Quantifying drivers of Arctic carbon-climate feedbacks across scales

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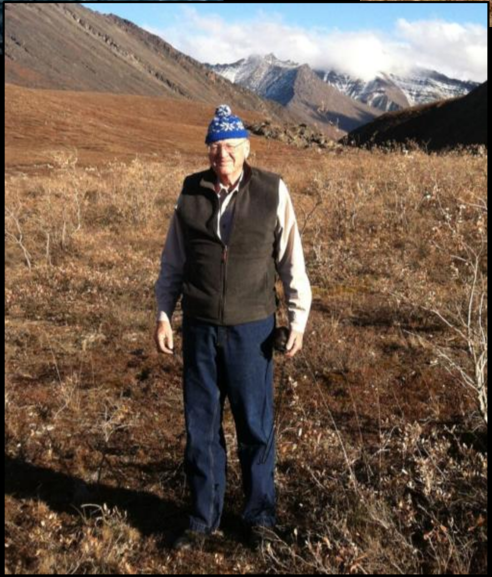
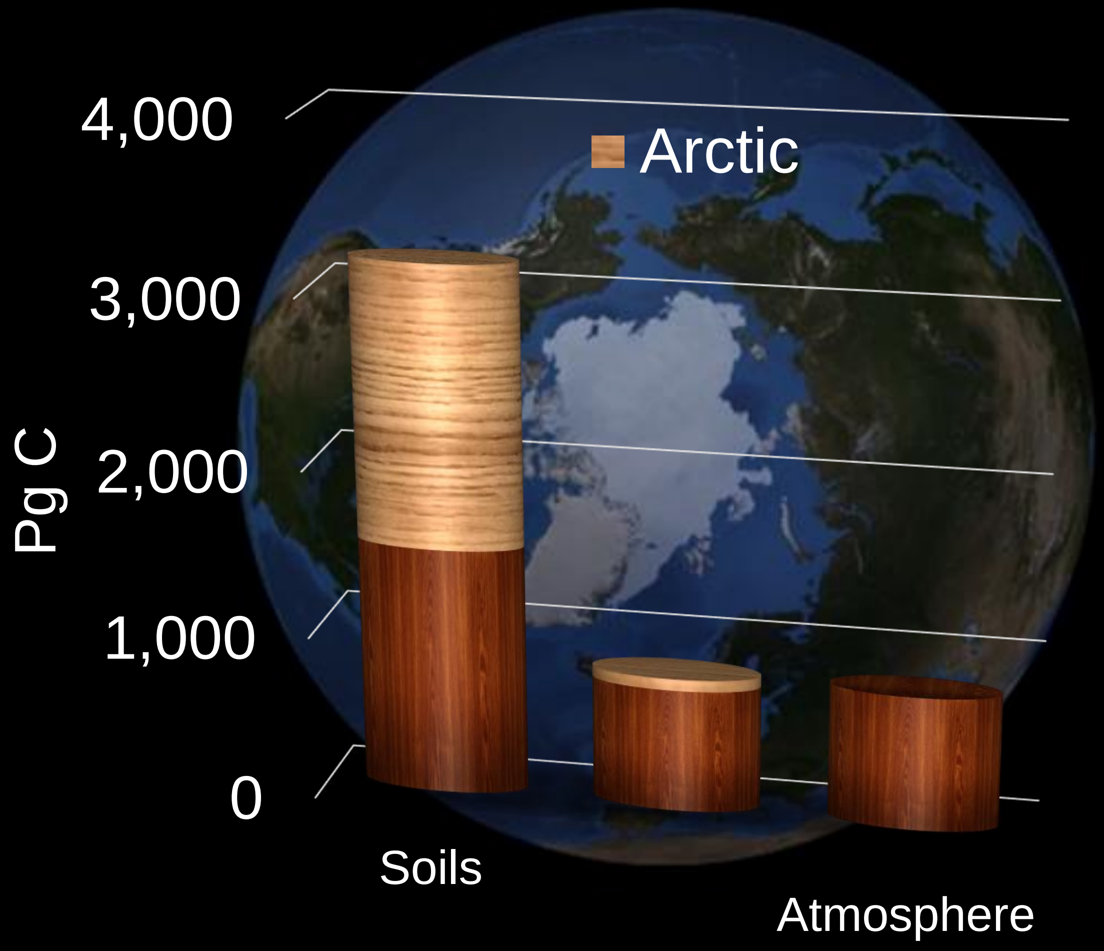
LTER

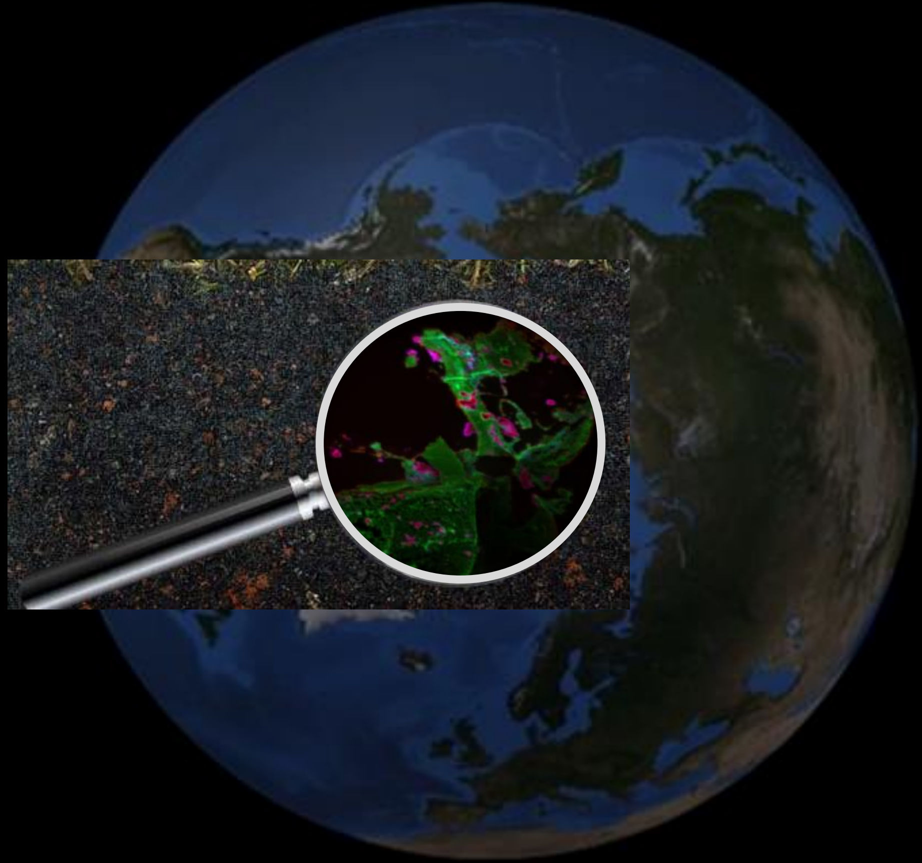




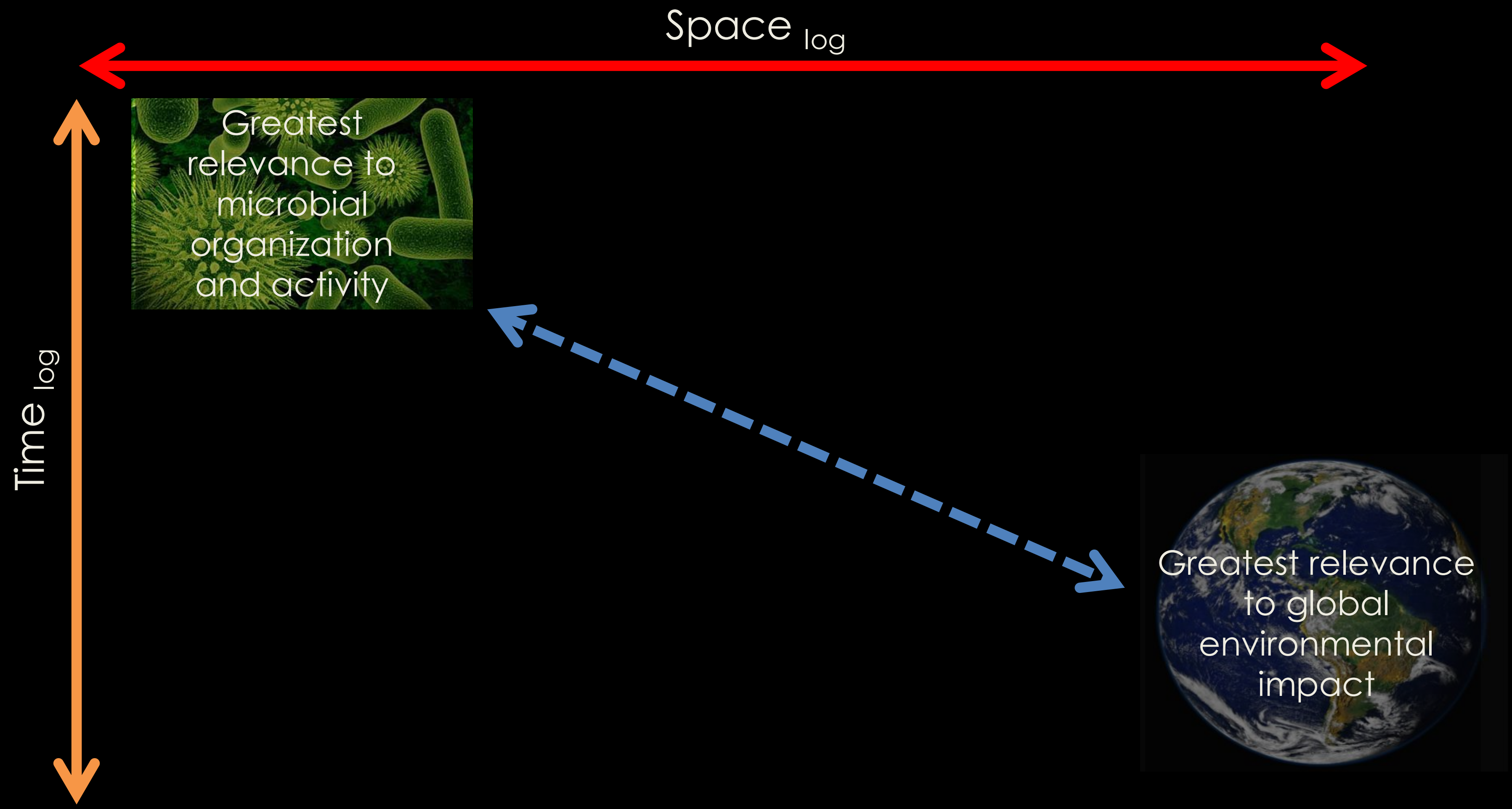
Arctic
4,000
3,000
2,000
1,000
0
Pg C
Soils
Atmosphere

