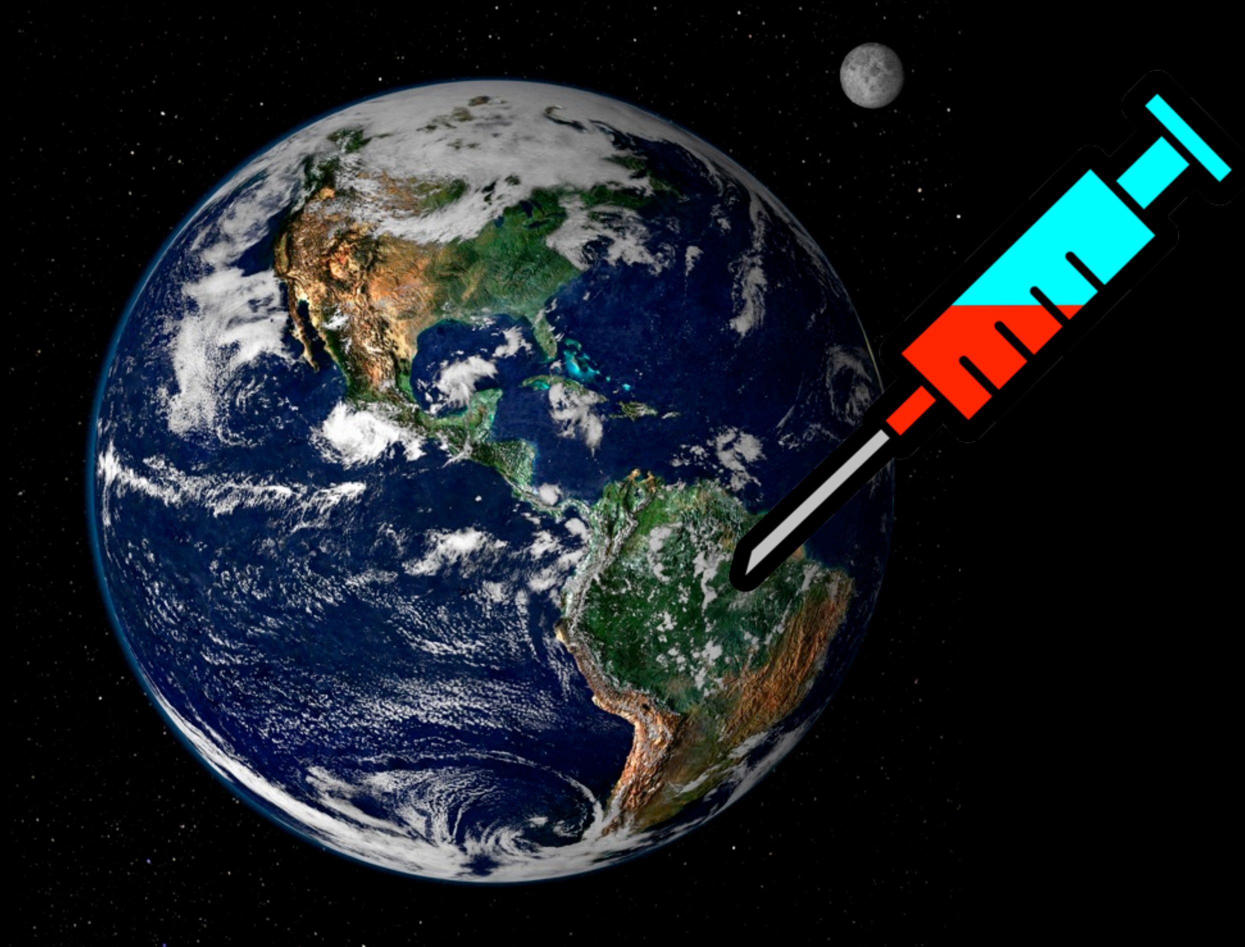
# Juicing the terrestrial C cycle

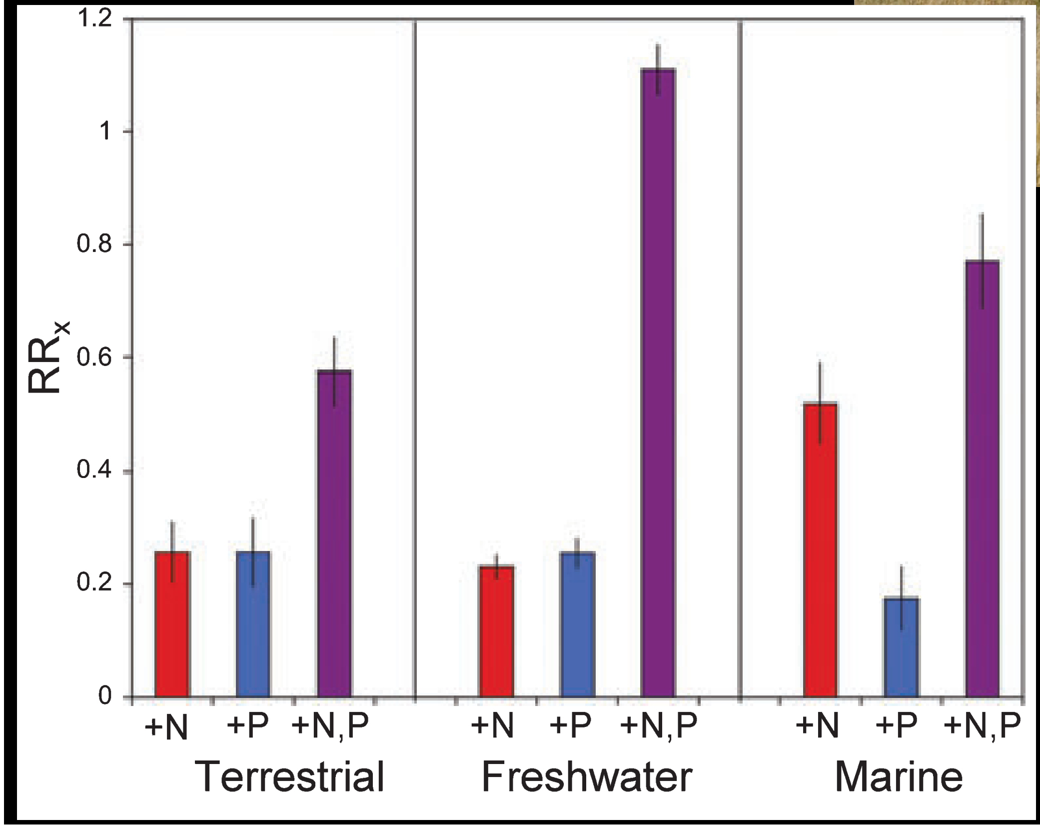


Will Wieder, Cory Cleveland,
Bill Smith, Kathe Todd-Brown

What happens if MORE leaves fall on a WARMER planet?

# Observations & Agriculture

## N and P matter



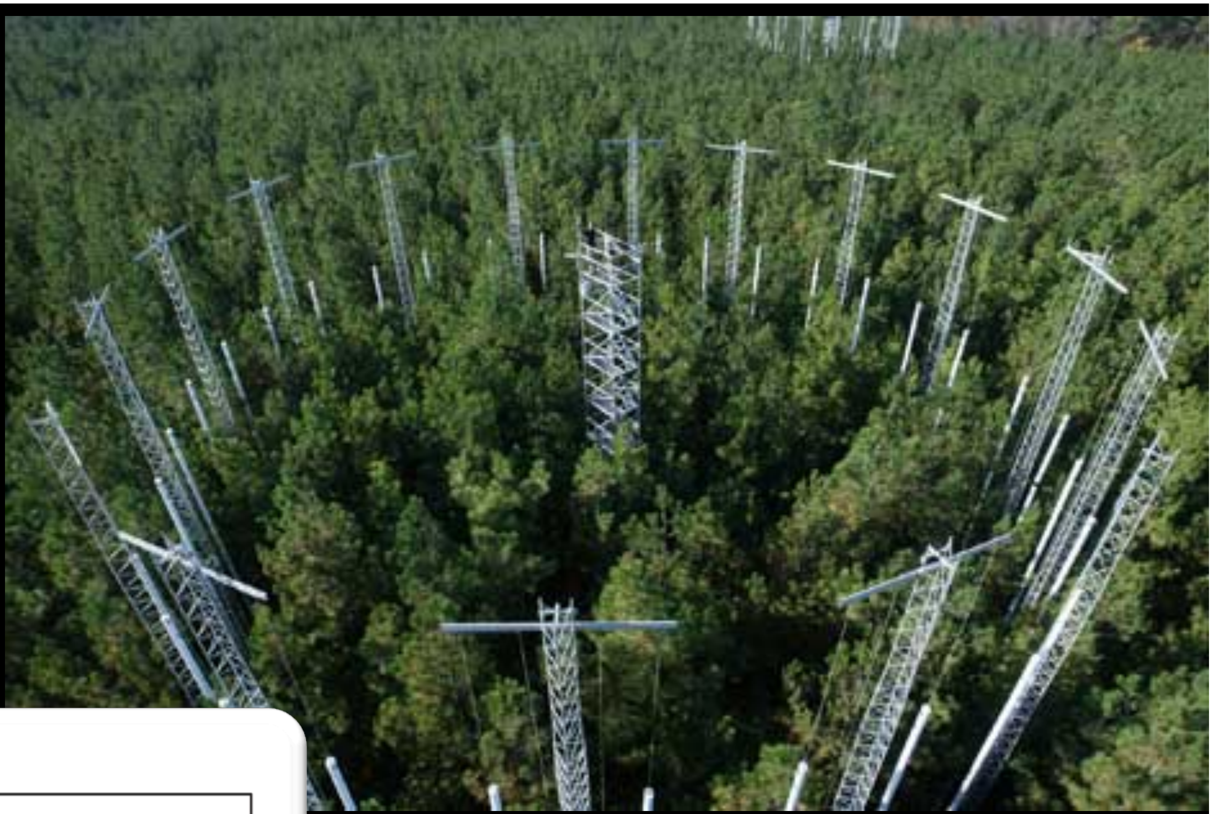

*Elser et al. 2007 *Eco. Letters*
Cleveland et al. 2011 *Eco. Letters*
Harpole et al. 2011 *Eco. Letters*

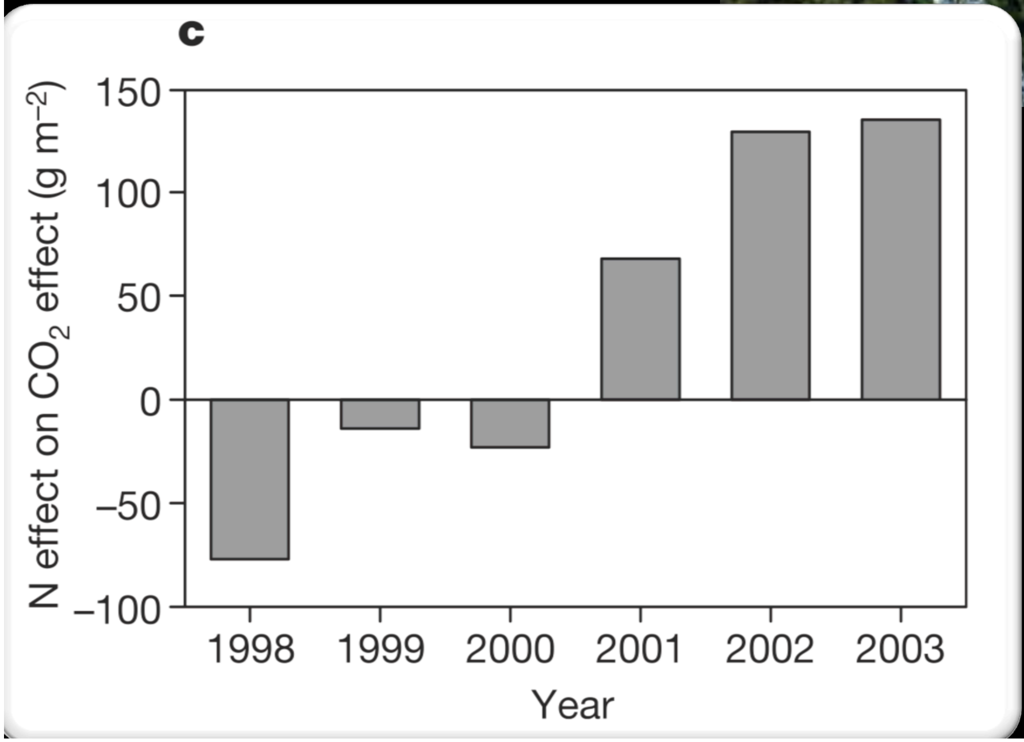
# Experiments

+ NPP …but…

≠ C storage

N matters






Norby & Zak 2012 *Ann. Rev.*

Finzi et al. 2007 *PNAS*.

