Including more plasticity of functional traits in a DGVM

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Functional diversity in DGVMs: The PFT problem

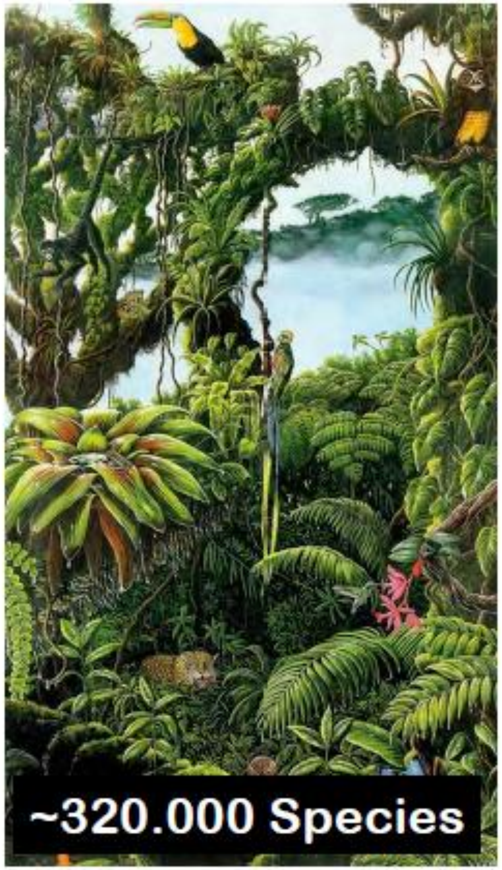
- Plant Functional Types (PFTs): represent whole biomes e.g. „tropical broadleaved evergreen tree“
- Fixed parameter settings (e.g. leaf longevity)

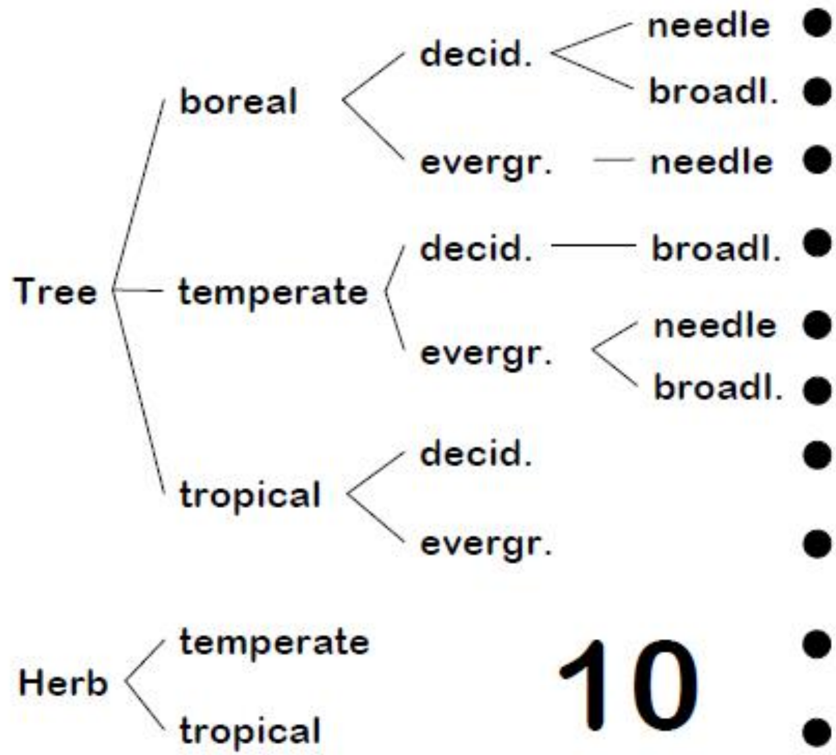
→ same plant on biome level

↷ no adaptation to environment

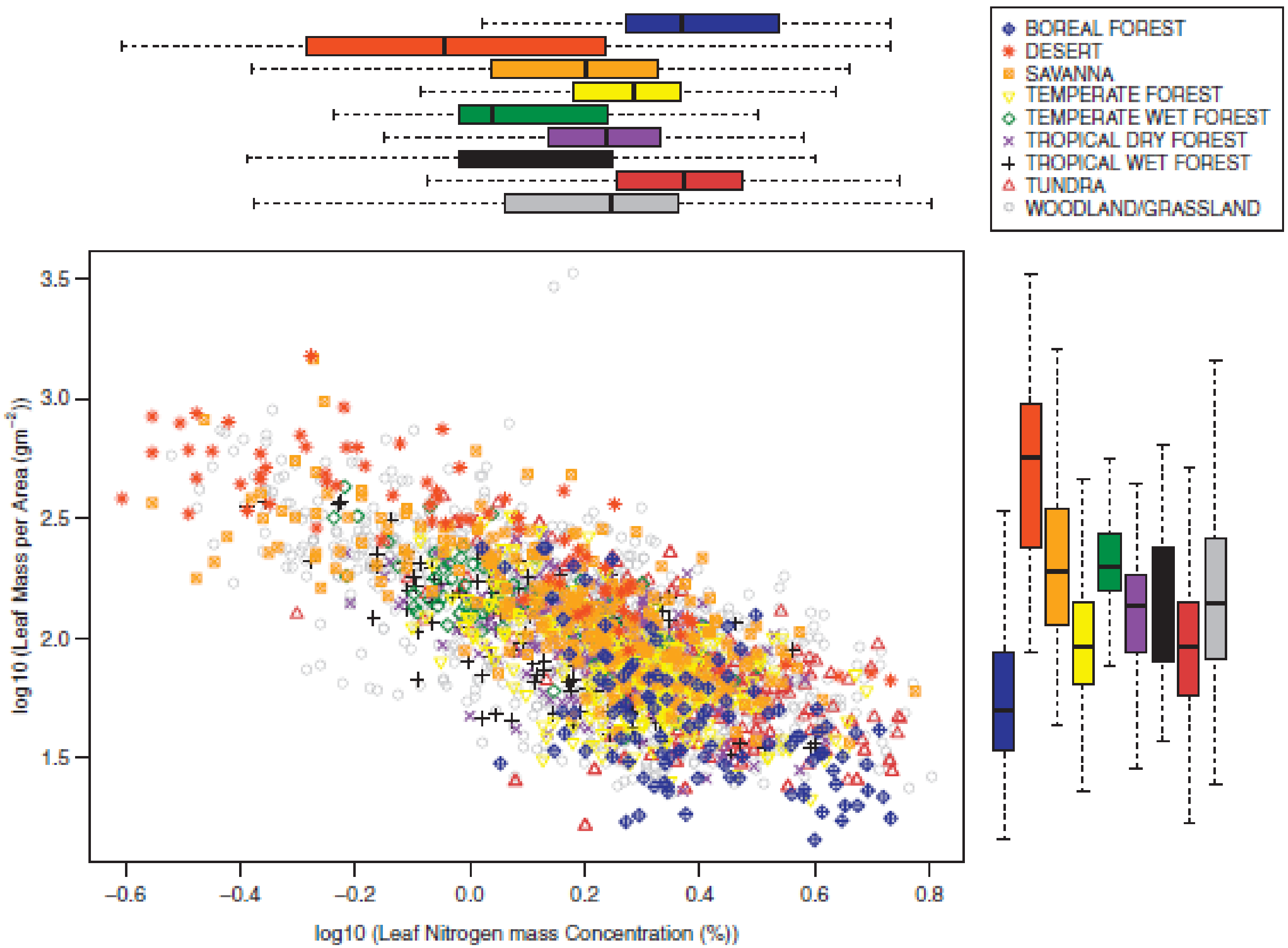
↷ no biodiversity effects on ecosystem processes

