E3SM v2 Land Model Updates: dynamic allocation and plant stoichiometry

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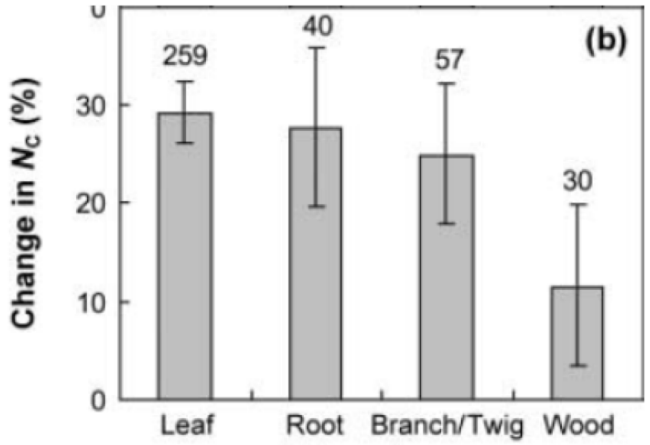
Outline

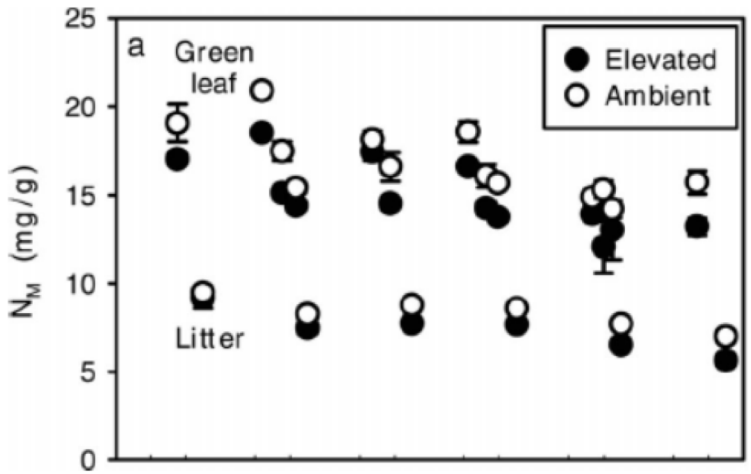
- Critical challenges in modeling ecosystem responses to environmental changes
- Dynamic plant allocation: case study 1
- Dynamic plant stoichiometry: case study 2
- v2 updates

