



Community Earth System Model

# Climate change impacts on mycorrhizae amplify nitrogen limitation on global plant growth

Land Model and Biogeochemistry Working Group Meeting | 23 - 25 February 2021 | Virtual Via Zoom

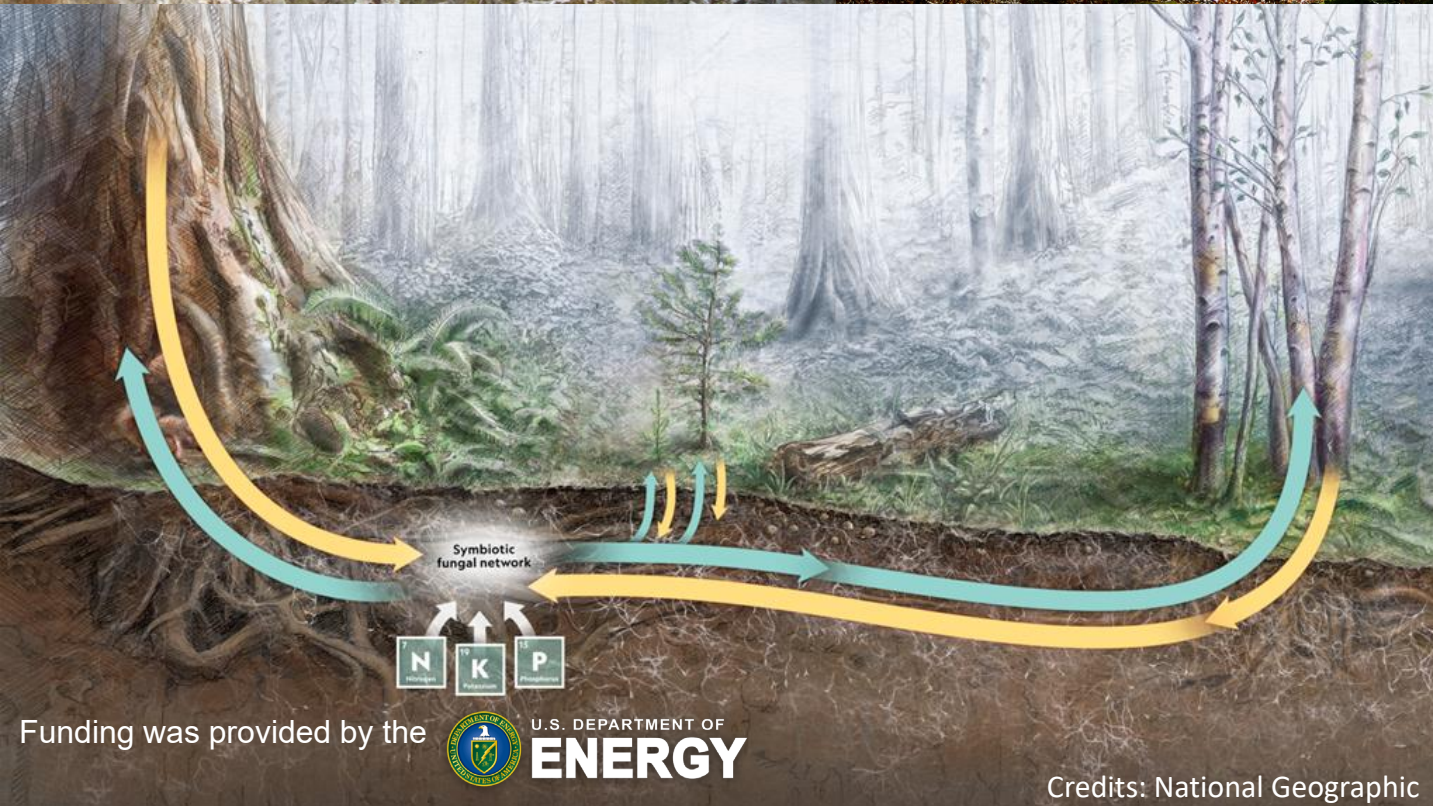
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<sup>1</sup>Joint Institute for Regional Earth System Science and Engineering,  
**UCLA**

Thursday, February 25<sup>th</sup> 2020

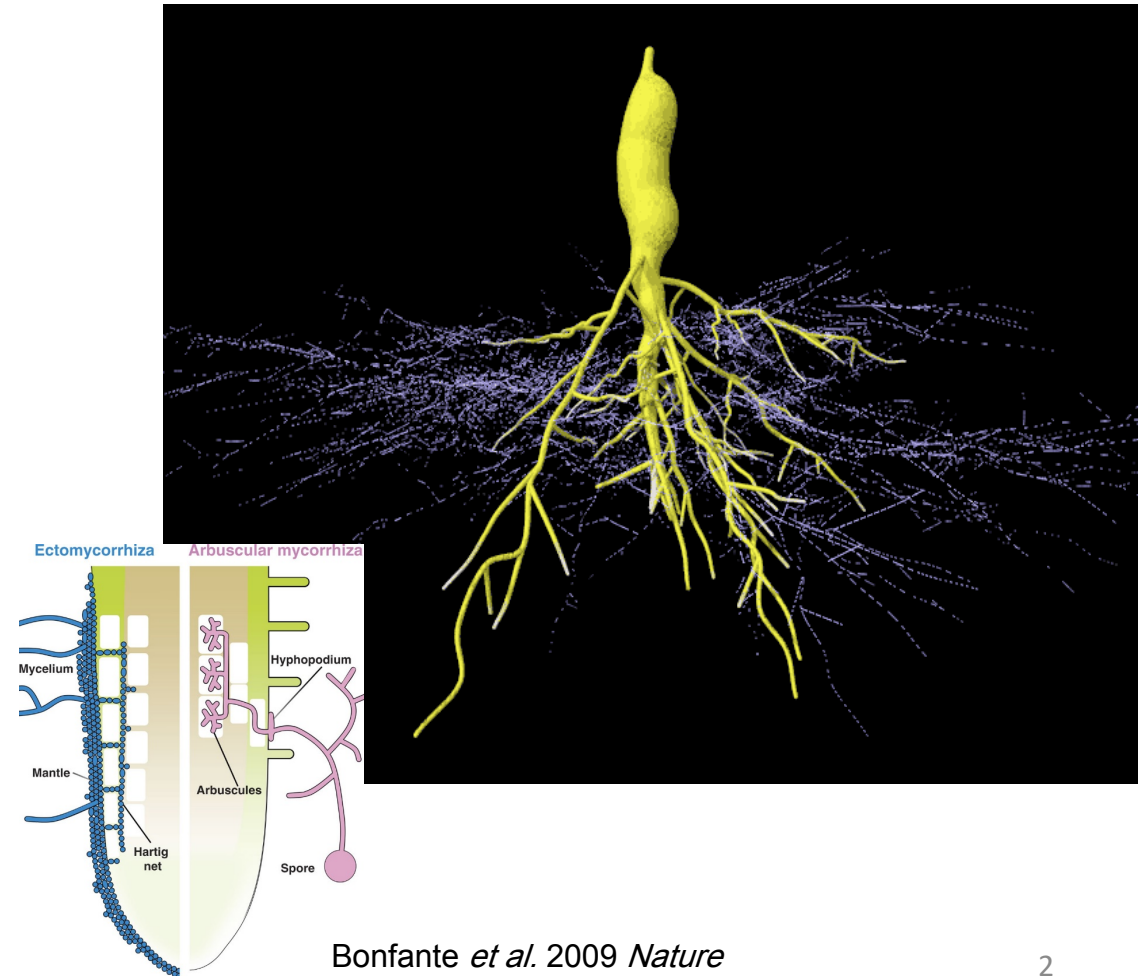
 <sup>2</sup>**Jet Propulsion Laboratory**  
California Institute of Technology