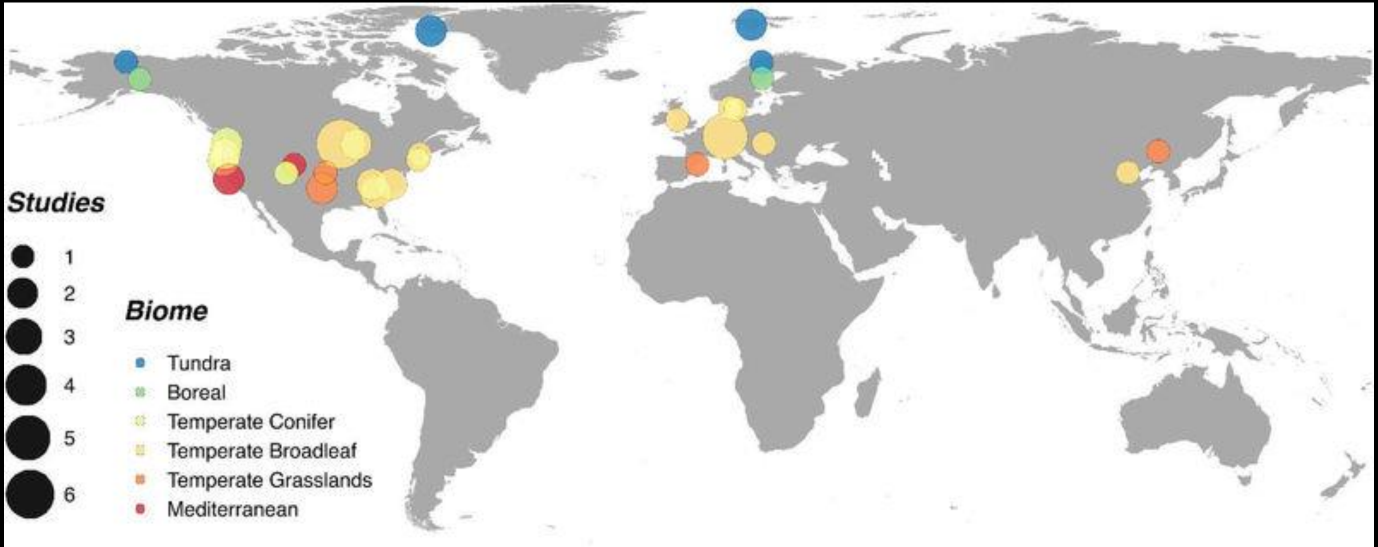
The need to think BIG and small

The role of microbes as climate engineers

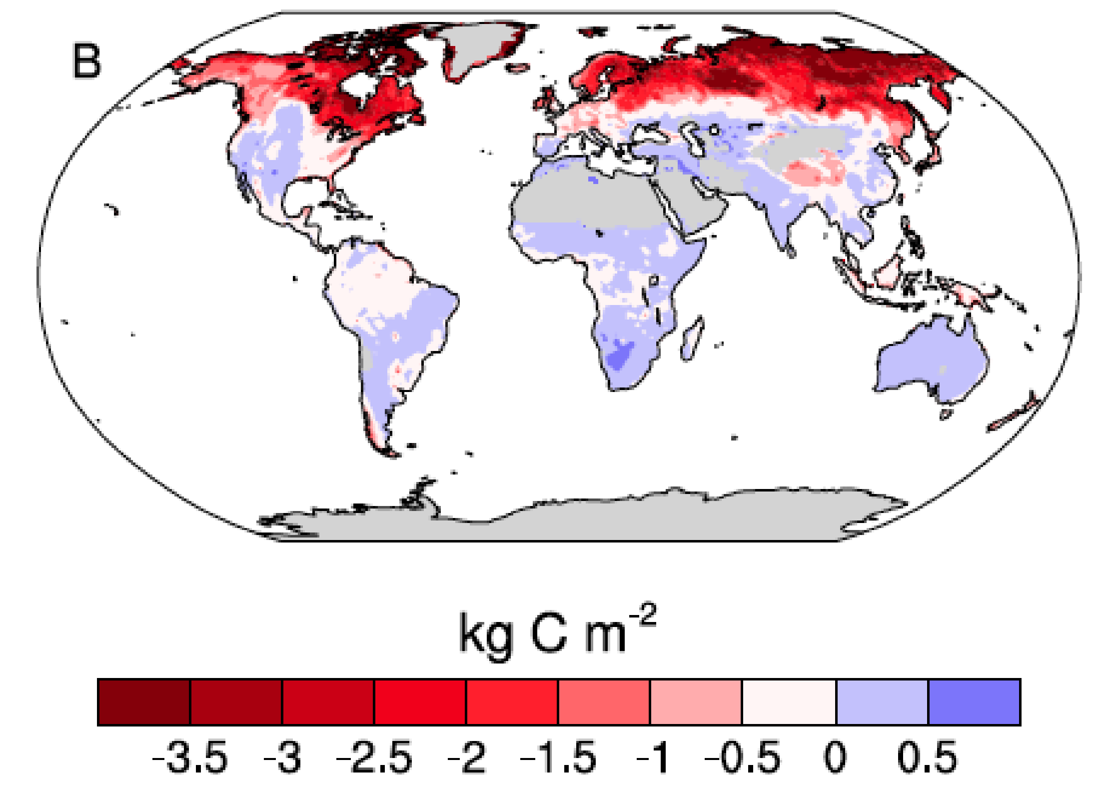


The need to think BIG and small

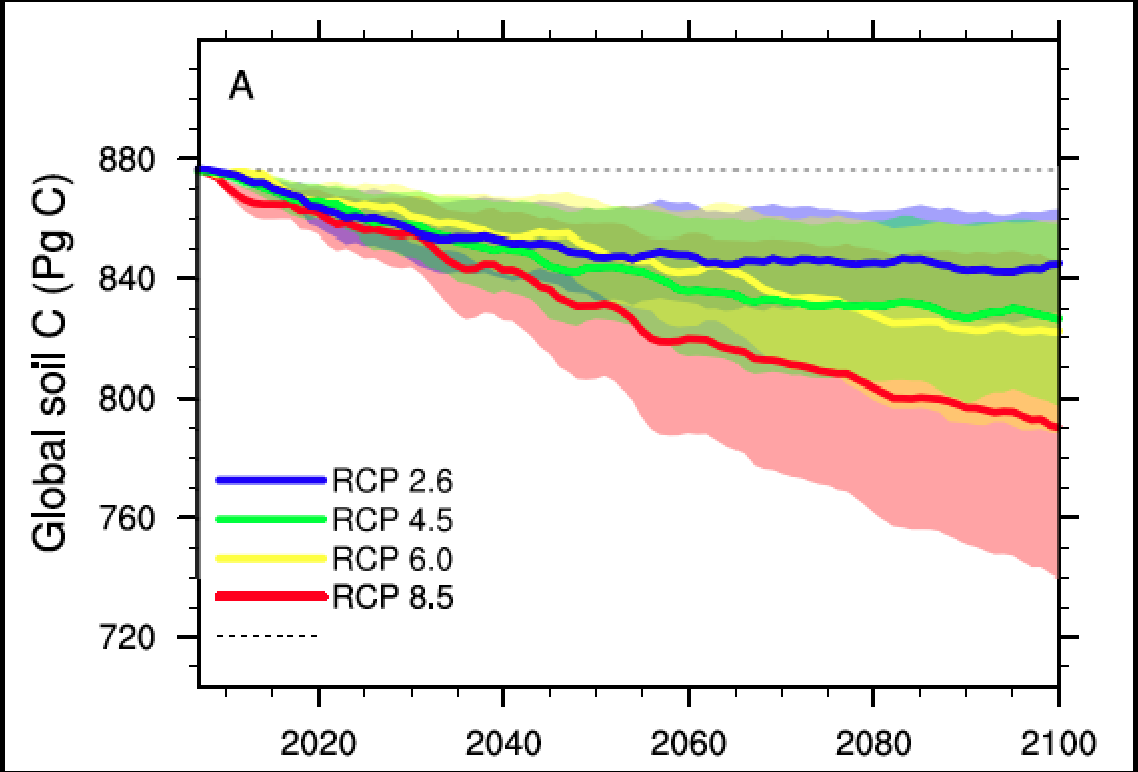




Crowther et al 2016, Nature
Crowther, Machmuller et al 2018, Nature
Carey et al 2016, PNAS
Machmuller, Wieder, Crowther, in prep



Crowther et al 2016, Nature
Crowther, Machmuller et al 2018, Nature



Crowther et al 2016, Nature
Crowther, Machmuller et al 2018, Nature

How do microbes interact with their environment?

Arctic greening and shrub expansion

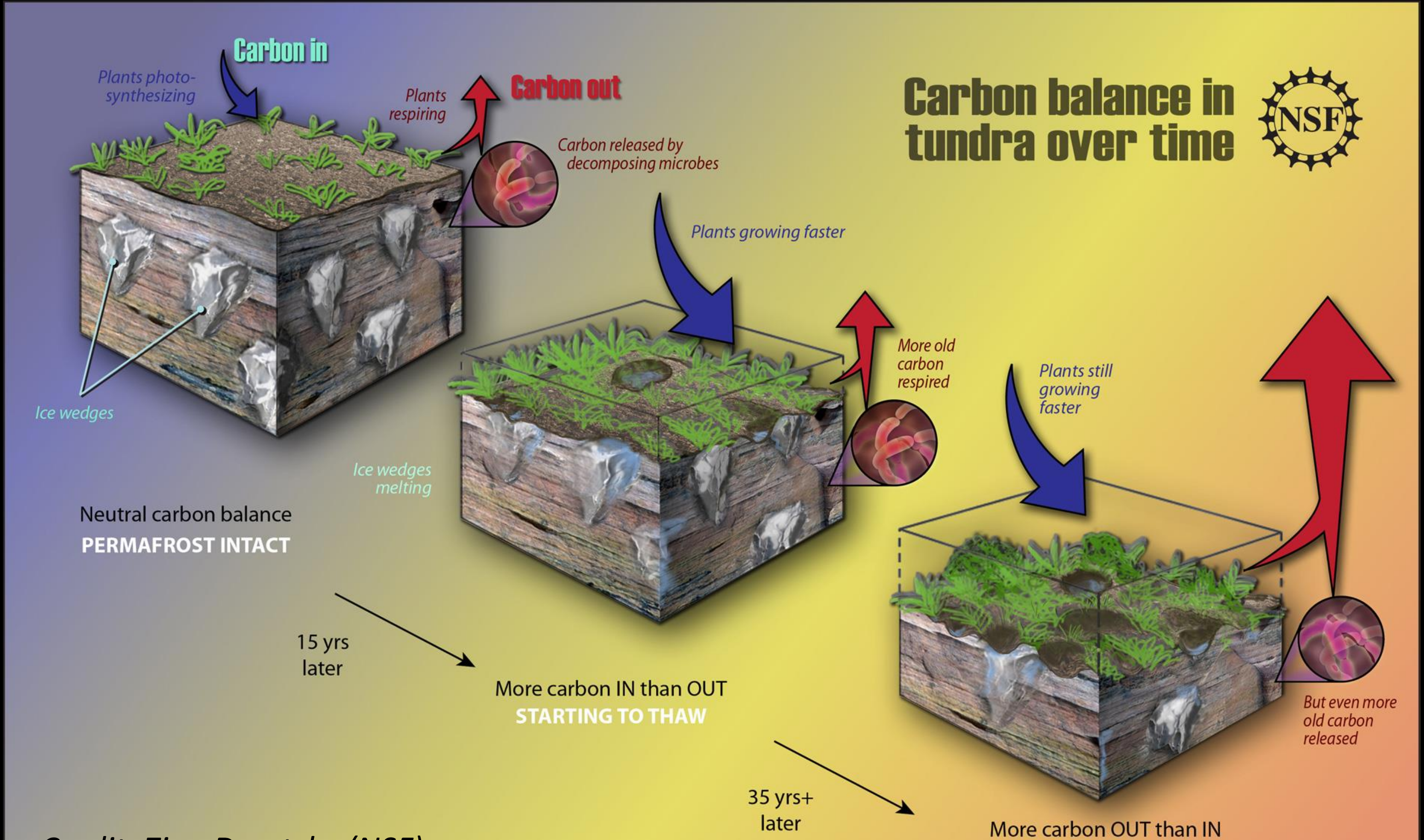
Time_{log}

Ju and Masek, 2016 (*Remote Sensing of Environment*)

Eriophorum vaginatum

Betula nana

LTER



Credit: Zina Deretsky (NSF)

Do plants regulate microbial substrate use and SOM priming?