A view of diversity in DGVMs





Trait variation is only partly captured by classification in biomes/PFTs



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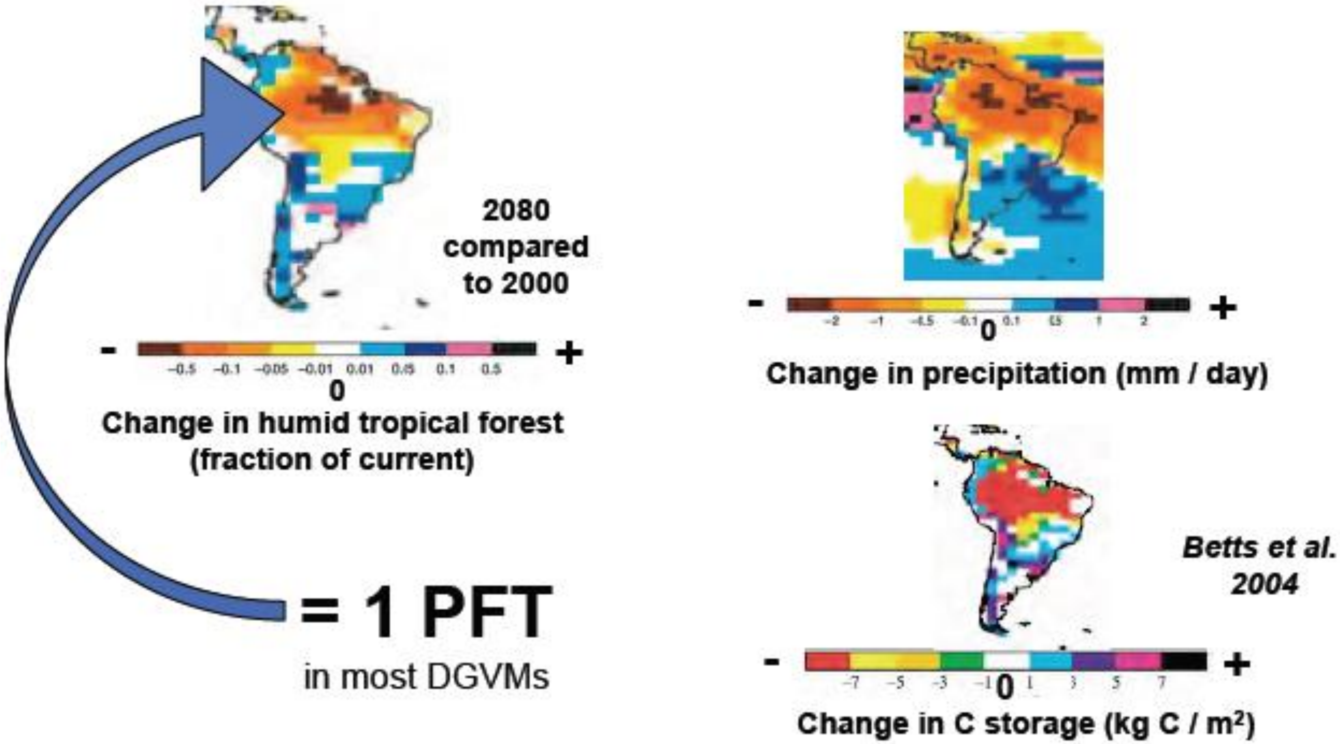
Van Bodegom et al. 2012 GEB

An example of PFT limitation

- Dieback of amazonian forest



first CLIMATE/CARBON coupled simulation show a total dieback of the amazonian Forest in 2080 with a high feedback of climate

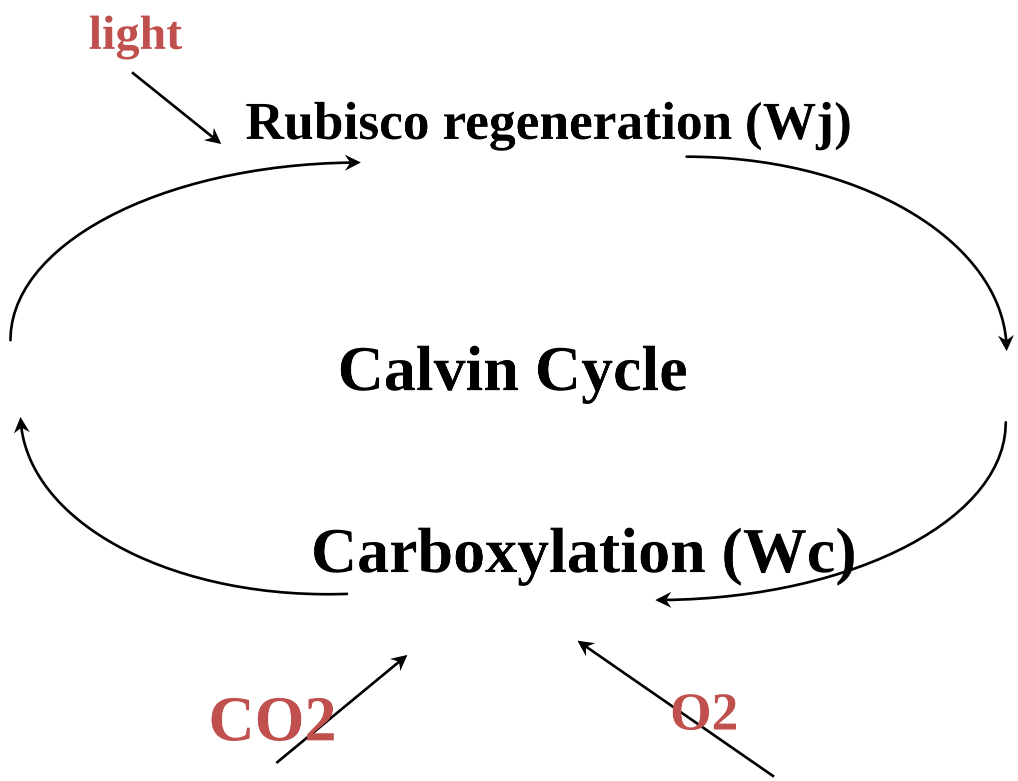
How to introduce more plasticity in DGVMs?

1. define empirical relationships between traits and environement *(Verheijen et al. 2013)*
2. Use ecological concepts of optimality (e.g coordination *(Chen et al. 1993)*
3. Use tradeoff between traits *(Wright et al. 2004)*

First attempt to use these concepts in ORCHIDEE DGVM

The coordinated photosynthesis

- Reminder on photosynthesis:



A= MIN (WC,WJ)

- Wc is proportional to rubisco concentration (i.e Vcmax)

And rubisco is the main source of N

(Vcmax=k3*N)

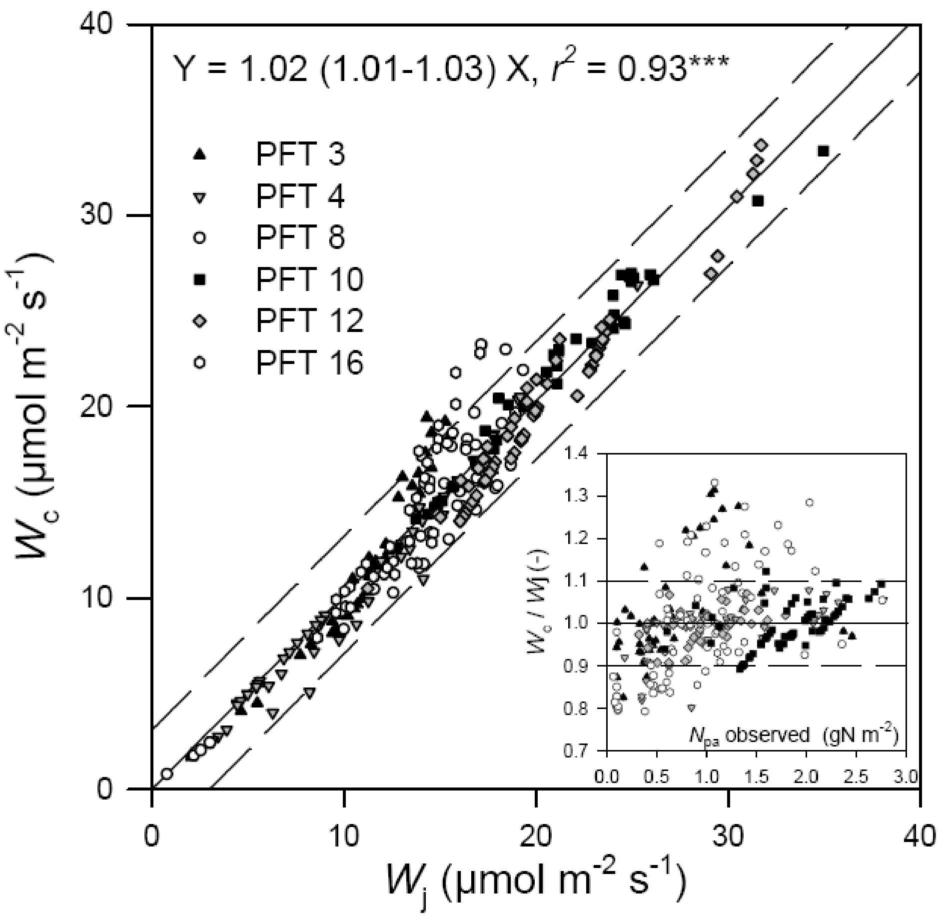
- Wj is proportional to energy (light available)