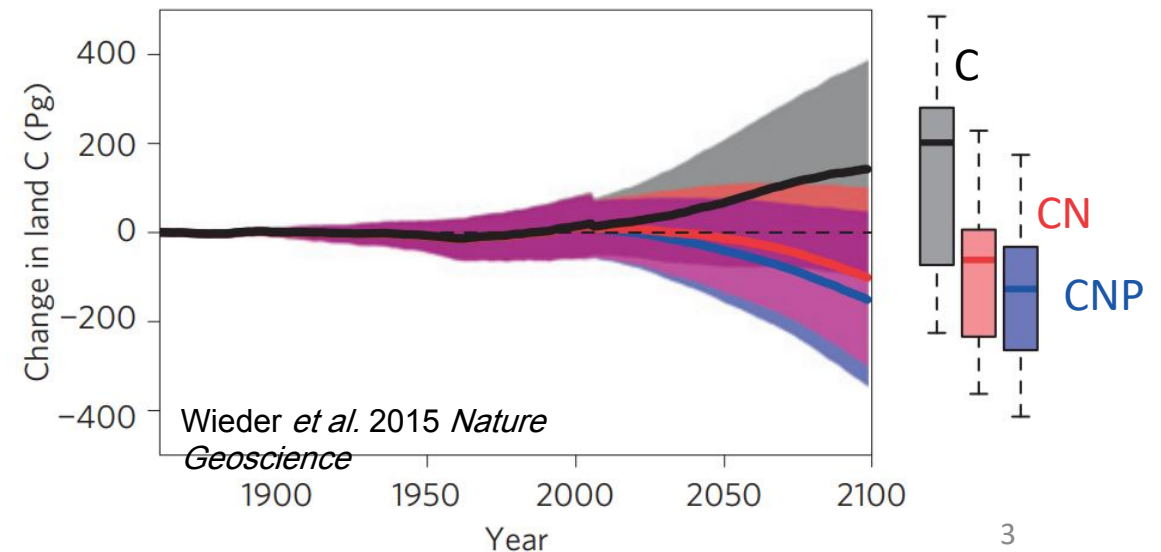
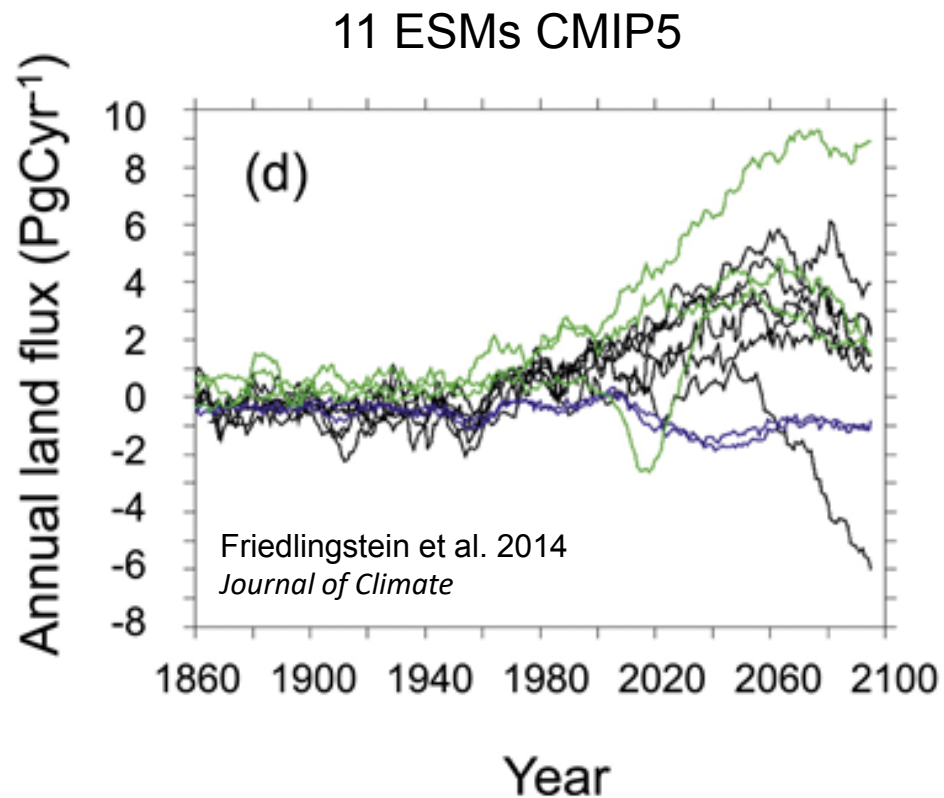
# What are *mycorrhizae*?

- “Myco” (fungus), “rhiza” (root) describes the mutually beneficial relationship between the **plant** and root **fungi**.
- Supports faster plant establishment through greater hyphae access to **water** and **nutrients** beyond the root zone.



