Understanding responses to environmental change in CLM5

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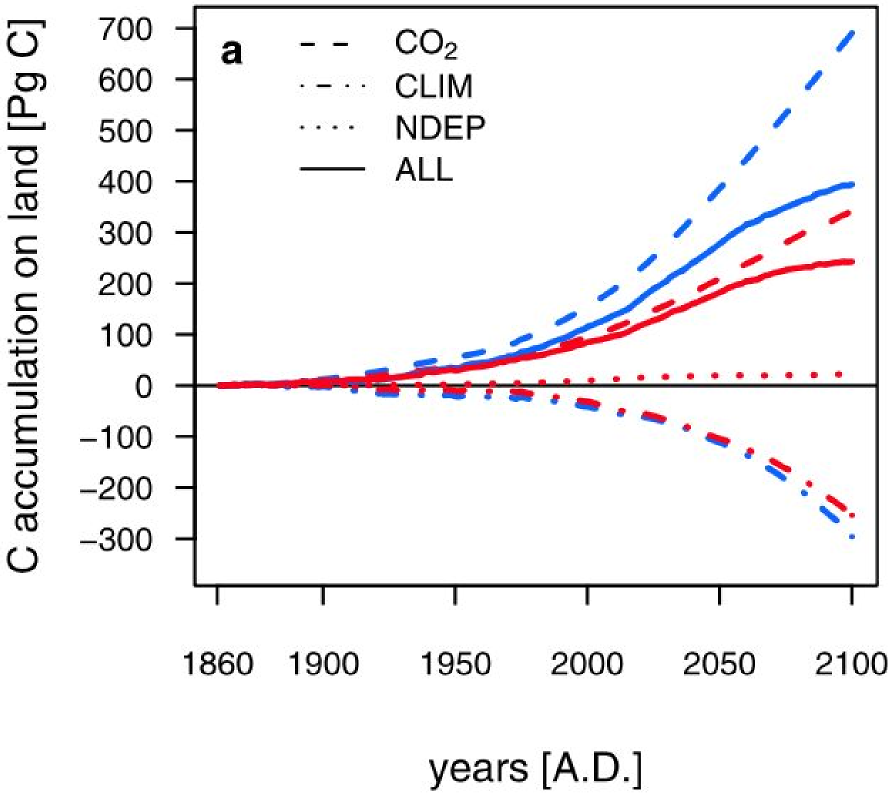
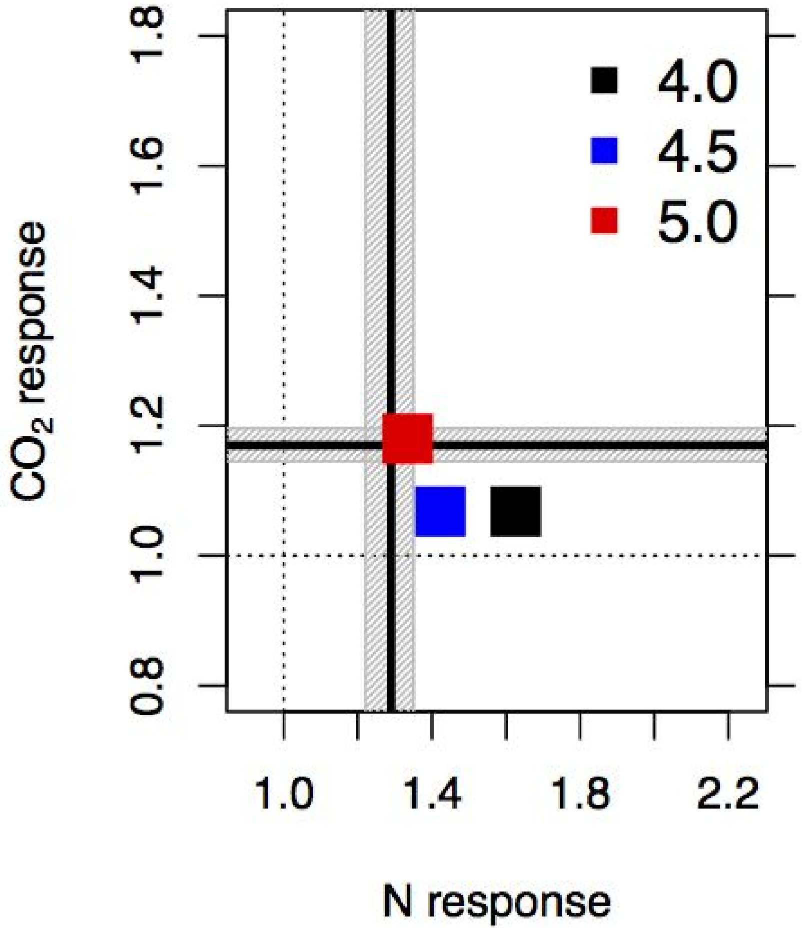
With input/inspiration from Will Wieder, Dave Lawrence, Ben Sanderson, Charlie Koven, Katie Dagon and the LMWG

It's generally important to understand these responses to CO2 and N because they have massive feedbacks on the global carbon budget.



Zaehle et al. 2010.

Slide from Will Wieder



Productivity in **CLM5**
responds
less to Nitrogen
and
more to CO2
than its forbears.

Why?

Why does CLM5 respond differently to N and CO_2?

"CLM5 allows us to increase N fixation by spending C on N uptake"

"CLM5 has lower maximum photosynthesis and so responds less to N addition"

"CLM5 occupies a different part of parameter space, it's nothing to do with model structure"

"CLM5 is awesome and that's why it nails the experimental results"

"Something is subtly different in the photosynthesis scheme in CLM5"

"My favourite parameter 'x' has huge impacts on the CO2/N response!"

To really answer these questions, we need to look at the parameter space and understand the model structure...

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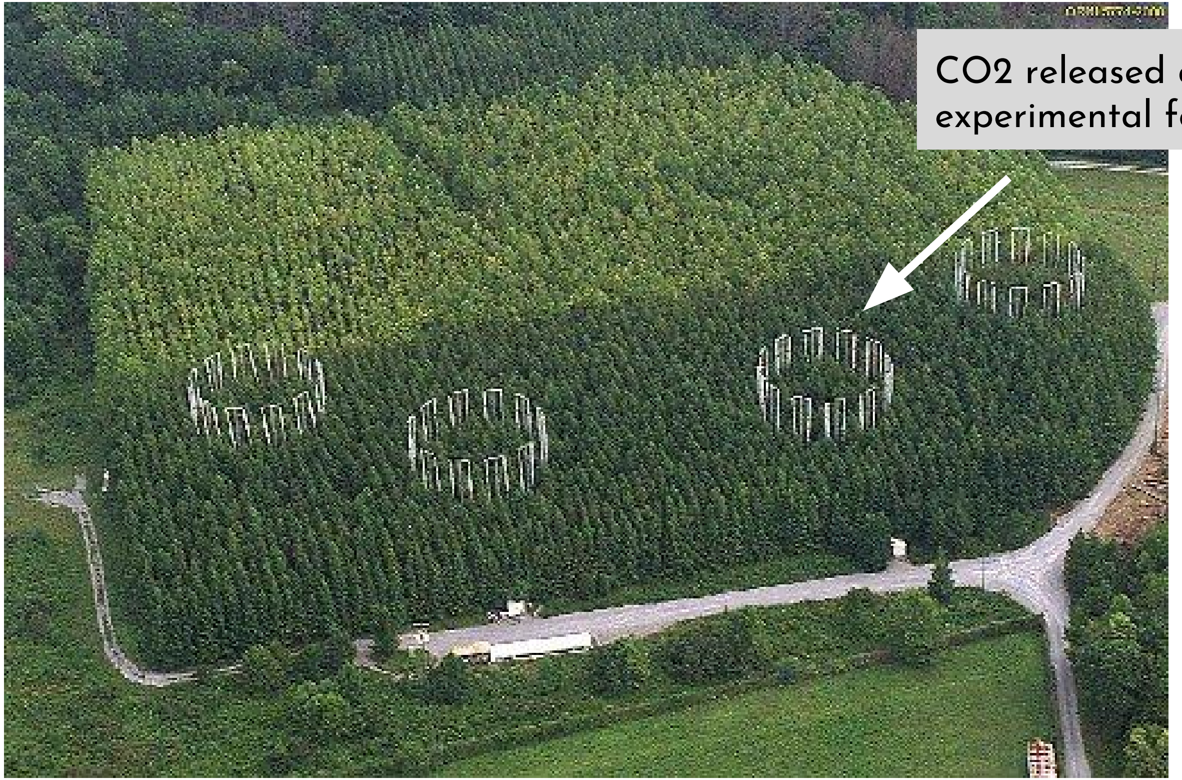
…& it is important to understand how robust this result is, to (help) assess how much weight we should ascribe to predictions.

Free Air Carbon Enrichment (FACE) at Oak Ridge.