➔If N is too low, Wc is the main limiting factor and A is not optimal

➔If N is sufficiently high Wj become the limiting factor and then additional N does not increase A and additional N intake has a cost !

So there is an optimum leaf N (Vcmax) concentration that plant will try to reach for which Wc=Wj

This is indeed observed in the reality

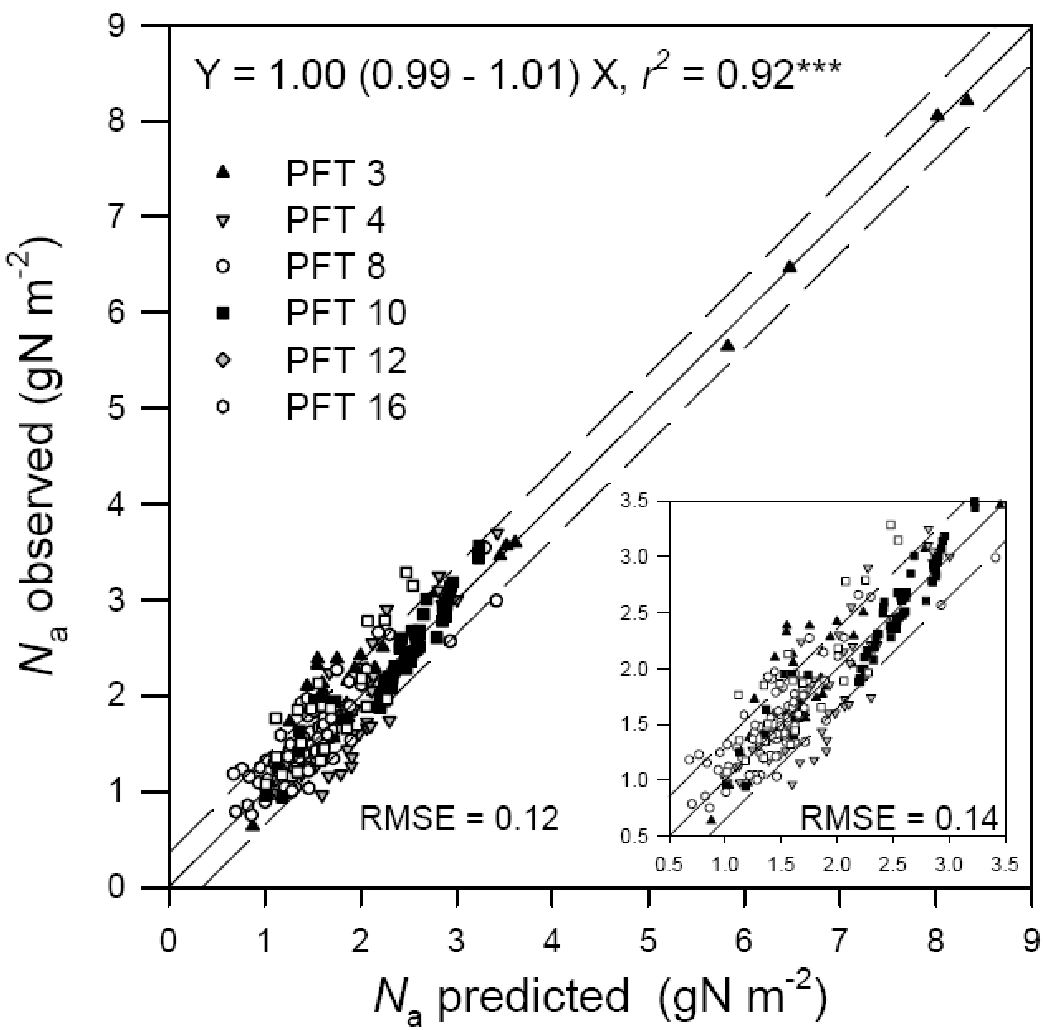


Synthesis from try database (Maire et al. 2010)

- From inversion of the Farqhuar model we can estimate the N of coordinated photosynthesis:

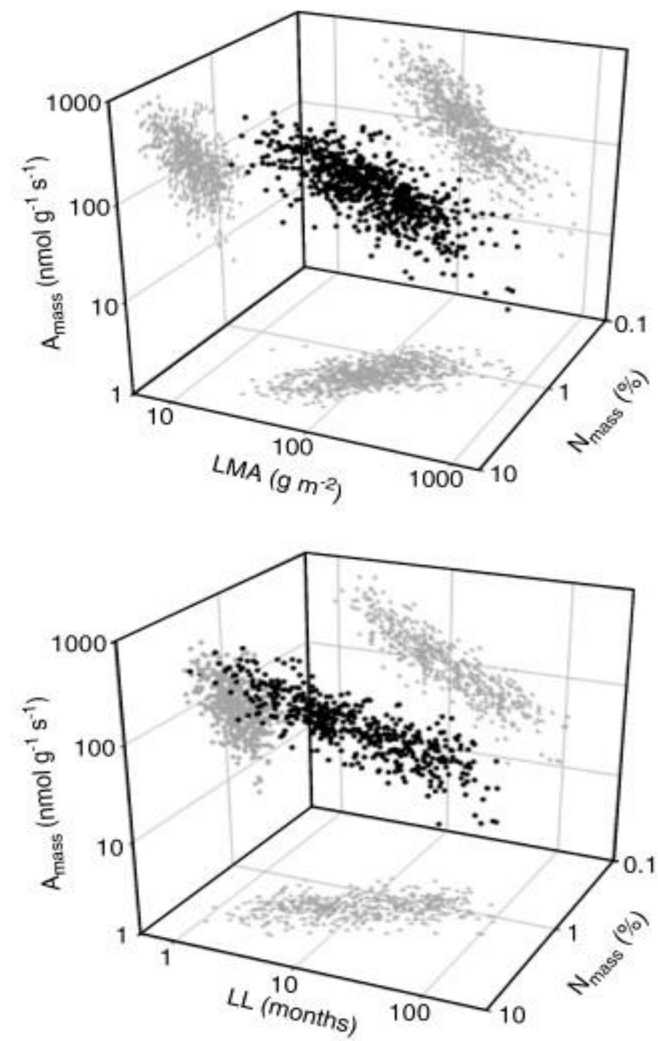
$$N_{\mathrm{pac}} = \frac{4 \cdot \alpha \cdot \mathrm{PPFD}}{k_3^{\mathrm{ac}}} \cdot \left(\left(\frac{\mathrm{C_i} + k_2}{\left(4 \cdot C_{\mathrm{i}} + 8 \cdot \Gamma^*\right) \cdot \Phi_{V_{\mathrm{c_{max}}}}} \right)^2 - \left(\frac{1}{J_{\mathrm{fac}}^{\mathrm{atc}} \cdot \Phi_{J_{\mathrm{max}}}} \right)^2 \right)^{1/2}$$