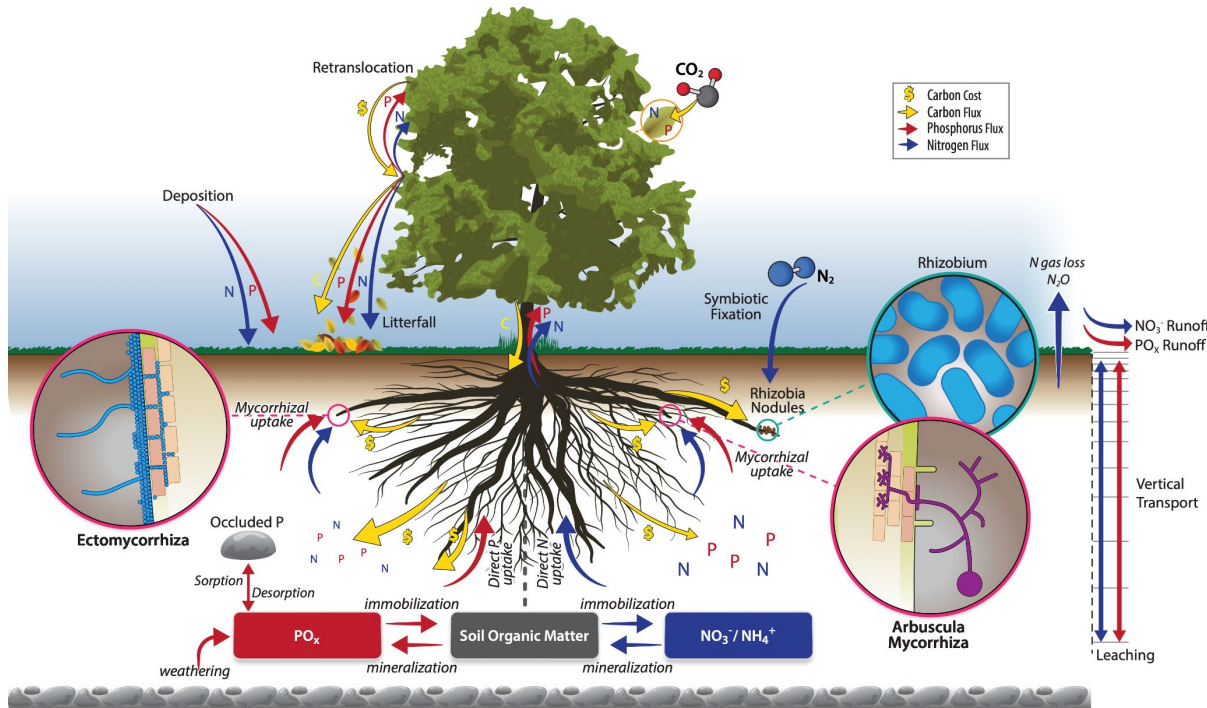
# Will the land surface remain a carbon sink by 2100?

- Projected NPP does not meet the stoichiometric demands of plant growth!

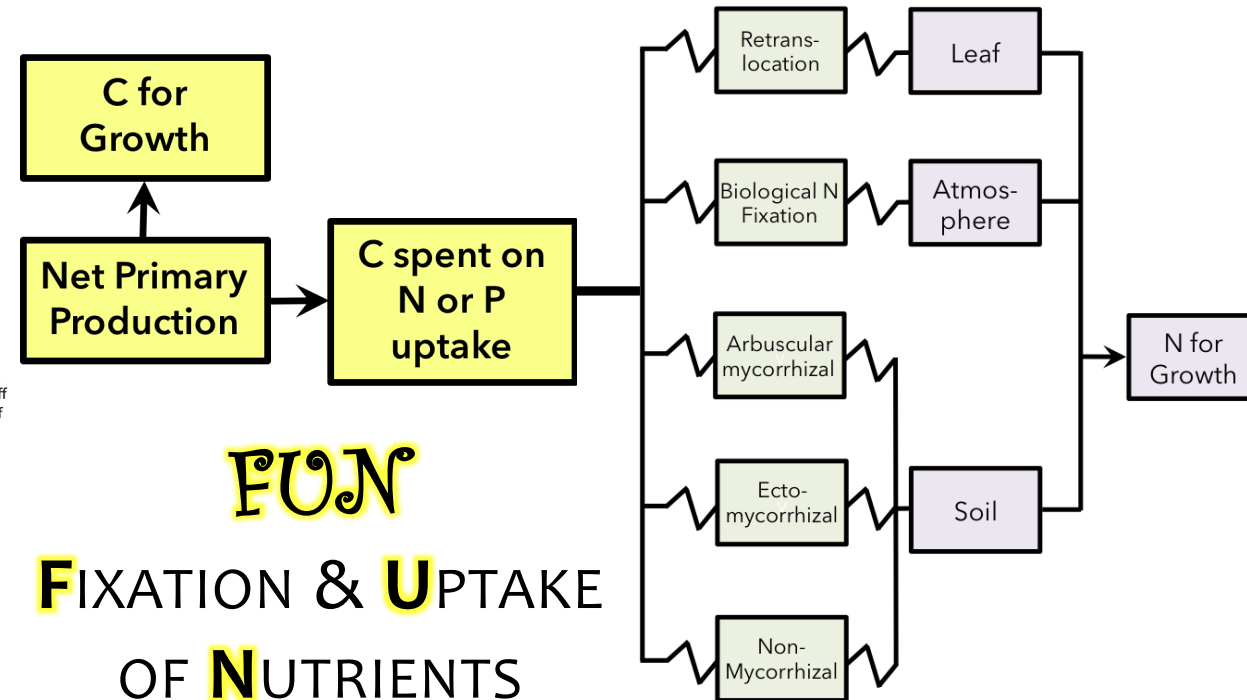


But plants can access nutrients through different pathways!

$$N_{cost,active,j} = \frac{k_{n,active}}{N_{smin,j}} + \frac{k_{c,active}}{C_{root,j}}$$



Braghiere et al., in review.