Norby et al. 2010 *PNAS*

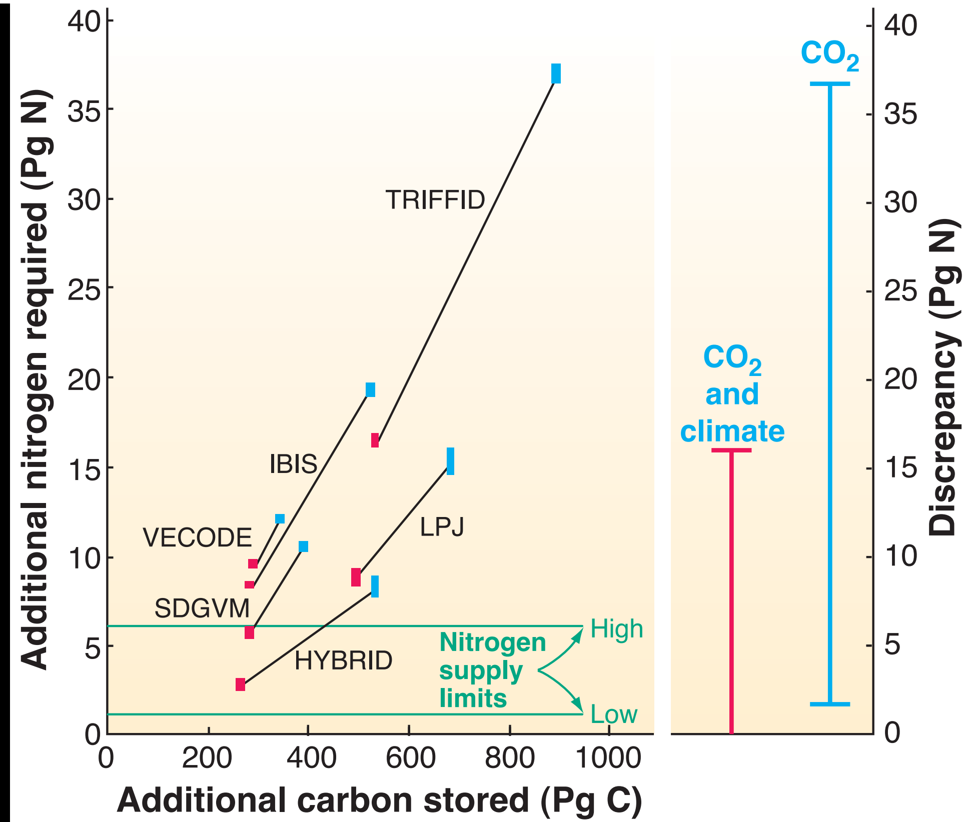
Hungate et al. 2009 *GCB*

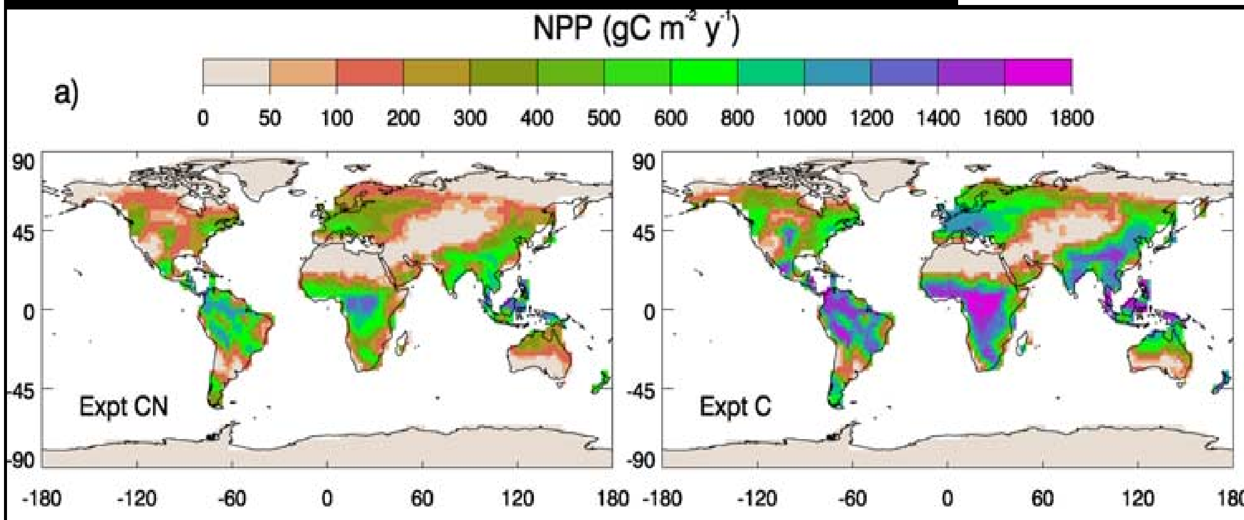
*Reich et al. 2006 *Nature*

# Theory & models

## N and P matter

(Constrain $CO_2$ fertilization effects)



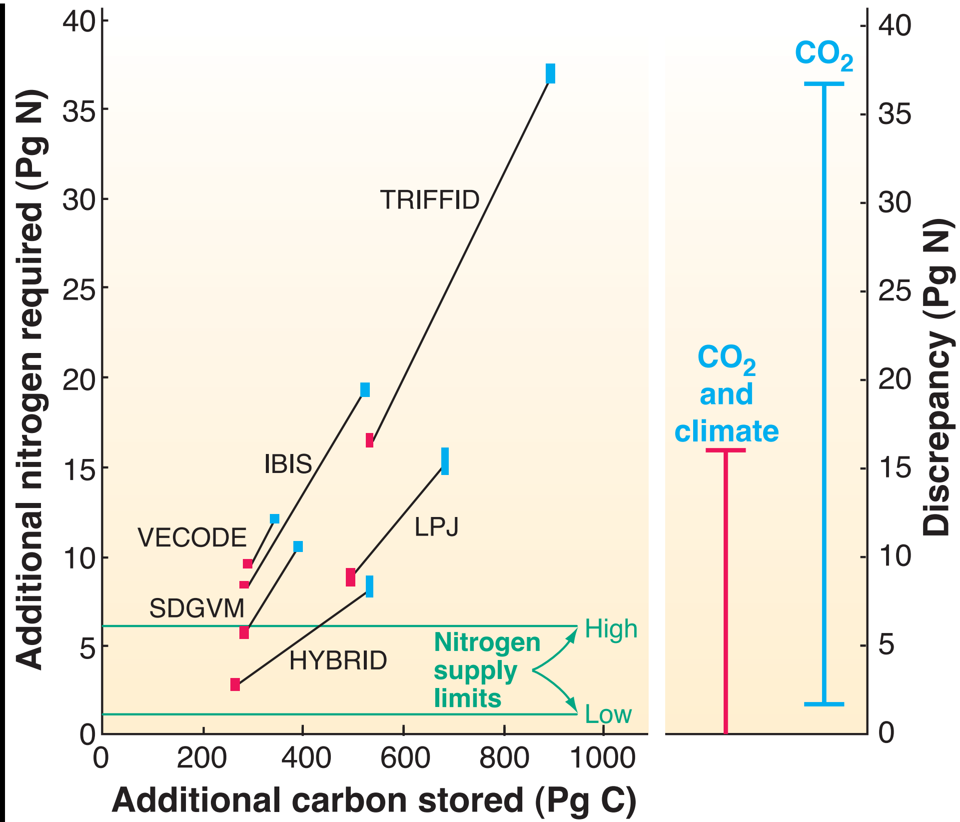




*Hungate et al. 2003 *Science*
Wang & Houlton 2009 GRL
Peñuelas et al. *Nat. Comm*. 2013

*Thorton et al. 2007 *GBC*
Wang et al. 2010 *Biogeosciences*
Gerber et al. 2010 *GBC*
Zaehle et al. 2010 *GRL*
Zhang et al. 2013 *GRL*

# Theory & models

- N effects on C storage
- Single NP model
- Soil C-N ≠ C-P



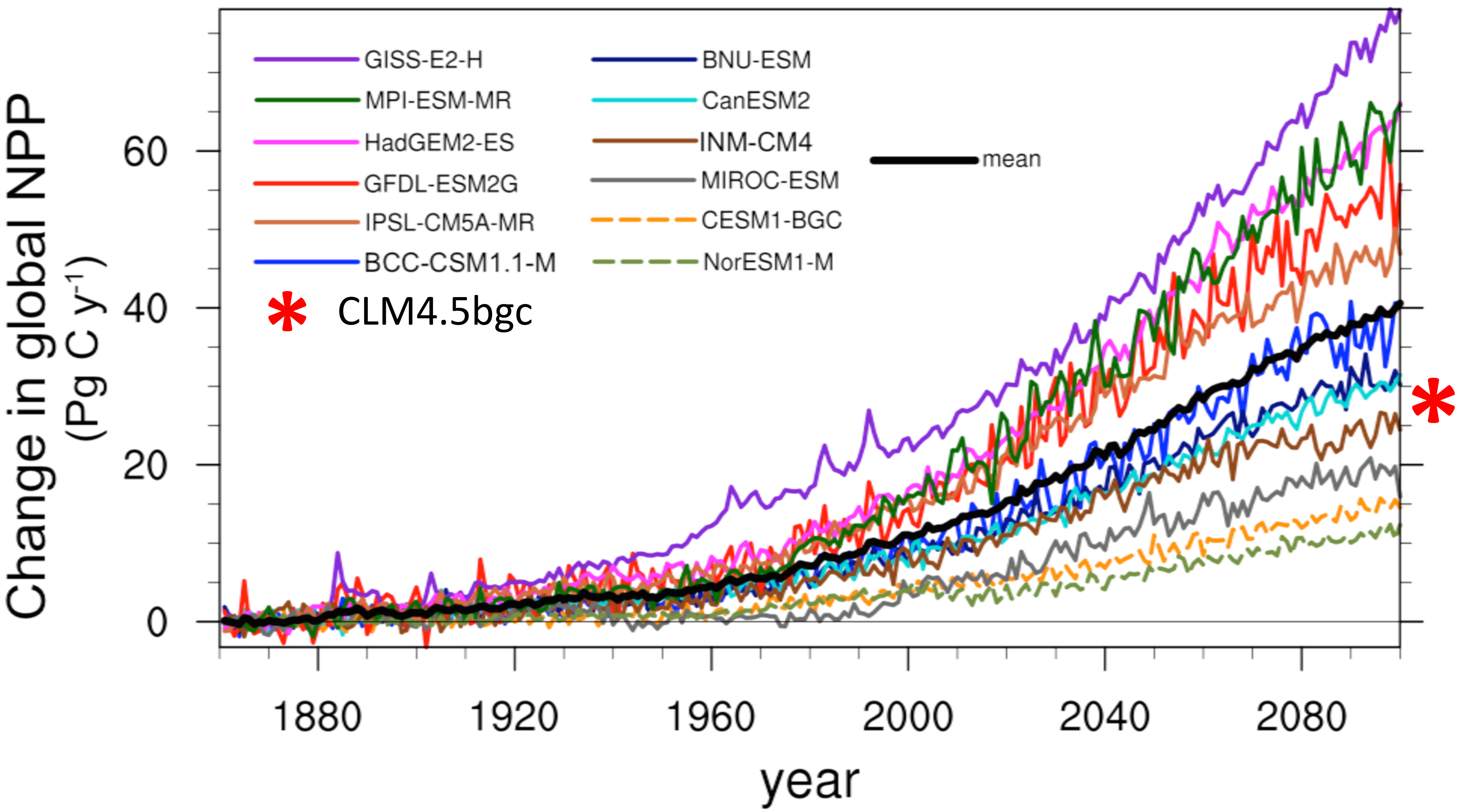

How may consideration of *P* dynamics inform global *NPP* projections?