CO2 released around volume of experimental forest

Where does the carbon go? A model–data intercomparison of vegetation carbon allocation and turnover processes at two temperate forest free-air CO_2 enrichment sites

Martin G. De Kauwe[1], Belinda E. Medlyn[1], Sönke Zaehle[2], Anthony P. Walker[3], Michael C. Dietze[4], Ying-Ping Wang[5], Yiqi Luo[6], Atul K. Jain[7], Bassil El-Masri[7], Thomas Hickler[8,9], David Wårlind[10], Ensheng Weng[11], William J. Parton[12], Peter E. Thornton[3], Shusen Wang[13], I. Colin Prentice[1,14], Shinichi Asao[12], Benjamin Smith[10], Heather R. McCarthy[15], Colleen M. Iversen[3], Paul J. Hanson[3], Jeffrey M. Warren[3], Ram Or

The ORNL FACE site has been the subject of many excellent terrestrial model inter-comparison studies, but no parameter perturbation experiments

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nature climate change

Using ecosystem experiments to improve vegetation models

Belinda E. Medlyn[1,2*], Sönke Zaehle[3], Martin G. De Kauwe[1], Anthony P. Walker[4], Michael C. Dietze[5], Paul J. Hanson[4], Thomas Hickler[6], Atul K. Jain[7], Yiqi Luo[8], William Parton[9], I. Colin Prentice[1,10], Peter E. Thornton[4], Shusen Wang[11], Ying-Ping Wang[12], Ensheng Weng[13], Colleen M. Iversen[4],
en[4], Ram Oren[14,15] and Richard J. Norby[4]

Evaluation of 11 terrestrial carbon–nitrogen cycle models against observations from two temperate Free-Air CO_2 Enrichment studies

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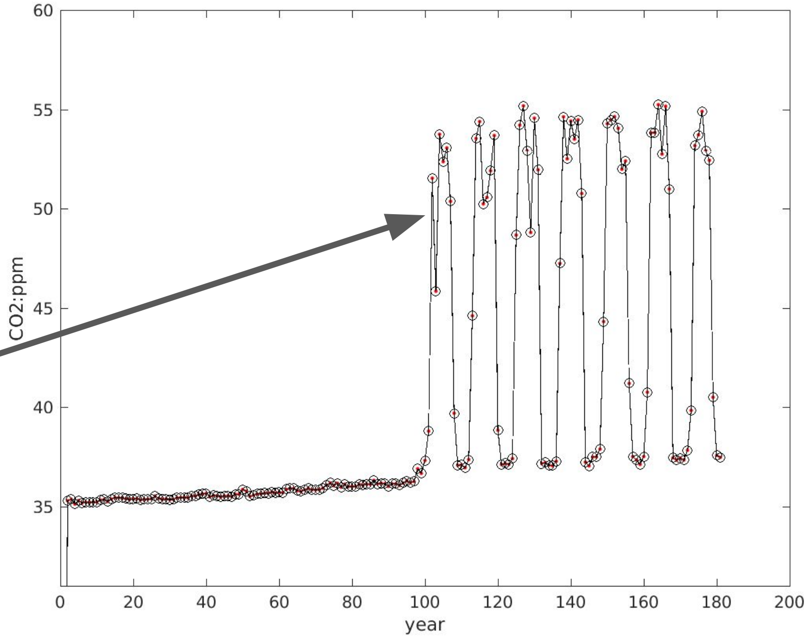
Single Point Perturbed Parameter Methodology.

1. Spin up base state in accelerated mode for 400 years.
2. Spin up base case in non-accelerated mode for 100 years
3. Perturb parameters (one at a time. x5)
4. Ensemble run: Spin up @1765
5. Ensemble run: Transient 1765-2010
6. Increase CO_2 (using site data)

100% deciduous broadleaf trees (DBT)

CO_2 only increased in growing season

Target 550ppm

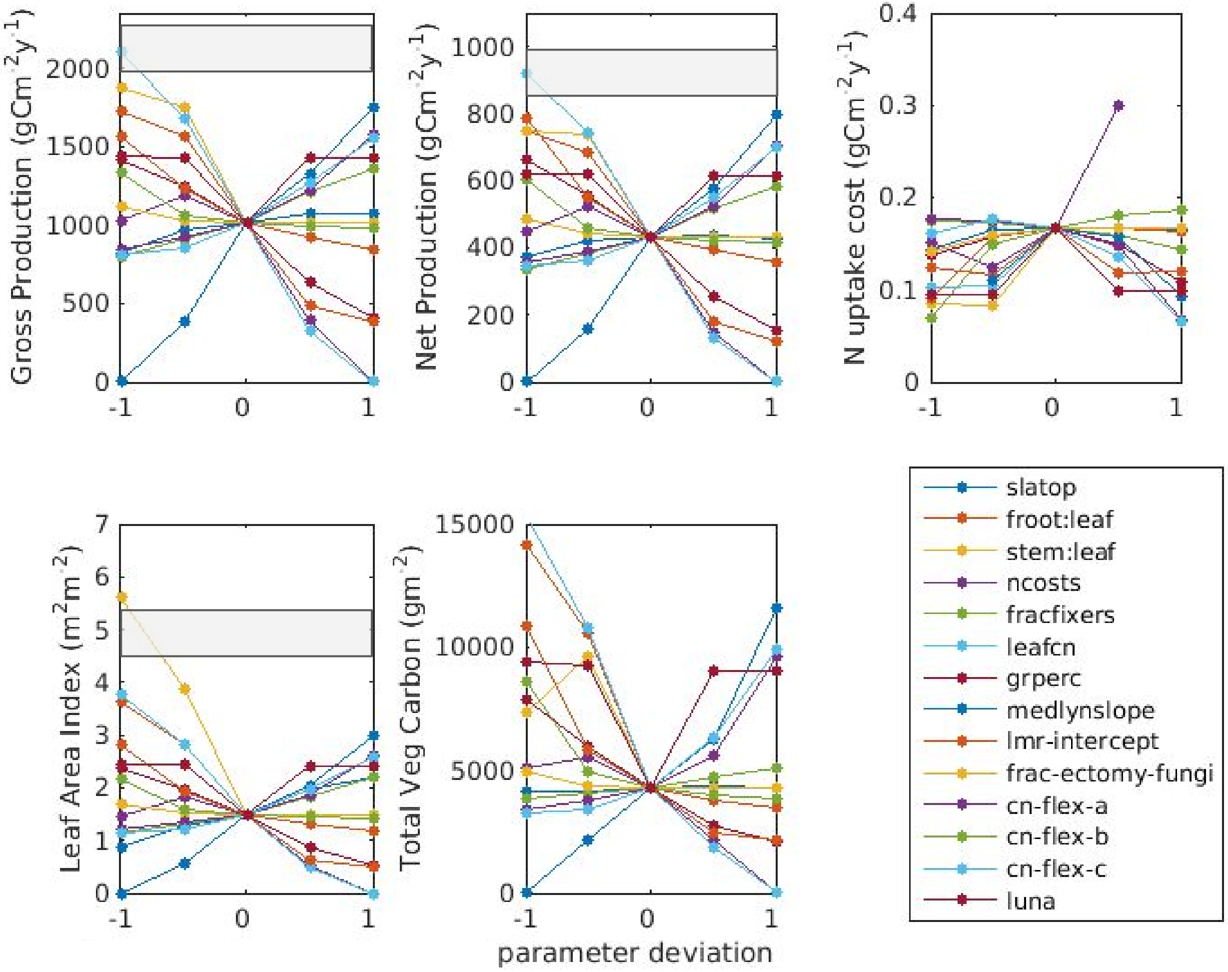


Parameter	Name	Range Determined By
Specific Leaf Area	SLATOP	TRY database
Leaf C:N ratio	LEAFCN	TRY database
Root:leaf ratio	FROOT_LEAF	Litton et al. (2011)
Stem:leaf ratio	STEM_LEAF	Litton et al. (2011)
Fraction N fixers	FRACFIXERS	Logical Range (0-1)
Growth Respiration	GRPERC	Atkin et al. 2018
Stomatal Slope	MEDLYN_SLOPE	Medlyn et al. 2011
Respiration BaseRate	LMR_INTERCEPT	Atkin et al. 2015
Fraction Ectomyccorrhizl fungi	PERECM	Logical Range (0-1)
Flexible CN ratio 'a'	FUN_FLEX_CN_A	Logical Range (0-1)
Flexible CN ratio 'b'	FUN_FLEX_CN_B	Sensitive Range (1-400)
Flexible CN ratio 'c'	FUN_FLEX_CN_C	Sensitive Range (1-32)
N Costs (x6 parameters)	N_COSTS	Sensitive range (4 ord.magnitude)

PARAMETER PERTURBATIONS:

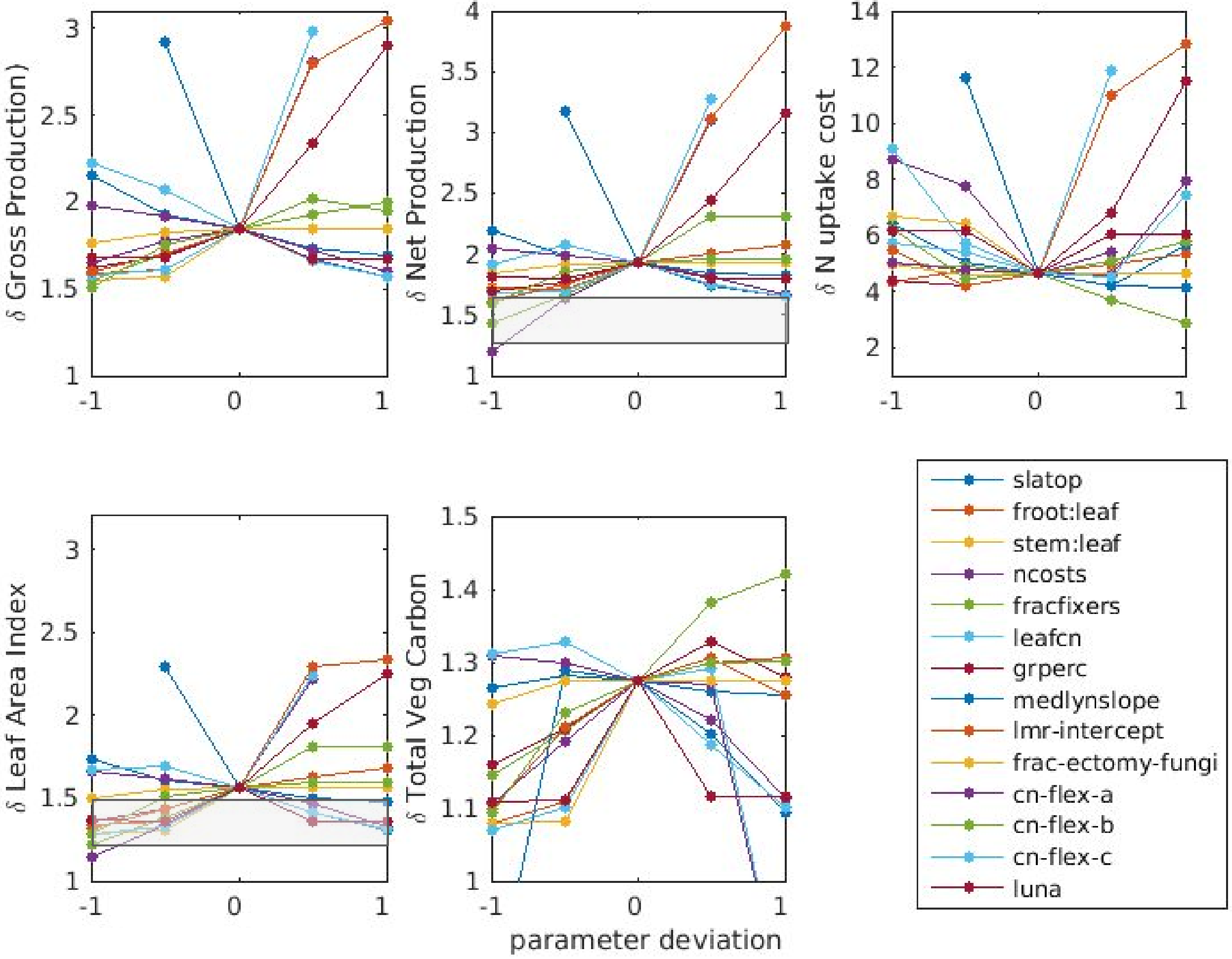
Focus on Carbon and Nitrogen cycling parameters.

System State: Default



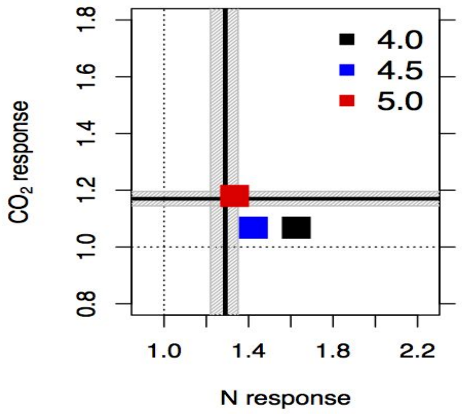
Default state has not got enough leaves!

CO2 response: Default

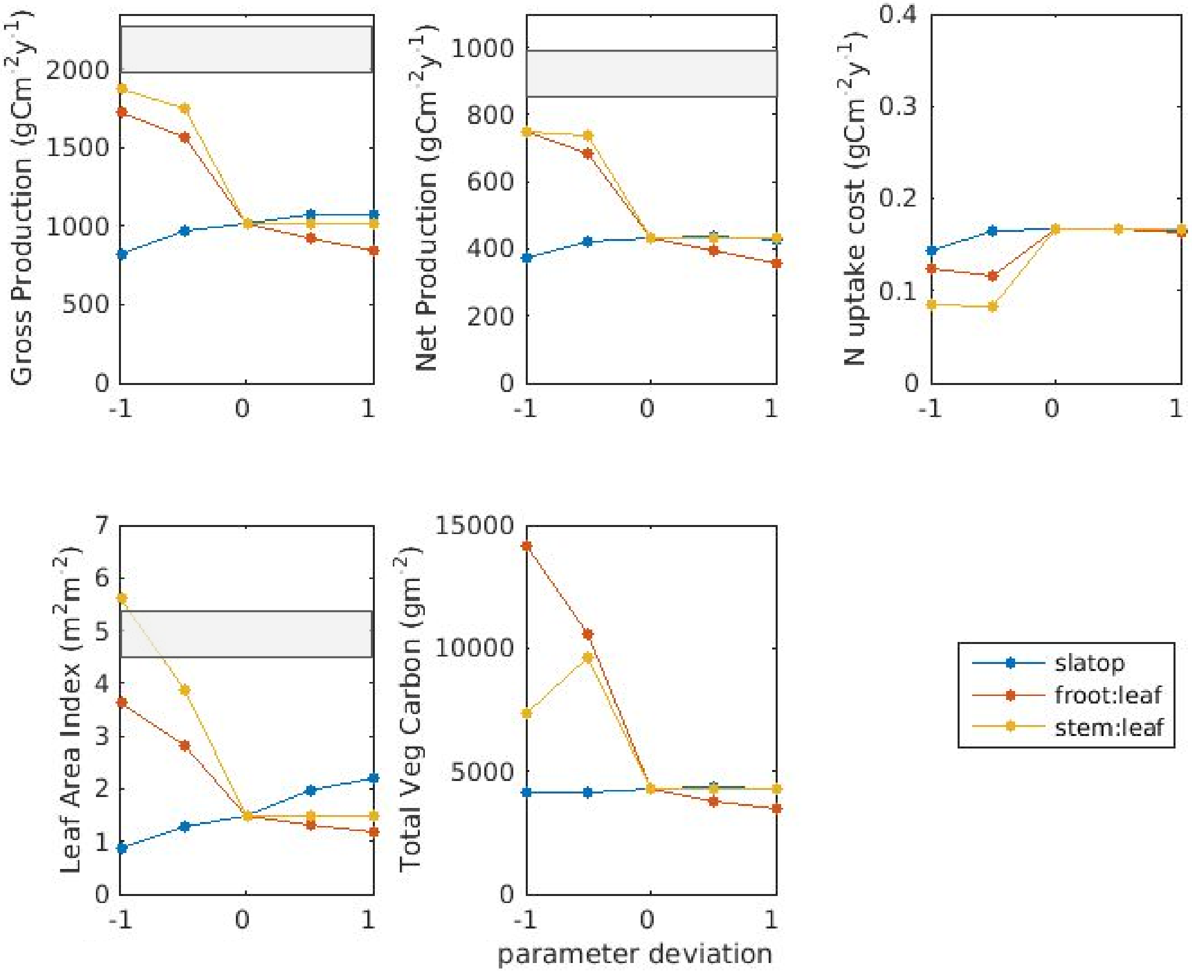


This means that everything is very sensitive to CO2 fertilization.

Increasing productivity increases leaf area which increases productivity. Hence whole system is **very** sensitive to fertilization