^{13}C Isotope Tracing

δ_G —f_G→ δ_S ←f_{SOM}— δ_{SOM}

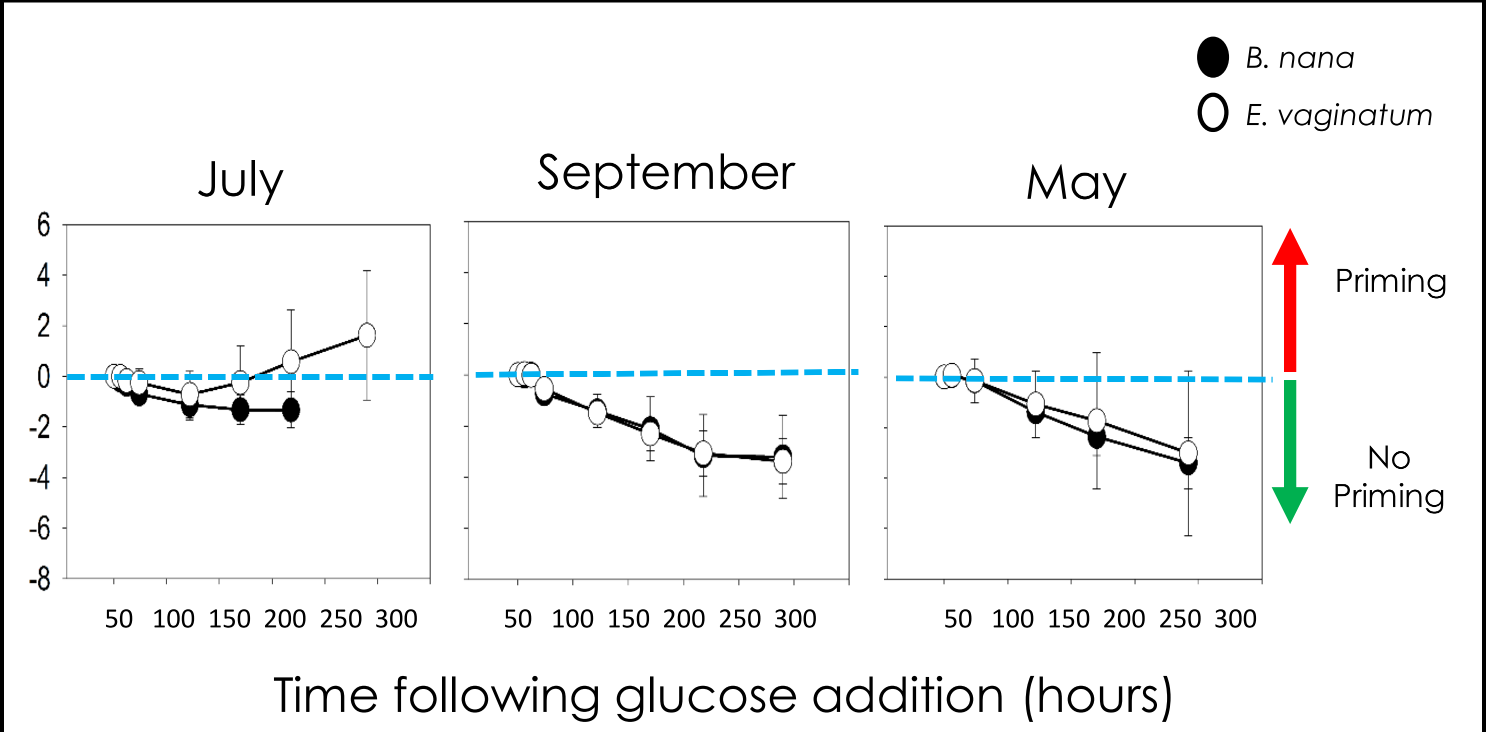
In Situ Soil Respiration

Soil Pools

^{13}C-glucose field application

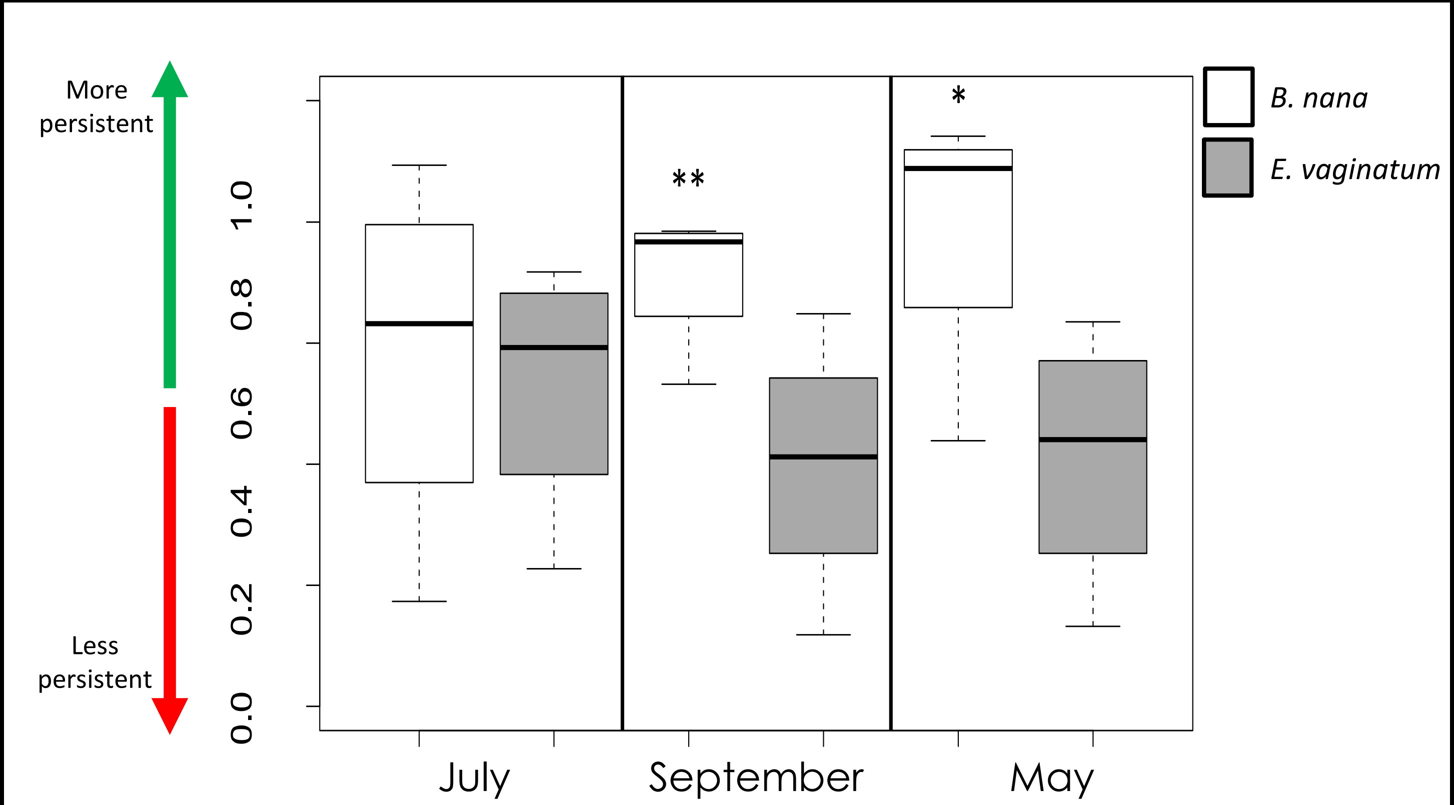
Microbial Biomass

SOM primed CO_2 flux (g CO_2 m^{-2})



Lynch, Machmuller et al, 2018 SBB

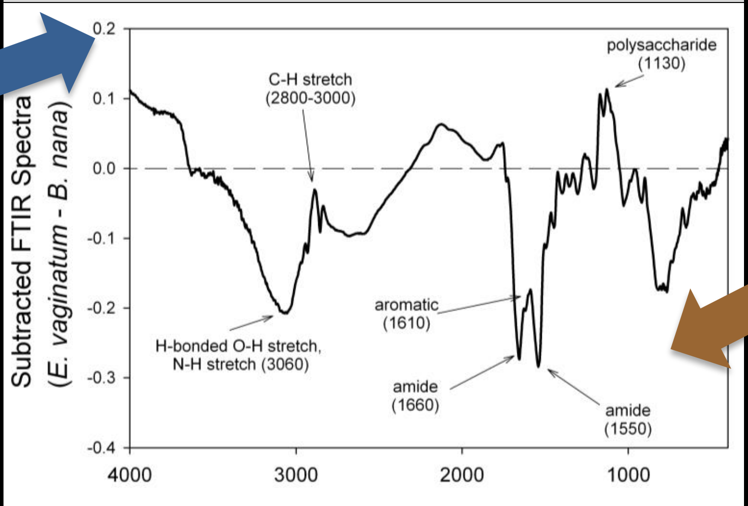
Substrate persistence influenced by vegetation

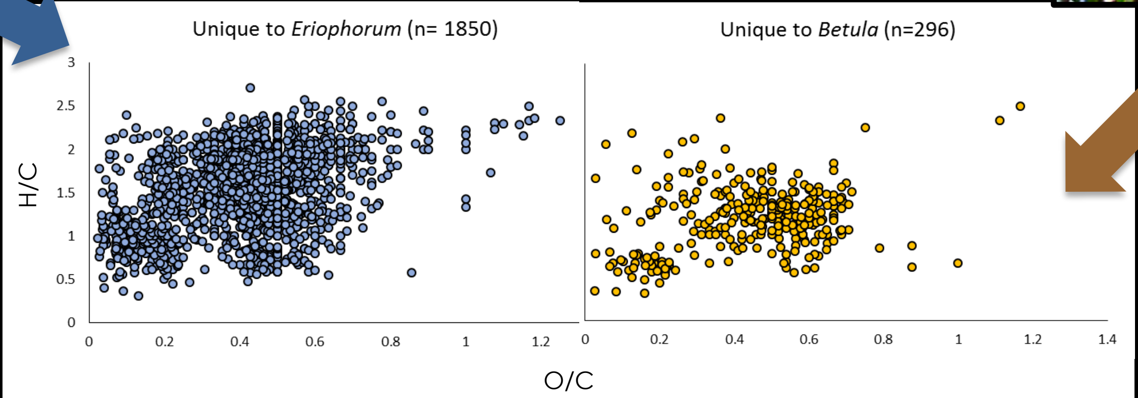


Lynch, Machmuller et al, 2018 SBB

Plant Litter Chemistry

FTIR Spectra Differences





FT-ICR-MS
van Krevelen diagrams

Root Exudate Chemistry

Tussock Birch

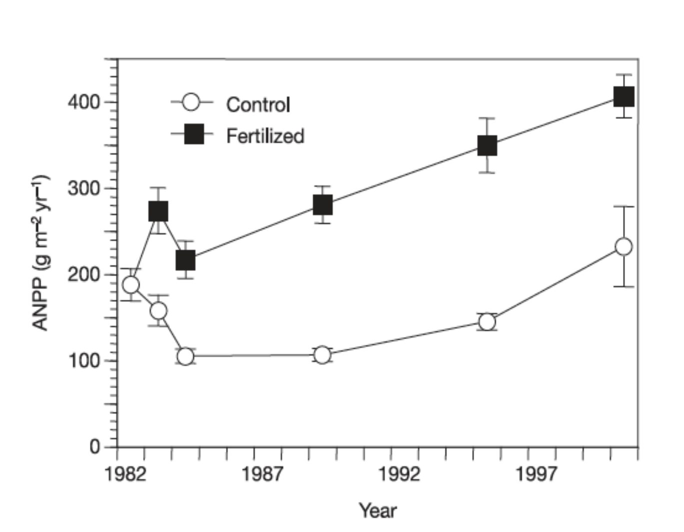
Space $_{log}$

Time $_{log}$

Will increased nutrient availability ameliorate or enhance C loss?

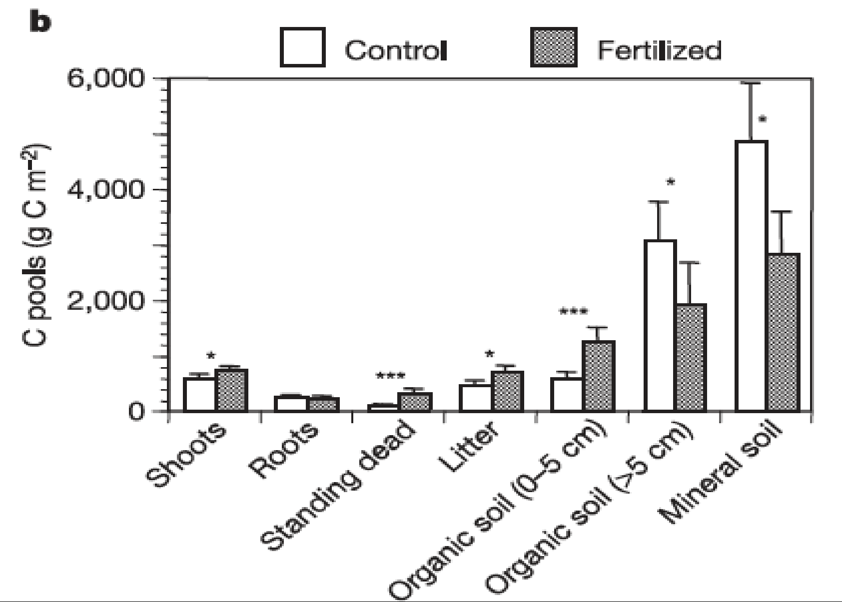
Field NP Fertilization Experiment [1981 – present]

After 20 years of nutrient fertilization…



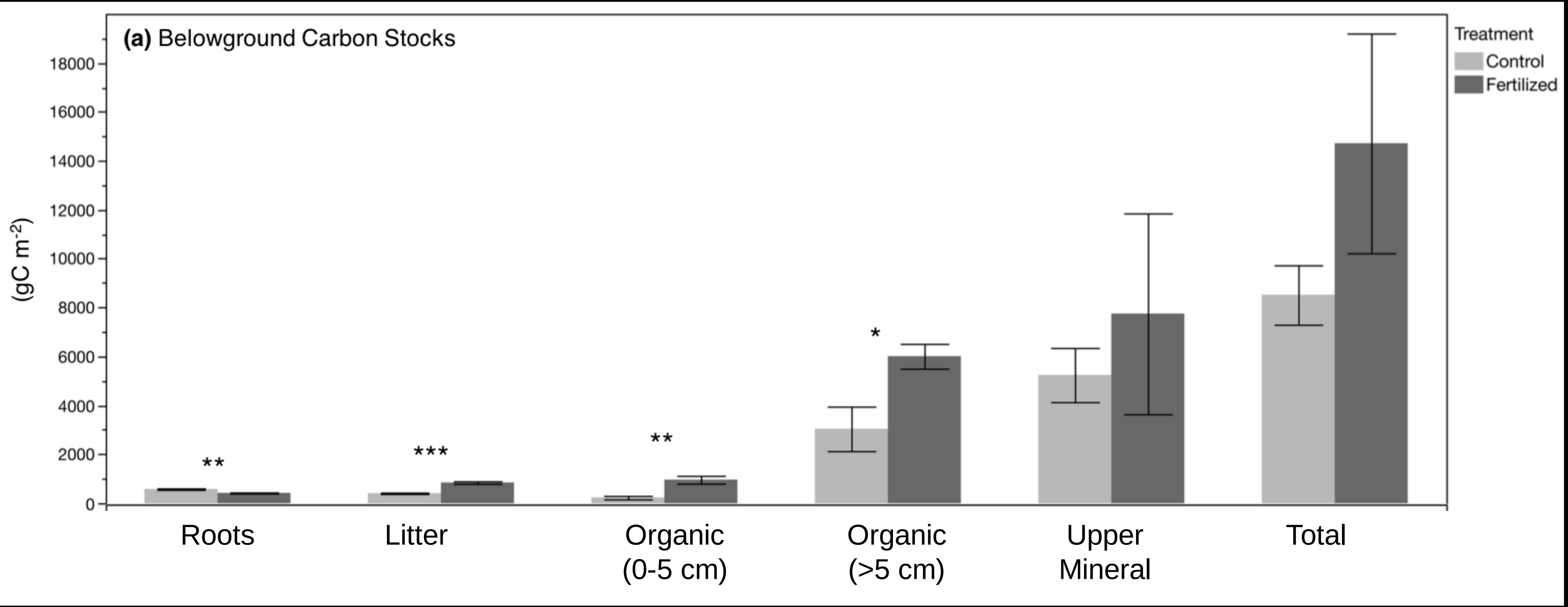
Ecosystem carbon storage in arctic tundra reduced by long-term nutrient fertilization

