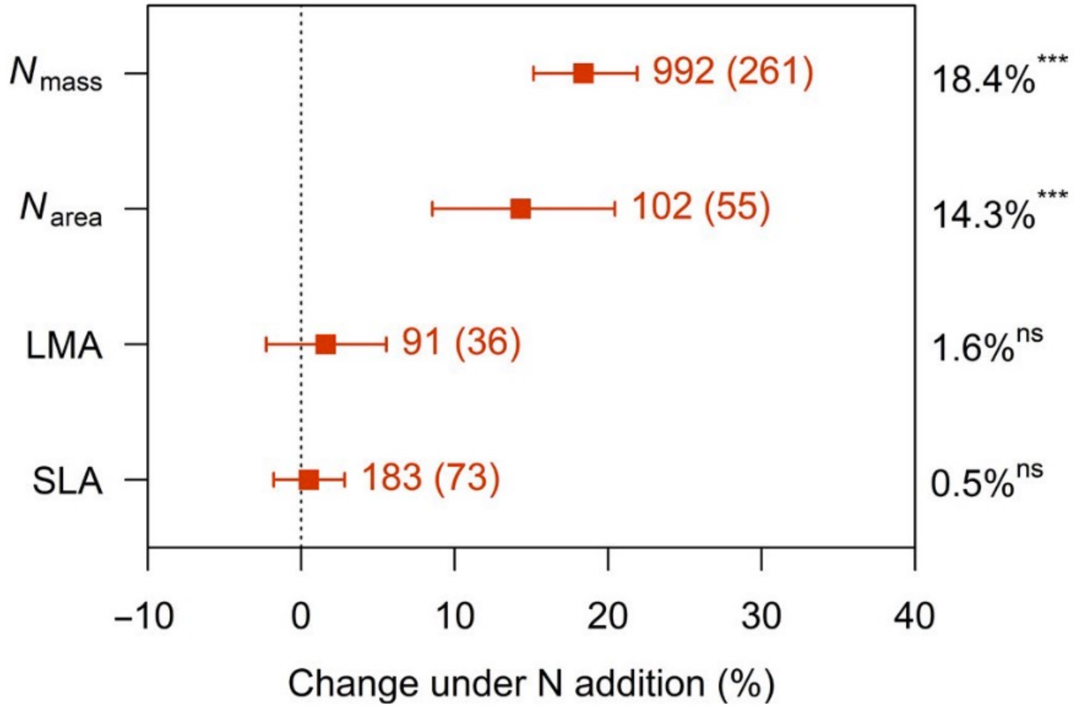
The cost of resource use for photosynthesis drives variance in leaf nitrogen content across a climate and soil resource availability gradient