*Hungate et al. 2003 *Science*
Wang & Houlton 2009 GRL
Peñuelas et al. *Nat. Comm*. 2013

Wang et al. 2010 *Biogeosciences*

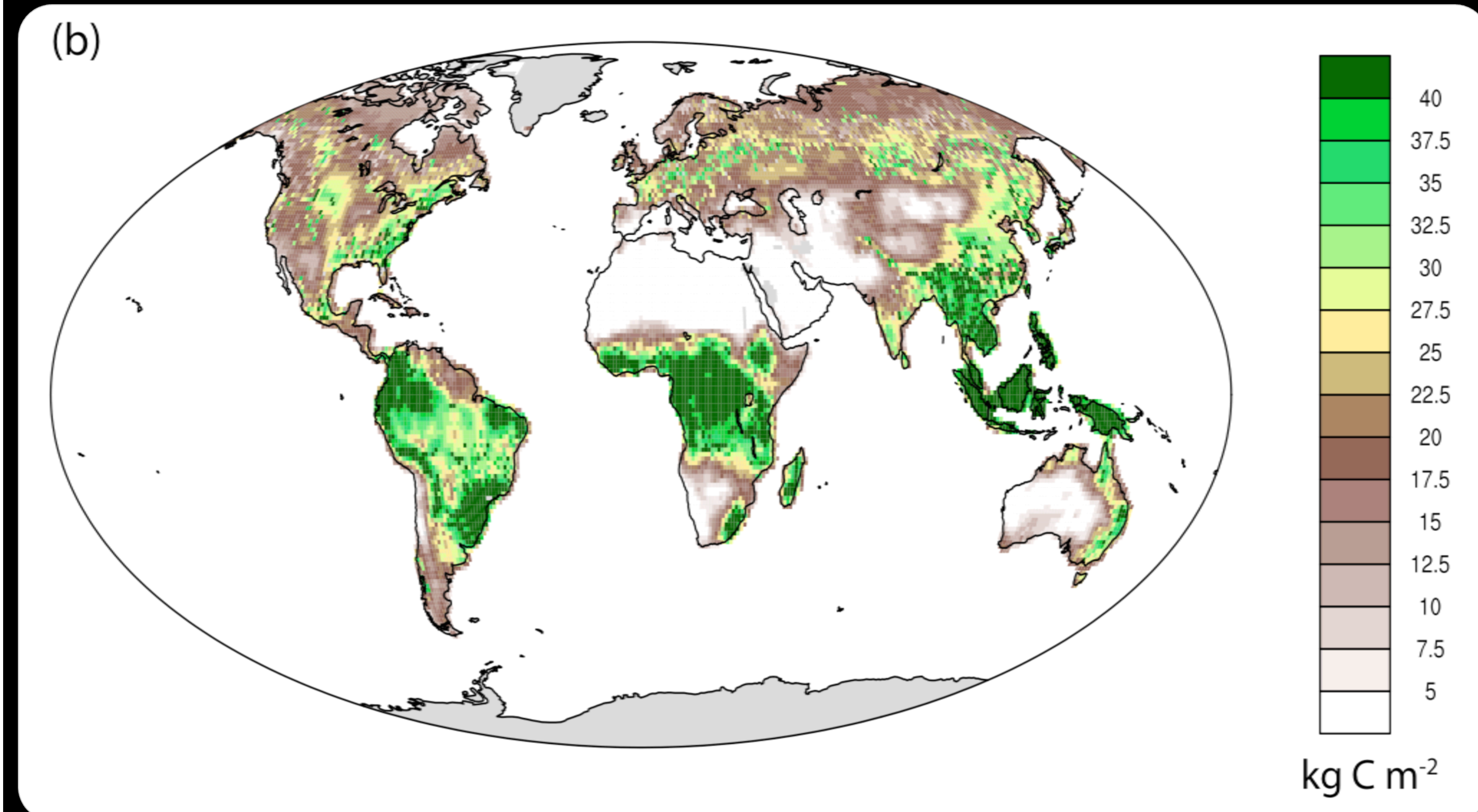
Zhang et al. 2013 *GRL*

# CMIP5 Models (RCP8.5)

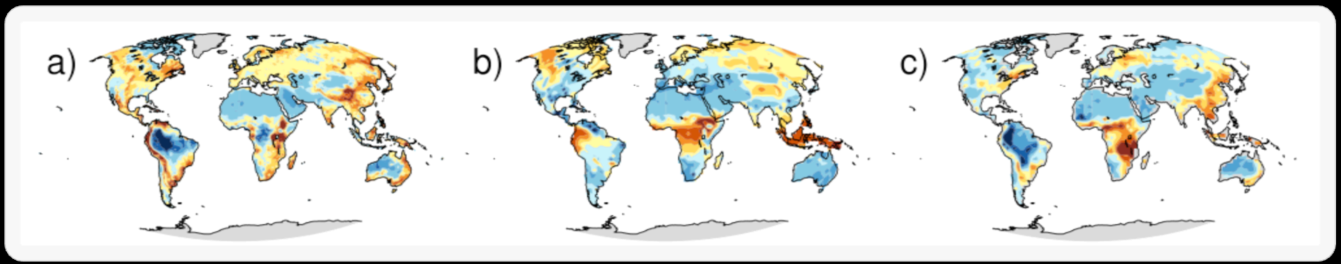


# Cumulative Land C inputs

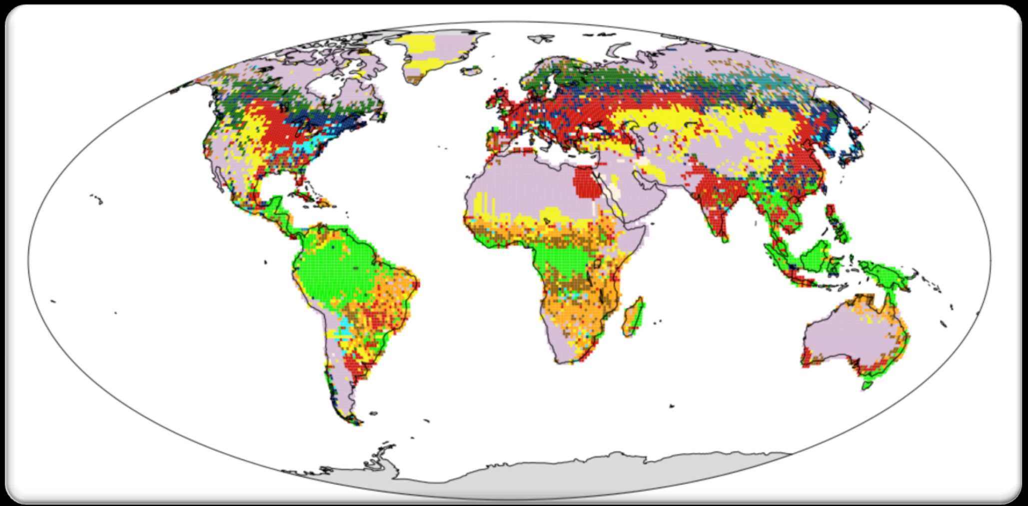
## ~3000 Pg C



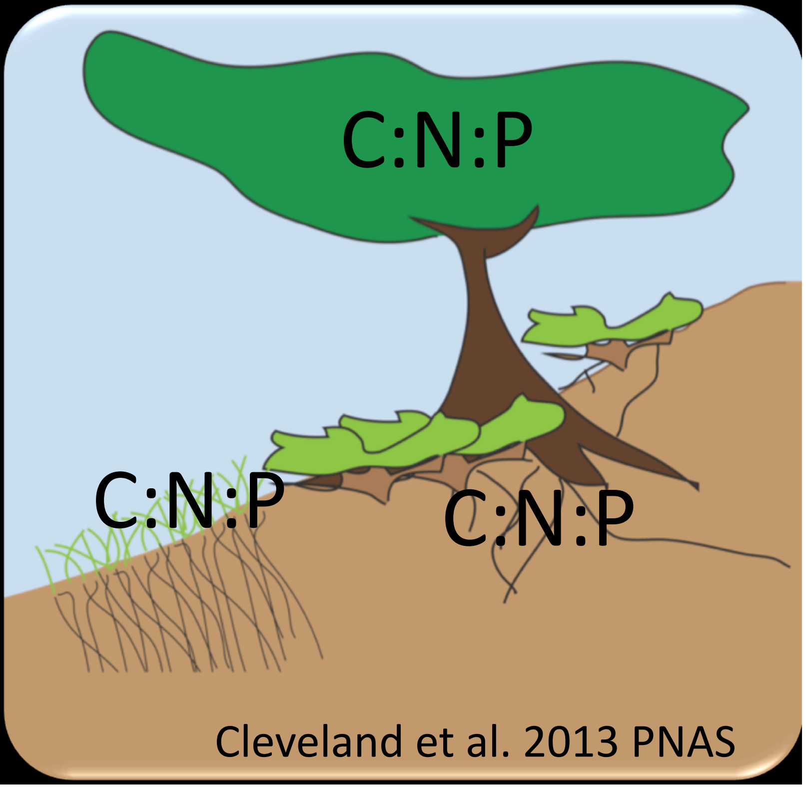
# NPP




## Biome

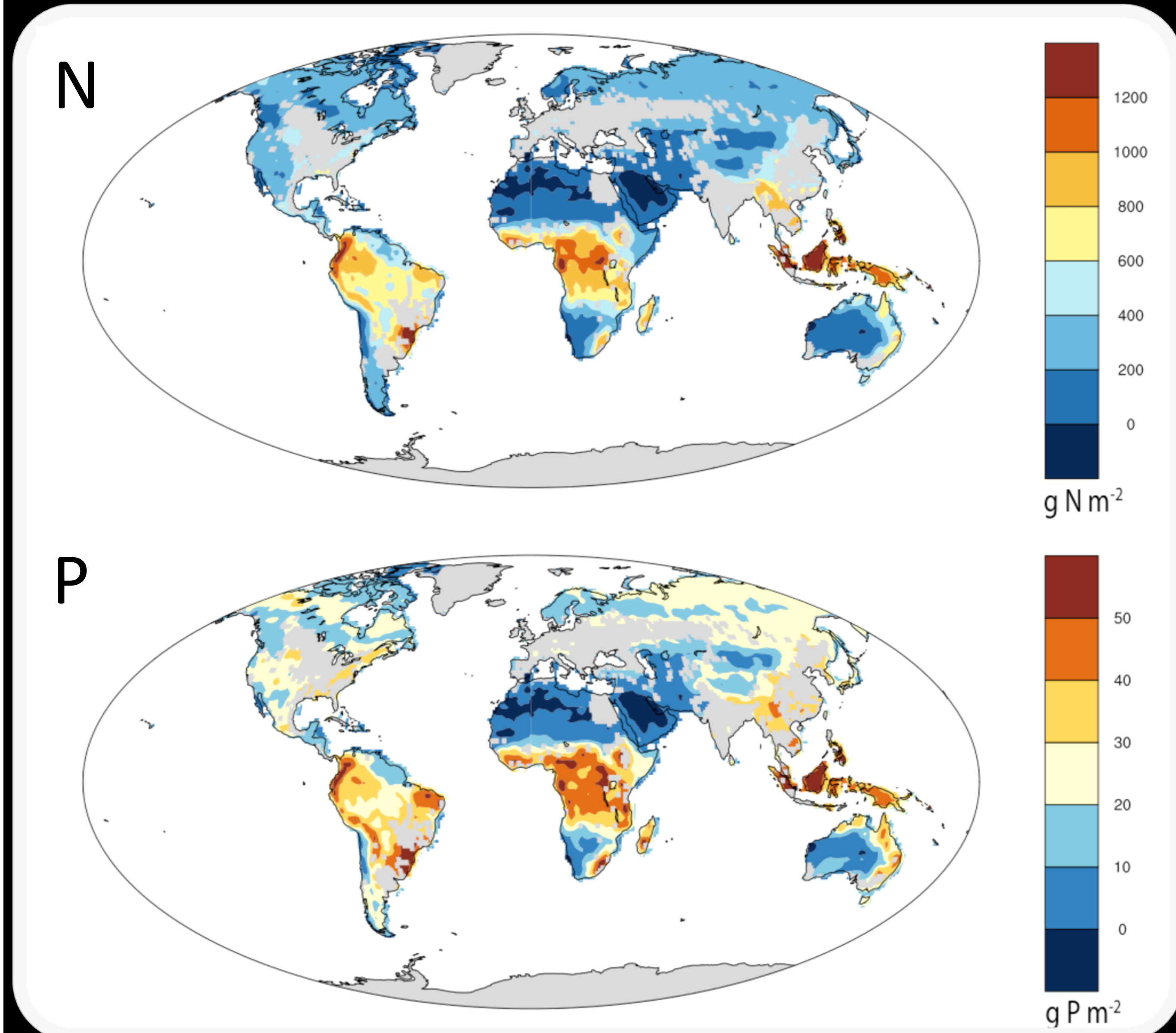