It gives satisfying results



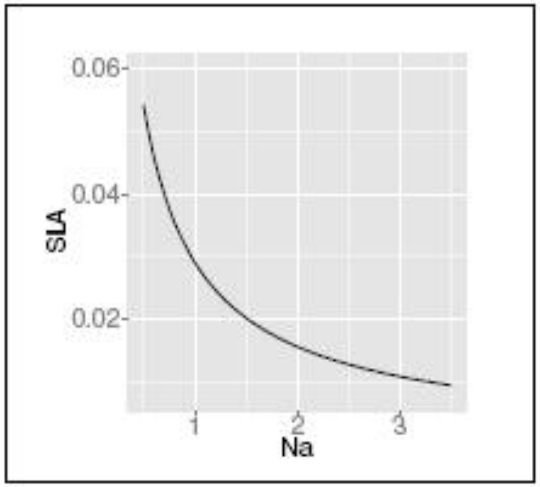
Coupling with the Leaf economic spectrum

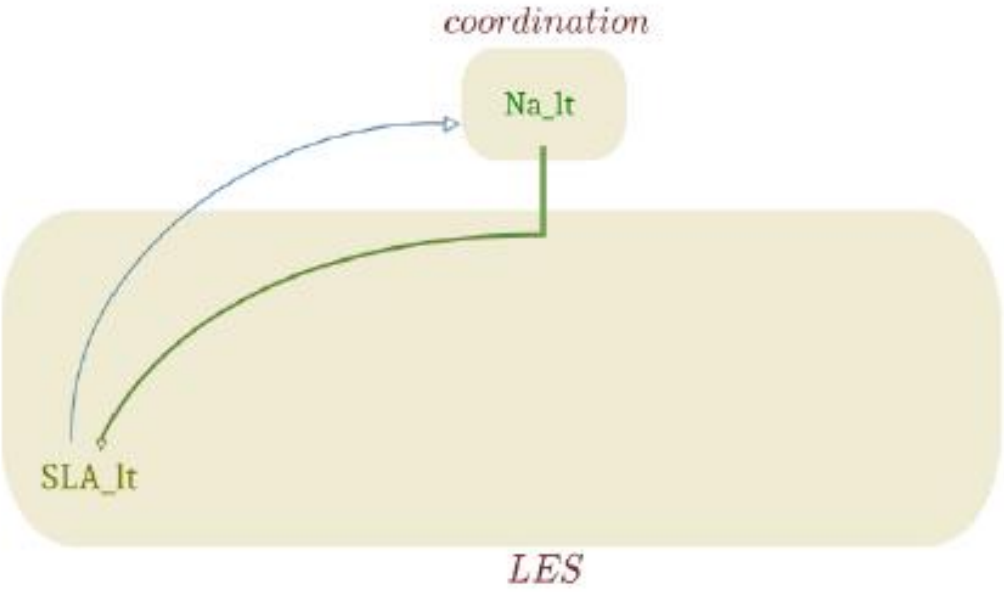
(Wright et al. 2004) showed that there is a correlation between 3 main parameters: Na, SLA, leaf longevity.