Michelle C. Mack[1]*, Edward A. G. Schuur[1]*, M. Syndonia Bret-Harte[2], Gaius R. Shaver[3] & F. Stuart Chapin III[2]



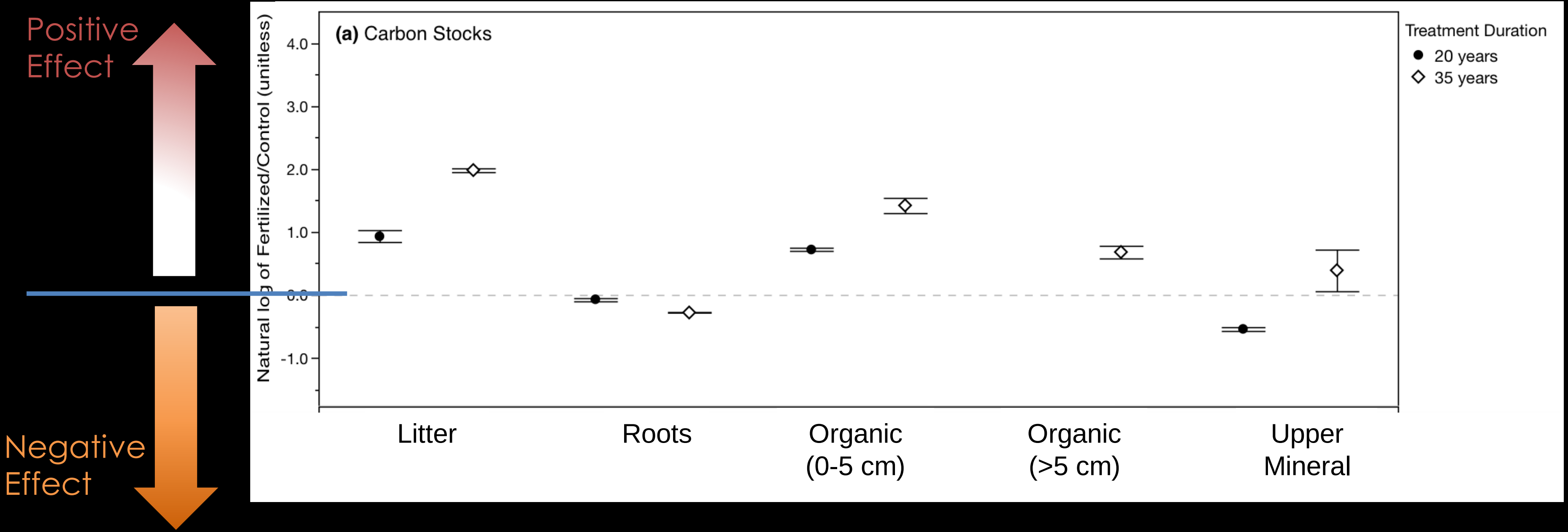
Mack et al, 2004 Nature

BUT after 35 years of nutrient fertilization…



Machmuller et al, in prep

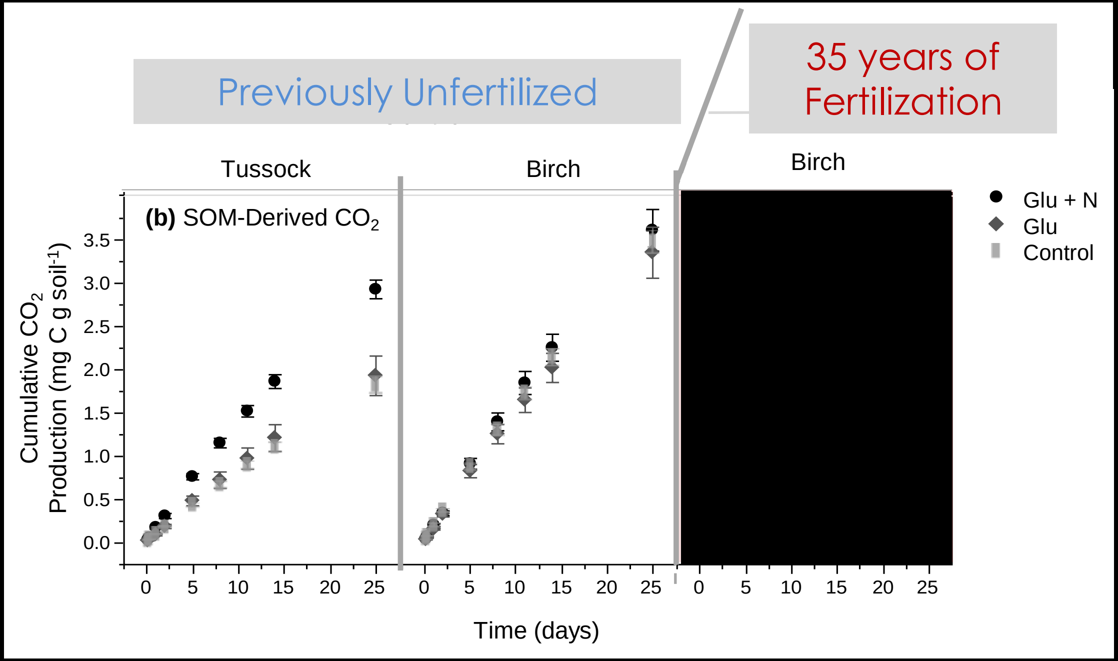
Long-term, complex feedbacks among ecosystem components lead to non-linear responses and possible state changes…



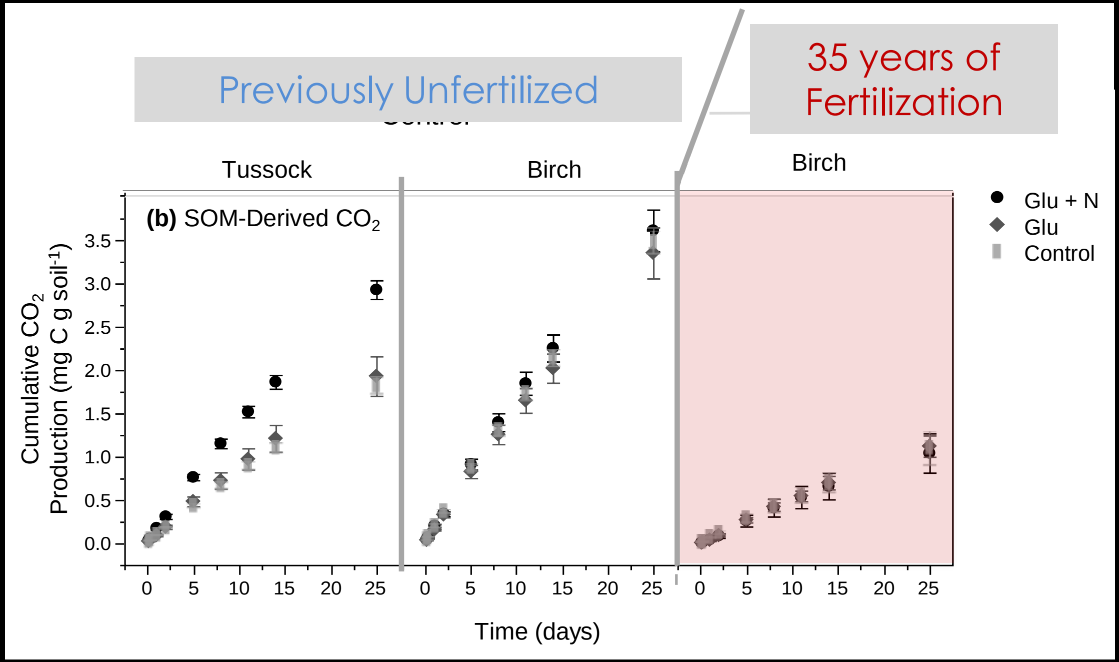
Why?

What are the mechanisms driving the fertilization effect?

Short-term C-N dynamics dependent on vegetation

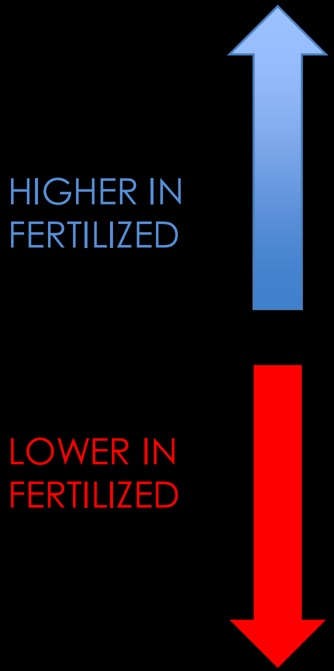


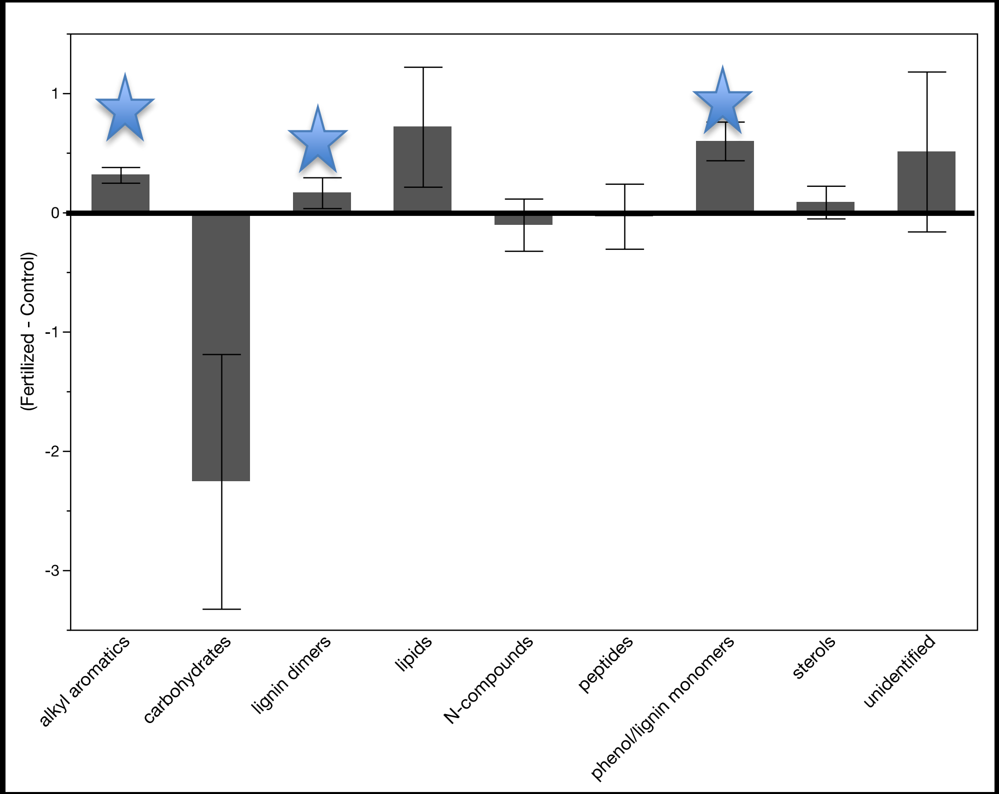
Short-term C-N dynamics dependent on vegetation