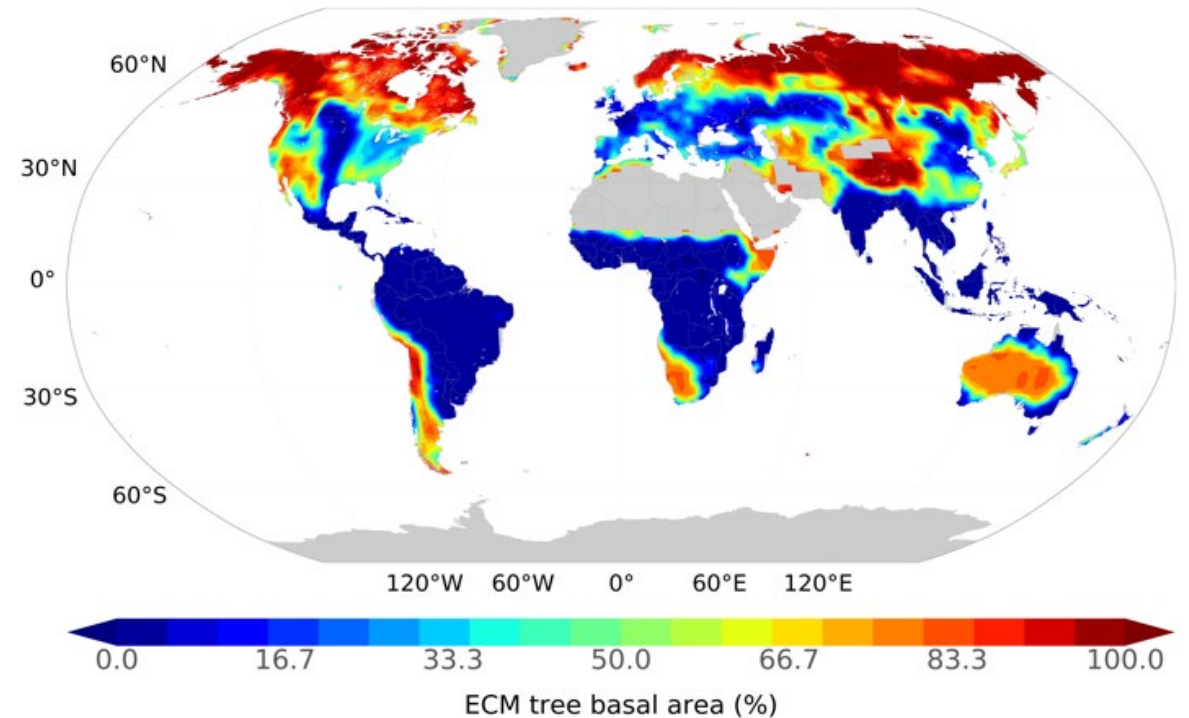
Fisher et al., 2010; Brzostek et al., 2014; Shi et al., 2016; Allen et al., 2020.

# CLM - FUN

- Assumptions about mycorrhizal spatial distribution...

**Table 2** The ratios of the arbuscular mycorrhizal (AM)-associated and ectomycorrhizal (ECM)-associated plants of the CLM4.0 PFTs

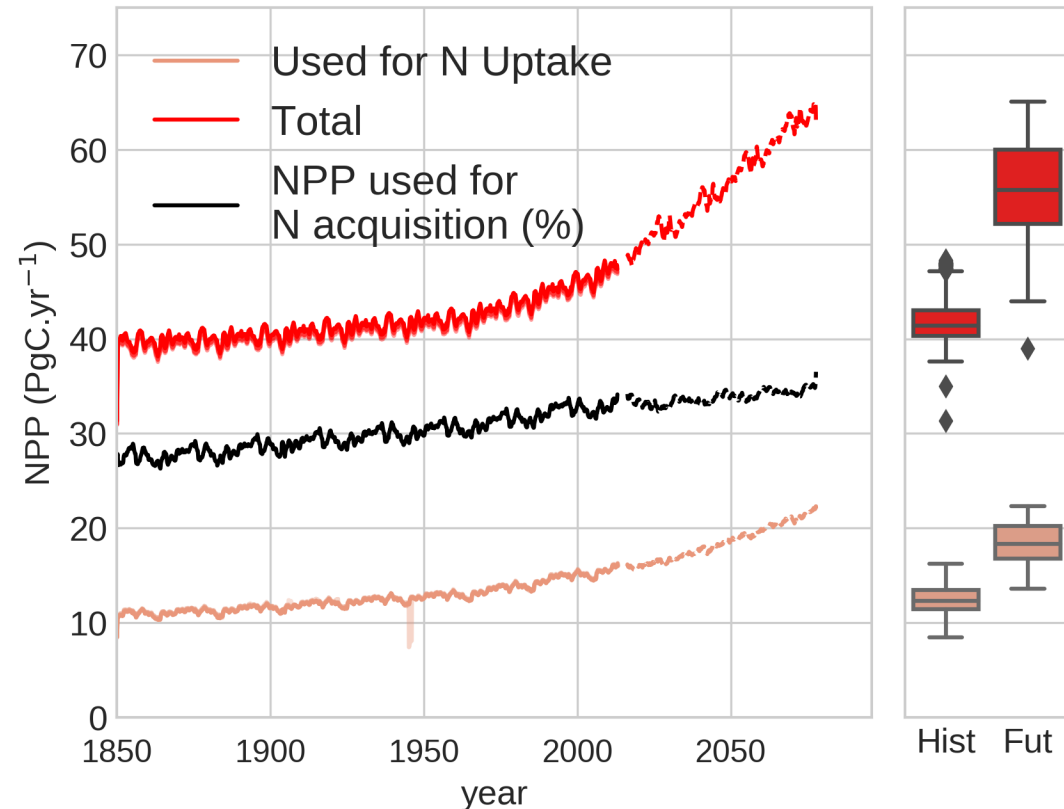
Name of the PFTs	AM (%)	ECM (%)
Bare soil (not vegetated)	0	100
Needleleaf evergreen temperate tree	0	100
Needleleaf evergreen boreal tree	0	100
Needleleaf deciduous boreal tree	0	100
Broadleaf evergreen tropical tree	100	0
Broadleaf evergreen temperate tree	100	0
Broadleaf deciduous tropical tree	100	0
Broadleaf deciduous temperate tree	50	50
Broadleaf deciduous boreal tree	0	100
Broadleaf evergreen shrub	0	100
Broadleaf deciduous temperate shrub	0	100
Broadleaf deciduous boreal shrub	0	100
C3 arctic grass	0	100
C3 nonarctic grass	100	0
C4 grass	100	0
Corn	100	0
Wheat	100	0



Braghiere *et al.*, in review.