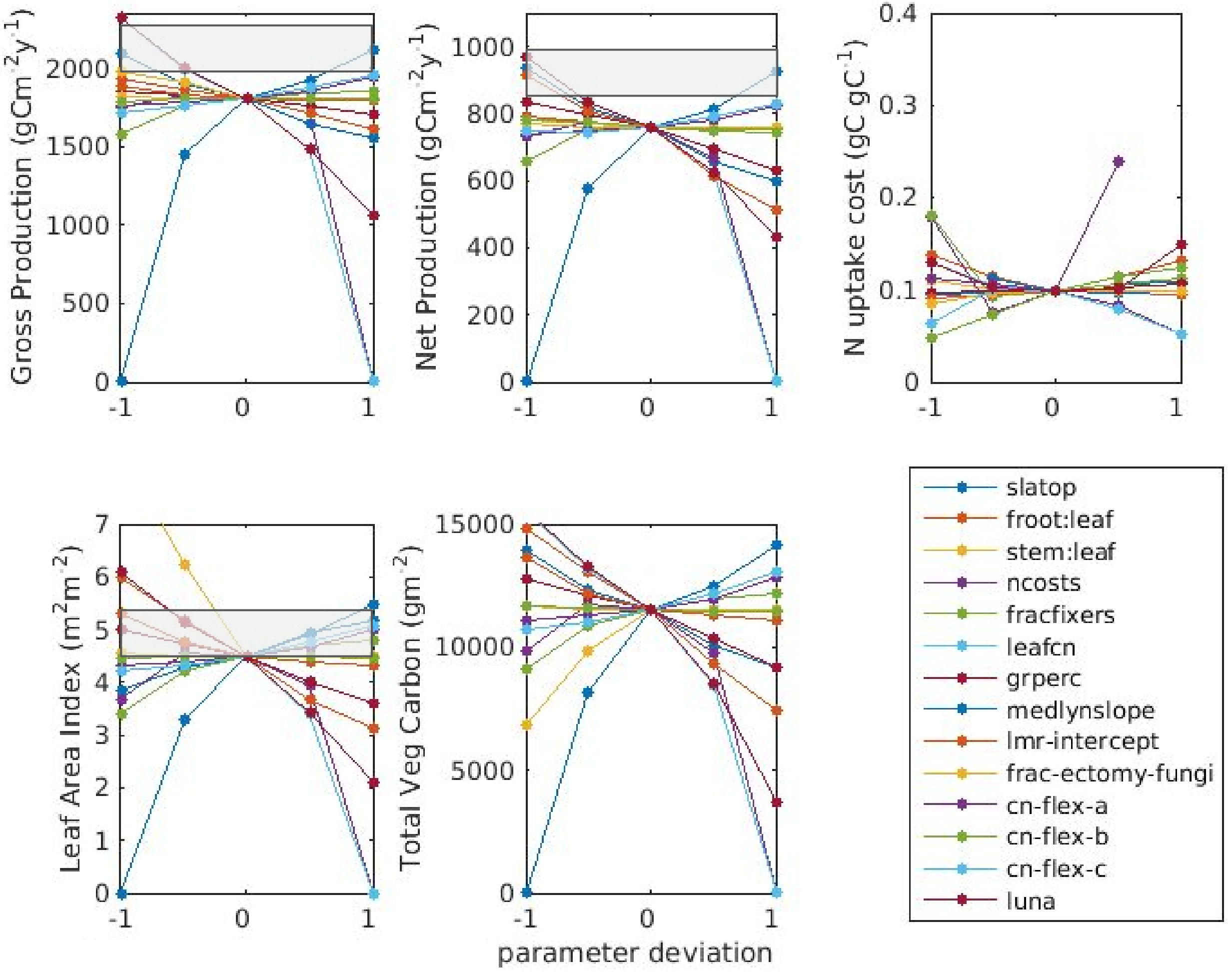


System State: Default



…mostly because it is trying to build too much root and stem tissue

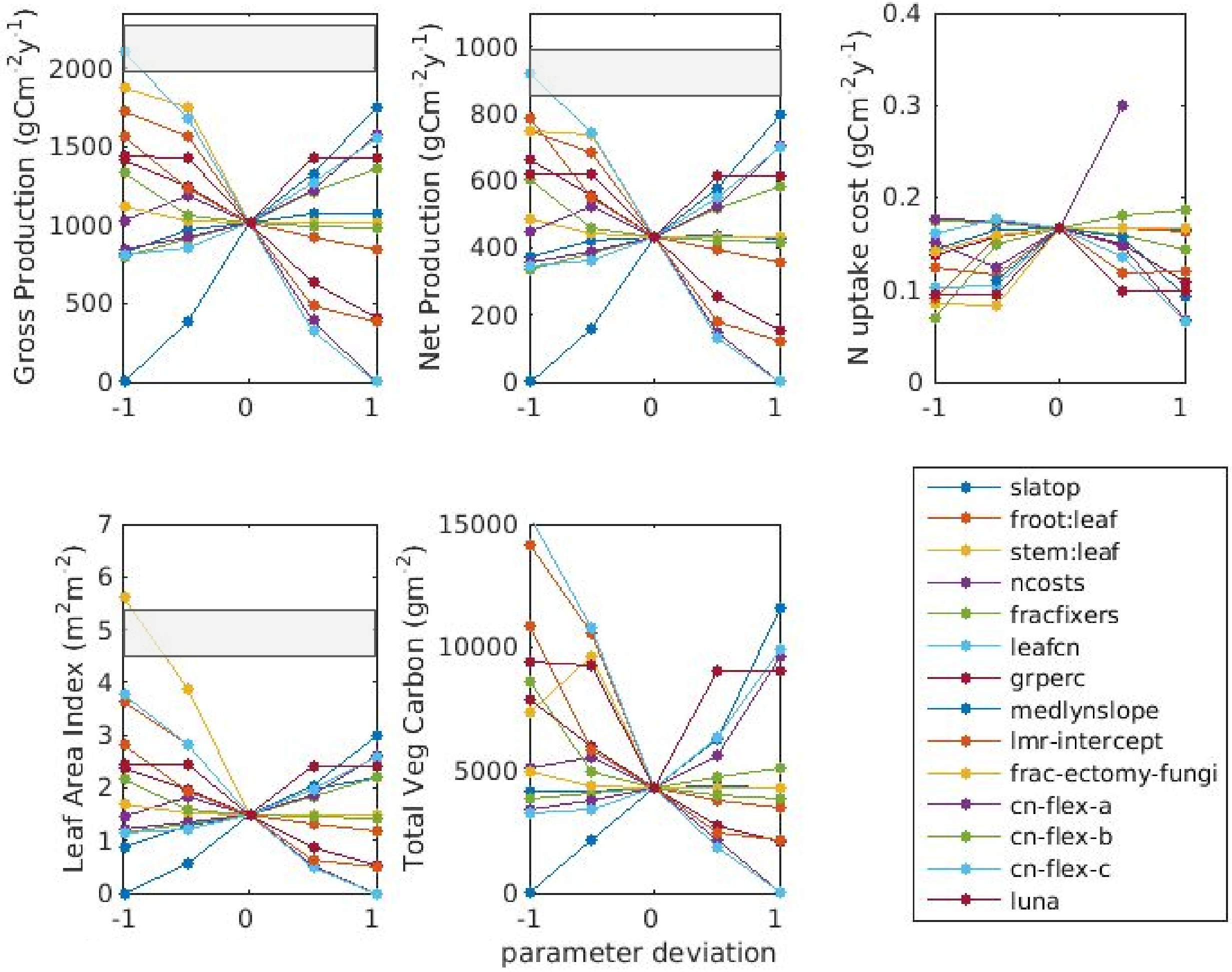
System State: High Leaf Allocation



Higher leaf allocation state is more realistic

froot_leaf
and
stem_leaf
adjusted down into observed range for deciduous broadleaf trees.