Multi-factor environmental changes

- eCO2, N deposition



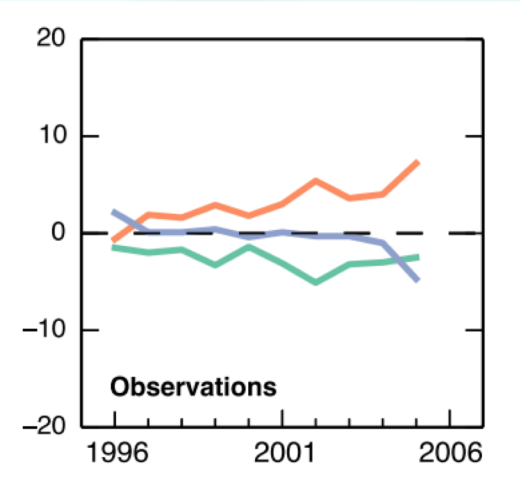
Xia 2008; N fertilization



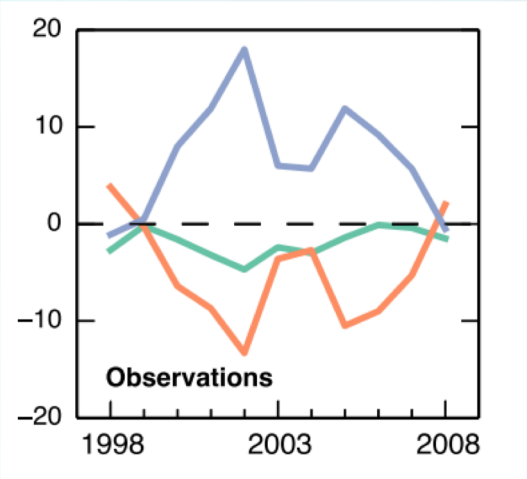
Norby 2006; Oak Ridge eCO2

Multi-factor environmental changes

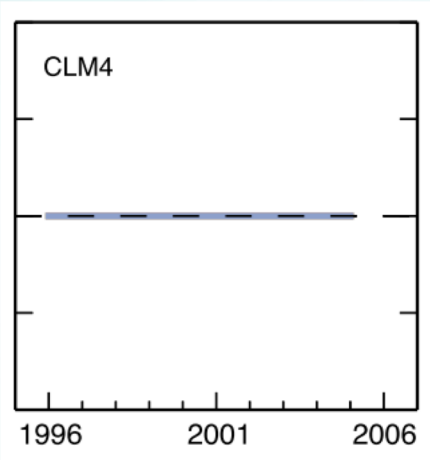
- eCO2, N deposition



Duke FACE



ORNL FACE

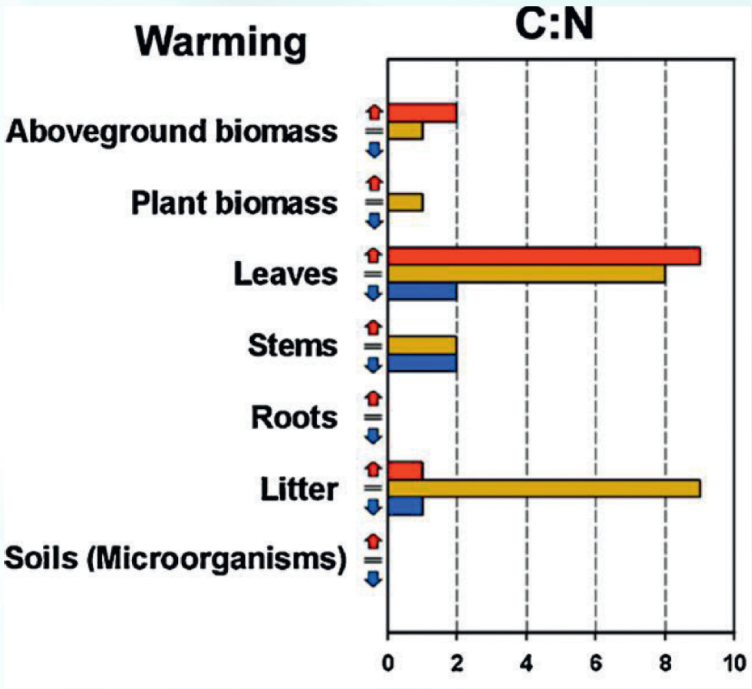


CLM4

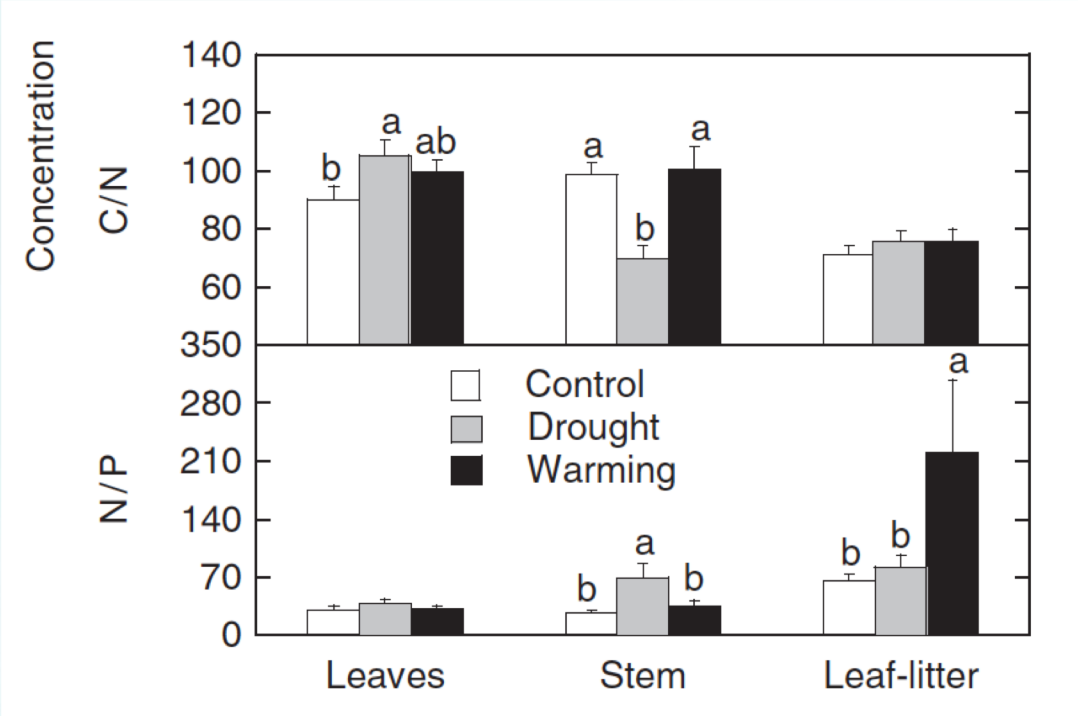
De Kauwe 2014

Multi-factor environmental changes

- Warming, drought



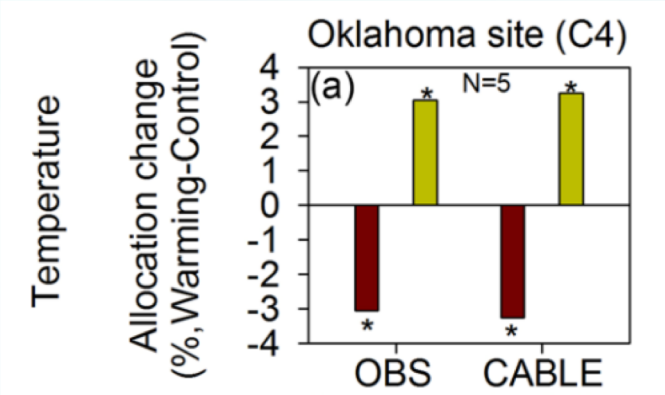
de Mello Prado - 2017

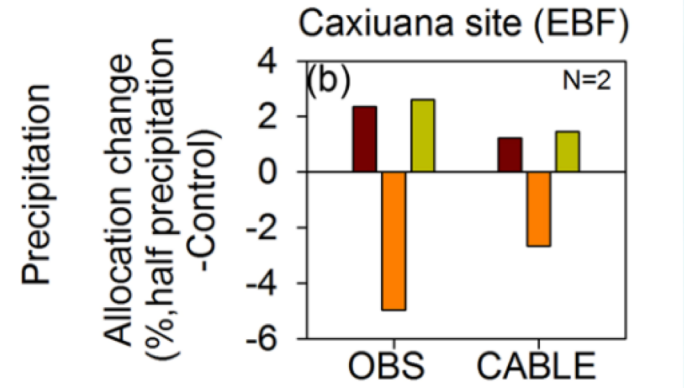


Sardans et al., 2008

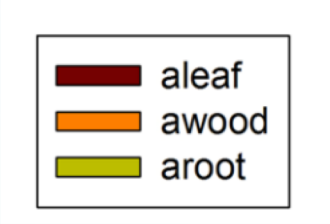
Multi-factor environmental changes

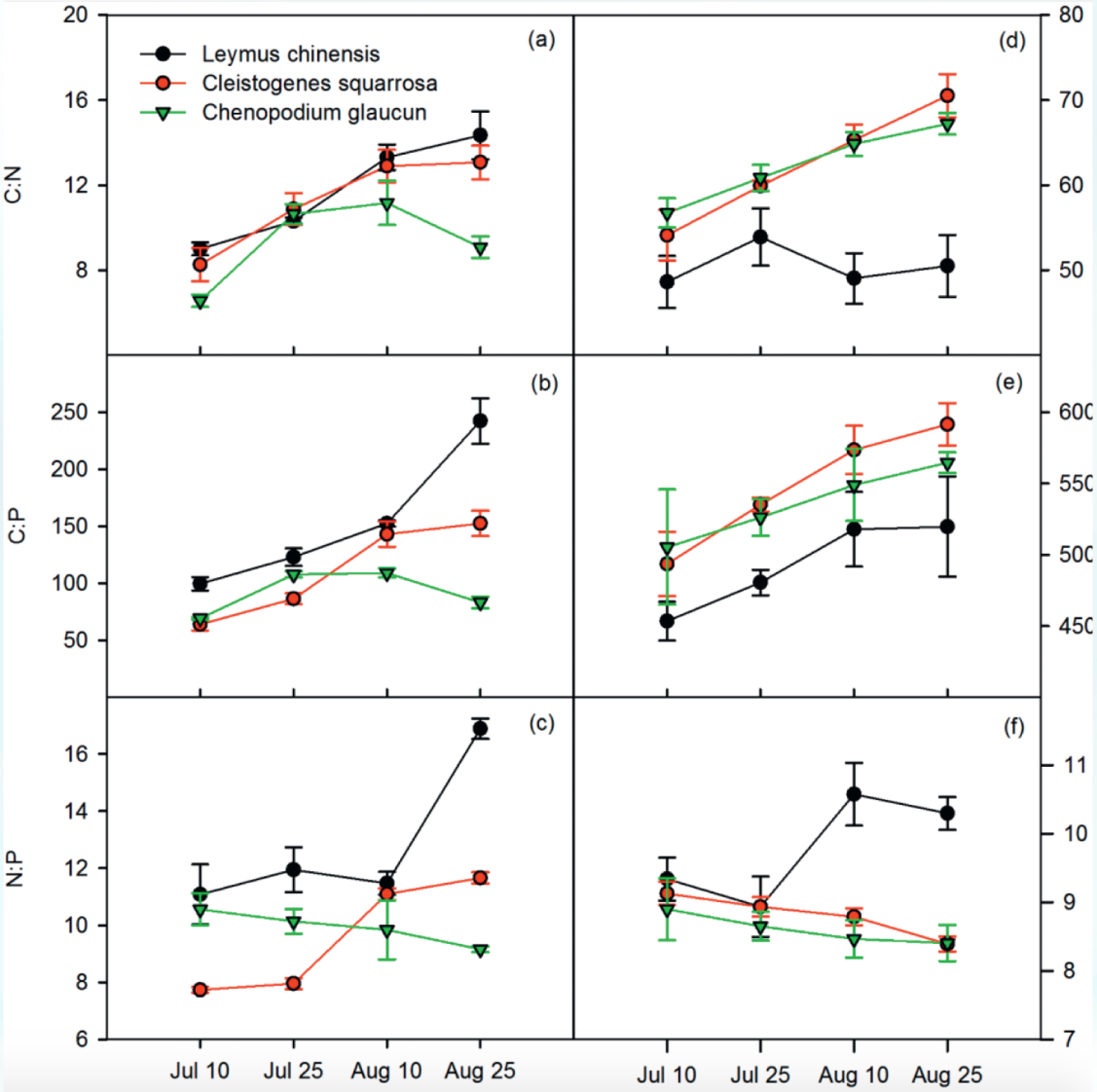
- Warming, drought





Xia et al. 2017





de Mello Prado - 2017