## Allocation & Stoichiometry




N & P Demand

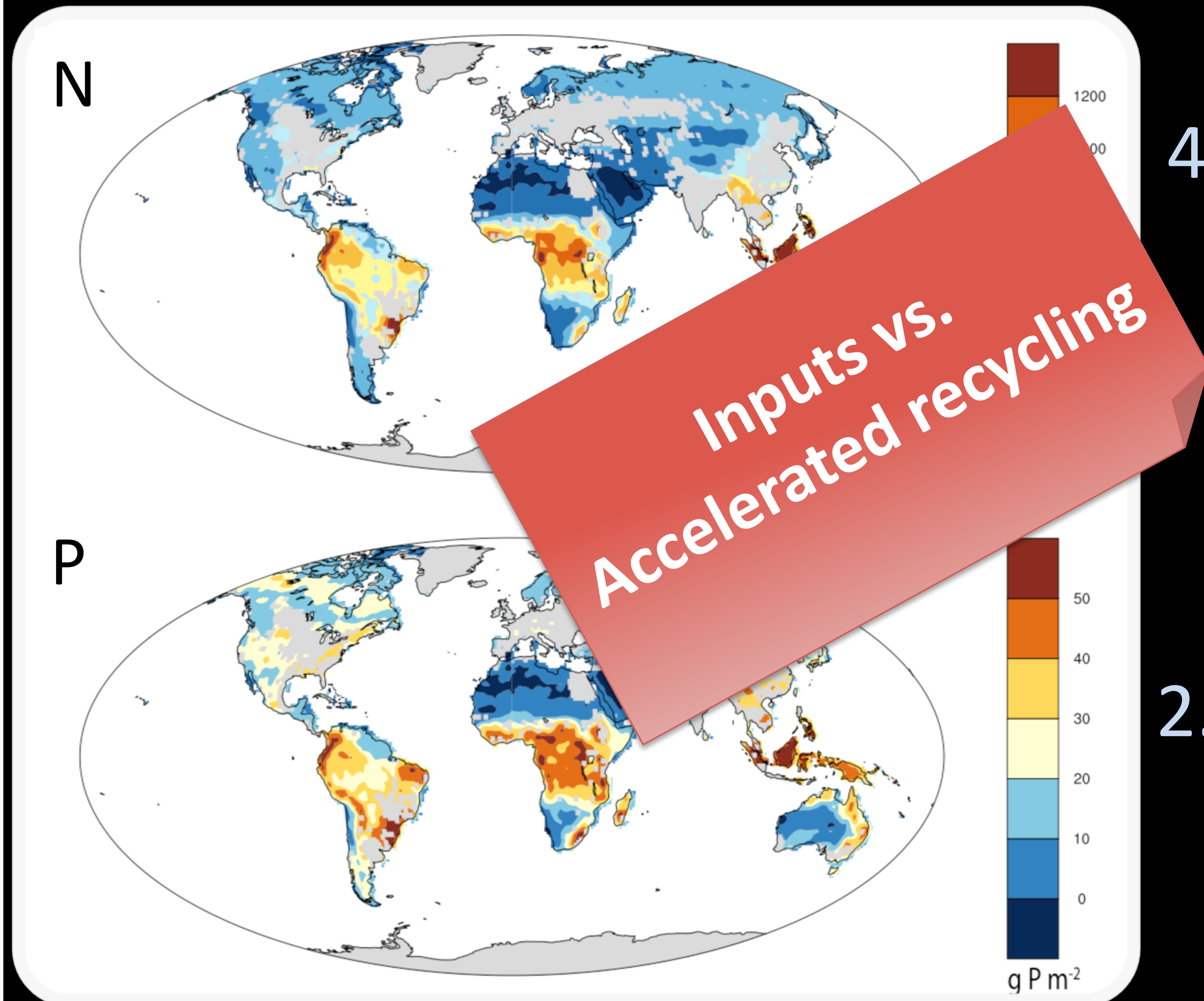
# "New" nutrient demand (1861-2099)




45 ± 24 Pg N

2.6 ± 1.4 Pg P

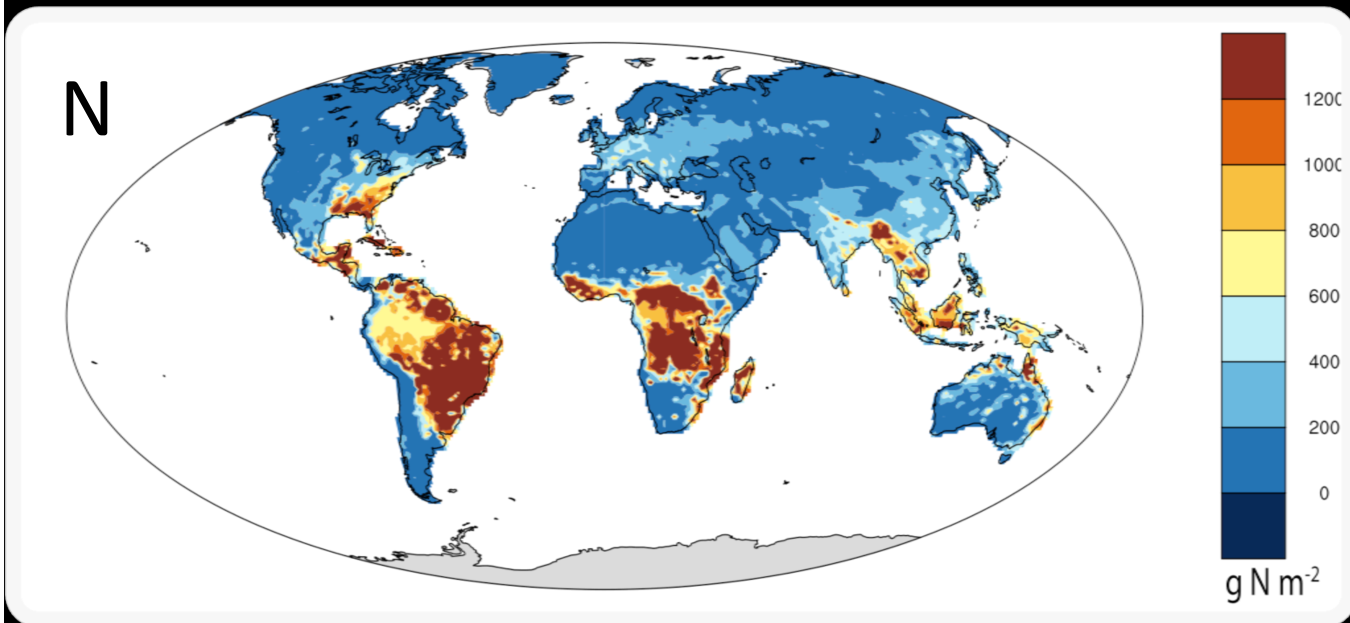
# “New” nutrient demand (1861-2099)




45 ± 24 Pg N

2.6 ± 1.4 Pg P

# Nutrient inputs (1861-2099)




56 Pg N

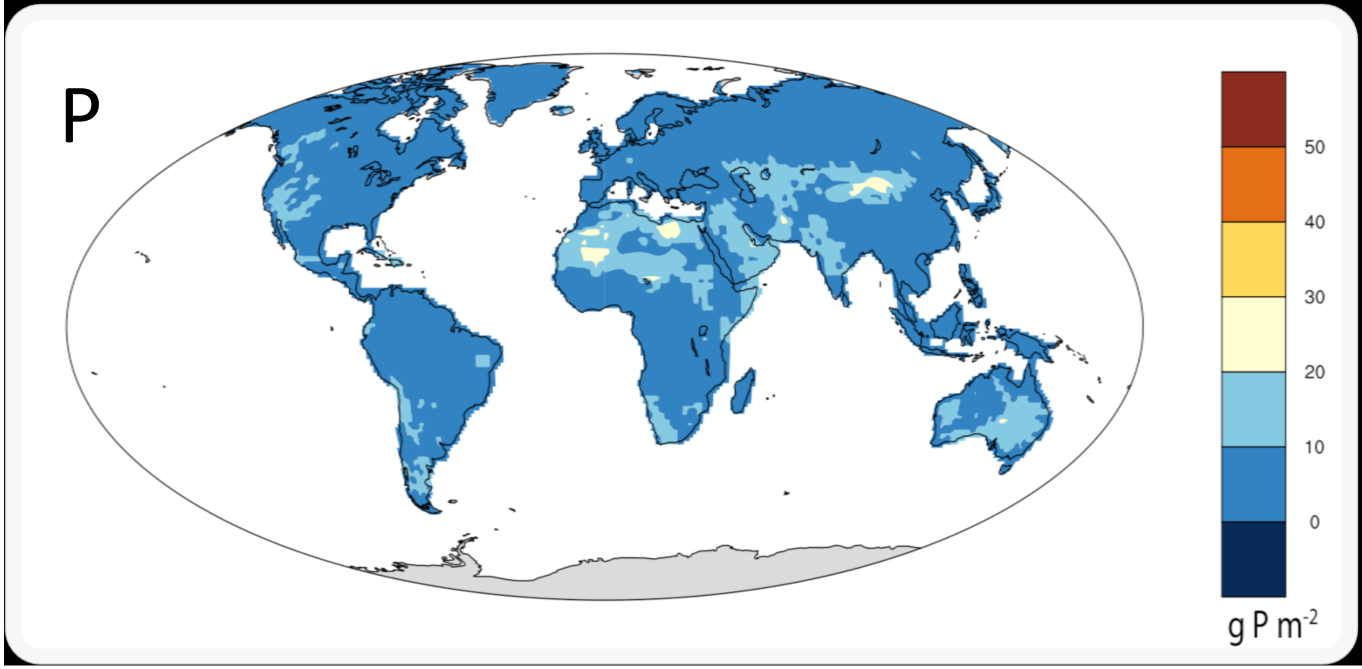
**<u>N Fixation</u>** Wang & Houlton 2009 GRL , Bai et al. 2012 BG