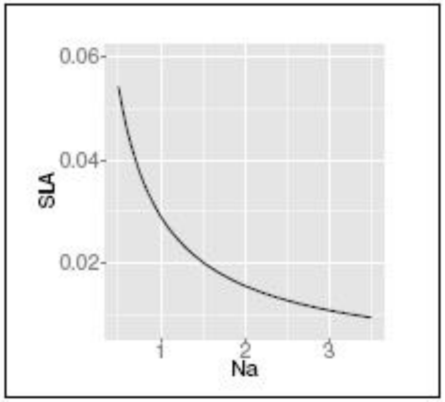


TRENDS in Ecology & Evolution

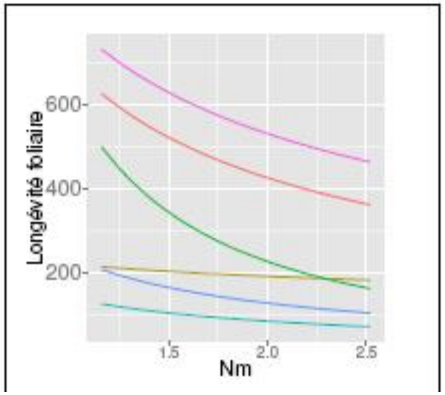
Algorithm



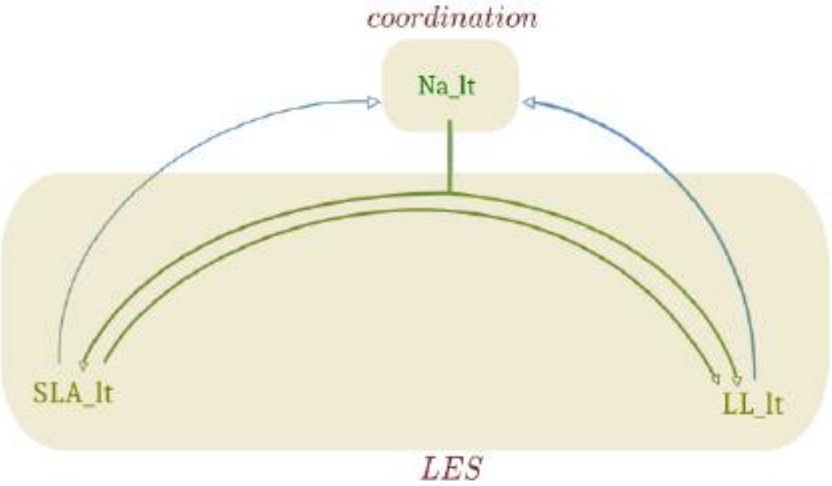




0.06
0.04
0.02
SLA
1
2
3
Na

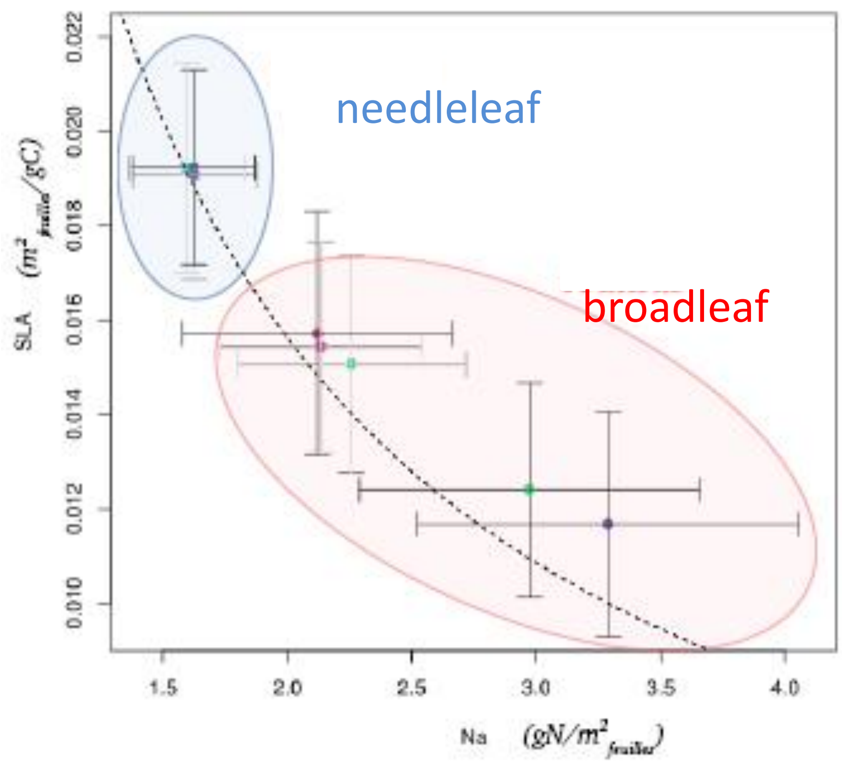


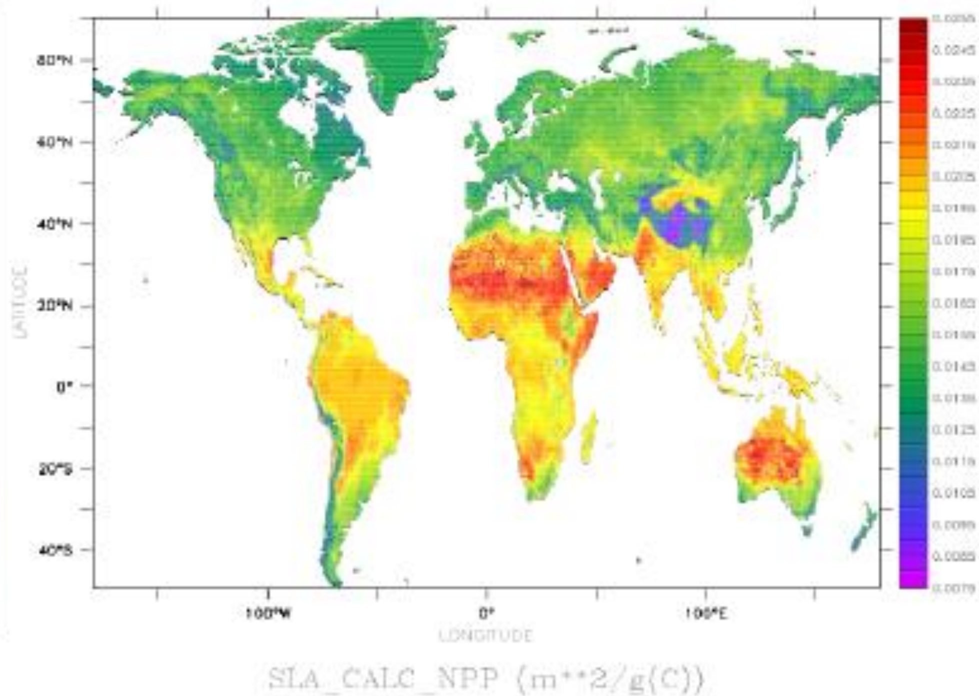
600
400
200
Longévité foliaire
1.5
2.0
2.5
Nm



coordination
Na_lt
SLA_lt
LL_lt
LES

Simulated SLA

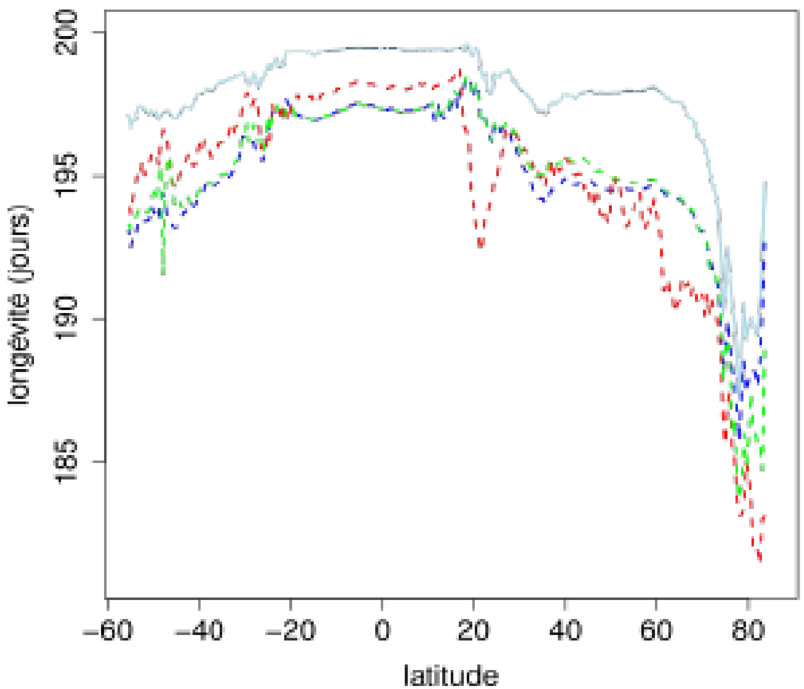




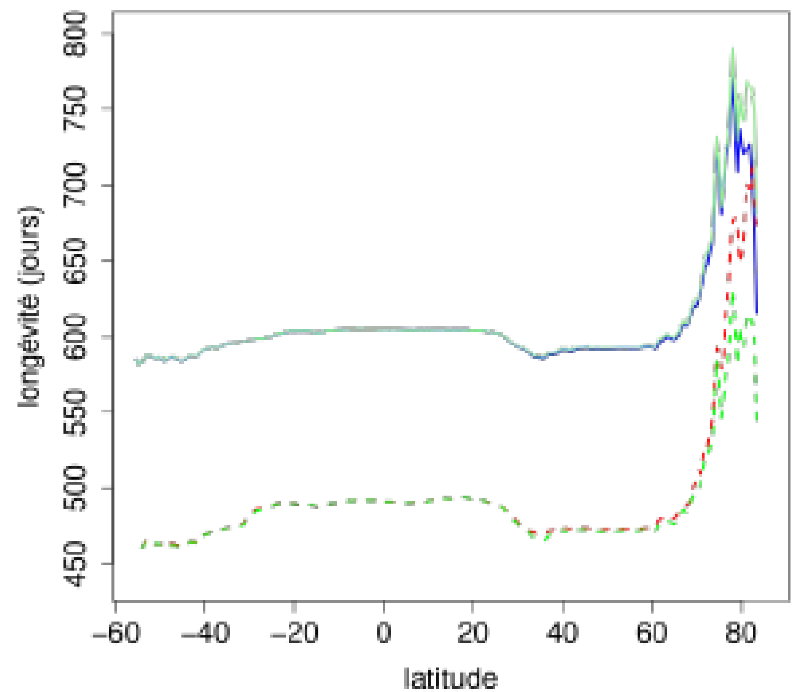
Good agreement between simulated and observed relationship