# Has the **C cost** associated with global **N acquisition** been changing with time?

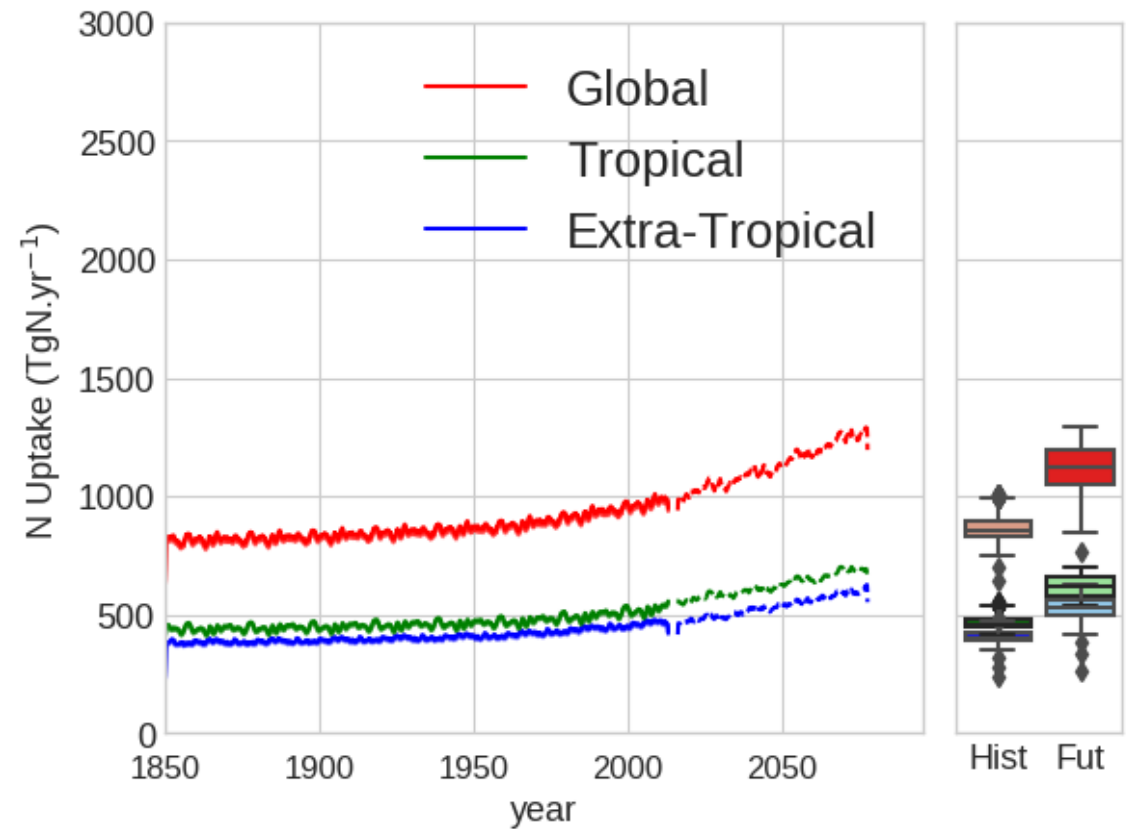
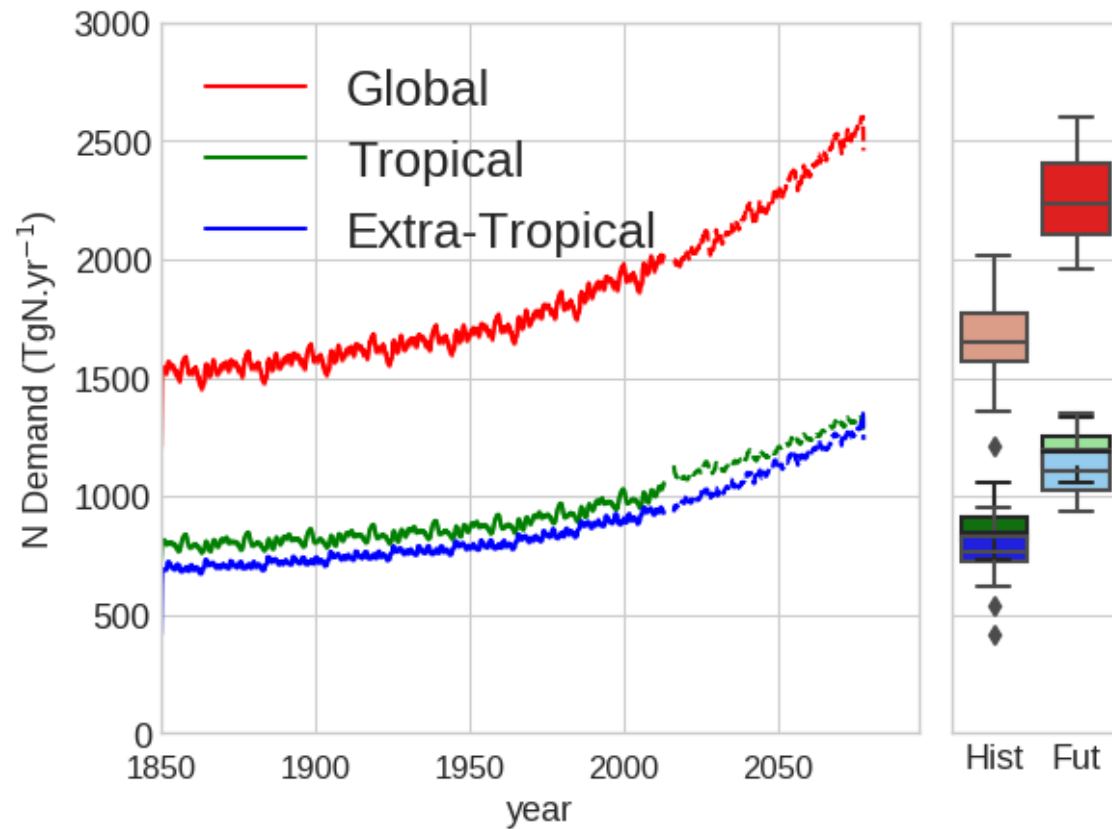
- CLM5-BGC (1.9x2.5):
  - Historical 1850 – 2010:
    - GSWP3 climate,
    - N deposition, and
    - variable atmospheric CO<sub>2</sub>;
  - SSP585 2015 – 2075:
    - SSP5-RCP8.5: extreme fossil fuel use,
    - CESM CMIP6 forcing.