Critical challenges

- Principles for changing C:N:P stoichiometry and carbon allocation?

- Variability of C:N:P stoichiometry and carbon allocation?

Principle: Carbon allocation scheme

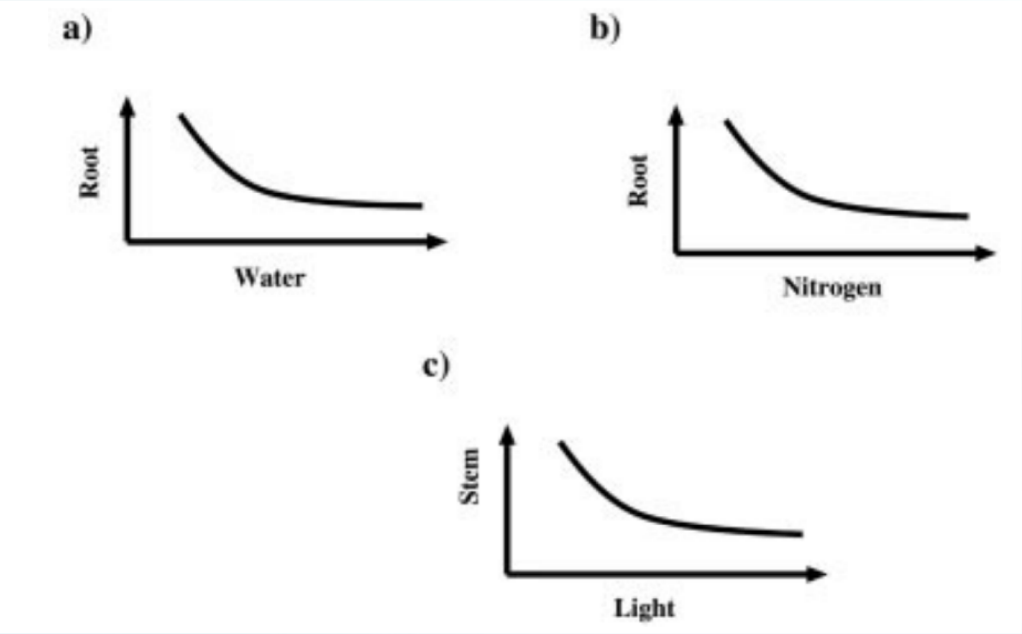
$$A \propto \frac{\sum X_i}{\sum X_i + \sum Y_j}$$

Friedlingstein et al., 1999

$$\rho = 3r_0 \frac{L}{L + 2min(W,N)}$$

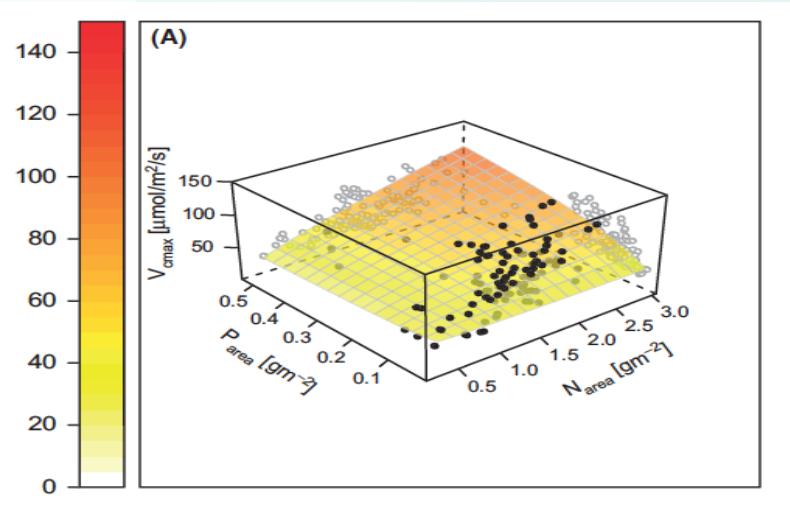
$$\sigma = 3s_0 \frac{min(W,N)}{2L + min(W,N)}$$

$$\lambda = 1 - (\sigma + \rho),$$



Principle: photosynthesis – dynamic stoichiometry relationship

- Flexible leaf C:N and N:P ratios feedback to photosynthesis rate
- Flexible leaf C:N and C:P ratios feedback to nutrient uptakes



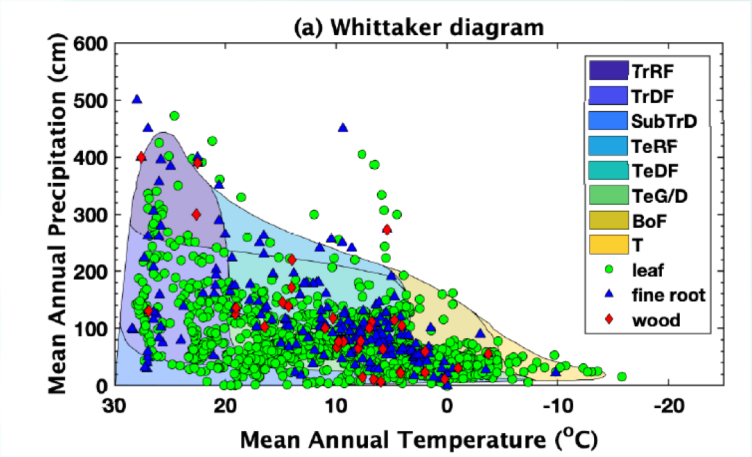
cn_scalar = f(N_{leaf})

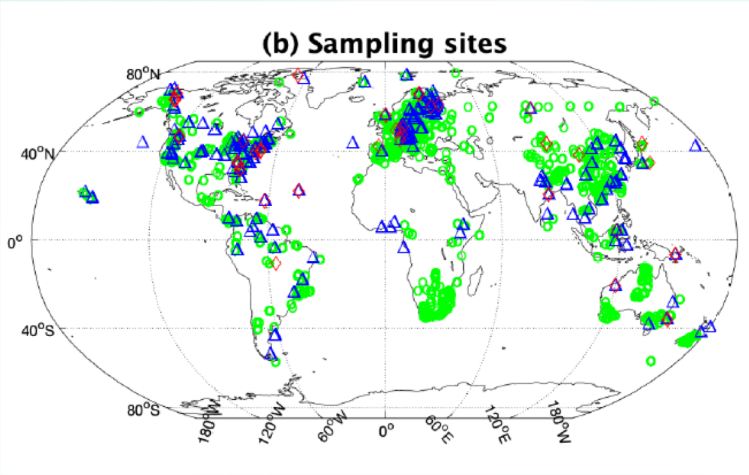
cp_scalar = f(P_{leaf})