Leaf longevity

Deciduous



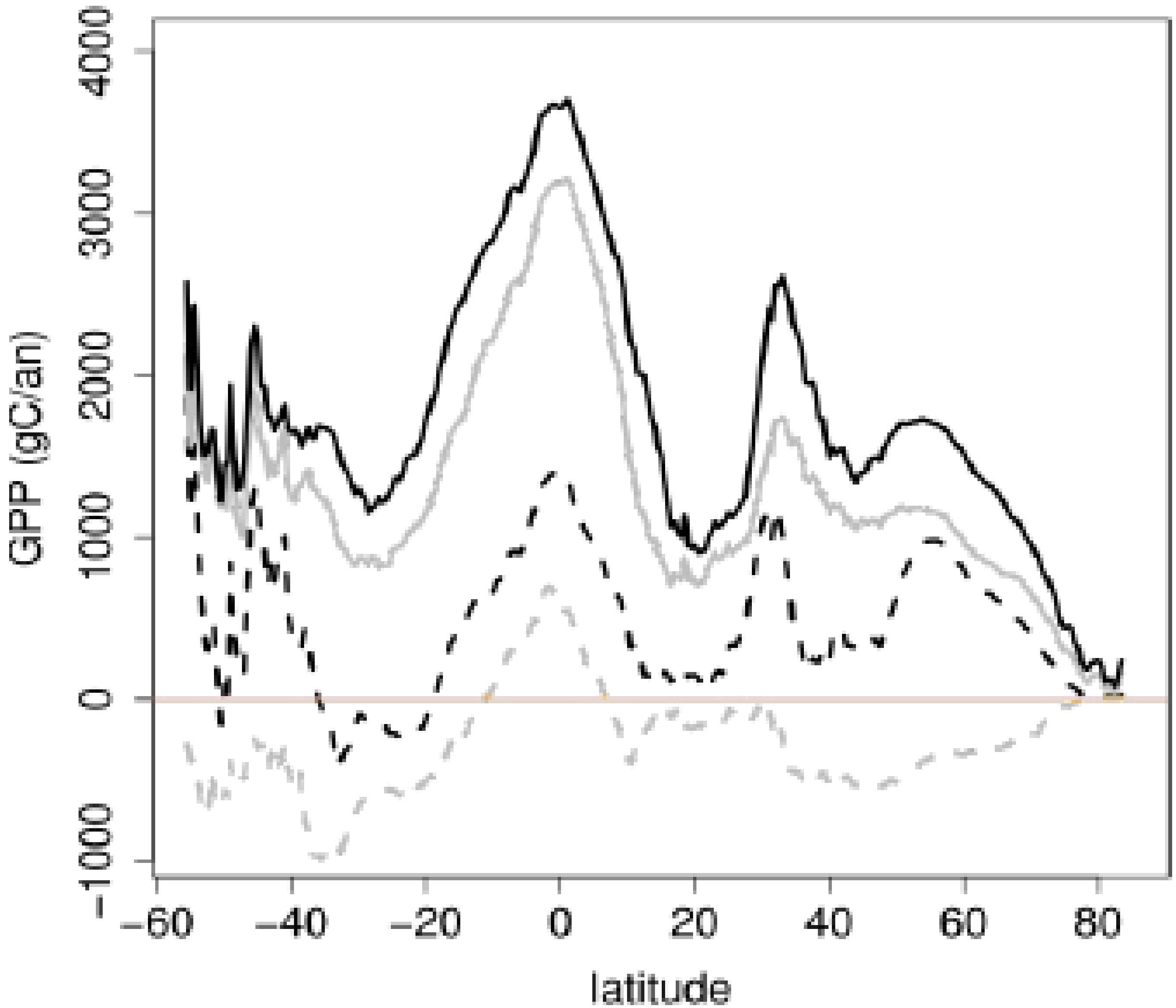
Evergreen



Red: tropical
Green: temperate
Blue: boreal

Dotted line: broadleaf
Continuous line: needleleaf

Difference in simulated GPP (with standard version)



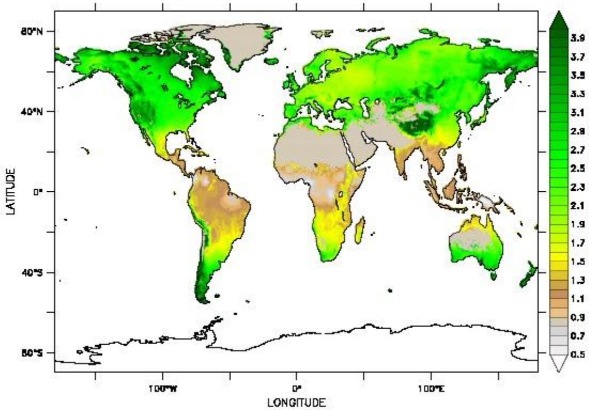
Dotted: broadleaf
Cont.: needle leaf
Black: sempervirens
Grey: deciduous

Coherent within the PFT envoloppe. Divergence outside

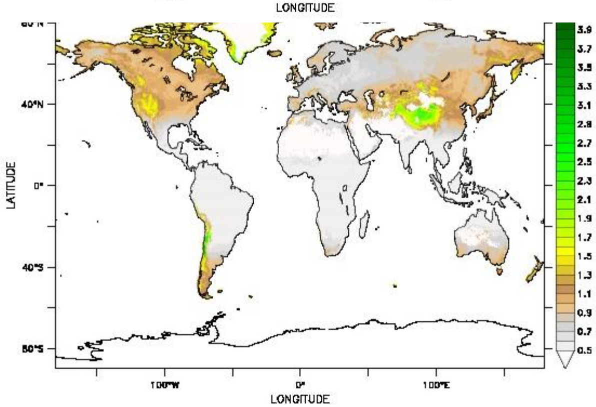
Impact of climate change on predicted traits