pH, Microbial Biomass

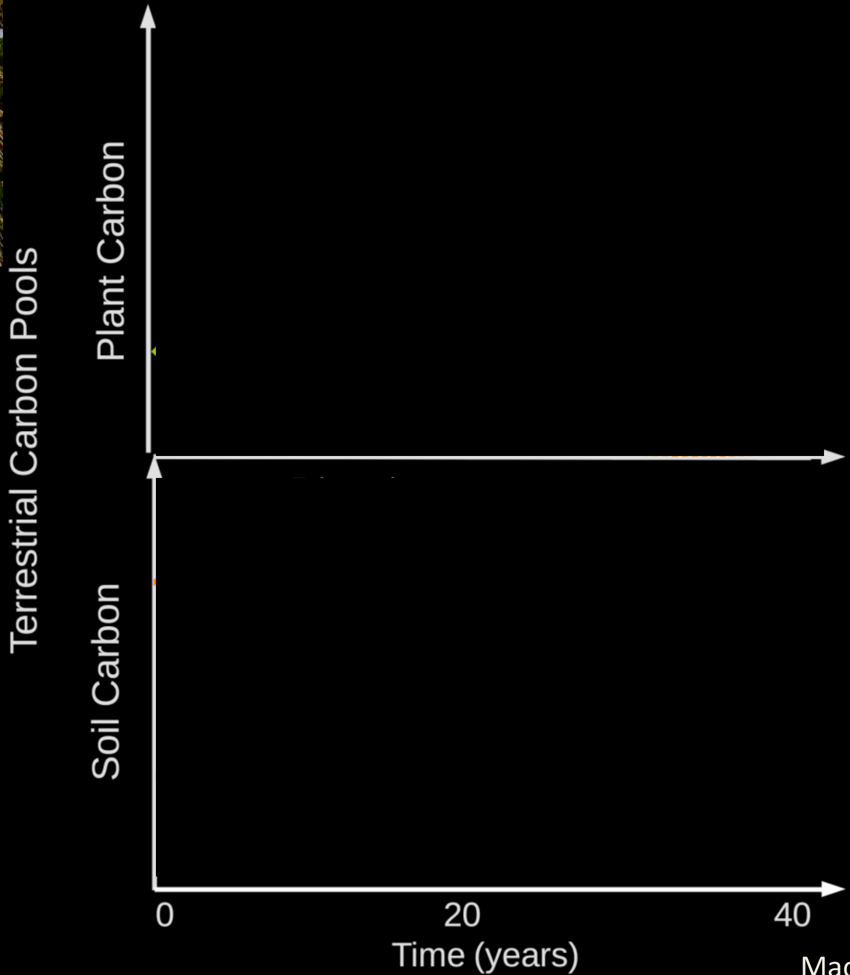
Shifts in SOM Chemistry



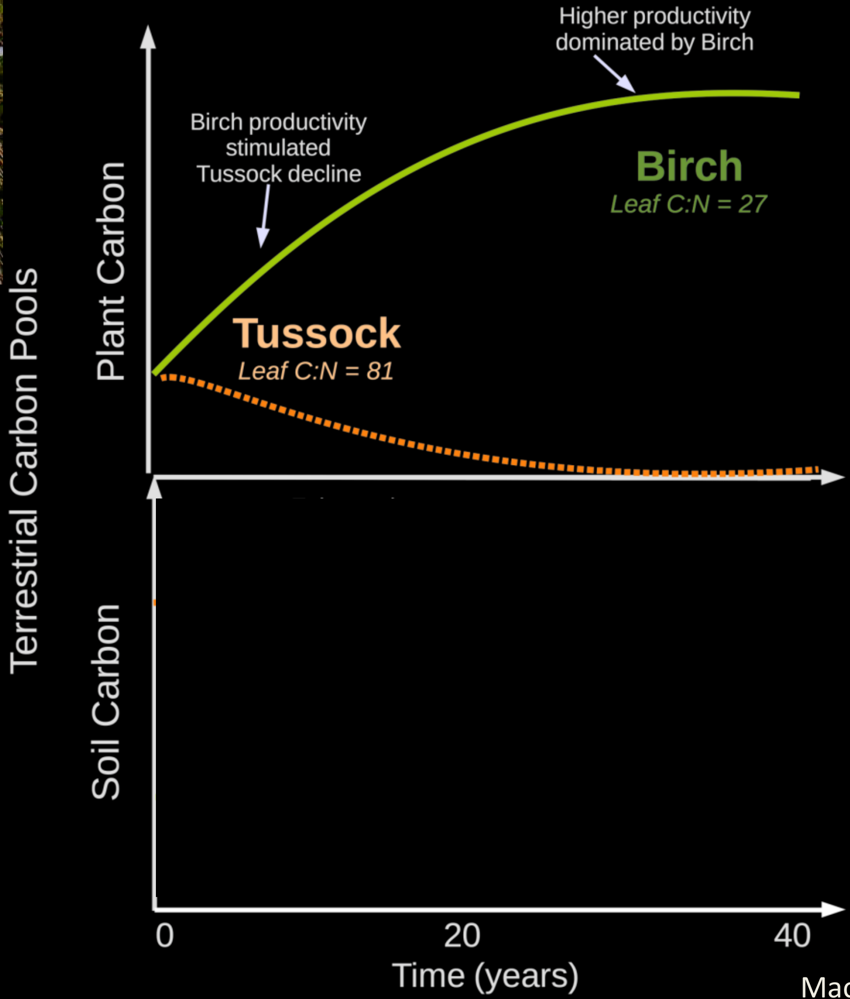



Chemically recalcitrant - aromatics

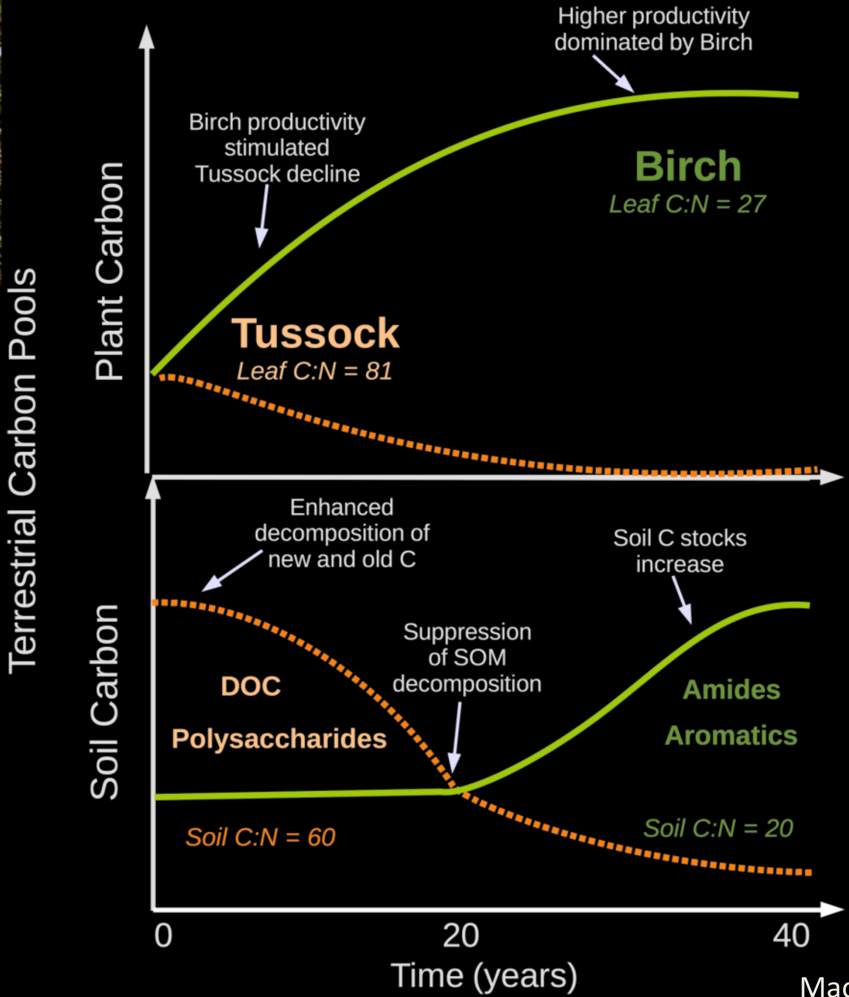
Machmuller et al, in prep



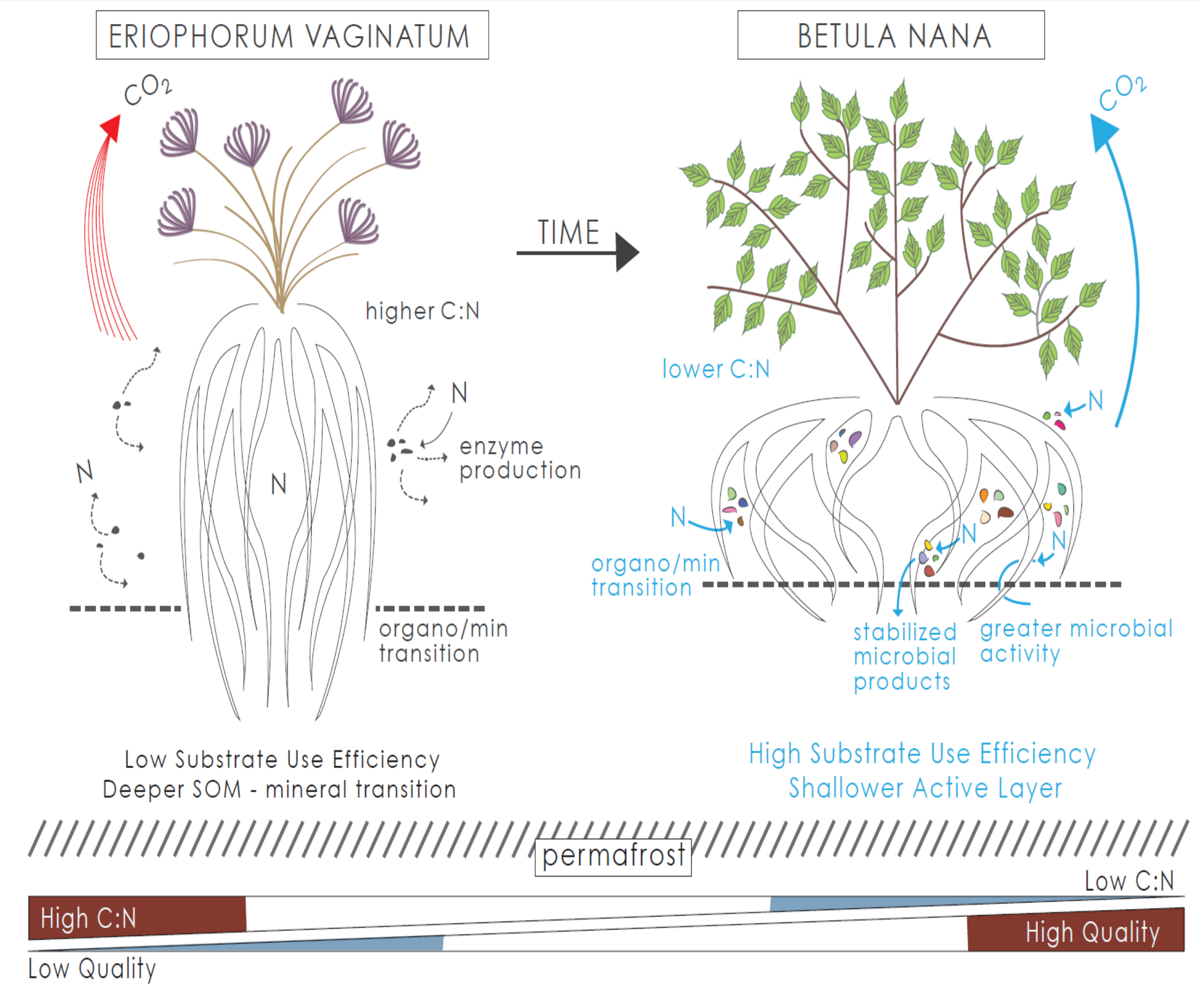
Machmuller et al, in prep



Machmuller et al, in prep

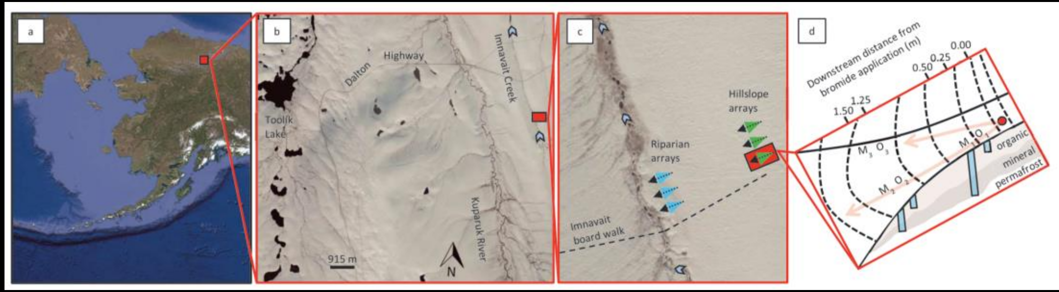


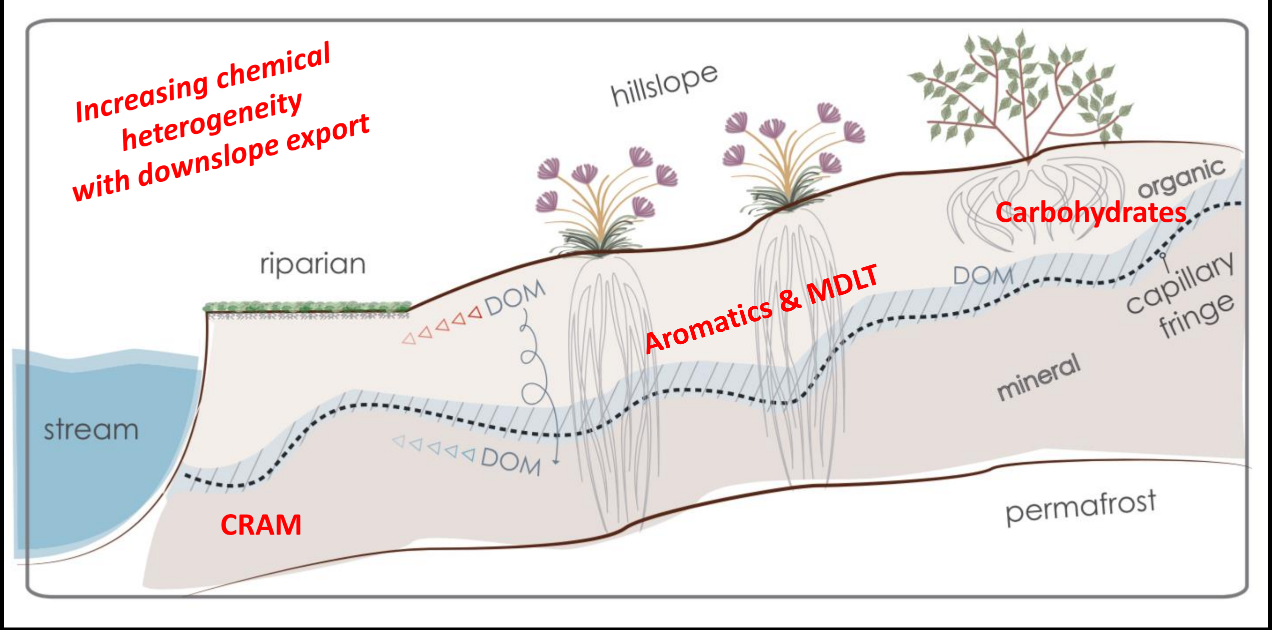
Machmuller et al, in prep



Lynch, Machmuller et al, 2018 SBB

