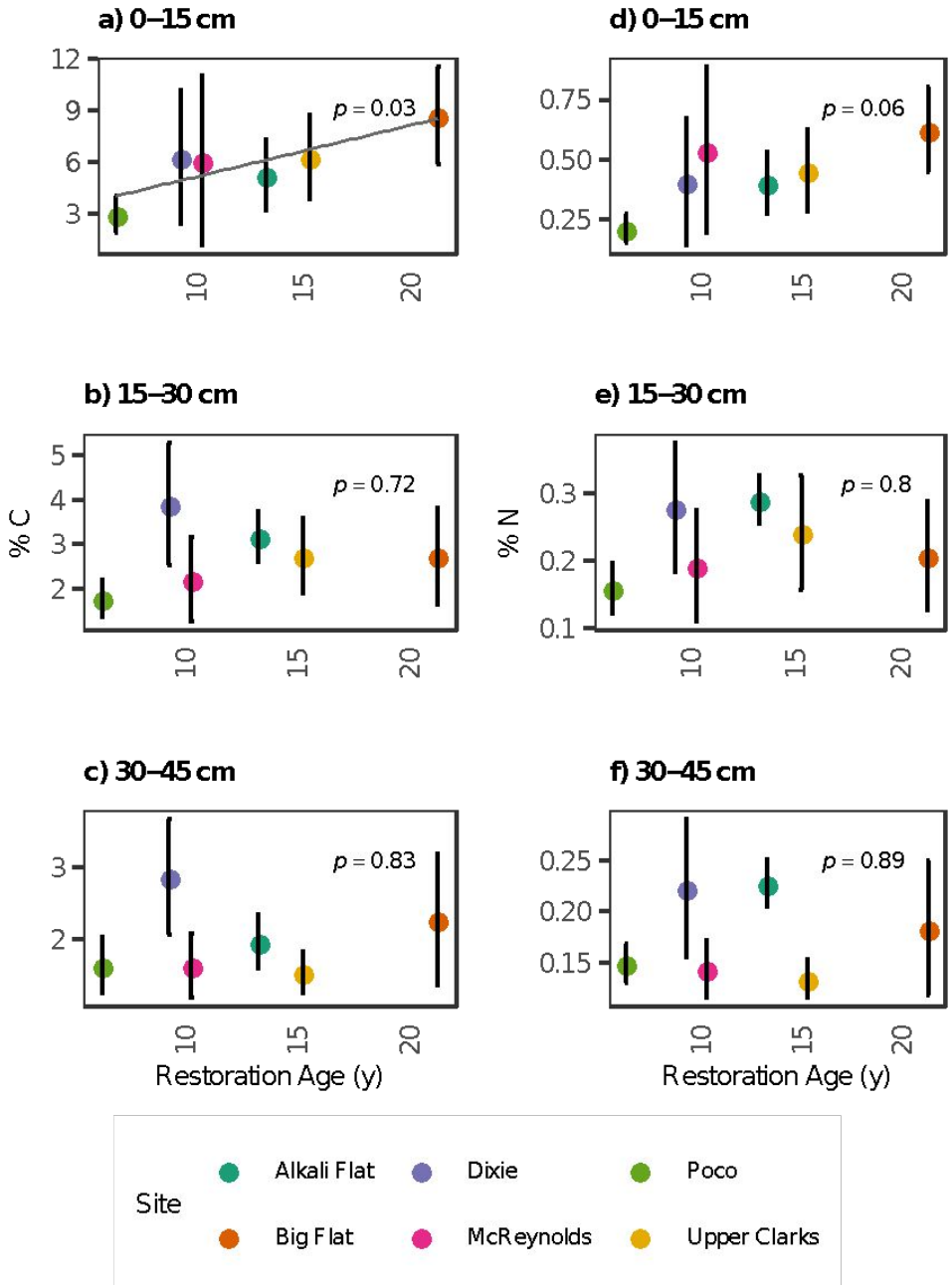
=

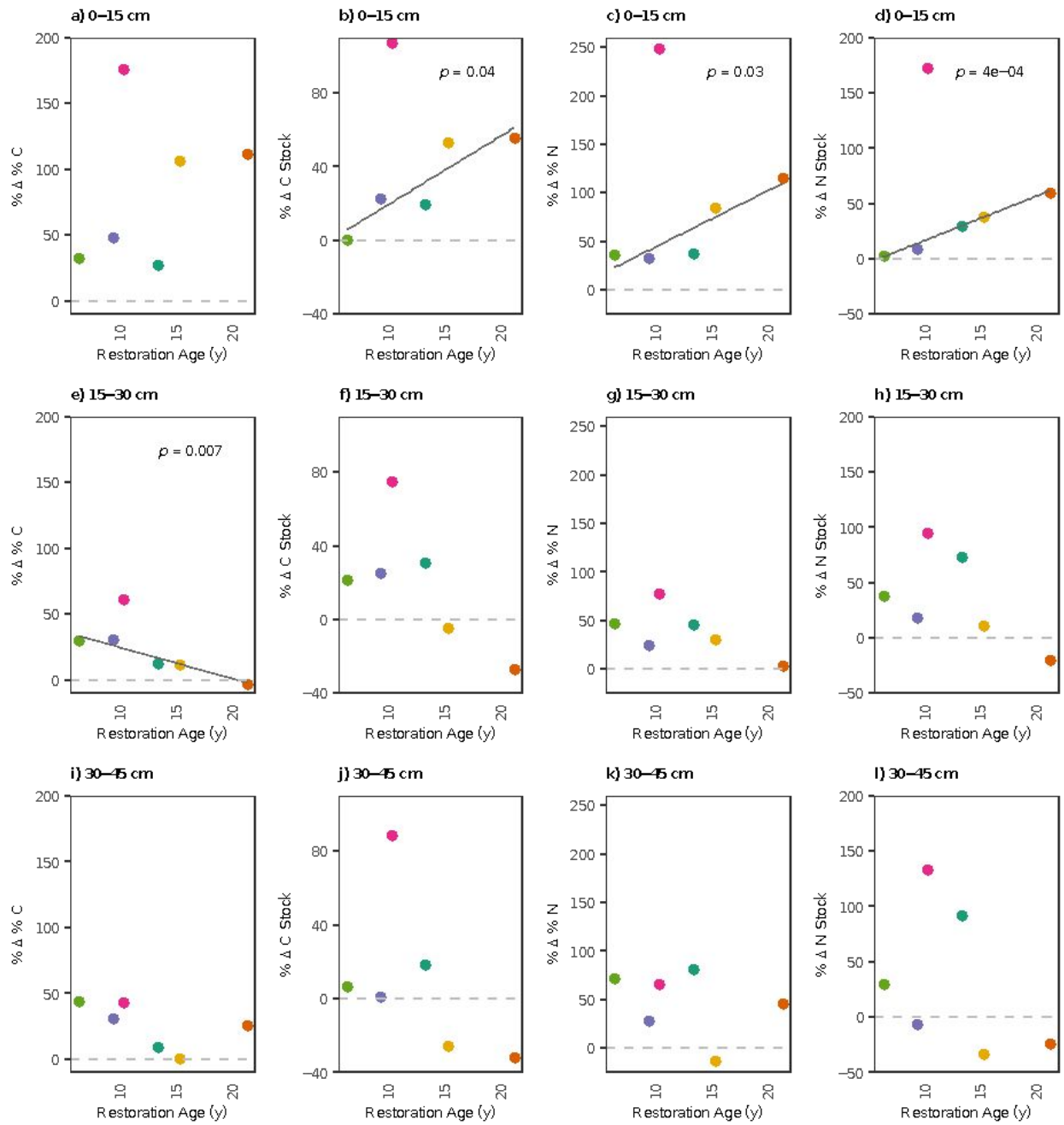
495,000 to 1.3 million MT C y^{-1}


Questions?
creed@cabnr.unr.edu


Soil C (kg m^{-2})
Soil N (kg m^{-2})
p = 0.39
p = 0.10
p = 0.003
p = 0.01
p = 0.43
p = 0.95
p = 0.04
p = 0.47
p = 2.5e−06
p = 2.3e−06
p = 0.89
p = 0.39
Poco (2010)
Dixie (2007)
McReynolds (2006)
Alkali Flat (2003)
Clarks (2001)
Big Flat (1995)


Vegetation Biomass (kg m^{-2})
1.5
1.0
0.5
0.0
p = 0.007
p = 0.003
p = 0.007
p = 0.004
p = 0.0002
p = 0.007
Root Biomass (kg m^{-2})
12.5
10.0
7.5
5.0
2.5
0.0
p = 0.04
p = 0.47
p = 0.0002
p = 0.01
p = 0.0005
p = 2.6e−08
Poco (2010)
Dixie (2007)
McReynolds (2006)
Alkali Flat (2003)
Clarks (2001)
Big Flat (1995)


a) 0–15 cm
p = 0.03
d) 0–15 cm
p = 0.06
b) 15–30 cm
p = 0.72
% C
e) 15–30 cm
p = 0.8
% N
c) 30–45 cm
p = 0.83
f) 30–45 cm
p = 0.89
Restoration Age (y)
Restoration Age (y)
Site
Alkali Flat
Dixie
Poco
Big Flat
McReynolds
Upper Clarks


a) 0–15 cm
b) 0–15 cm
p = 0.04
c) 0–15 cm
p = 0.03
d) 0–15 cm
p = 4e−04
e) 15–30 cm
p = 0.007
f) 15–30 cm
g) 15–30 cm
h) 15–30 cm
i) 30–45 cm
j) 30–45 cm
k) 30–45 cm
l) 30–45 cm
% Δ % C
% Δ C Stock
% Δ % N
% Δ N Stock
Restoration Age (y)
Site
Alkali Flat
Big Flat
Dixie
McReynolds
Poco
Upper Clarks