Walker et al., 2014; Zhu et al., 2019

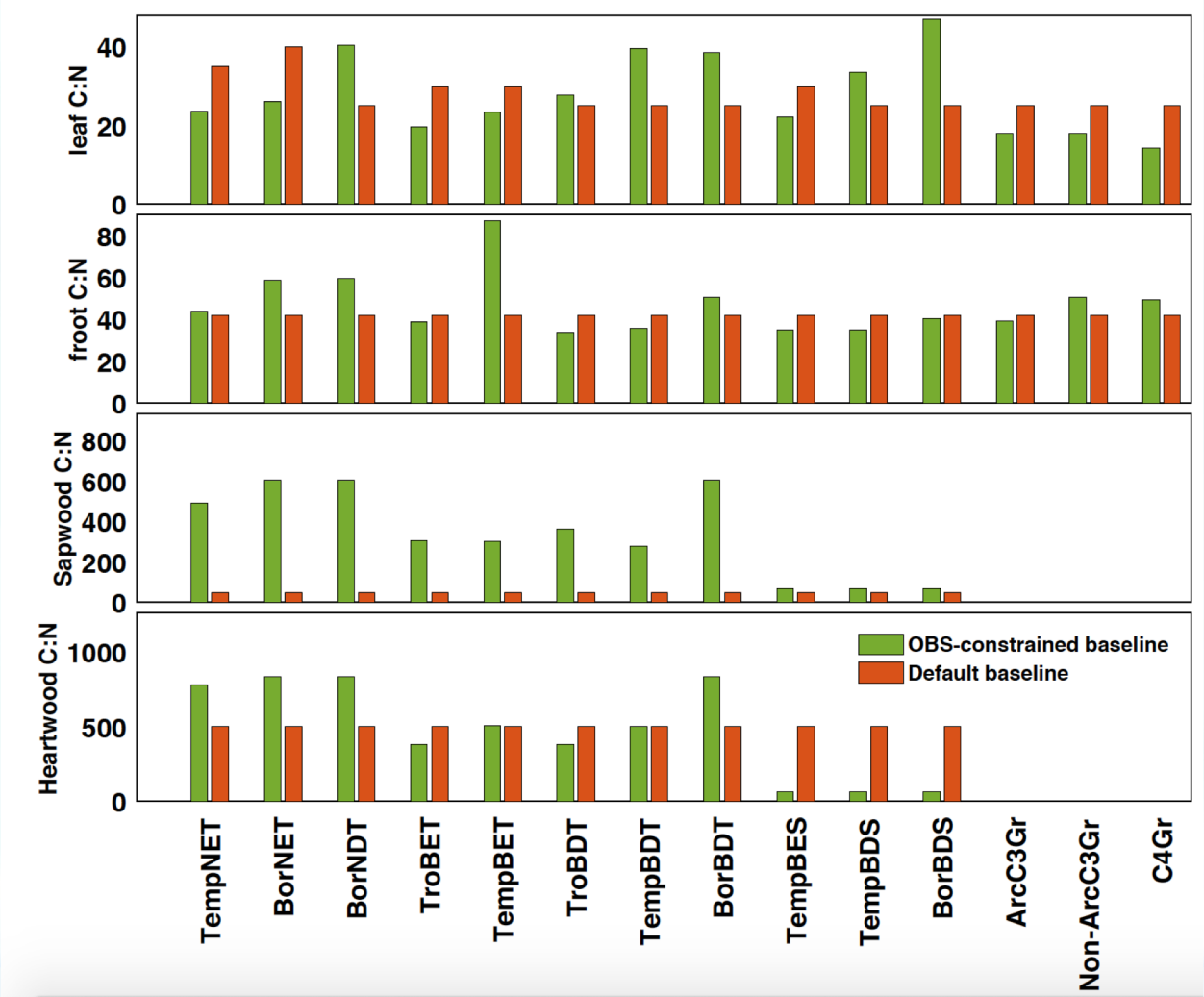
C:N:P variability: plant stoichiometry synthesis