DOM Transport Across the Landscape…





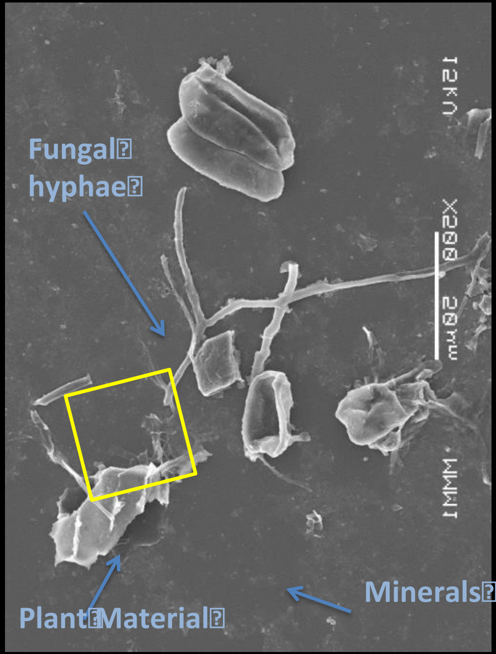
Plant-derived DOM

Microbial-derived DOM

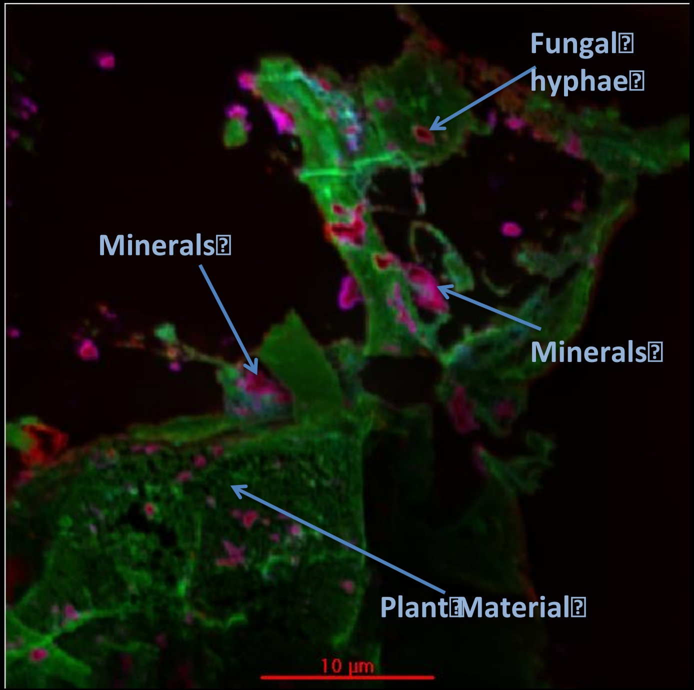
Lynch, Machmuller et al, 2019 GBC

The need to think BIG and small

Plants-Soil-Microbe Interactions



SEM



nanoSIMS*

Machmuller et al, in review

EcoCore

Colorado State University

NATIONAL SCIENCE FOUNDATION

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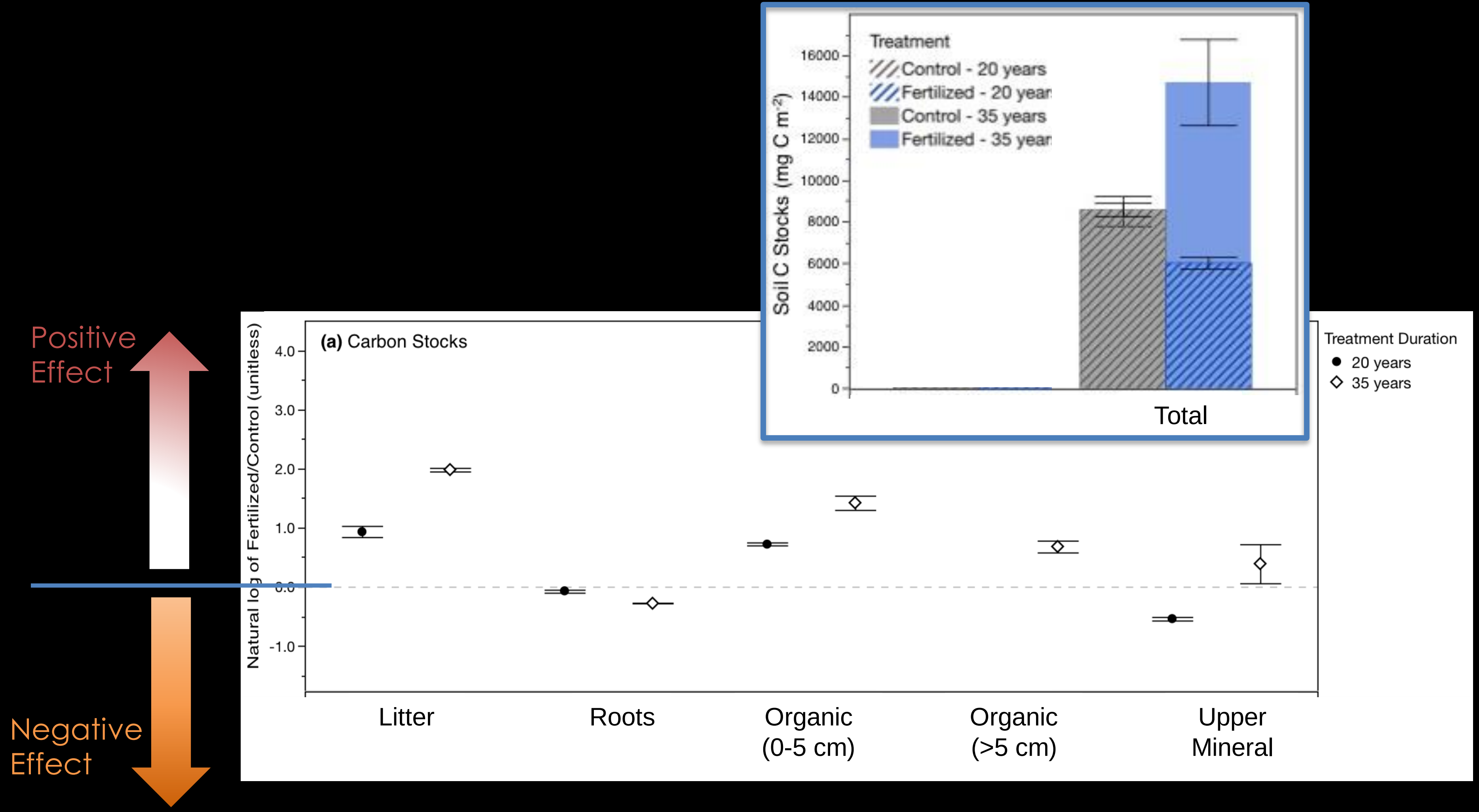
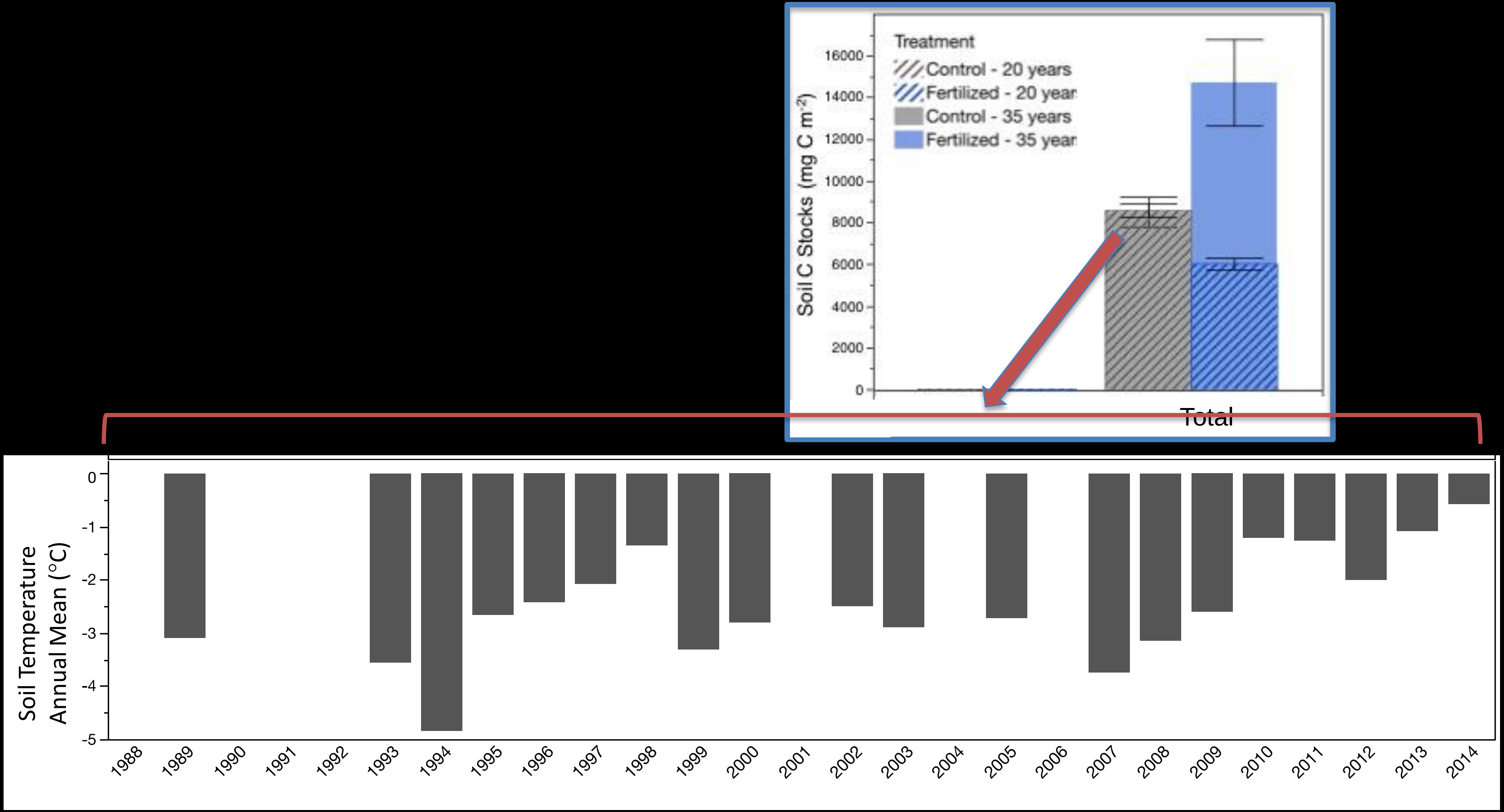
EMSL