N Deposition Lamarque et al. 2011 Clim. Ch.; 2010 *Atmos. Chem. Phys.*

# Nutrient inputs (1861-2099)

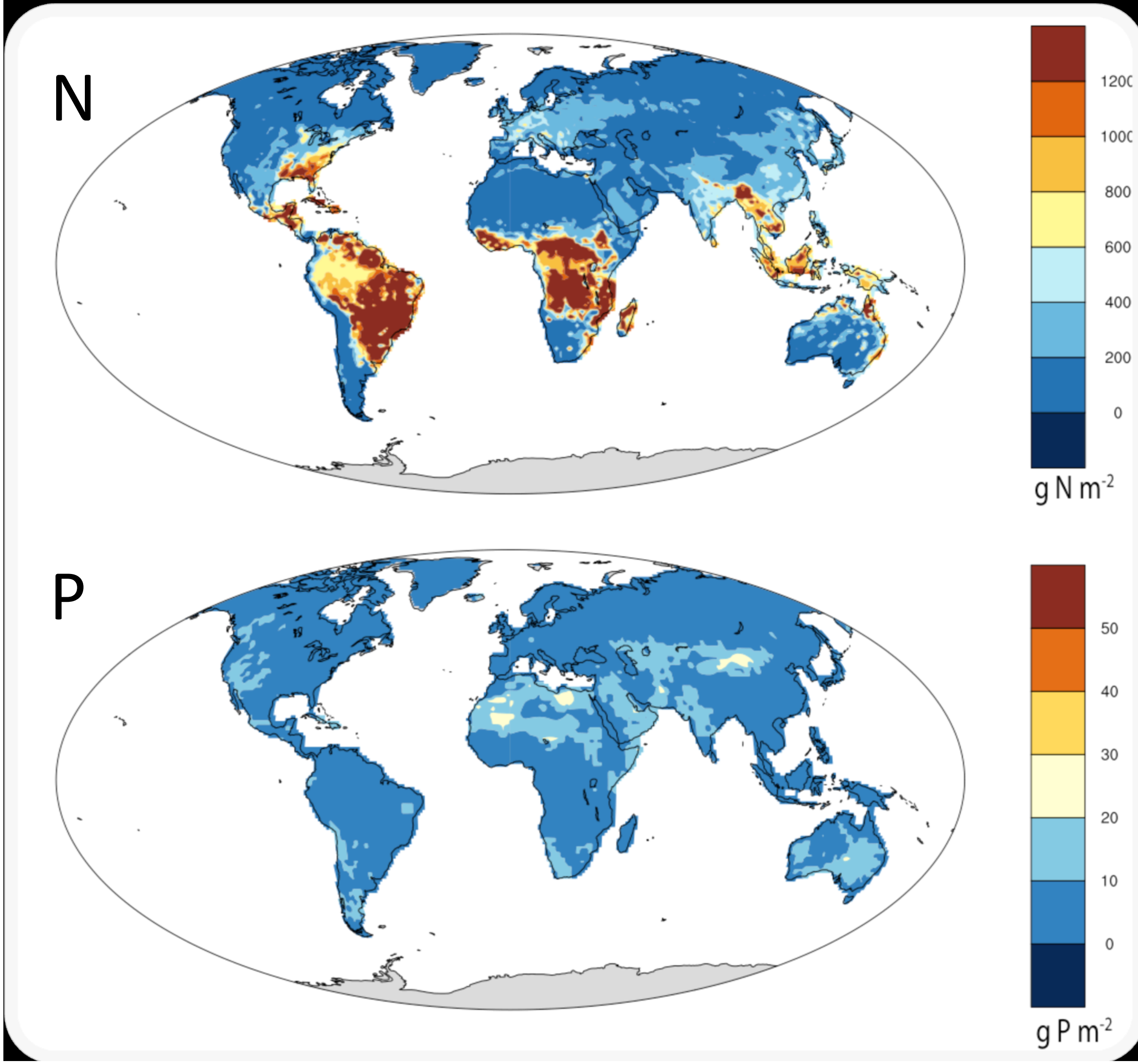
**P Weathering** Wang et al. 2010 BG

P Deposition Mahowald et al. 2008 GCB; Mahowald 2013 *Ecological Systems*




0.7 Pg P

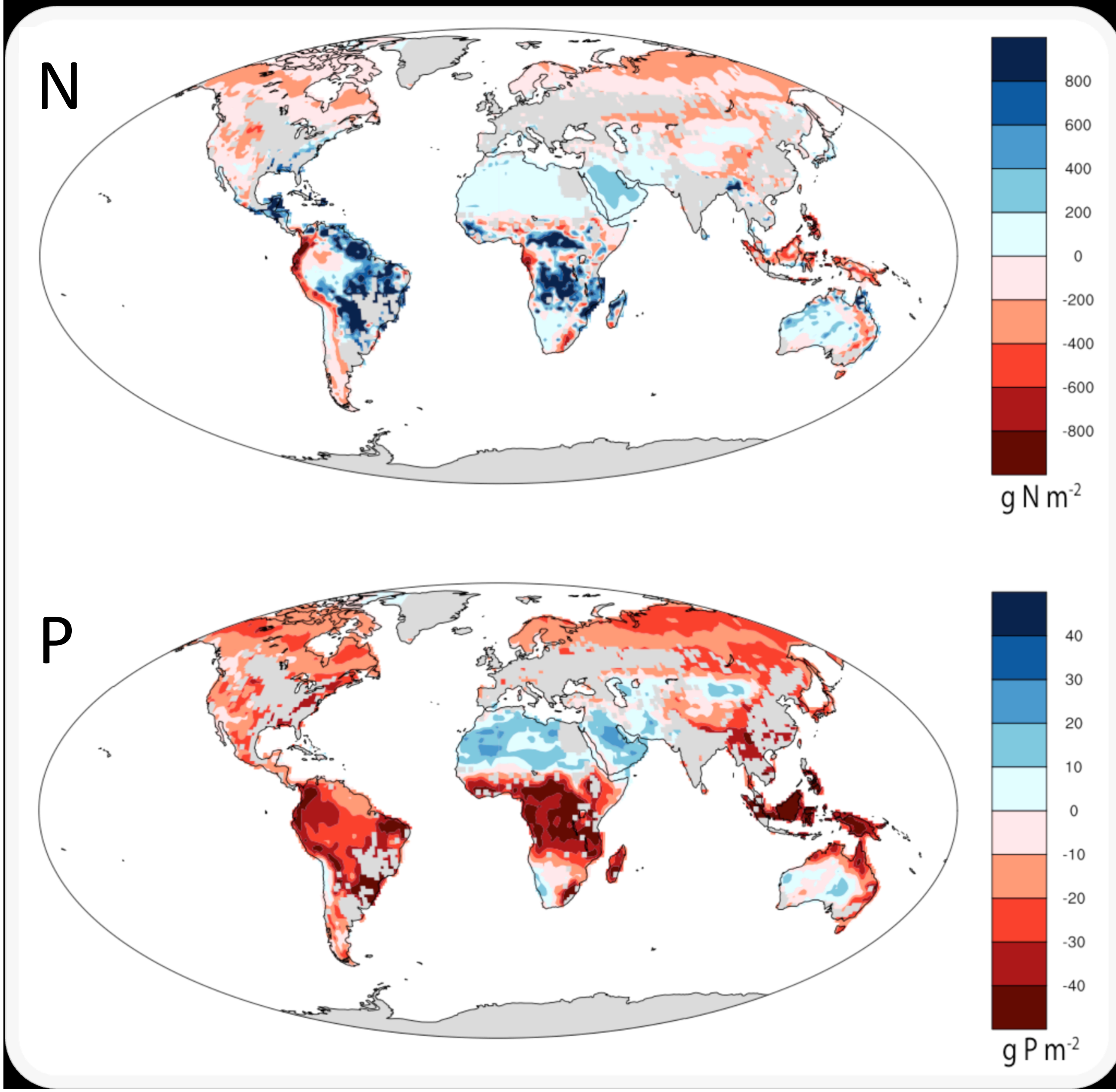
# Nutrient inputs (1861-2099)