System State: Default



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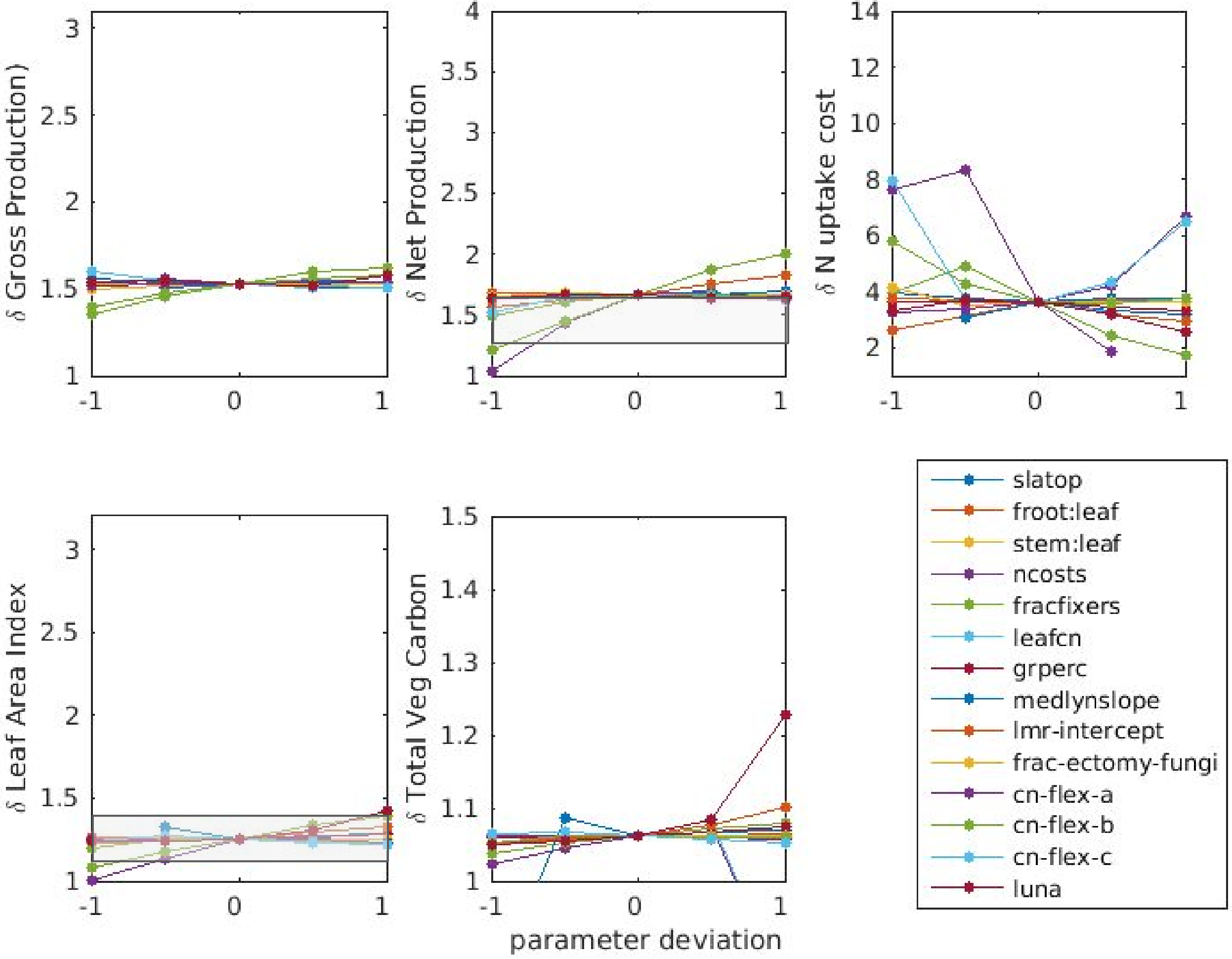
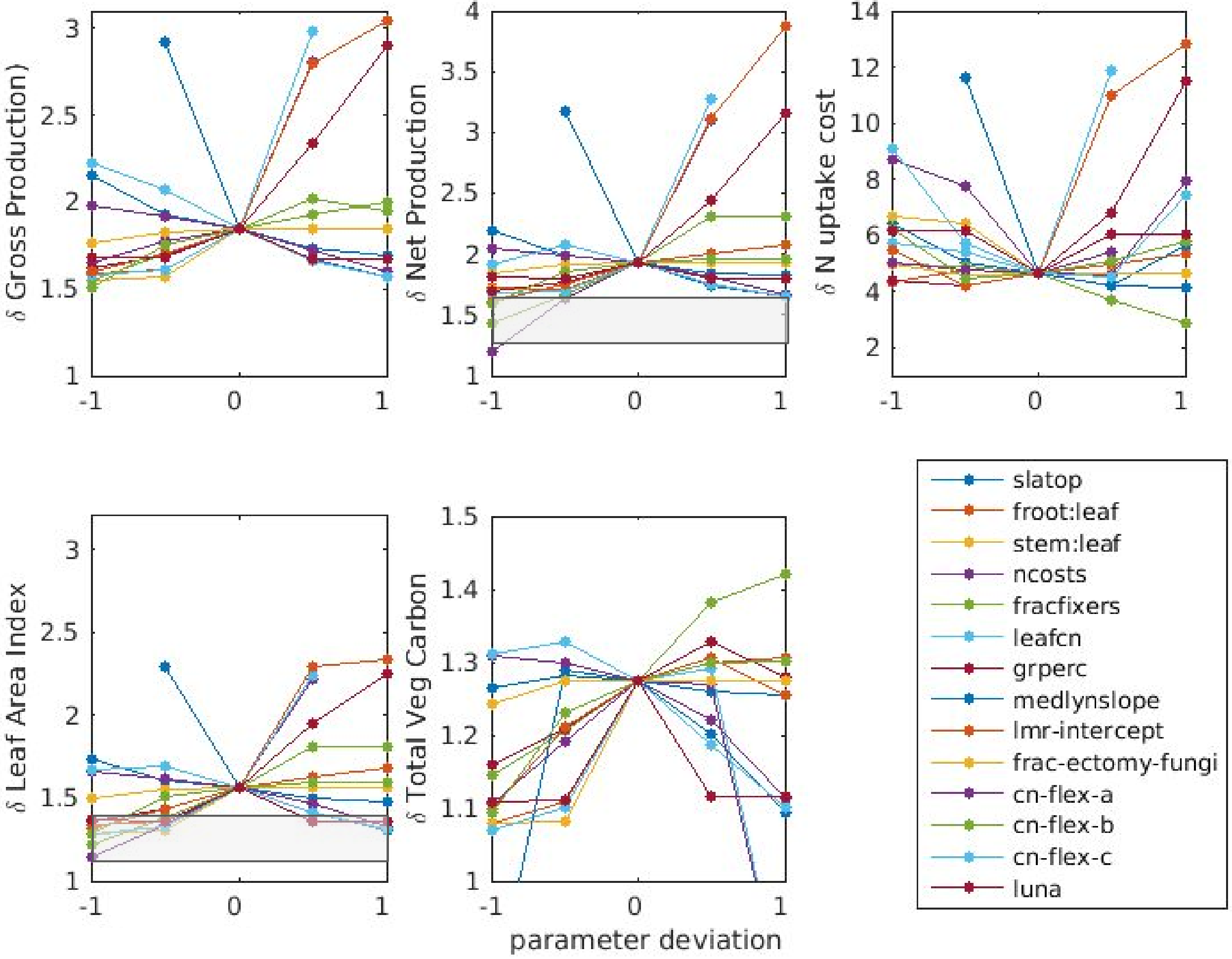
CO2 response: Higher leaf allocation



Higher leaf allocation state has more conservative response to CO2

At closed canopy, changes in leaf area do not feed back on productivity as light interception is saturated....

CO2 response: Default



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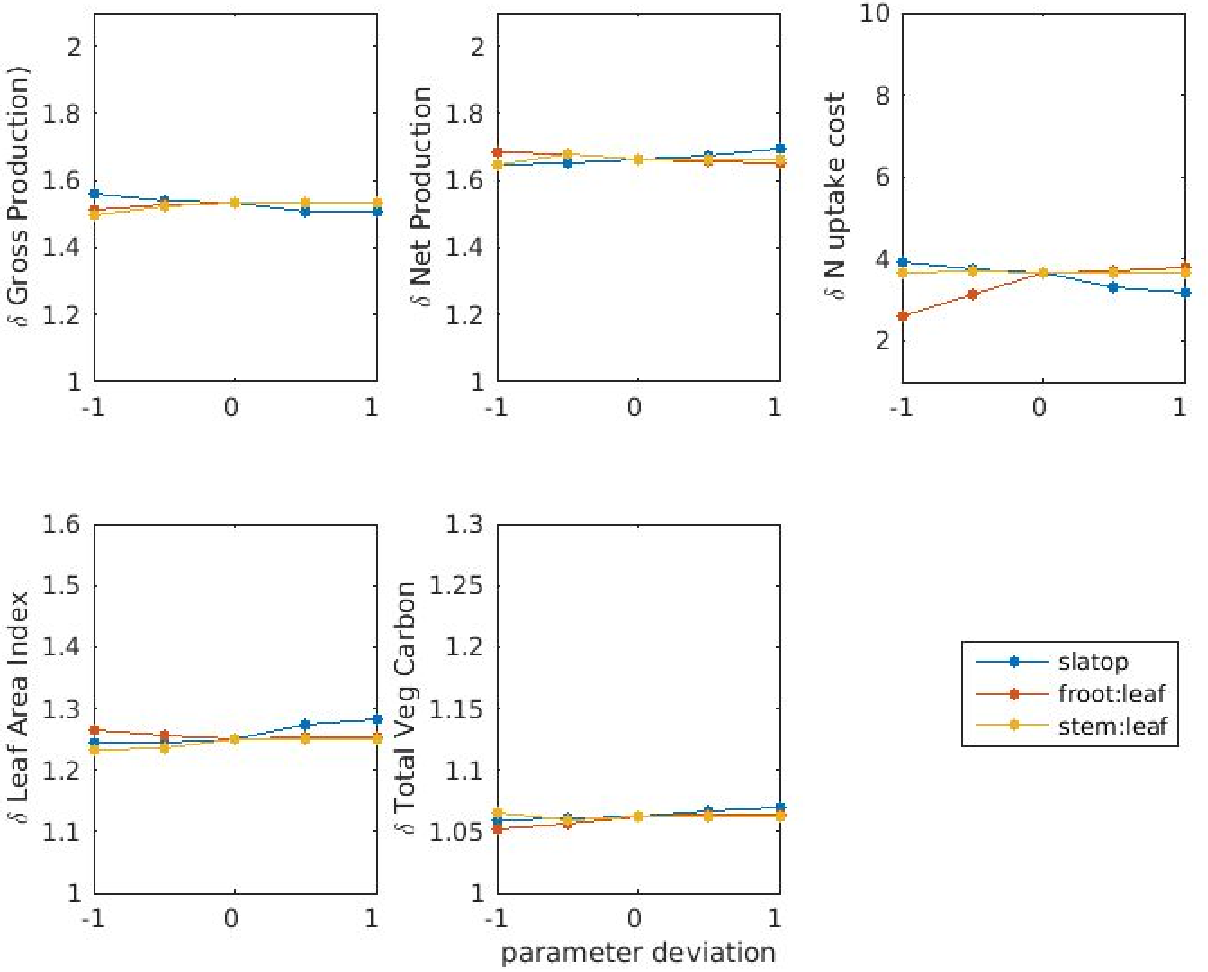
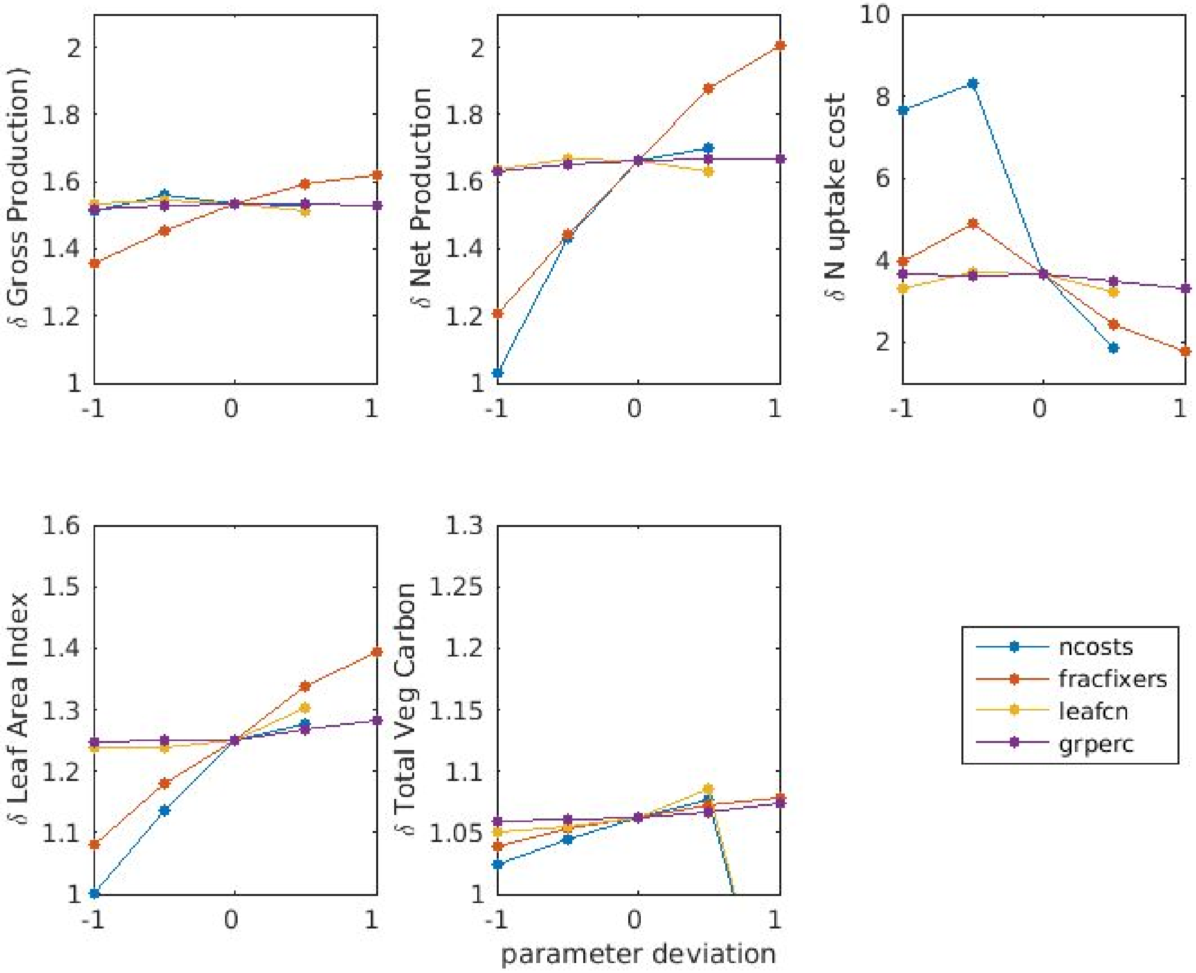
CO2 response: Higher leaf allocation