- TRY (Kattge 2011)
- FRED (Iversen 2017)
- Other synthesis

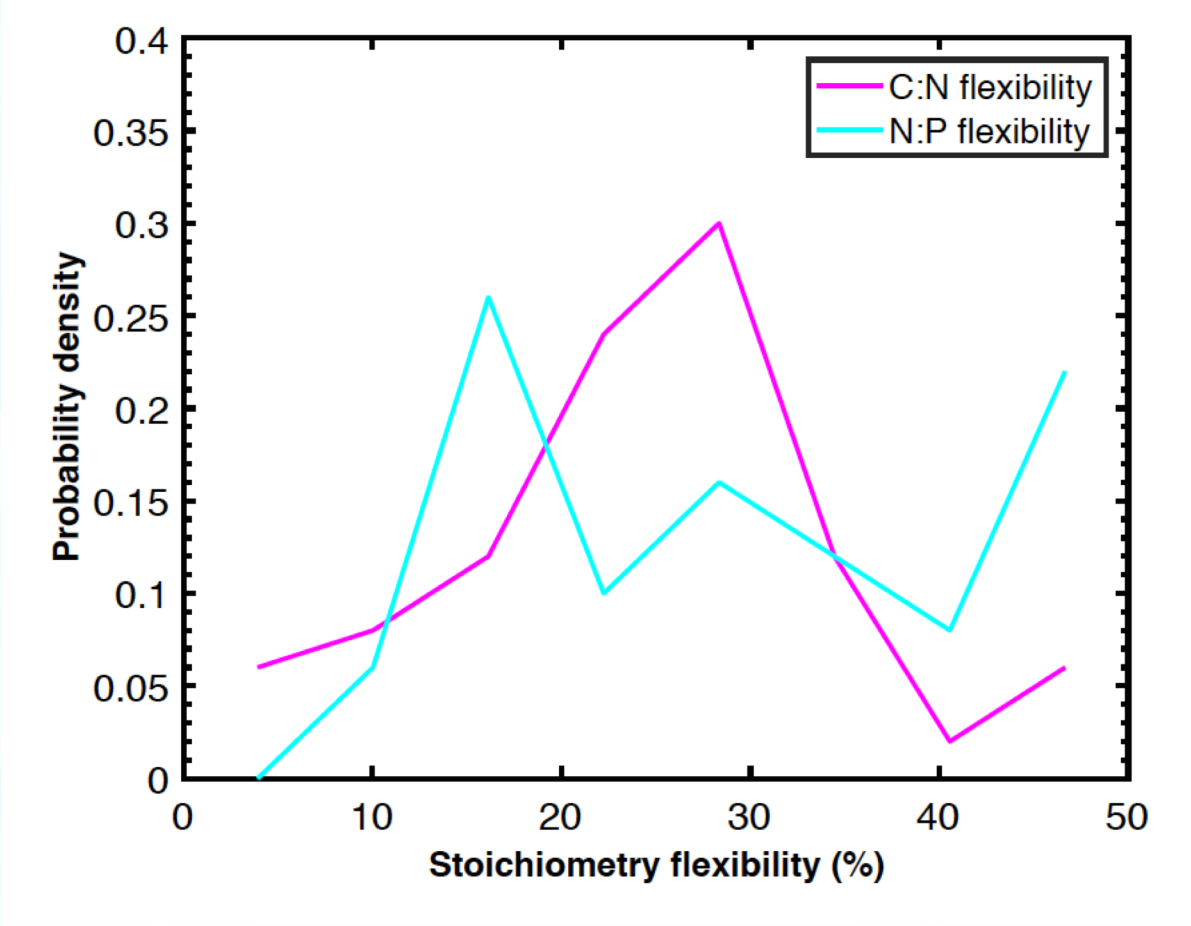




Plant stoichiometry synthesis



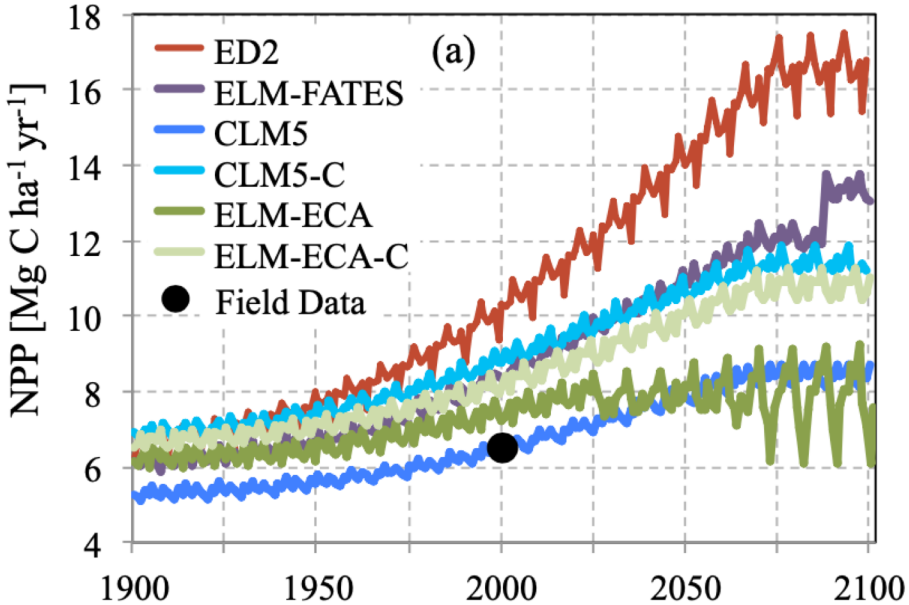
Plant stoichiometry flexibility

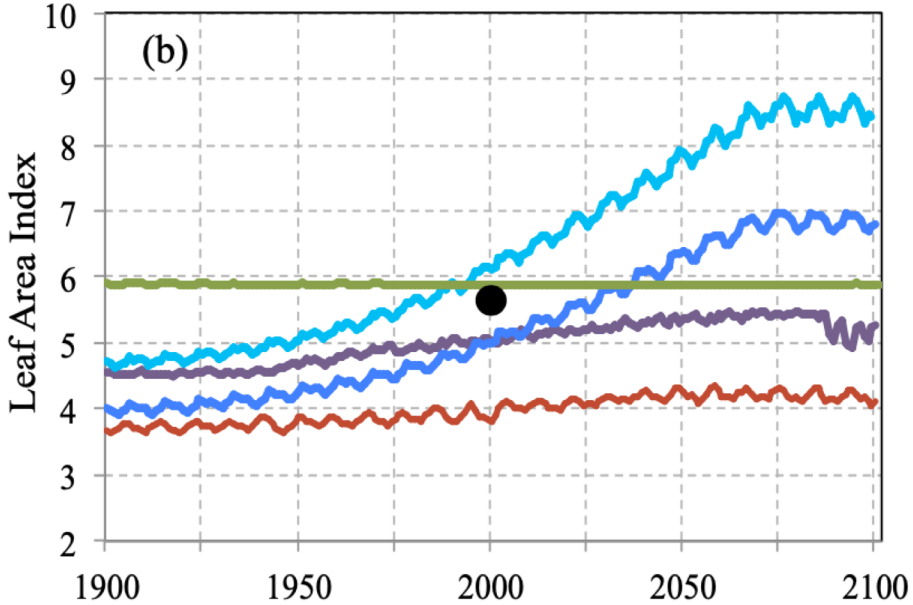


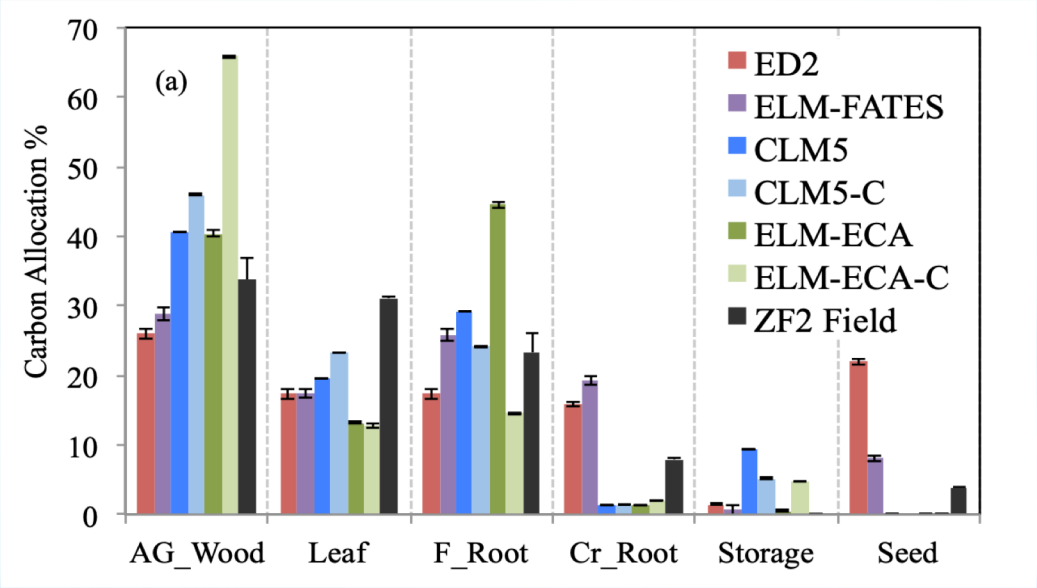
Case 1: tropical forest site

- Amazon forest biomass sink under current and future atmospheric CO_2?