# Will natural ecosystems run out of **N** in the future?

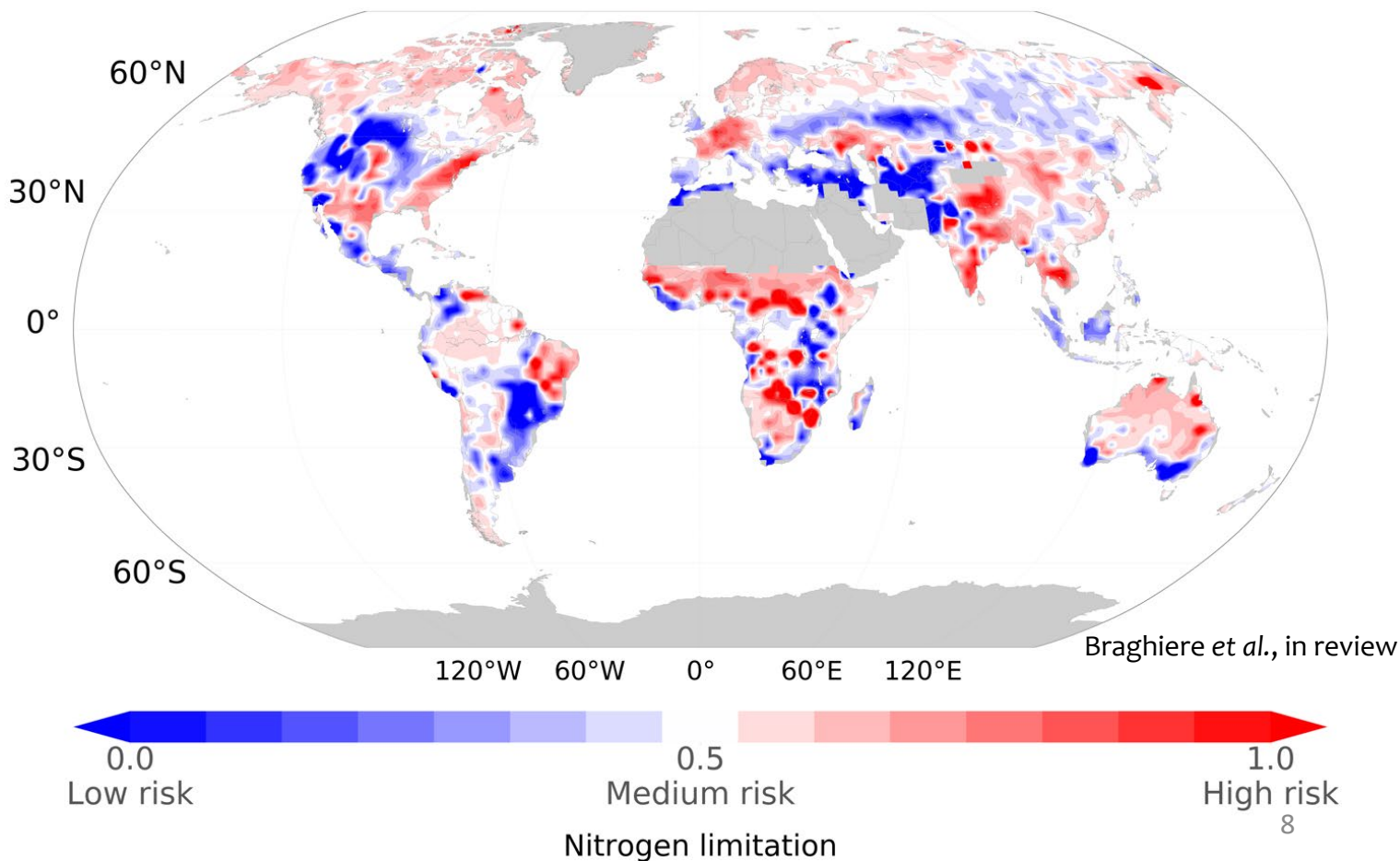
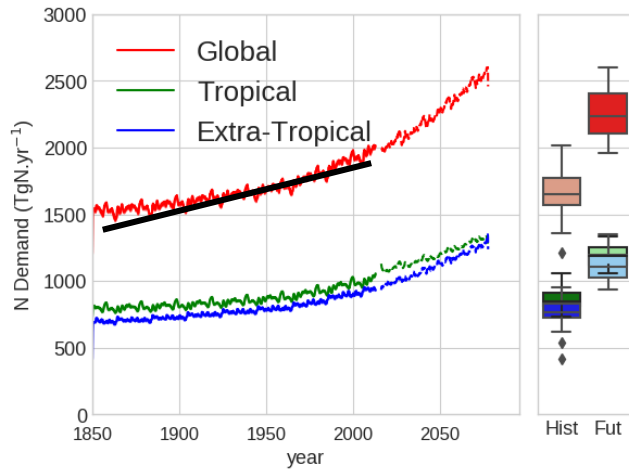
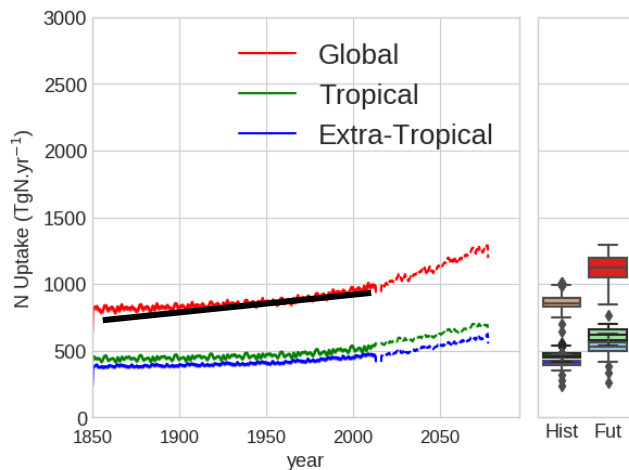


Braghiere et al., in review.



# Risk of Nitrogen limitation

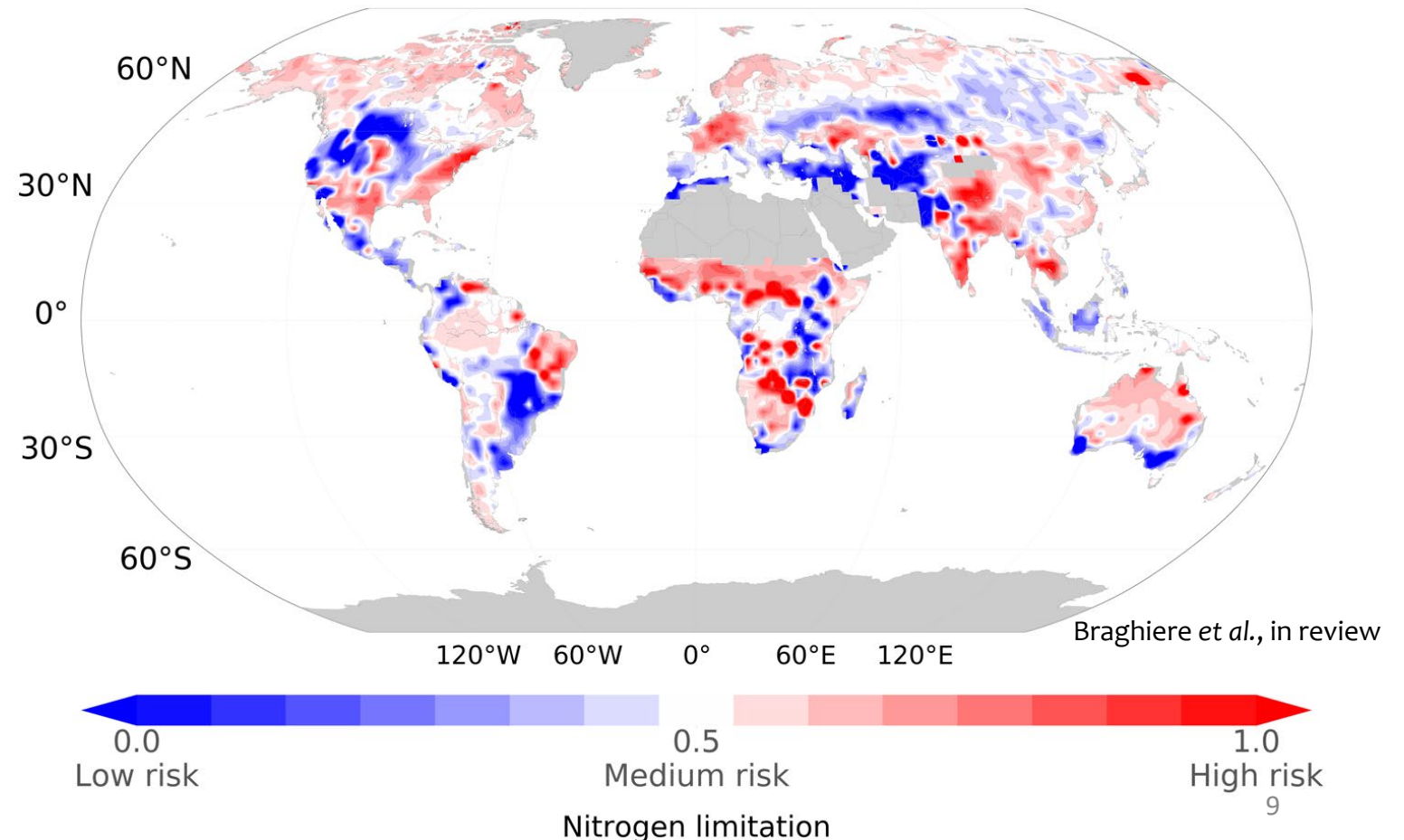
$$RNL = 1. - \frac{\alpha_1(i,j)}{\alpha_2(i,j)}$$