Allocation parameters don't affect CO2 response

(these act linearly on C cycle)

CO2 response: Higher leaf allocation



N uptake parameters DO affect response

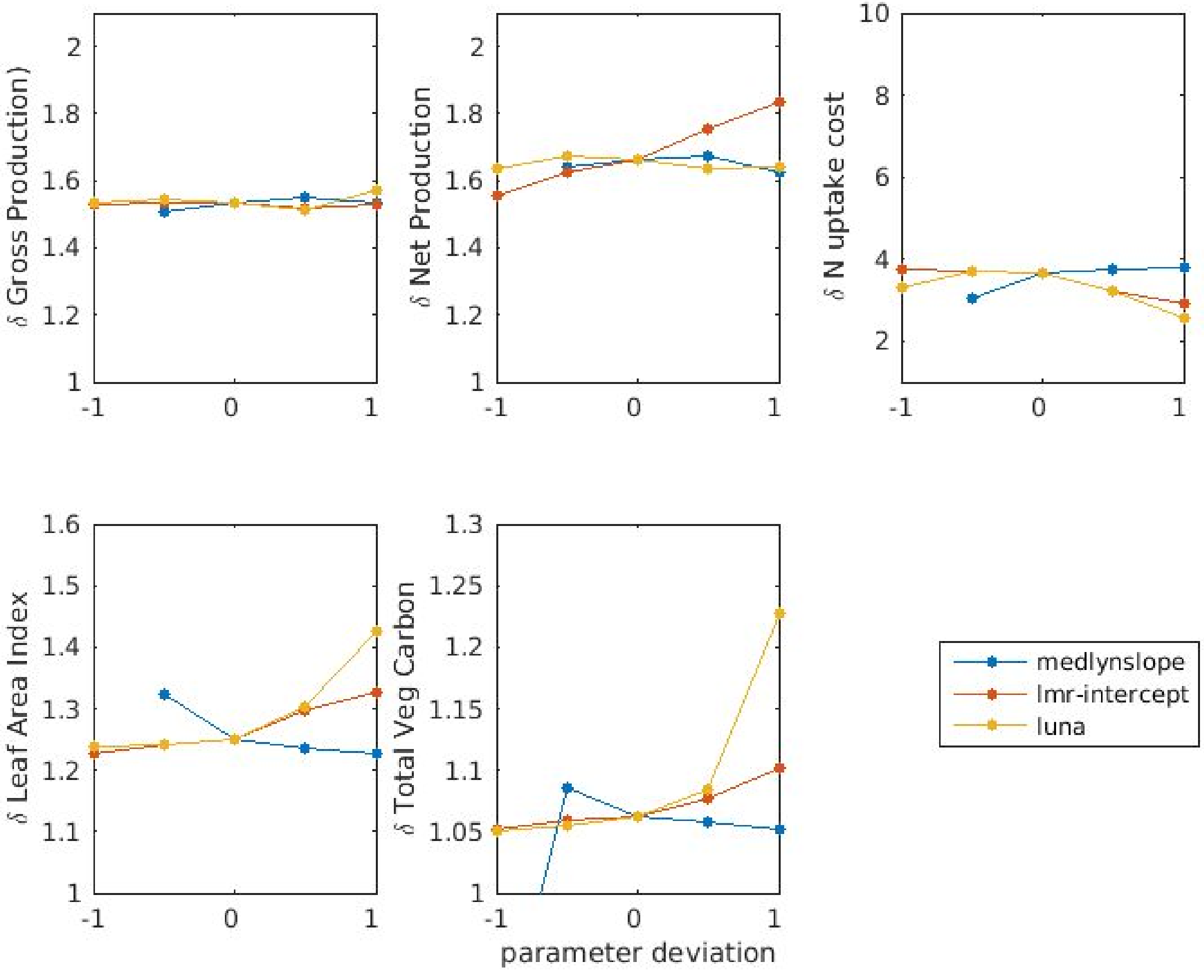
Fraction of fixers significantly alters result

As does cost of N uptake

So, the Nitrogen cycle **is** constraining the CO2 response…

..and in CLM5, plants can **buy their way out** of that problem!