DEPARTMENT OF ENERGY UNITED STATES OF AMERICA
U.S. DEPARTMENT OF ENERGY


Photo Credit: Justin Johnson



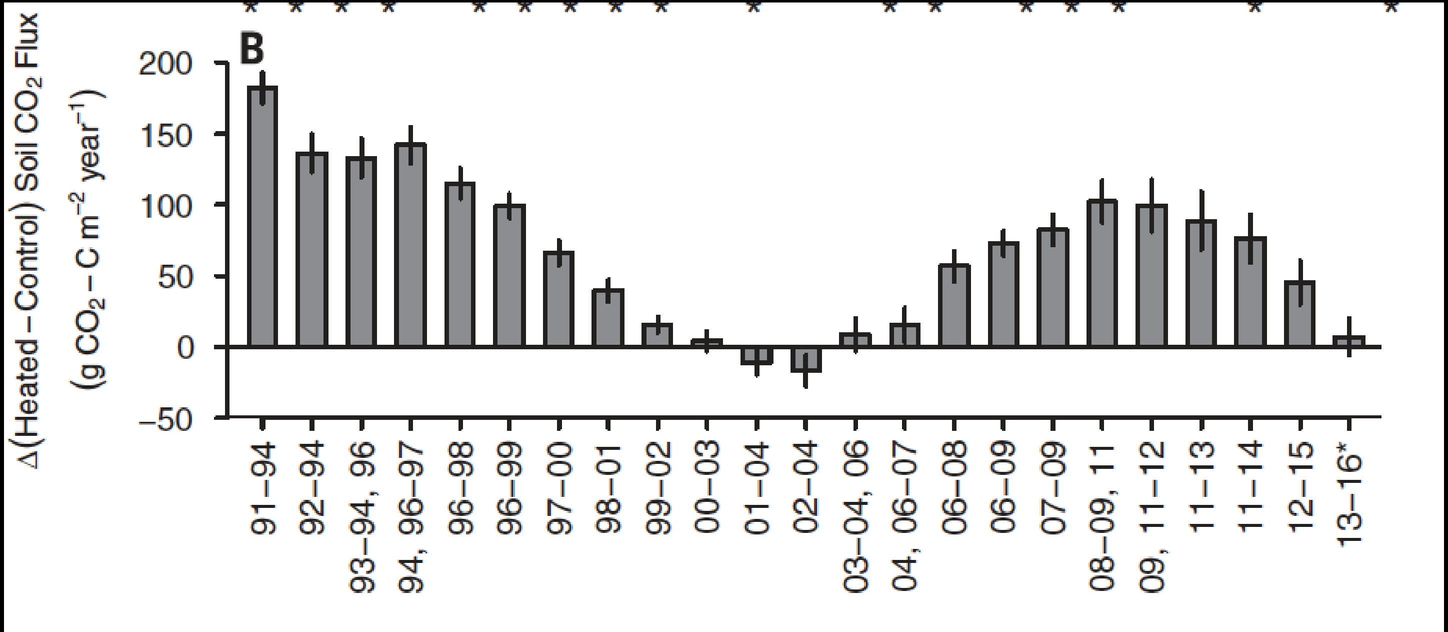
Positive Effect
Negative Effect
(a) Carbon Stocks
Natural log of Fertilized/Control (unitless)
4.0
3.0
2.0
1.0
0.0
-1.0
Litter
Roots
Organic (0-5 cm)
Organic (>5 cm)
Upper Mineral
Treatment Duration
20 years
35 years
Treatment
Control - 20 years
Fertilized - 20 years
Control - 35 years
Fertilized - 35 years
Soil C Stocks (mg C m^{-2})
16000
14000
12000
10000
8000
6000
4000
2000
0
Total



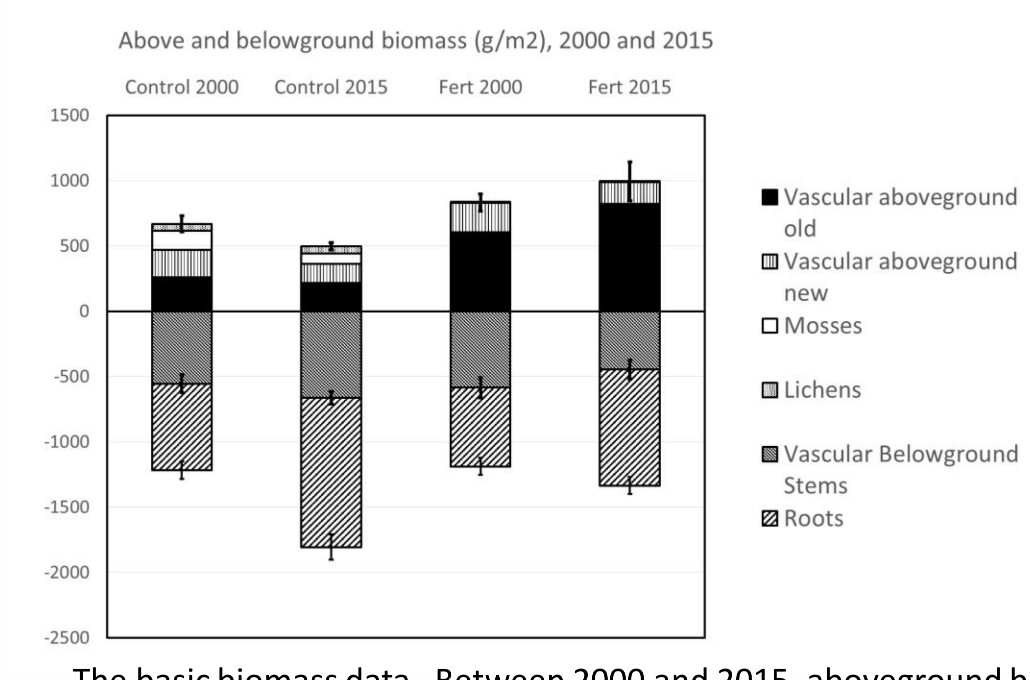
Treatment
Control - 20 years
Fertilized - 20 year
Control - 35 years
Fertilized - 35 year
Soil C Stocks (mg C m⁻²)
16000
14000
12000
10000
8000
6000
4000
2000
0
Total
Soil Temperature
Annual Mean (°C)
0
-1
-2
-3
-4
-5
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014

Long-term pattern and magnitude of soil carbon feedback to the climate system in a warming world

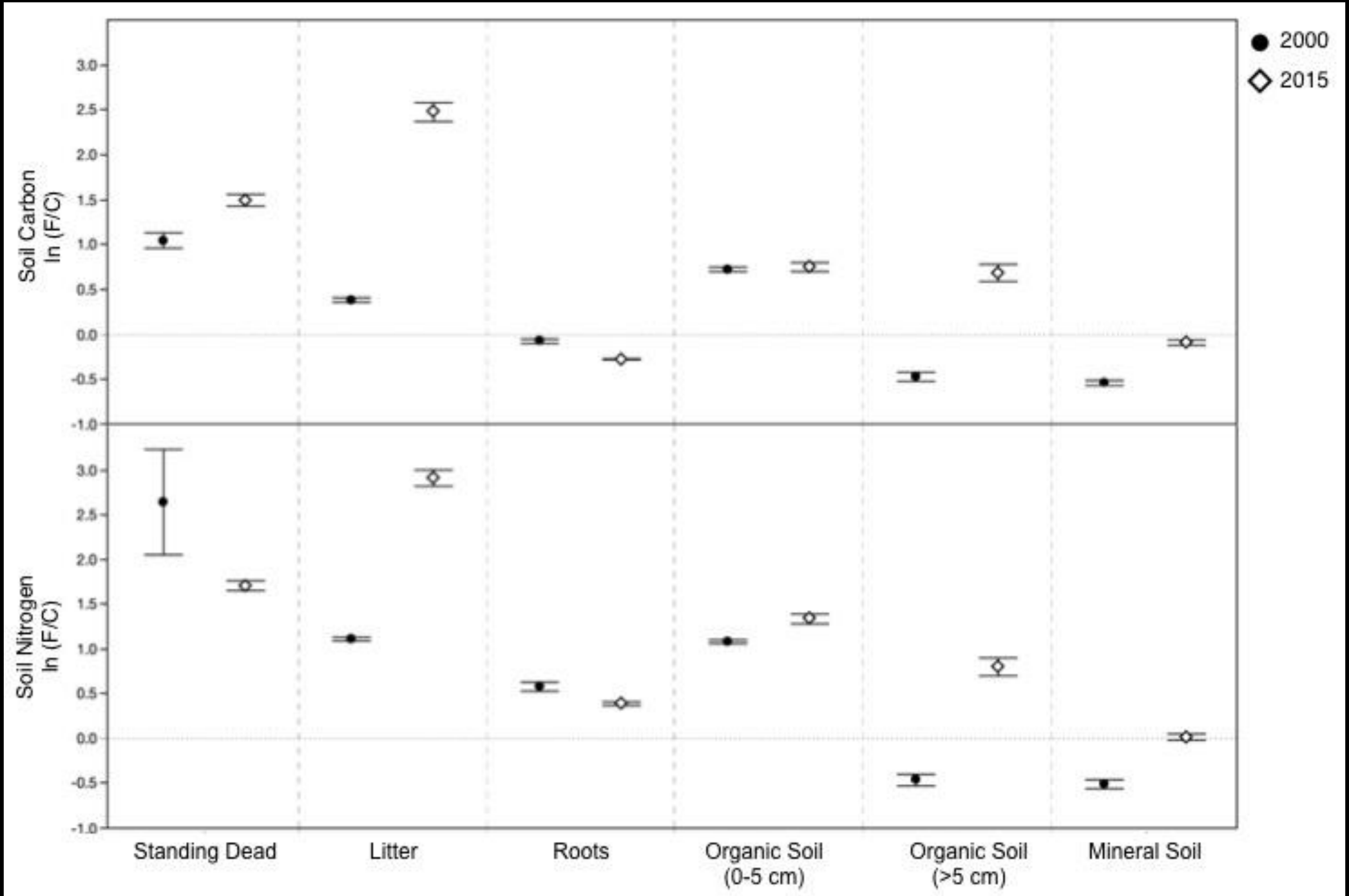
J. M. Melillo,[1*] S.D. Frey,[2] K. M. DeAngelis,[3] W. J. Werner,[1] M. J. Bernard,[1]
F. P. Bowles,[4] G. Pold,[5] M. A. Knorr,[2] A. S. Grandy[2]