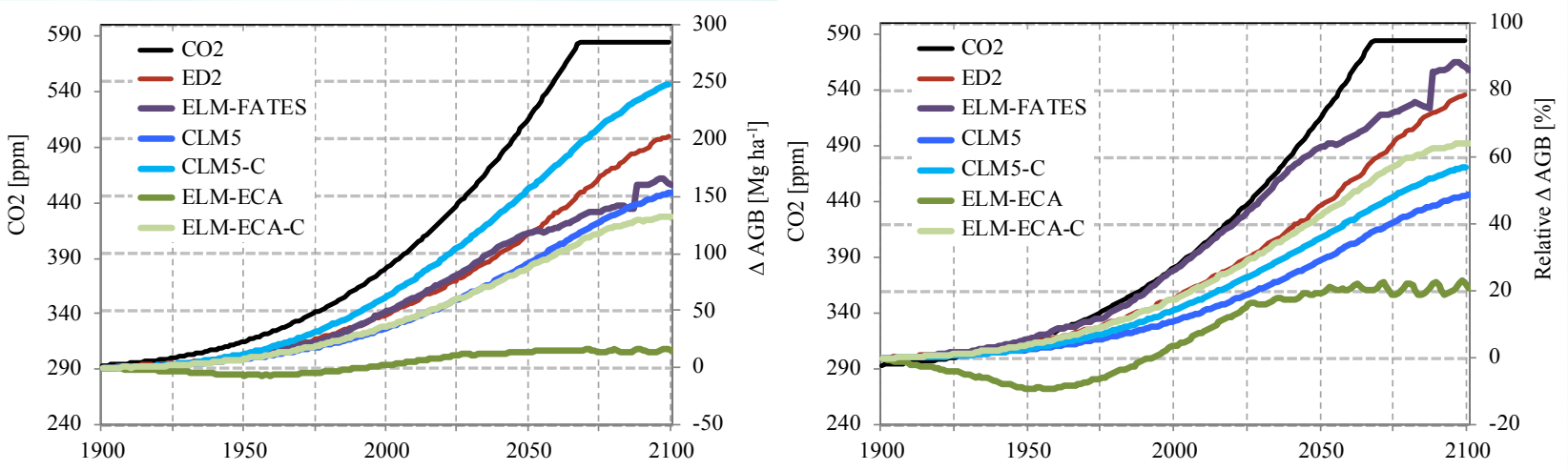
Holm et al., under revision

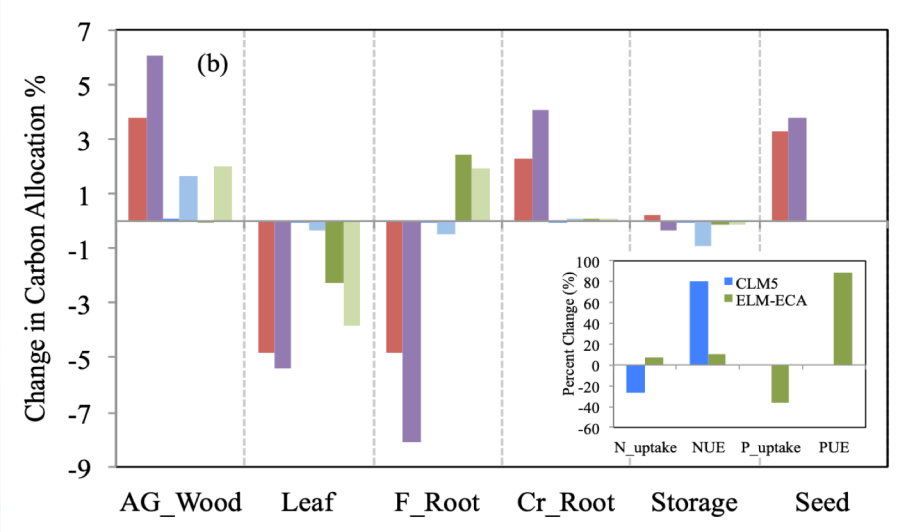

(a)
ED2
ELM-FATES
CLM5
CLM5-C
ELM-ECA
ELM-ECA-C
Field Data
NPP [Mg C ha-1 yr-1]
18
16
14
12
10
8
6
4
1900
1950
2000
2050
2100


(b)
Leaf Area Index
10
9
8
7
6
5
4
3
2
1900
1950
2000
2050
2100

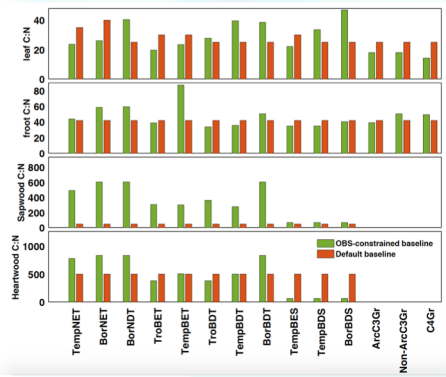

(a)
ED2
ELM-FATES
CLM5
CLM5-C
ELM-ECA
ELM-ECA-C
ZF2 Field
Carbon Allocation %
70
60
50
40
30
20
10
0
AG_Wood
Leaf
F_Root
Cr_Root
Storage
Seed