## Risk of Nitrogen limitation

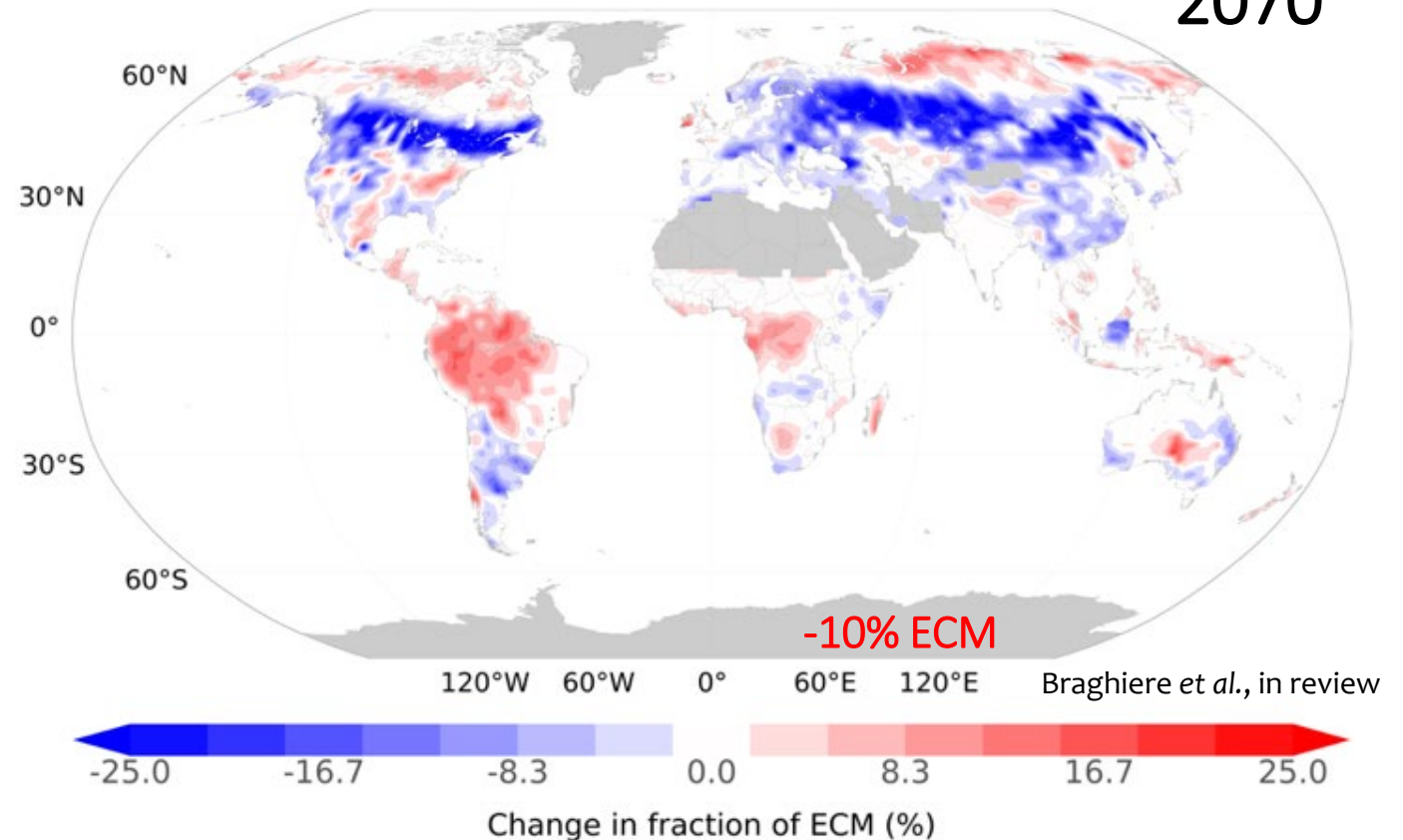
- Areas of **savannas** and **forest-grasslands** transition zones present a **higher risk of N limitation** to plant growth, which aligns with values of **N-fixation peaking** (Pellegrini et al. *Ecology* 2016)