CO2 response: Higher leaf allocation

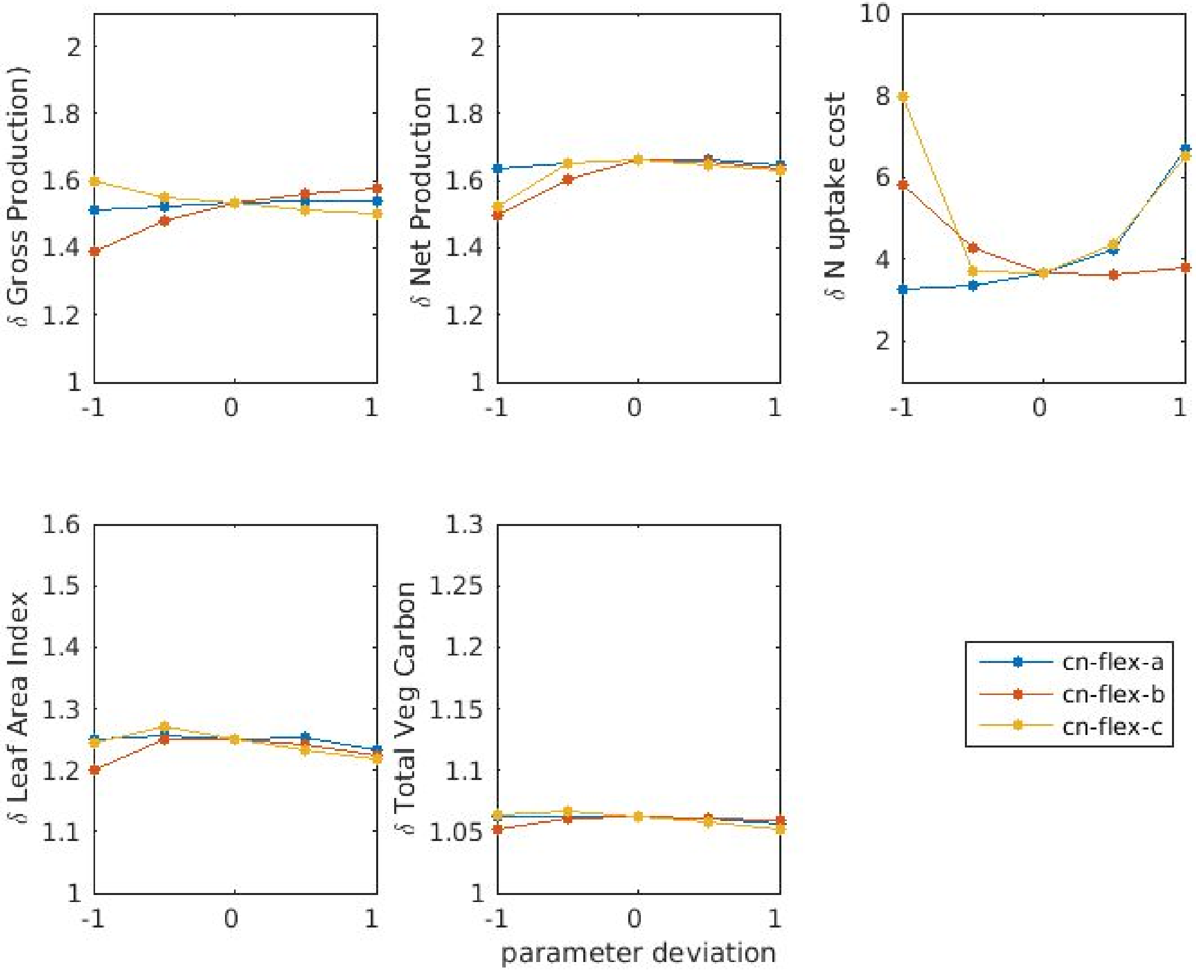


Photosynthesis parameters are less fundamental to impact

Stomatal slope is generally found to have a large impact.

Further evidence of primacy of N cycling parameters.

CO2 response: Higher leaf allocation



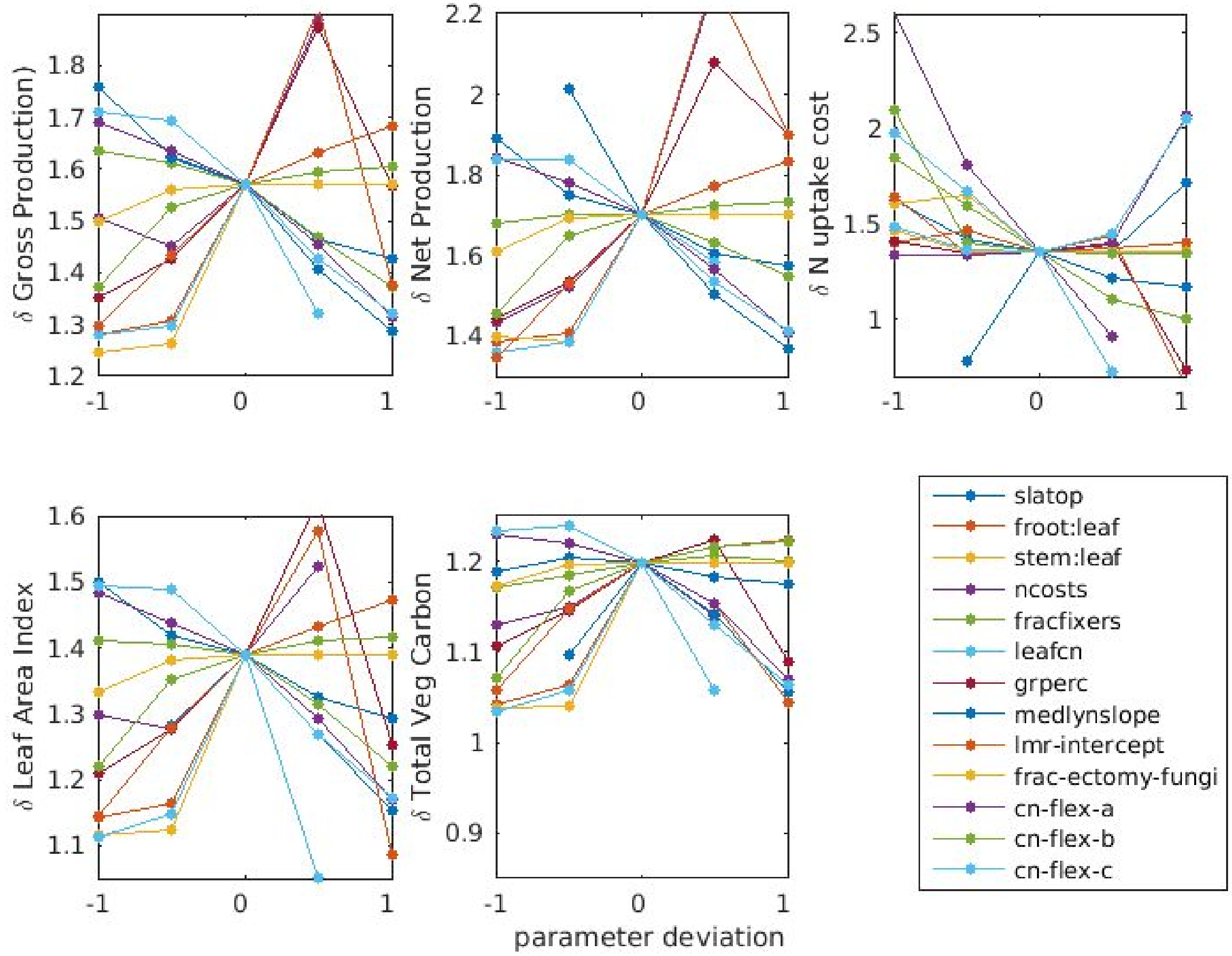
C:N flexibiility parameters are not of 1st order importance

This is mildly surprising, since 'diluting' Nitrogen is one way around limitation

(but diluting Nitrogen also reduces growth)

These parameters are highly unconstrained...

Nitrogen response: Default



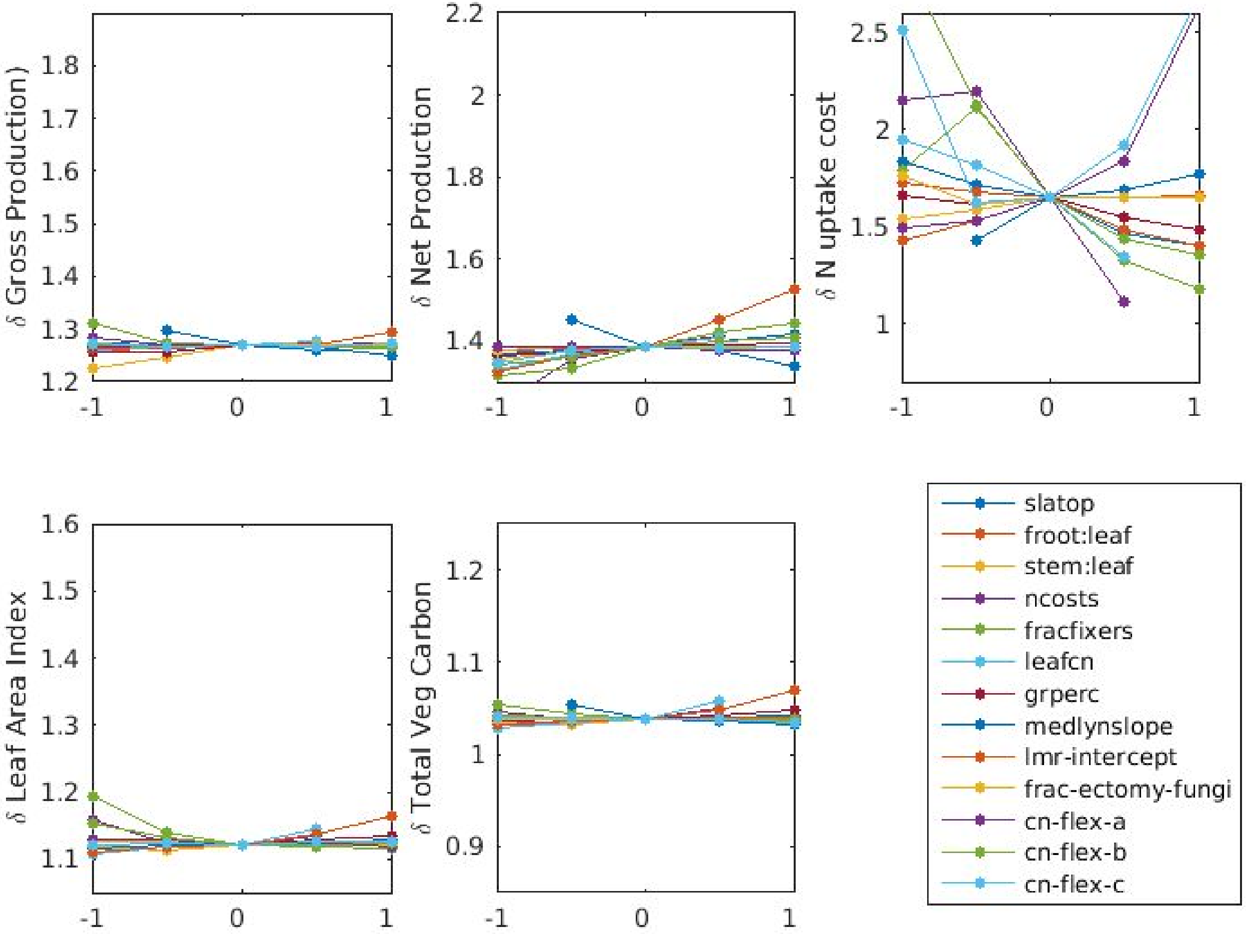
Wide range of responses to N fertilization.