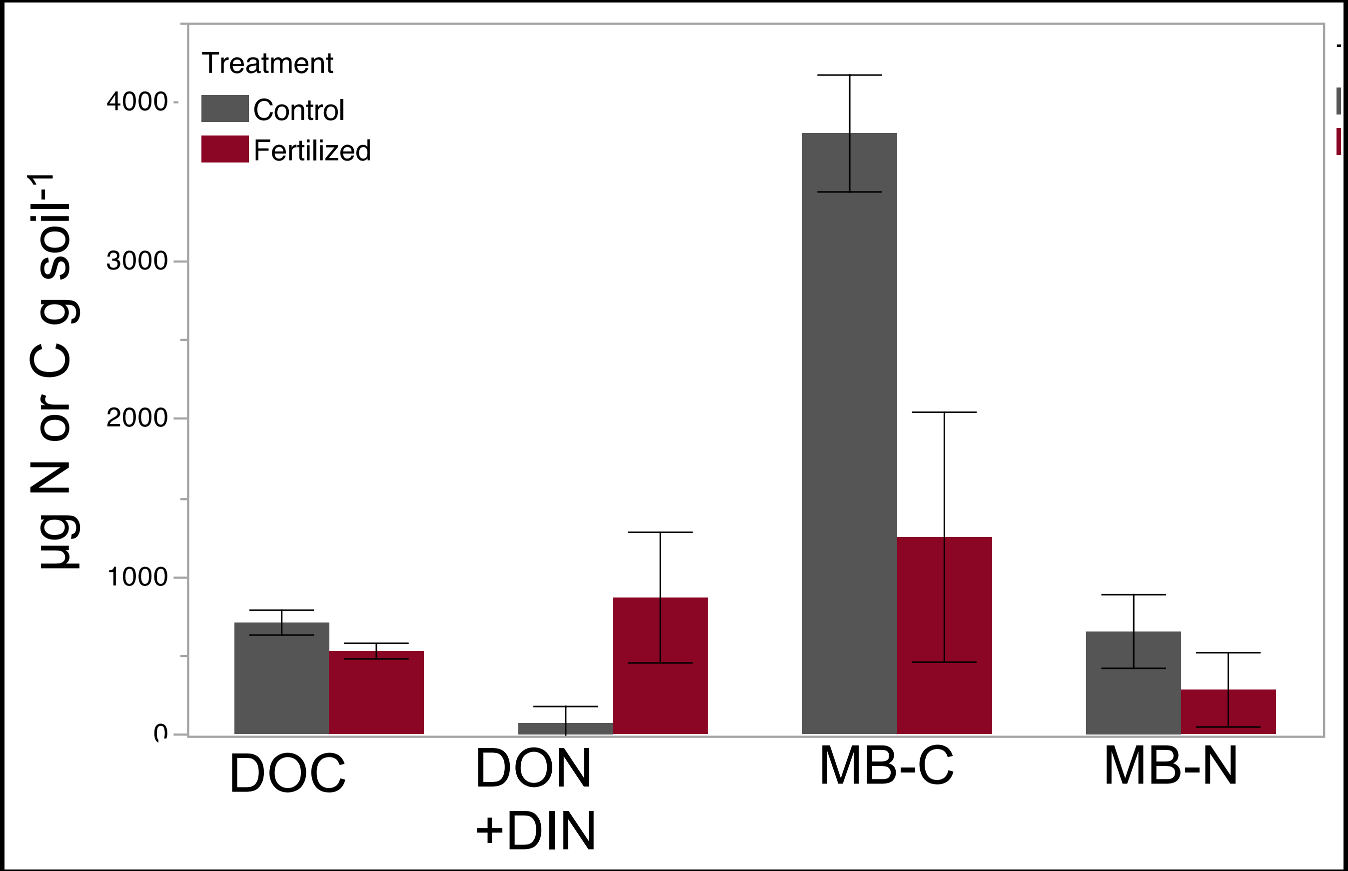
Melillo et al 2017, Science



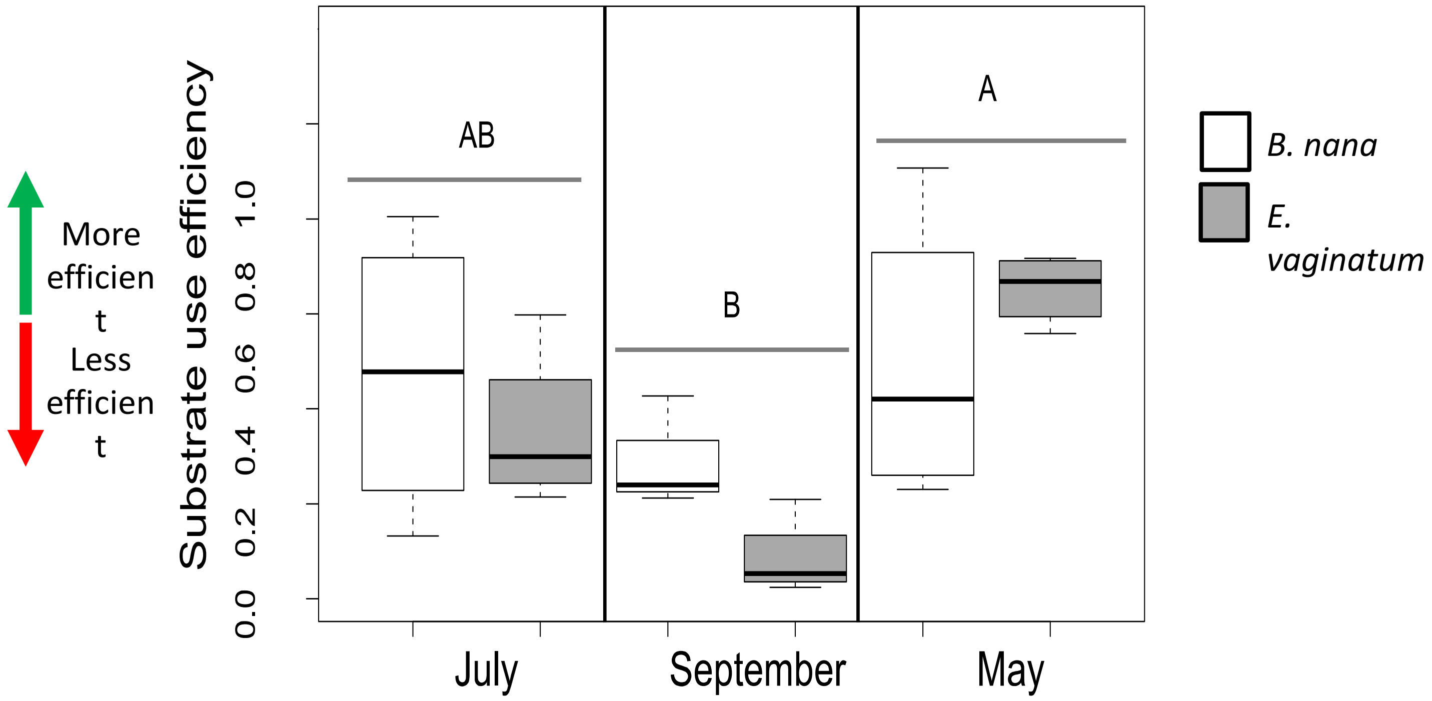
The basic biomass data. Between 2000 and 2015, aboveground biomass in CT declined while root biomass increased. In Fert, both above and belowground biomass did not change significantly between years (nonsignificant increase---but still need to do the statistics on this). Aboveground biomass in Fert was higher than CT in both years but root biomass in Fert was either no different from CT (in 2000) or less than CT (in 2015)



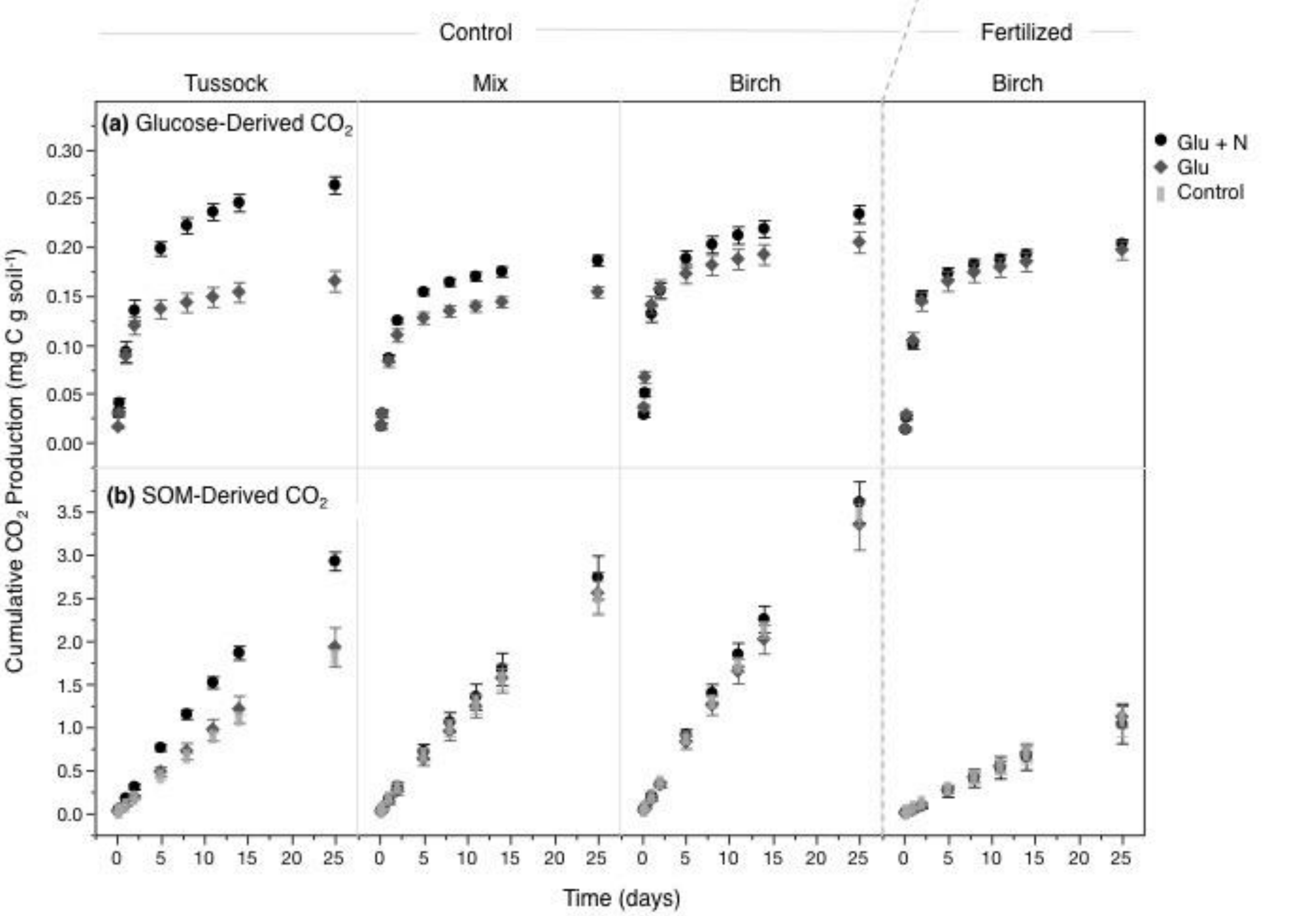
Machmuller et al, in prep


Treatment
Control
Fertilized
μg N or C g soil-1
4000
3000
2000
1000
0
DOC
DON
+DIN
MB-C
MB-N

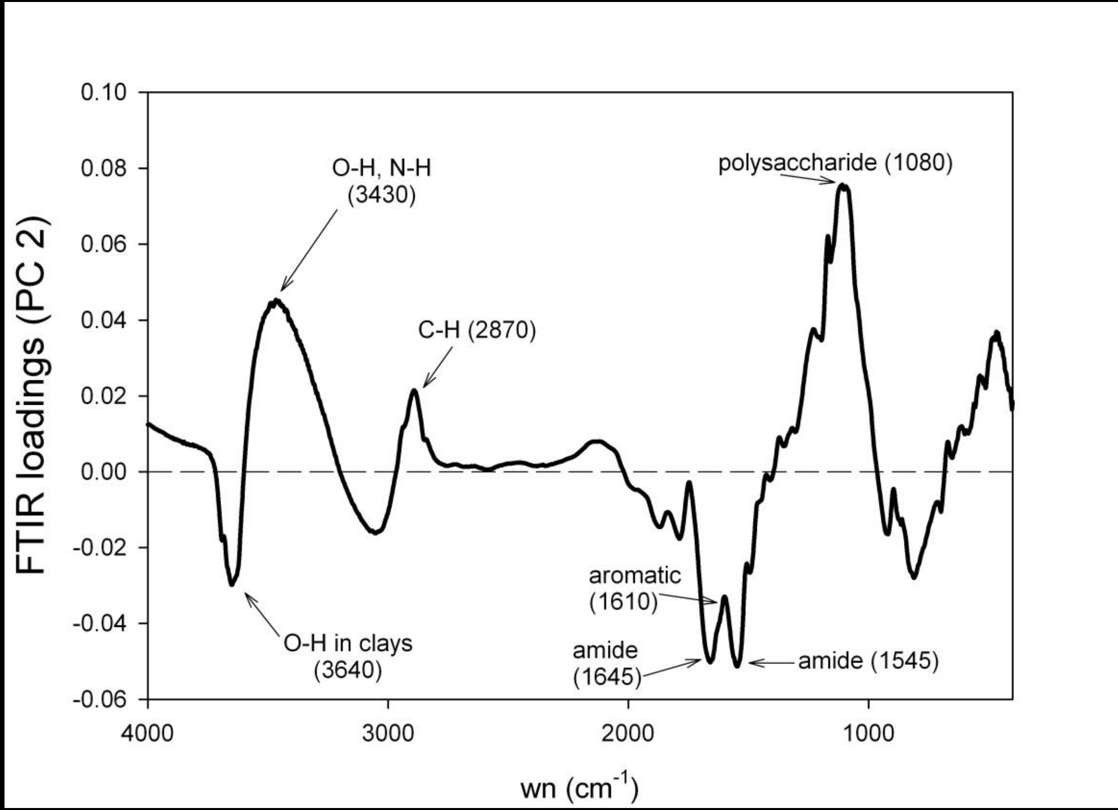
Season, not vegetation drives SUE



$$SUE = {}^{13}MB / ({}^{13}MB + {}^{13}CO_2)$$



Control
Fertilized
Tussock
Mix
Birch
Birch
(a) Glucose-Derived CO2
(b) SOM-Derived CO2
Glu + N
Glu
Control
Cumulative CO2 Production (mg C g soil-1)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0 5 10 15 20 25
Time (days)



FTIR loadings (PC 2)
0.10
0.08
0.06
0.04
0.02
0.00
-0.02
-0.04
-0.06
4000
3000
2000
1000
wn (cm-1)
O-H, N-H
(3430)
C-H (2870)
O-H in clays
(3640)
polysaccharide (1080)
aromatic
(1610)
amide
(1645)
amide (1545)