# Will climate change impact the CO<sub>2</sub> fertilization effect via spatial changes in mycorrhizal association?

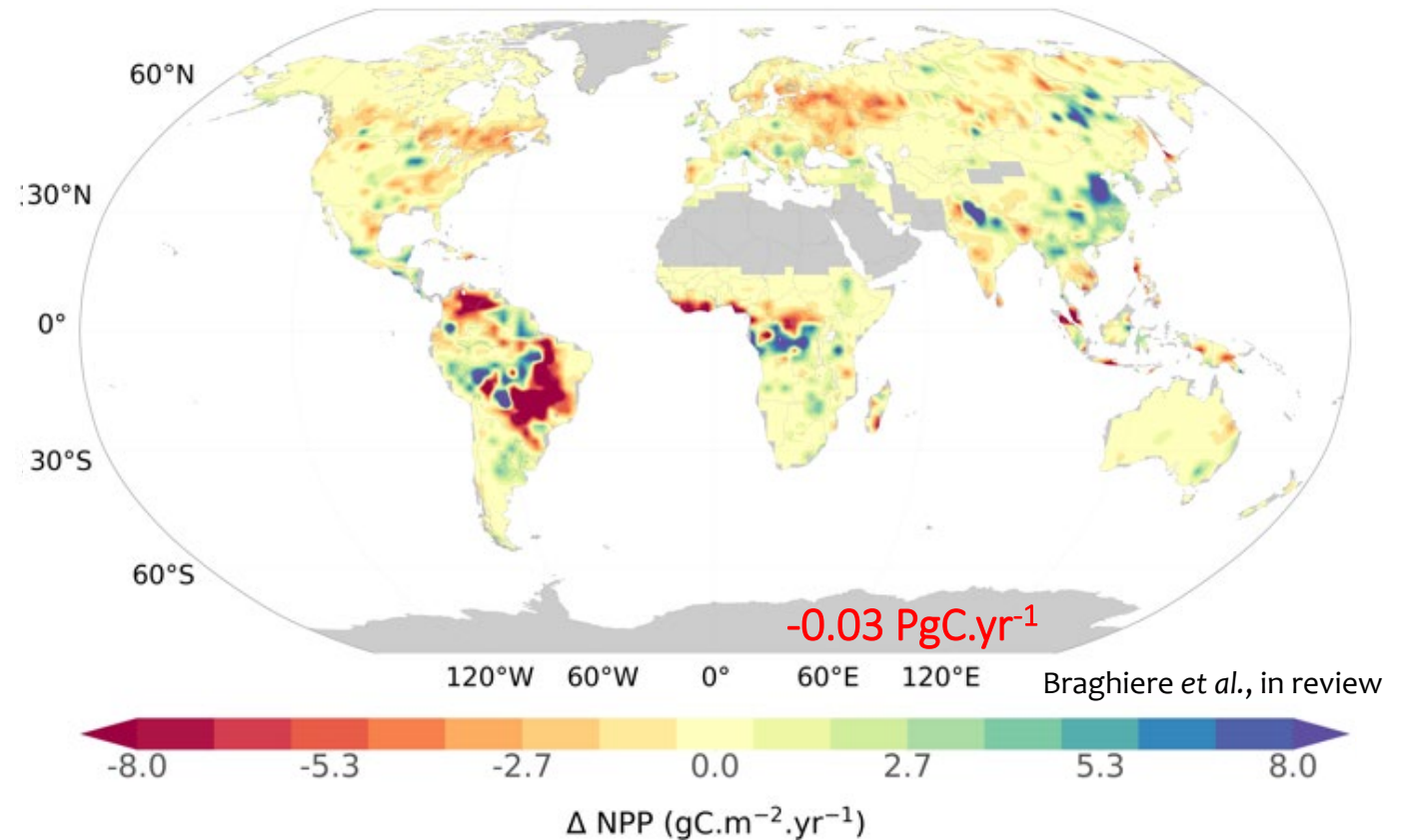
2070

- CLM5-BGC (1.9x2.5):
  - SSP585 2015 – 2075:
    - SSP5-RCP8.5,
    - CESM CMIP6 forcing,
    - **Present day** Mycorrhizal map;
  - SSP585 2015 – 2075:
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    - CESM CMIP6 forcing,
    - **2070 projection** Mycorrhizal map (Steidinger et al., *Nature* 2019).



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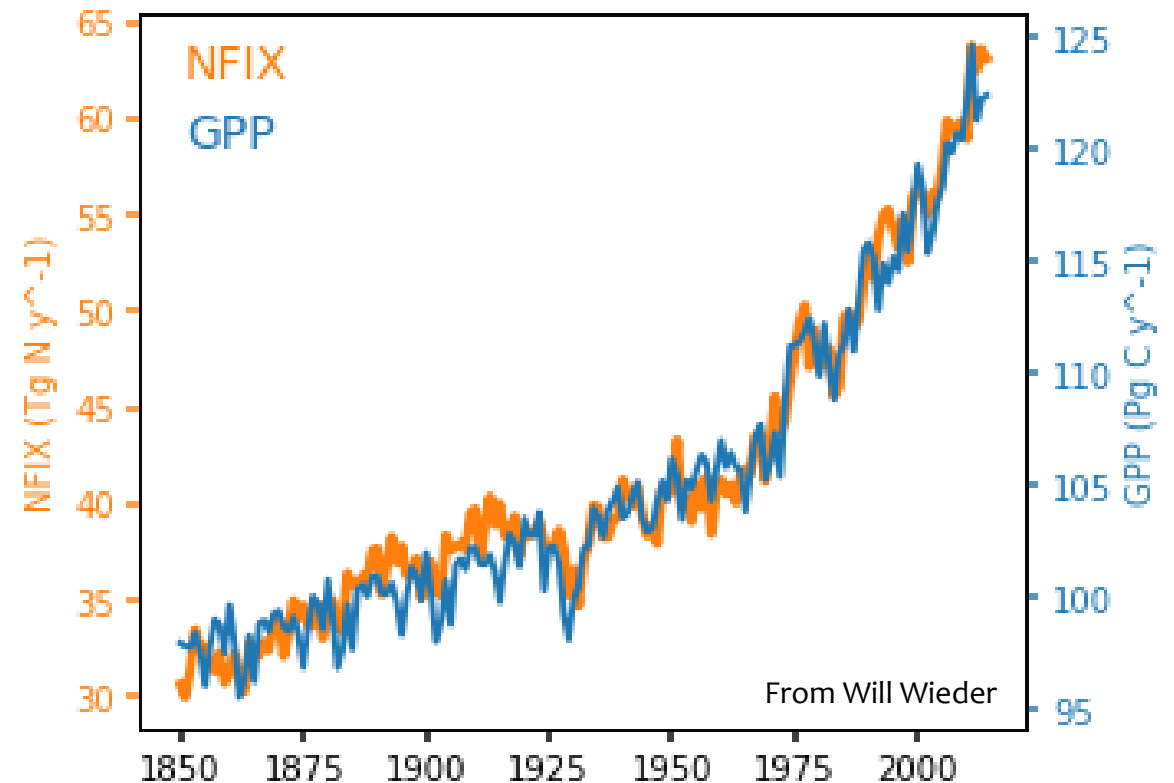






# Will **climate change** impact the CO<sub>2</sub> fertilization effect via spatial changes in **mycorrhizal association**?

- While **future** changes in NPP due to spatial shifts in mycorrhizal association seem negligible...
  - **N fixation** (NFIX) follows GPP in CLM5-FUN and potentially **alleviates** future **N limitation**;
  - Changes in future **flexible stoichiometry** are not taken into account;
  - The addition of **P dynamics** may increase these changes.





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