56 Pg N

0.7 Pg P

# Demand – Inputs = Nutrient balance



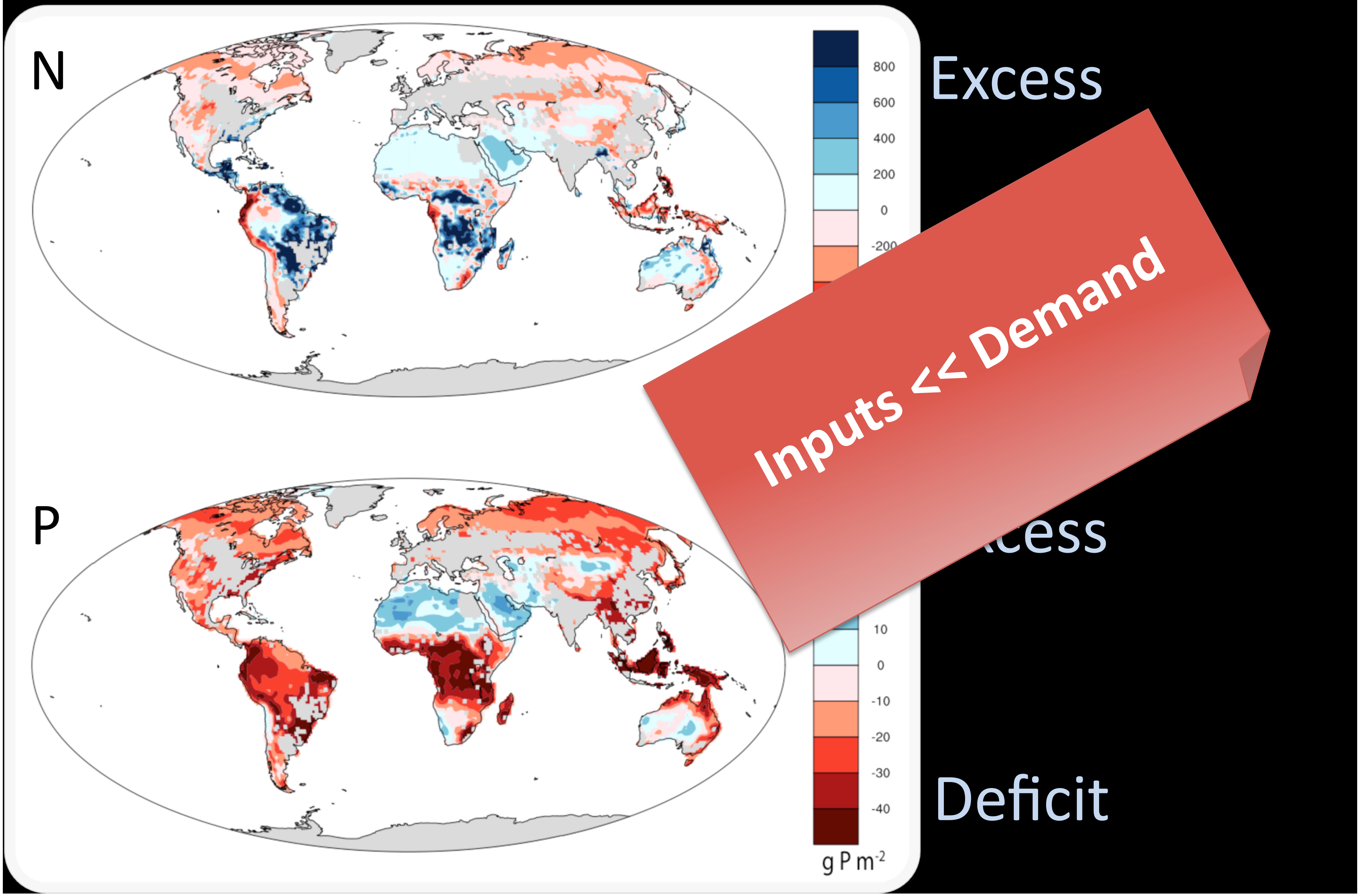

Excess

Deficit

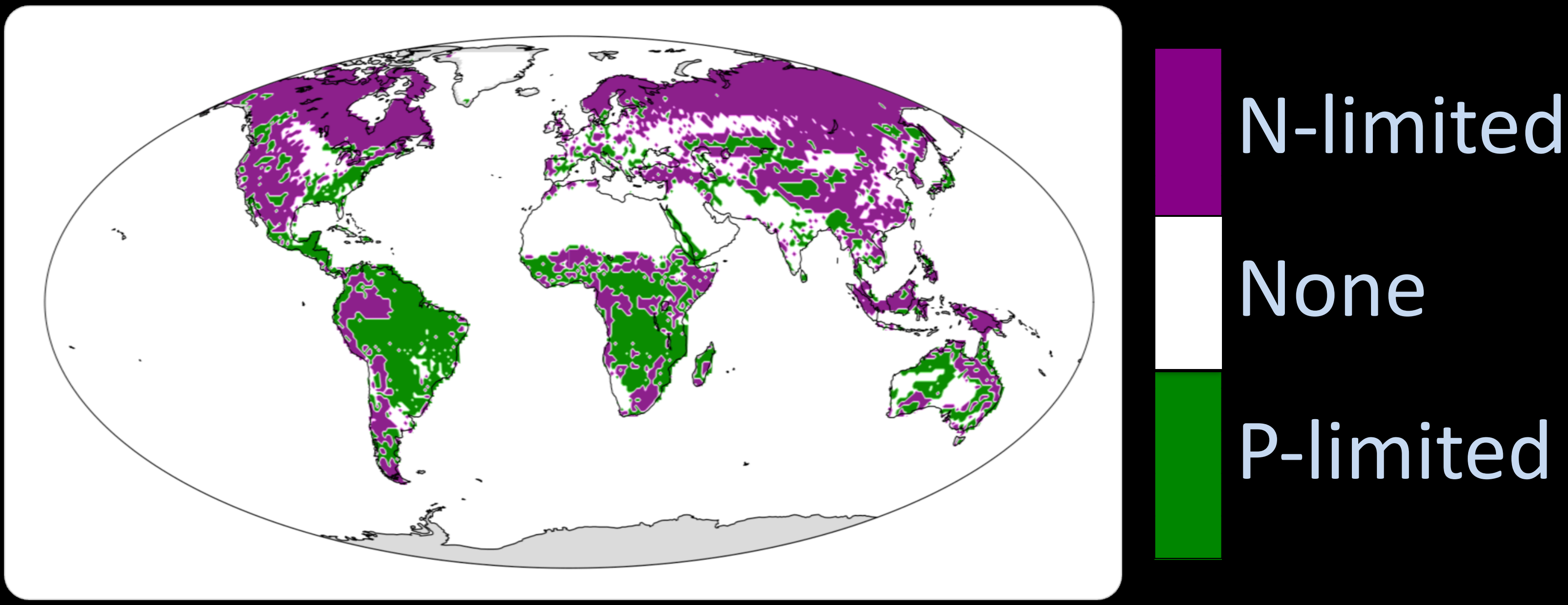
Excess

Deficit

# Demand – Inputs = Nutrient balance

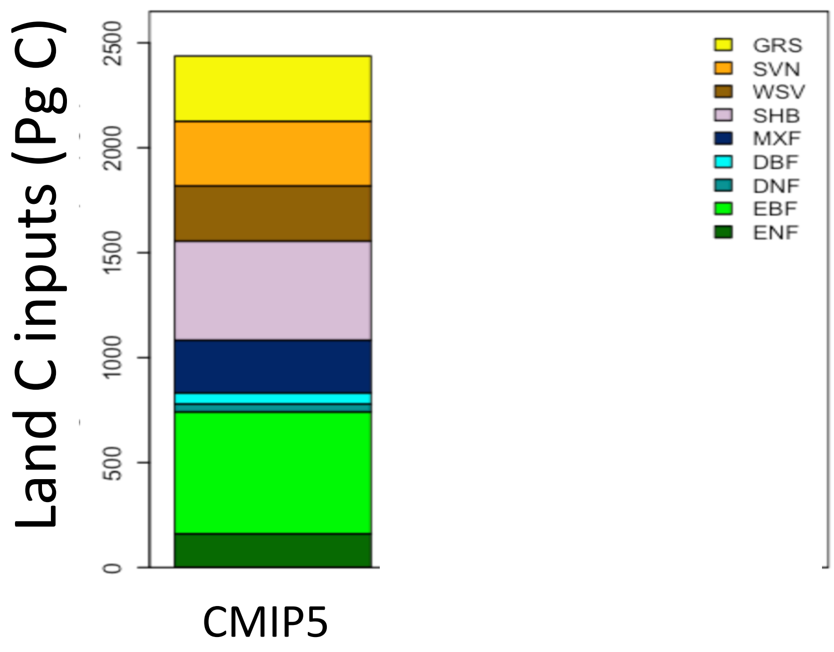


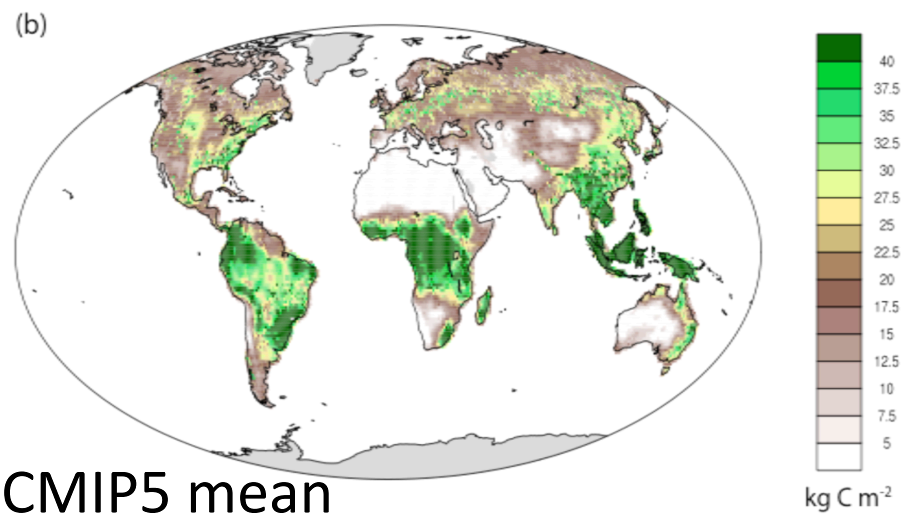
# Nutrient Limitation



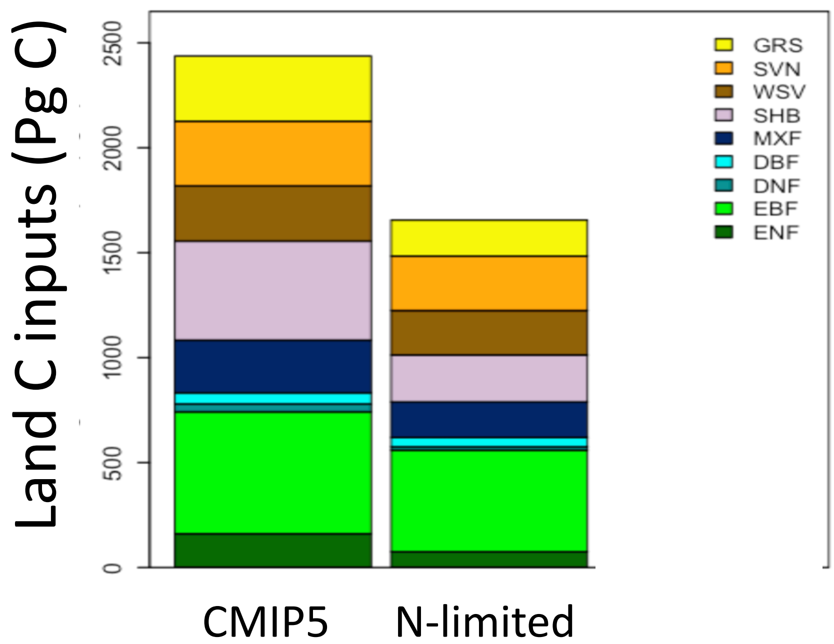

What are C consequences?