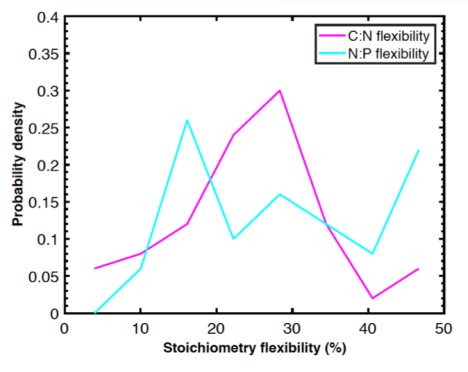
Dynamic allocation of carbon



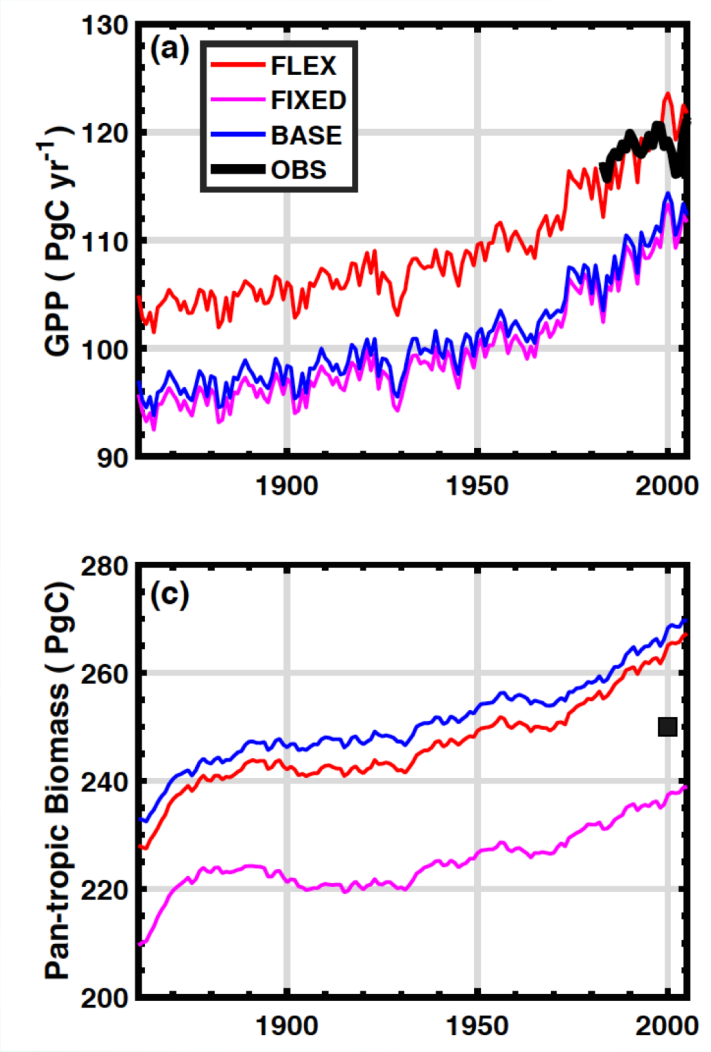


Case 2: global scale





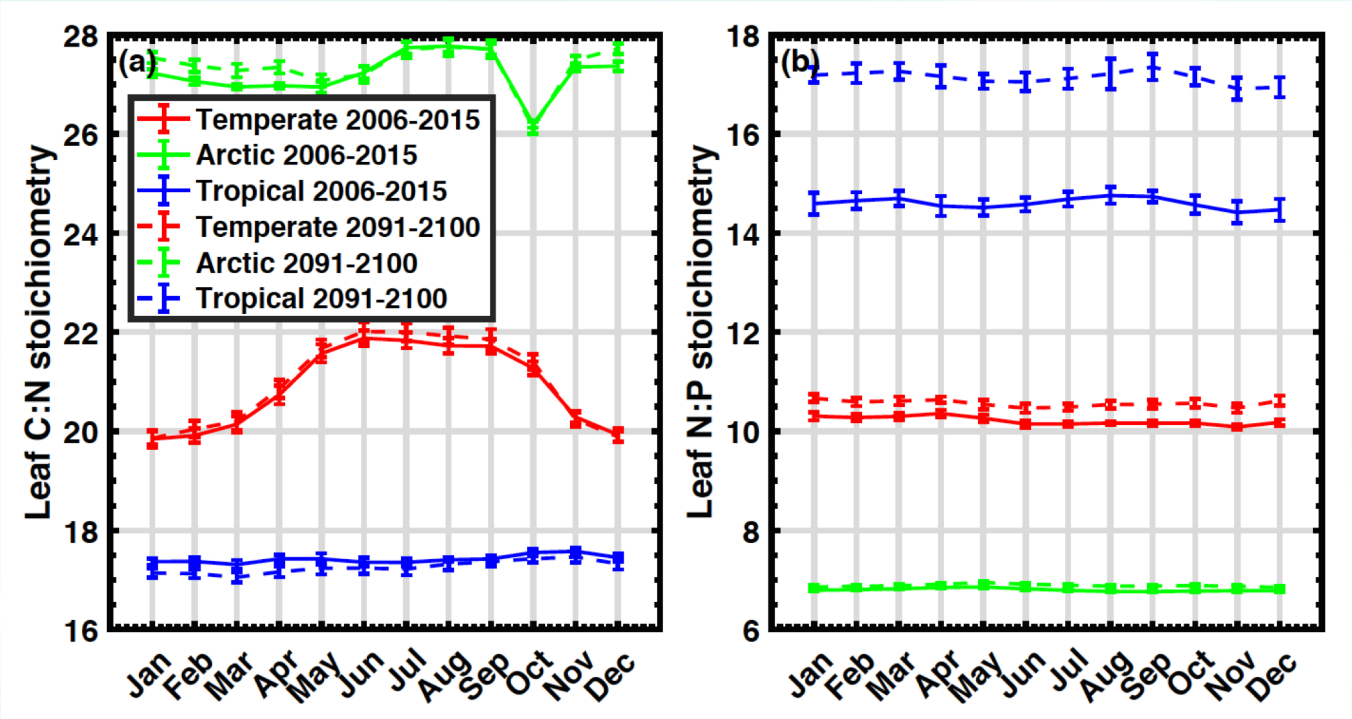
ELM



Zhu et al. under review

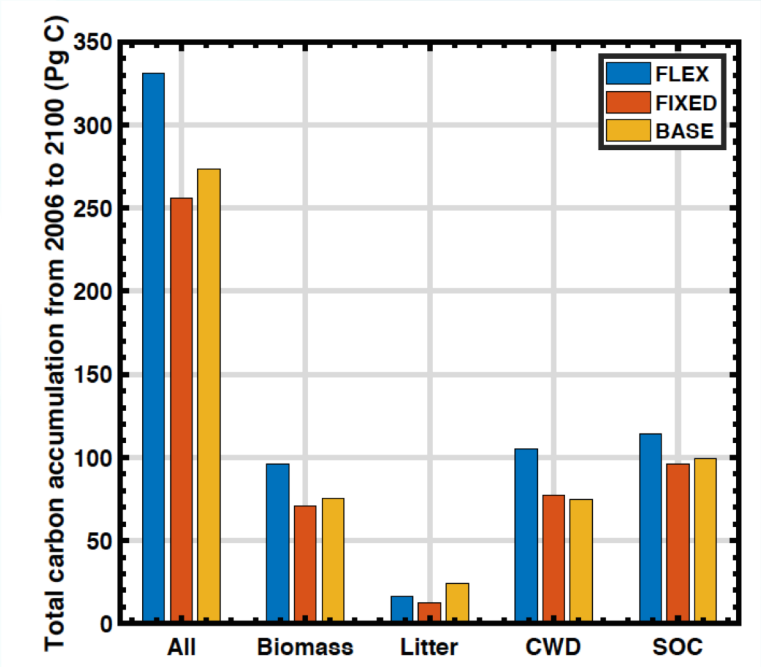
Global mean stoichiometry

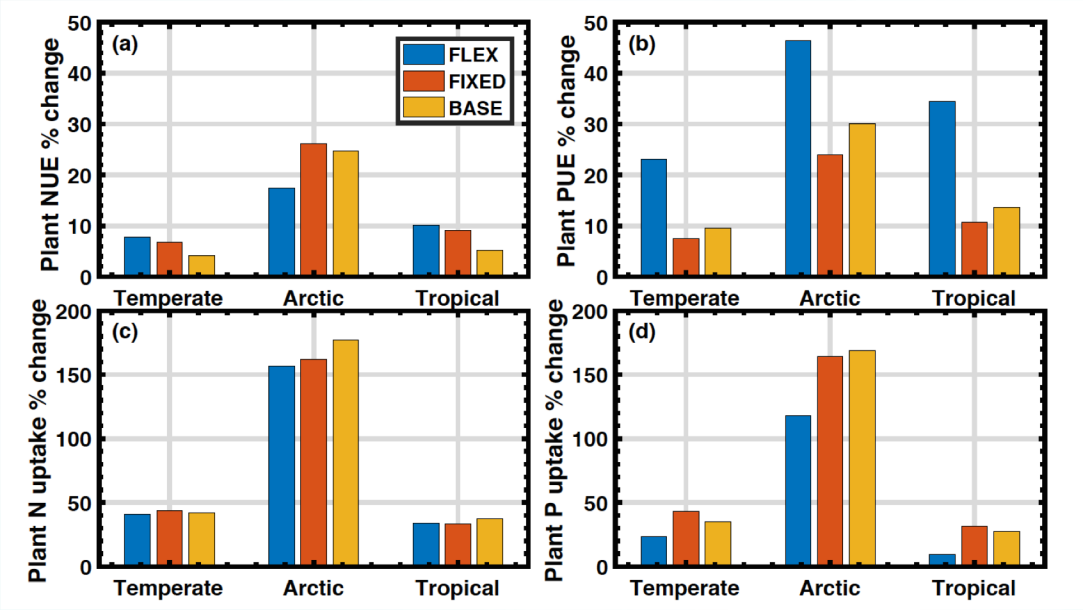
- Strong seasonal cycle of C:N ratio at temperate ecosystems
- Tropical forest N:P ratio changed significantly