Simulation with ISIMIP scenario IPSL rcp8.5

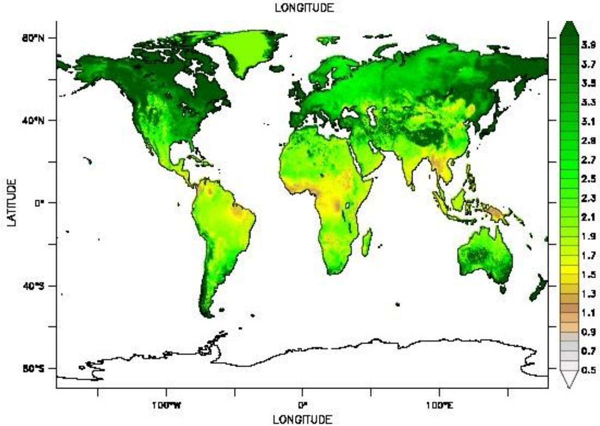
Impact on coordinated Nitrogen



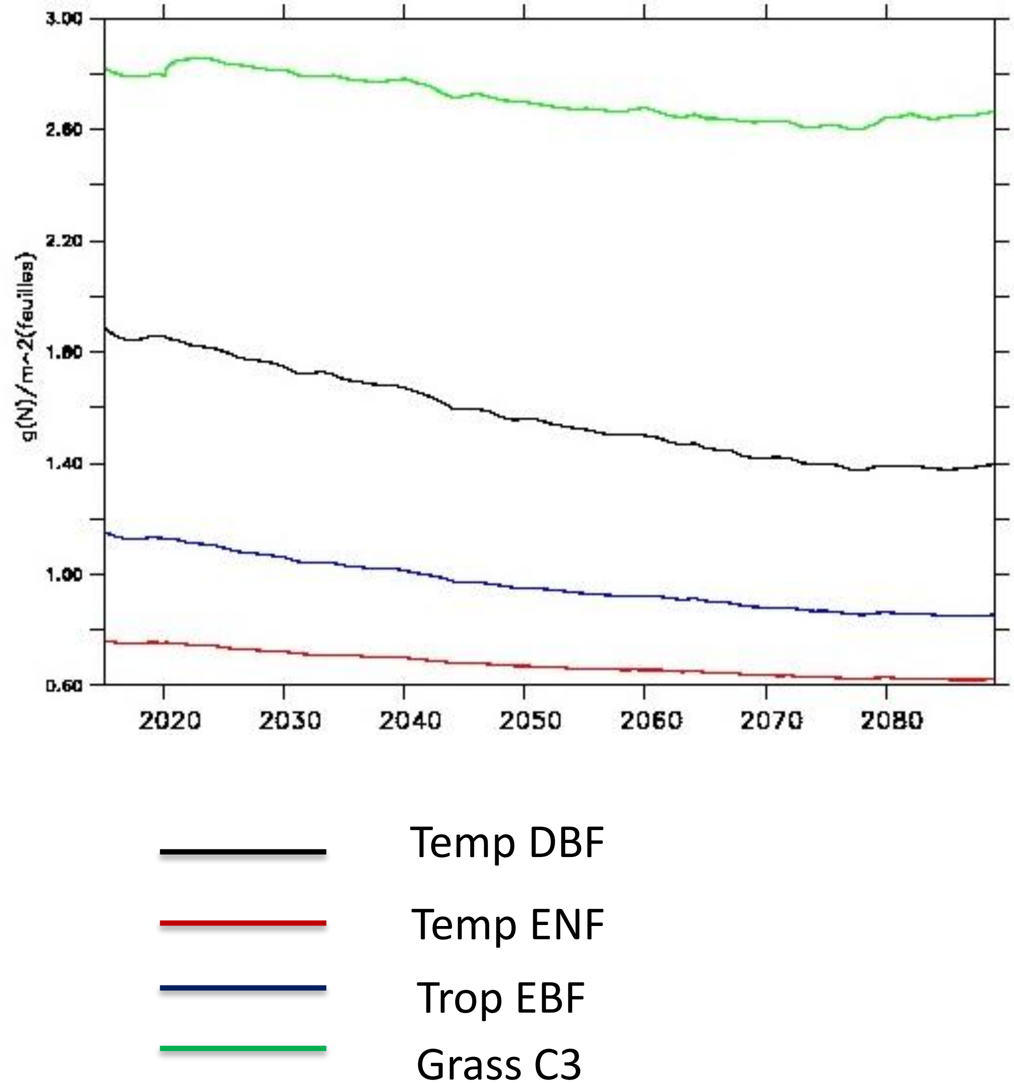
TENF



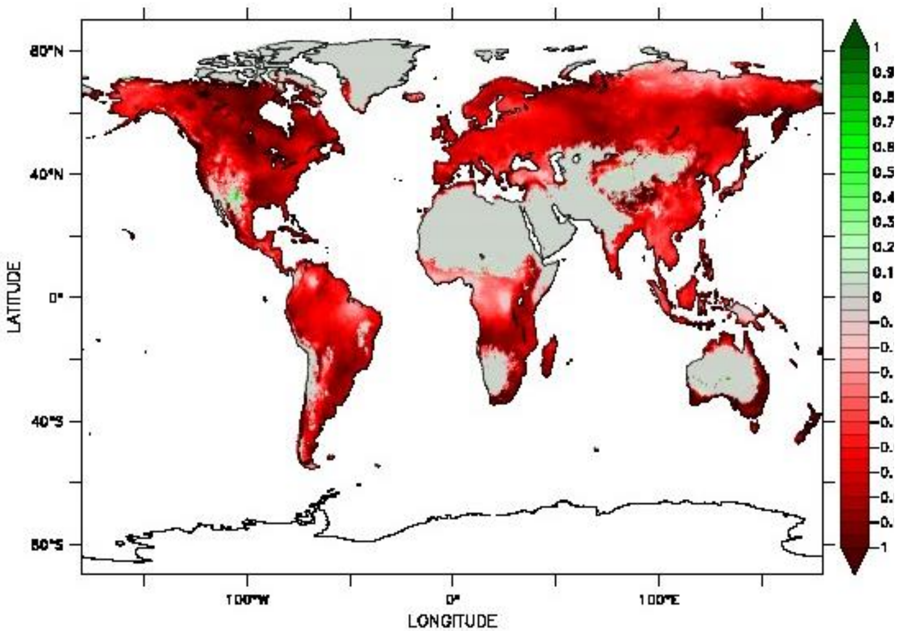
TDBF



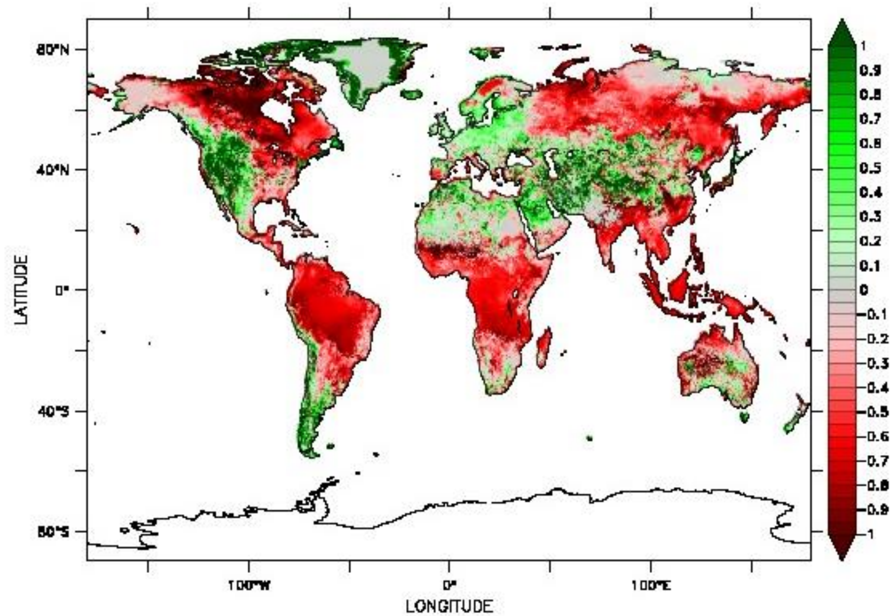
Grass C3



Spatial differences of N between 2100 and 2010



Temp DBF



Grass C3

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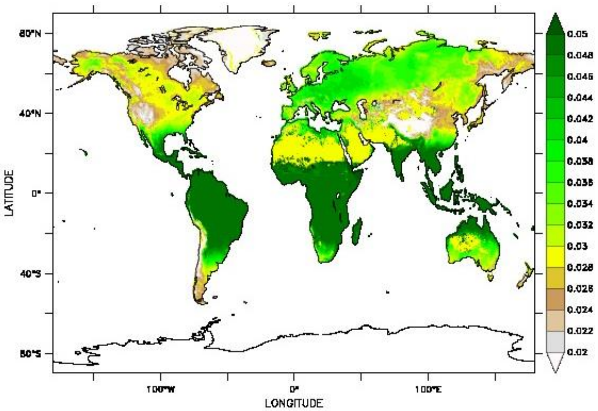
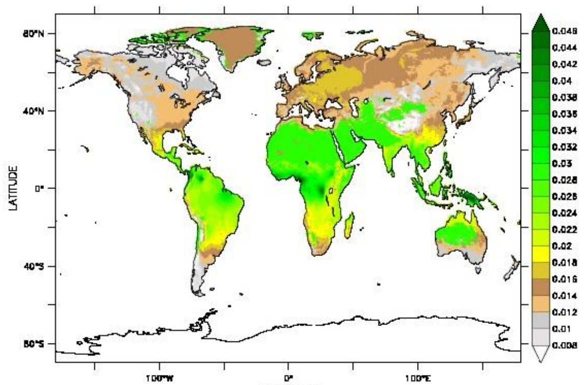
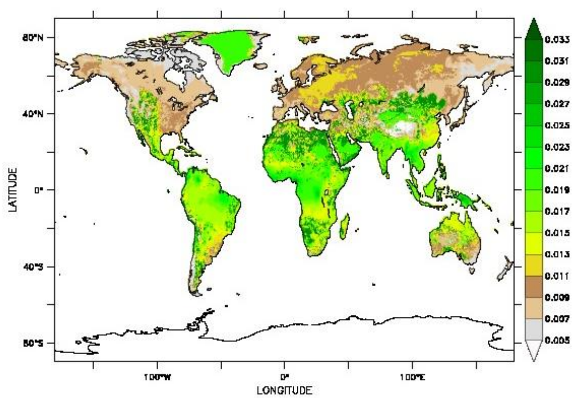
Impact on simulated SLA