# Land C inputs



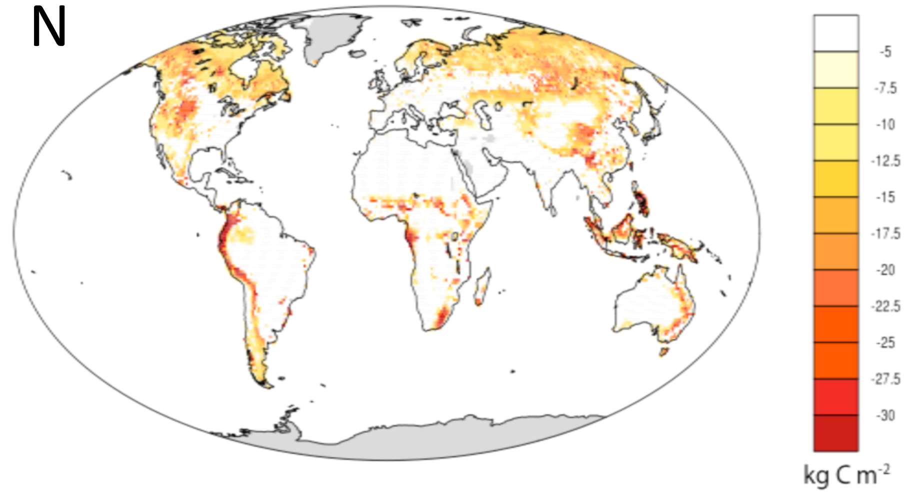



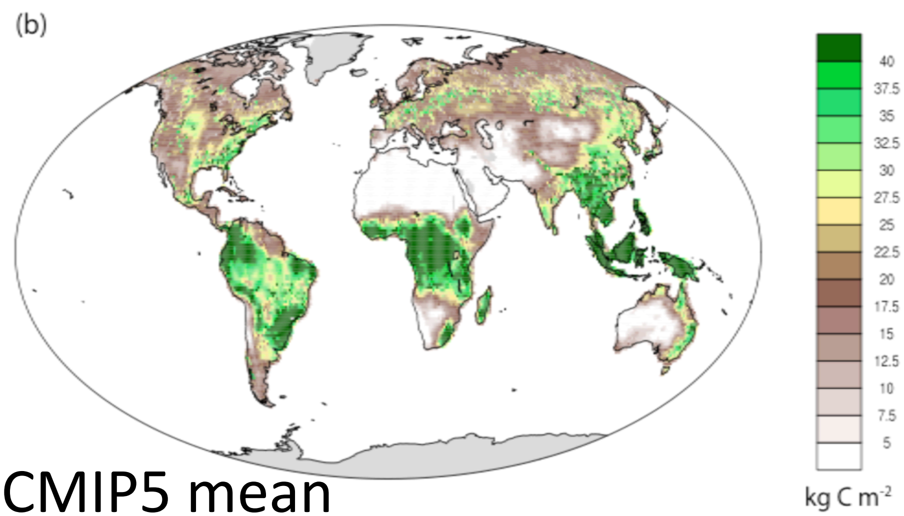
# Land C inputs




Reductions in land C inputs

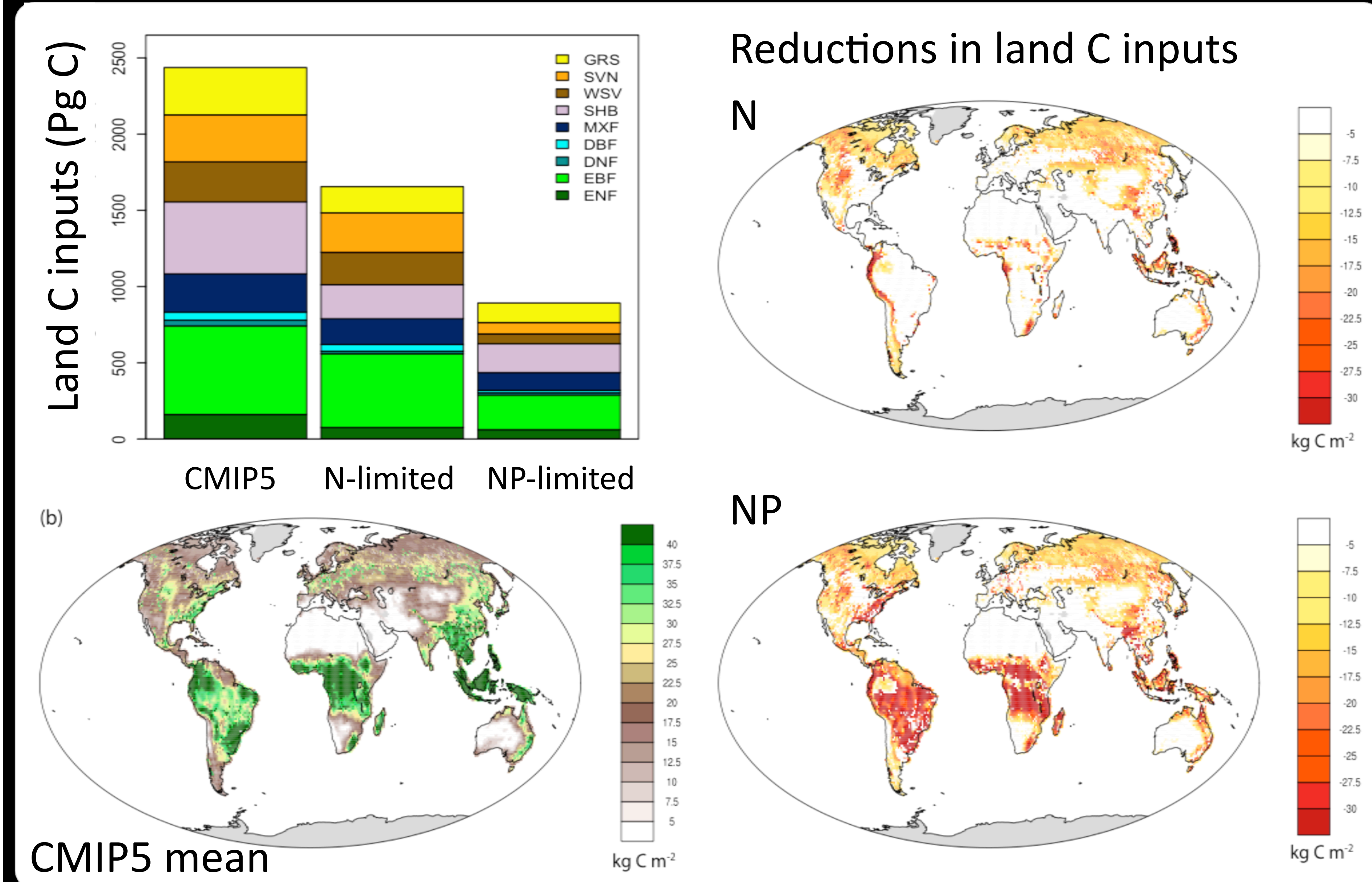
N



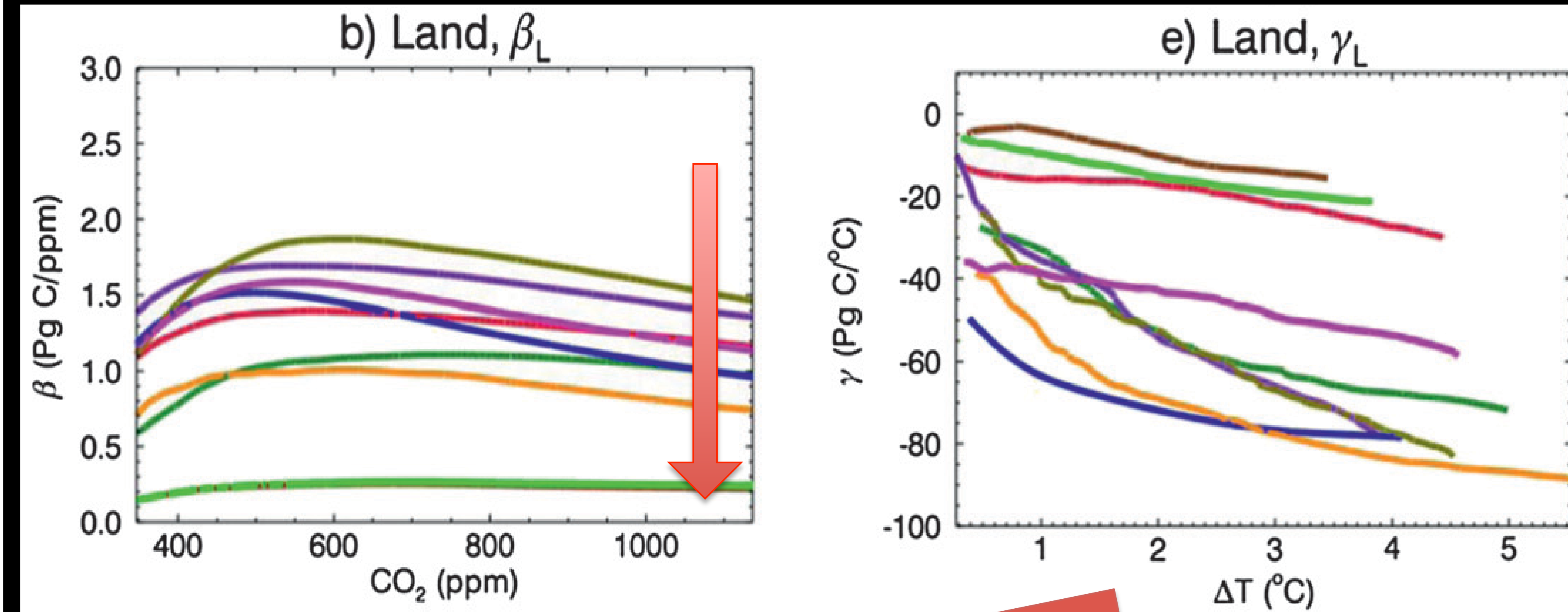




CMIP5 mean

# Land C inputs



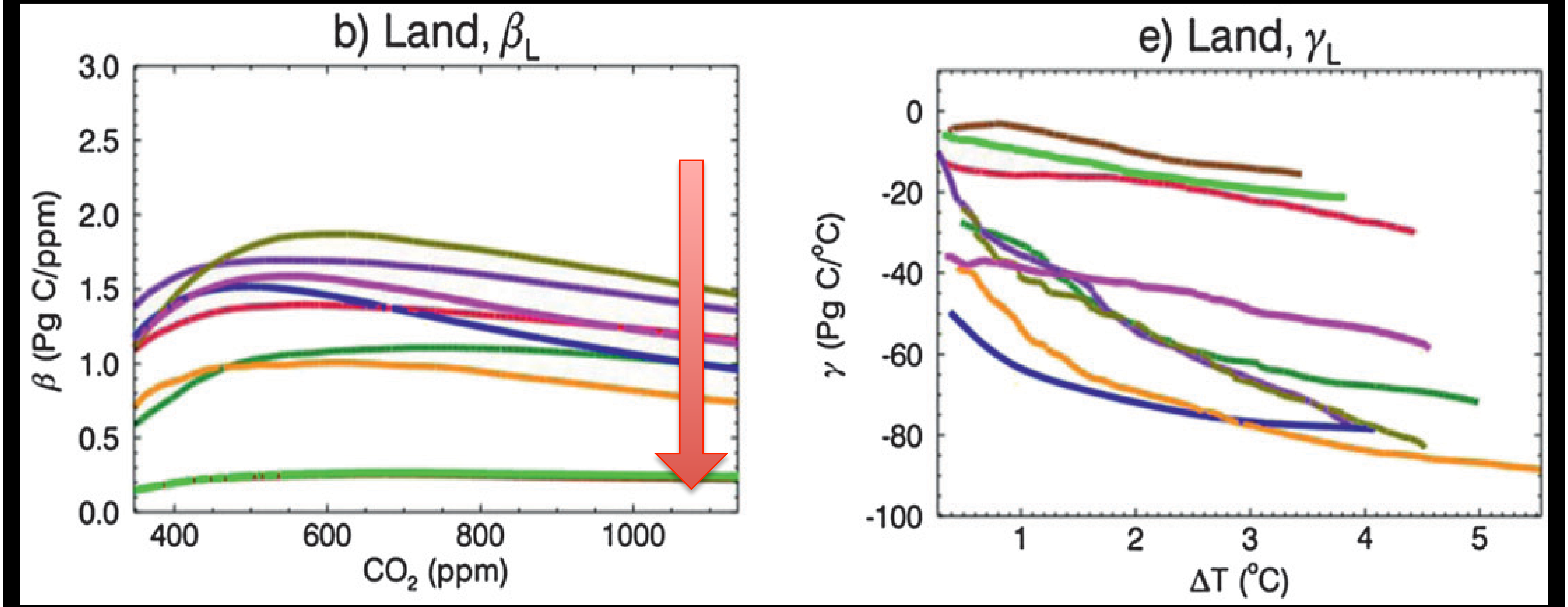
# Implications (i)