Consequences of flexible stoichiometry

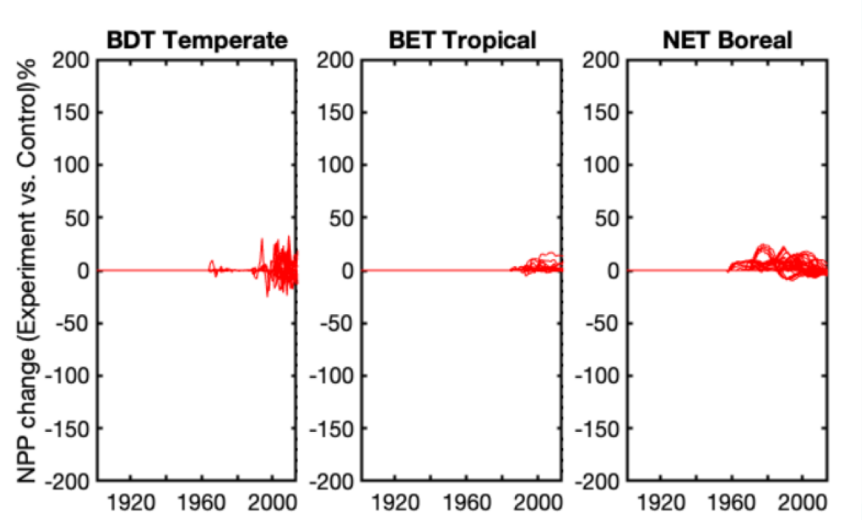
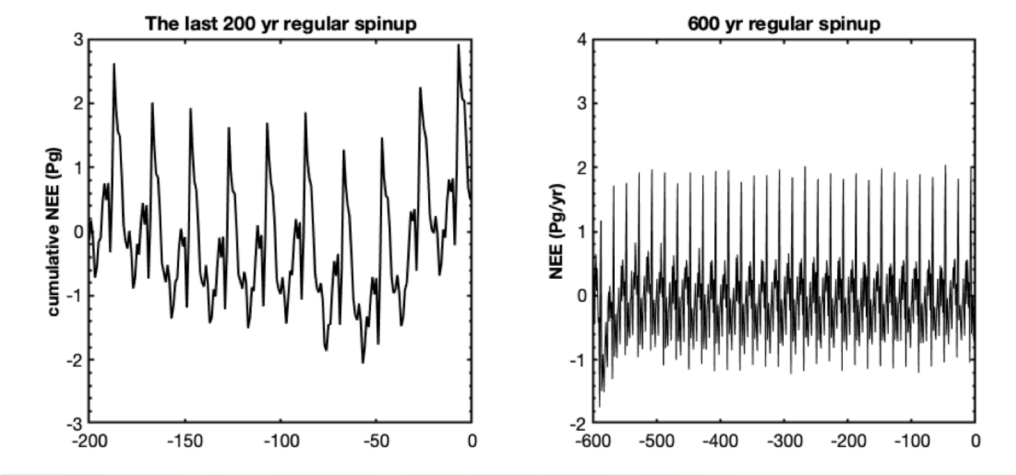
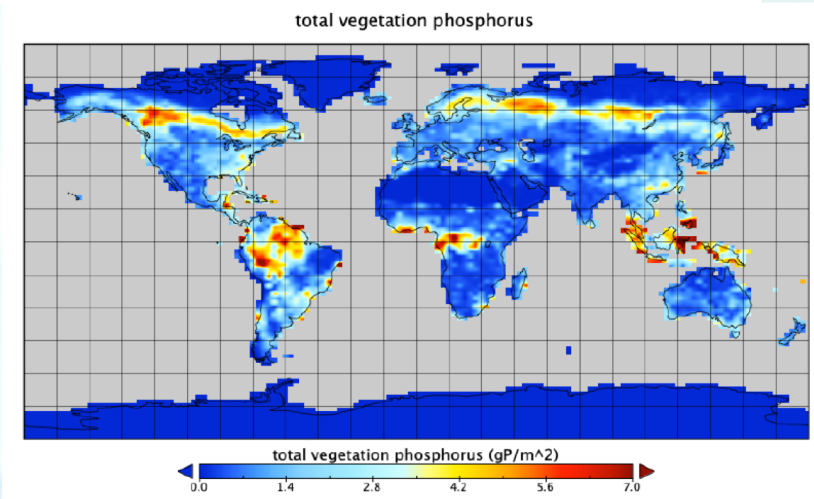
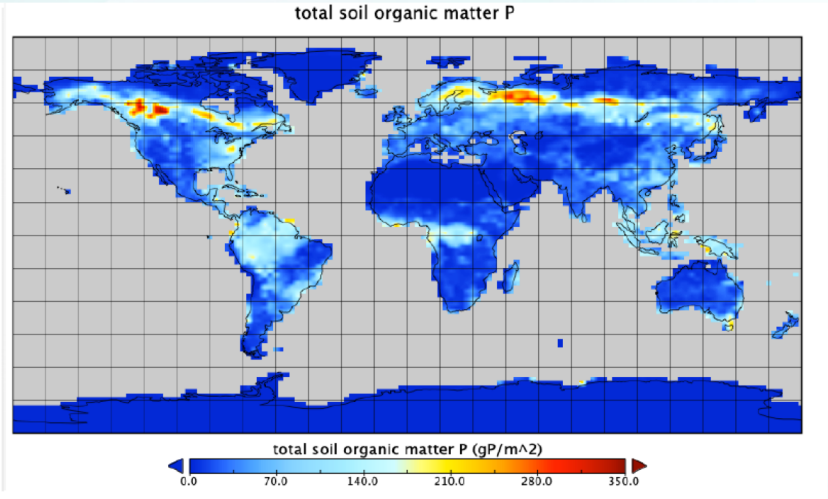
- Higher biomass and SOC accumulation
- Higher phosphorus use efficiency





summary

- Plants dynamically adjust carbon allocation in response to multiple environmental changes
- Plant C:N:P stoichiometry dynamically evolves to reflect imbalance between carbon assimilation and belowground nutrient uptake
- Plant trait database provide strong constrain on baseline and variability of stoichiometry
- Dynamic allocation and C:N:P stoichiometry provide significant implication into future carbon accumulation across different ecosystems

backup

Updates on dynamic allocation/stoichiometry v2 integration