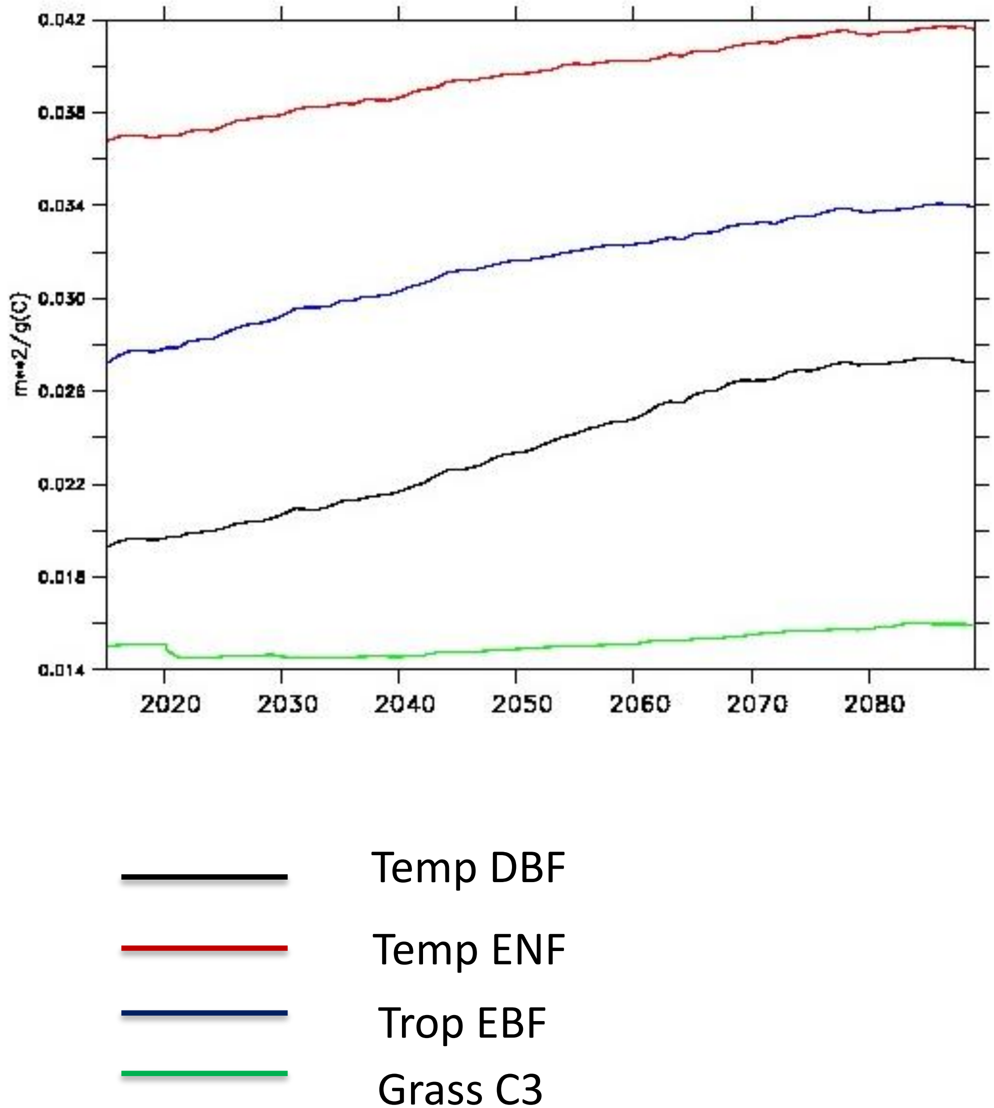
TENF



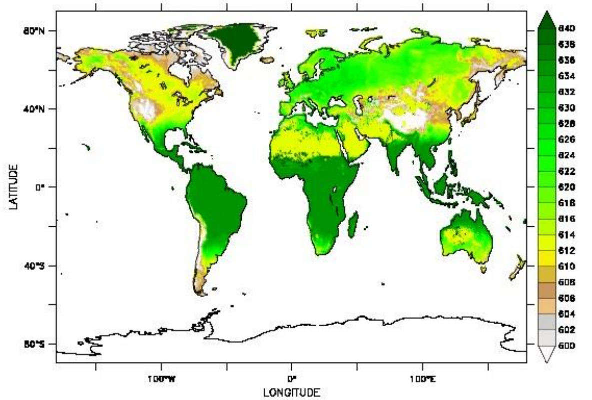
TDBF



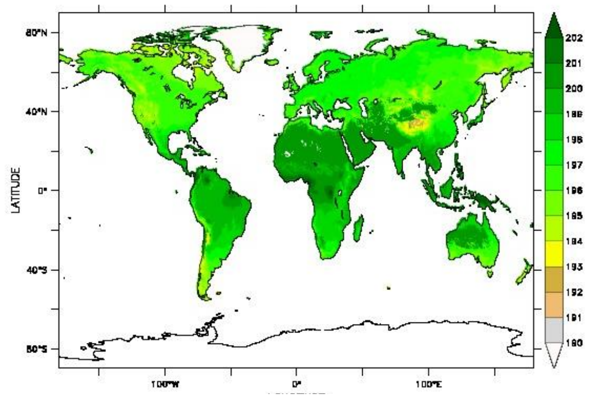
Grass C3



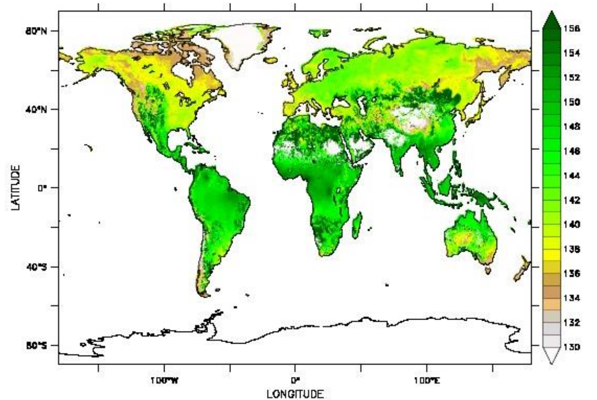
Impact on leaf longevity



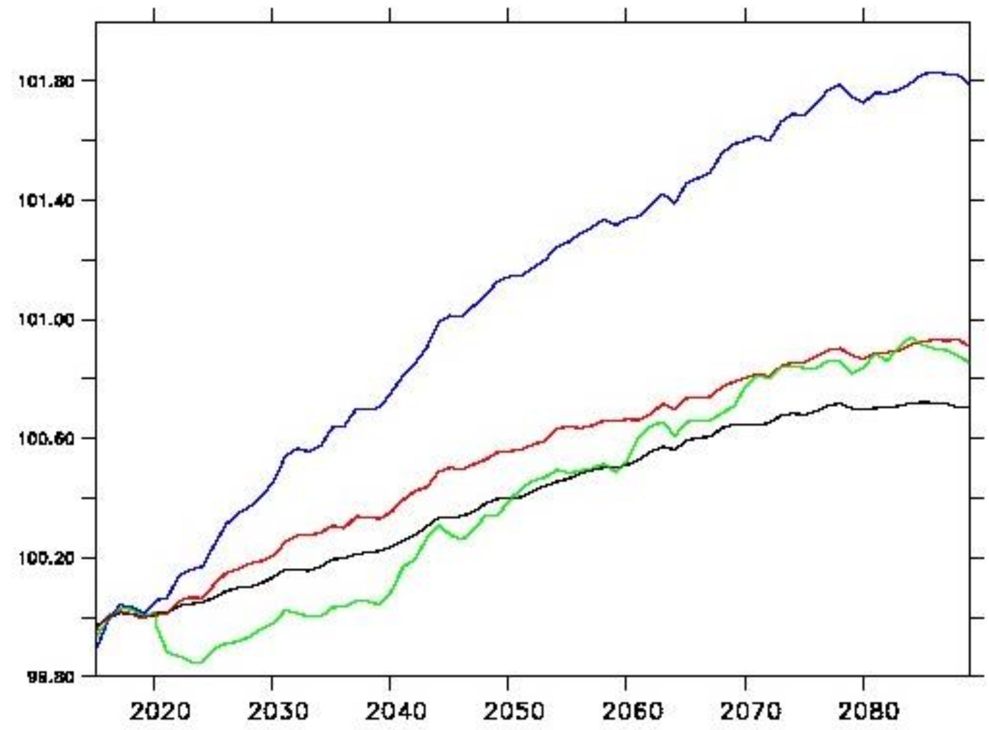
TENF



TDBF



Grass C3



Temp DBF

Temp ENF

Trop EBF

Grass C3

conclusion

- Preliminary results but:

➔ Simulated N/SLA/LL is coherent with expected variation between PFTs

➔ simulated GPP is correct where PFT is present

But diverge outside of climate enveloppe

➔Decreasing N with climate change (CO_2 effect ?)

But different response for different PFTs.