**Overly optimistic land sink**

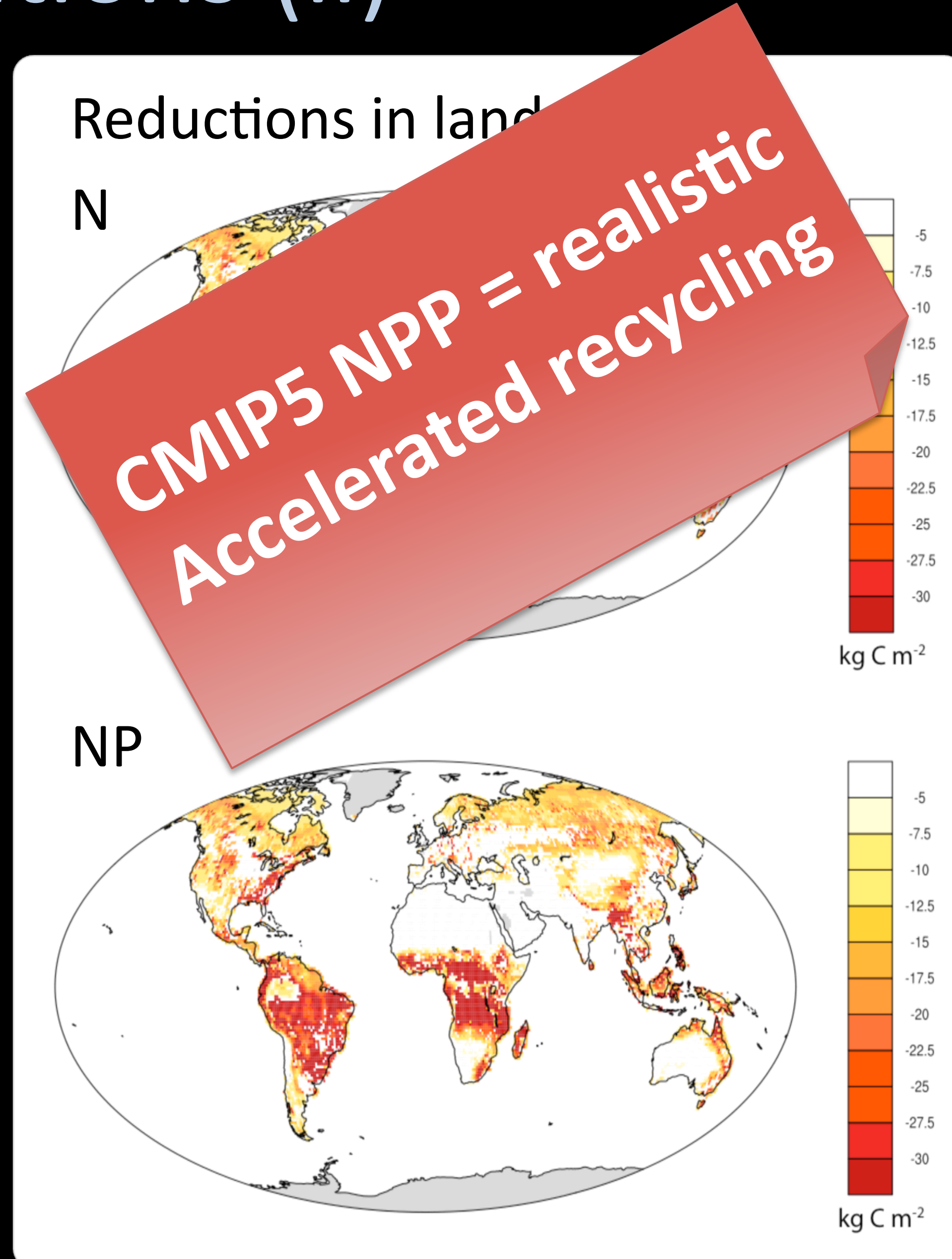
Arora et al. 2013 *J. of Climate*

# Implications (i)

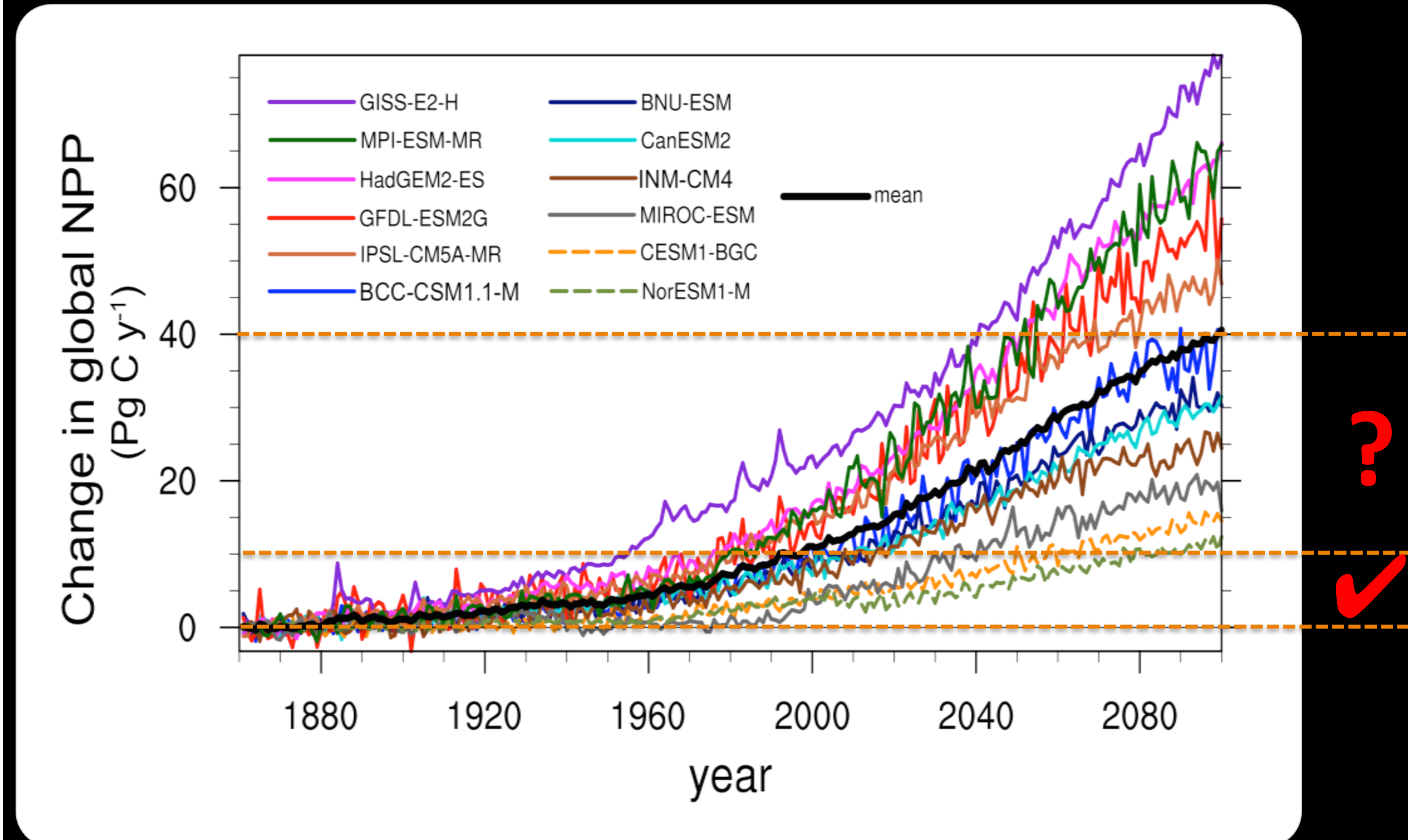



| | Soil C inputs (Pg C $y^{-1}$) | Soil C storage (Pg C) | $\Delta[CO_2]$ (ppm) |
|---|---|---|---|
| CMIP5 | 81 ± 21 | +68 ± 115 | |
| N limitation | 75 ± 18 | -41 ± 91 | 51 ± 33 |
| NP limitation | 68 ± 15 | -159 ± 104 | 107 ± 68 |

# Implications (ii)



# Nutrients and NPP




Melillo et al. 2011 *PNAS*
Finzi et al. 2006 *Ecology*

# Implications (ii)

**Adapted to conditions**

- Physical
- Biological
- Chemical

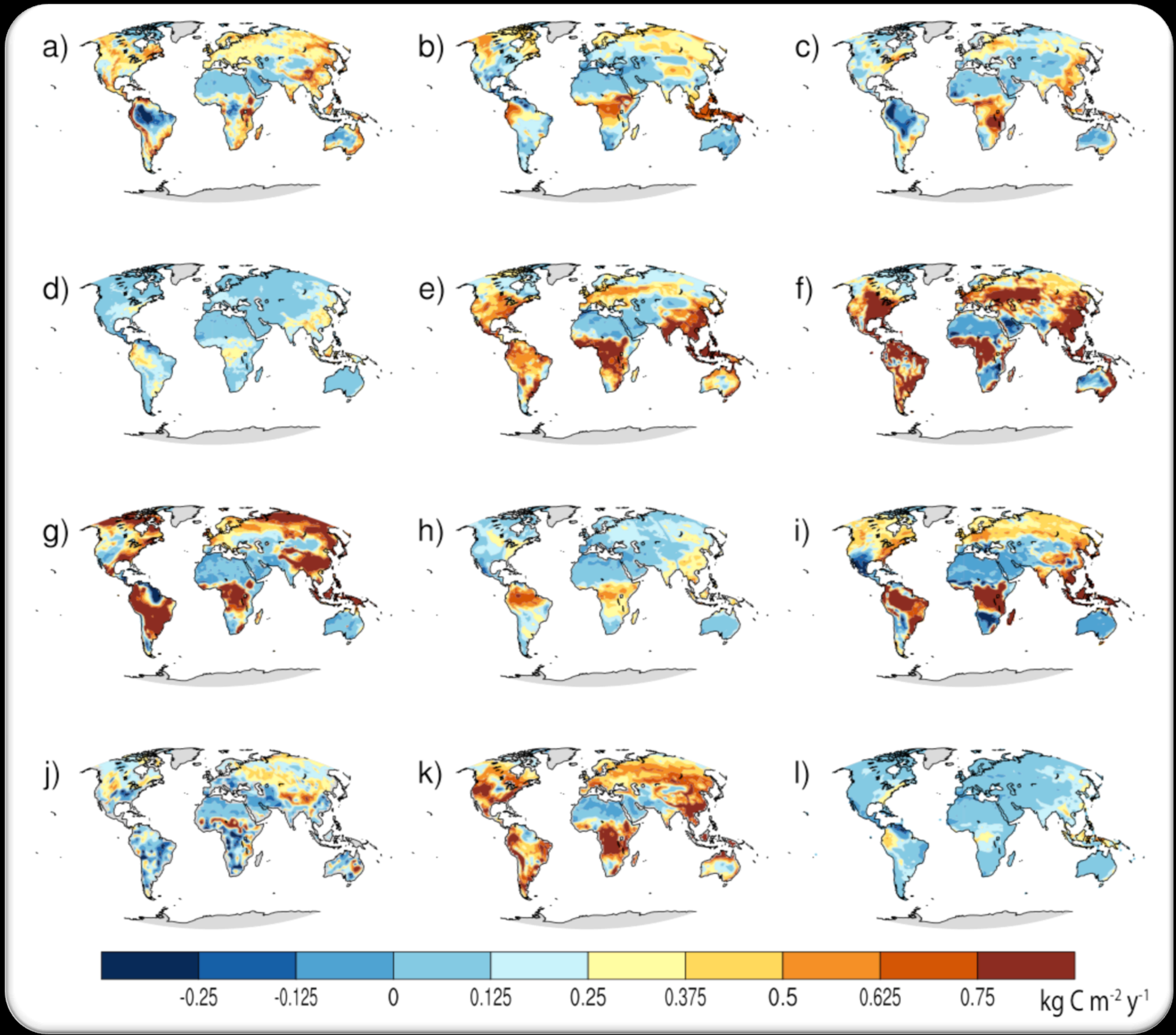

Lloyd et al. 2001 in *Gl. Bio.l Cyc. in the Cl. System*
Chambers & Silver 2004 *Phil Trans-B*
Drigo et al 2010 *PNAS*
Phillips et al 2011 *Ecology Letters*

# CMIP6: What do we hope to learn?

- N matters…
- Shifting C allocation?
- Plant soil interactions?
- Tropics?
- Experiments?

# THANK YOU

# NPP Change
## (2100-1860)



# CESM1-BGC: Cumulative change in land C inputs (2100-1860)