This is the default state...

Parameters behaving as expected.

Need to re-run with realistic leaf area.

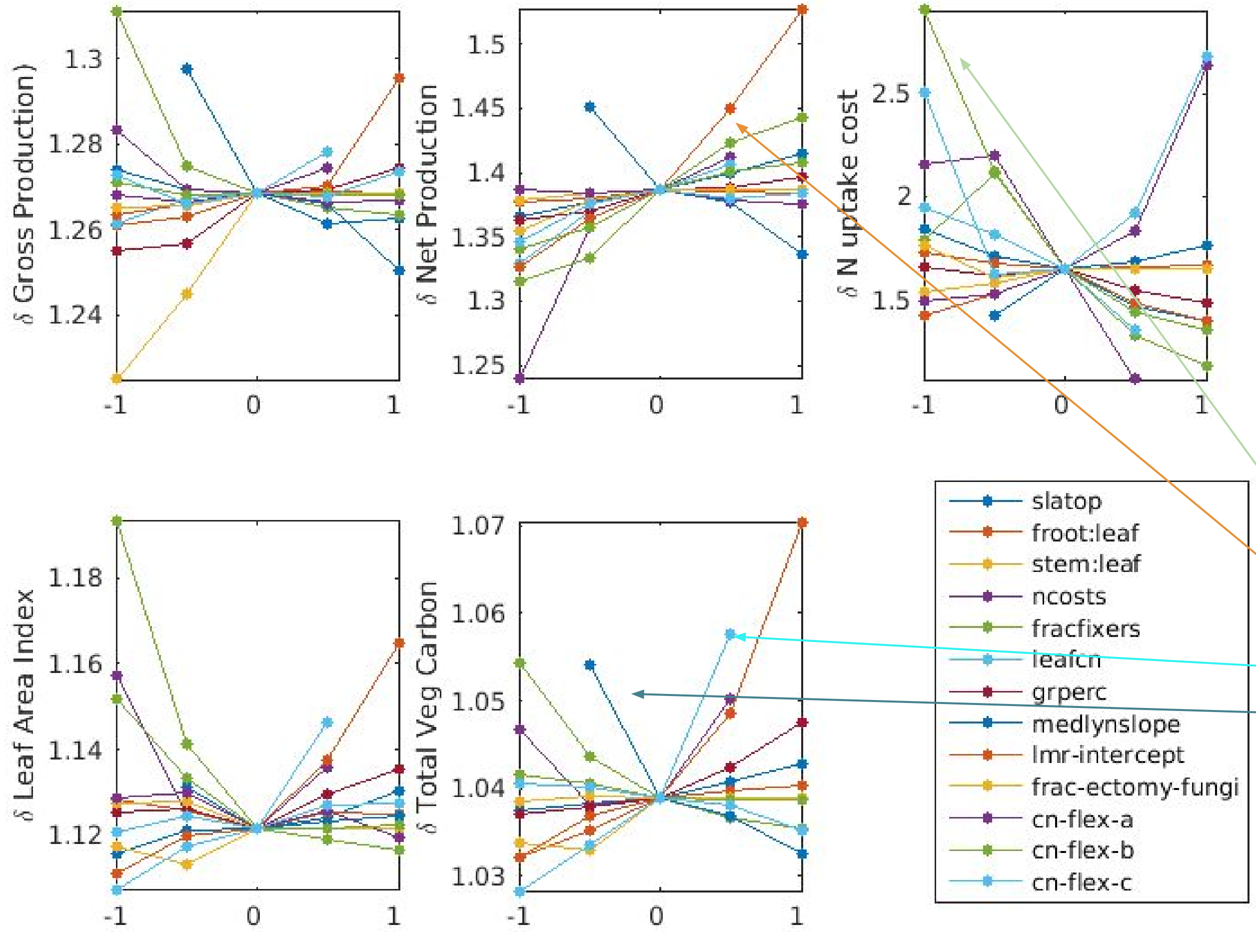
Nitrogen response: Higher leaf allocation



Closed canopy reduces

1. Sensitivity to NDEP
2. Sensitivity of model response to parameters.

Nitrogen response: Higher leaf allocation (bigger scale) year 4



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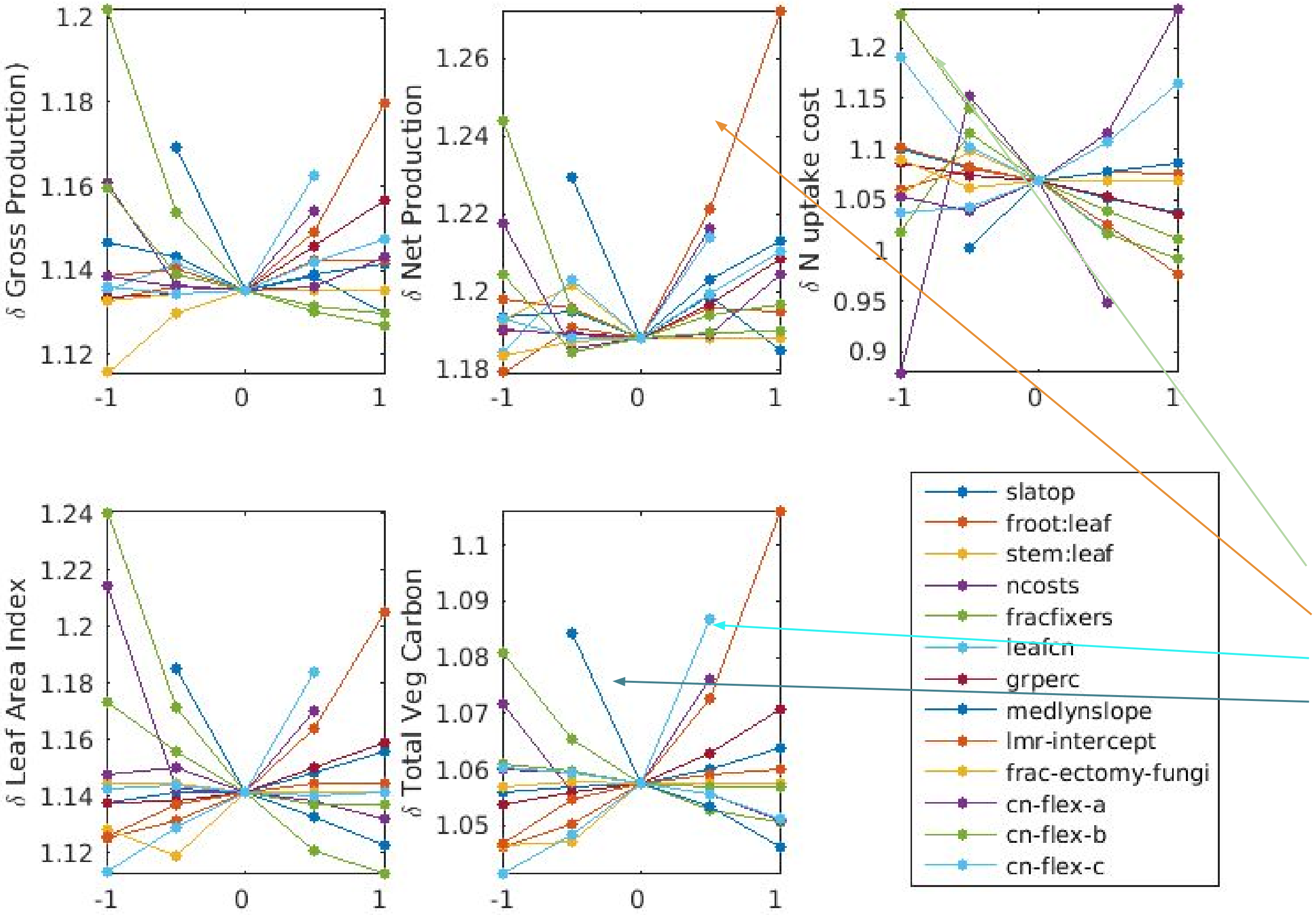
Model parameters of greatest impact are:
frac_fixers
lmr_intercept
leafcn
medlyn_slope

Nitrogen response: Higher leaf allocation (bigger scale) year 8



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Response changes through fertilization transient...

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To be continued...

1. Latin Hypercube ensemble to test full spread to most sensitive parameters.
2. Extend analysis to other ecosystems
3. Add other drivers (temperature, rainfall, humidity)
4. Linkages with biophysical parameter investigation (Katie Dagon)