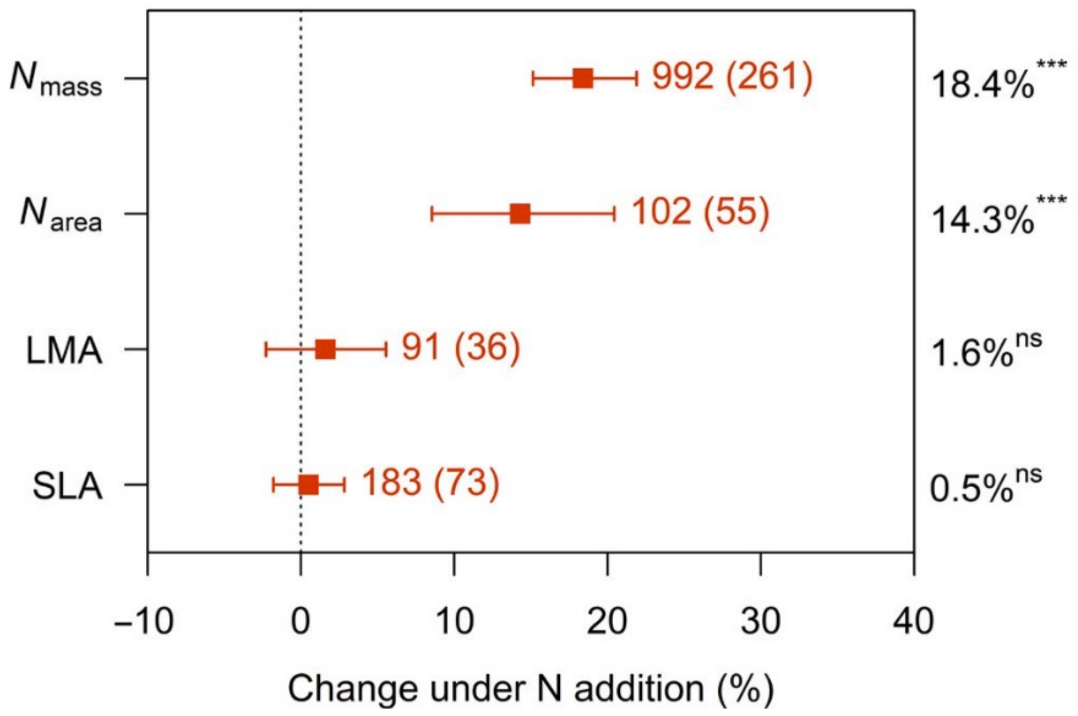
Evan A. Perkowski; Nicholas G. Smith

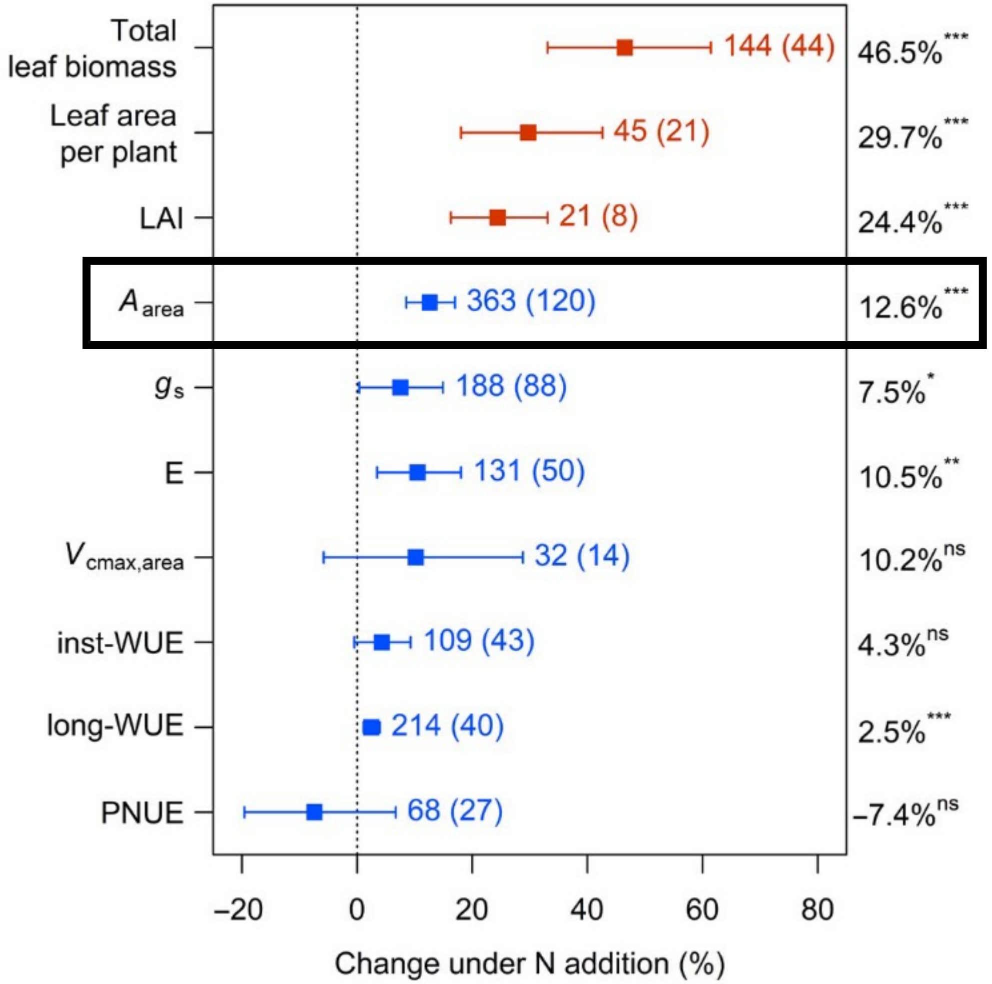
Soil nitrogen generally increases leaf nitrogen…



Liang et al. (2020) *Global Change Biology*

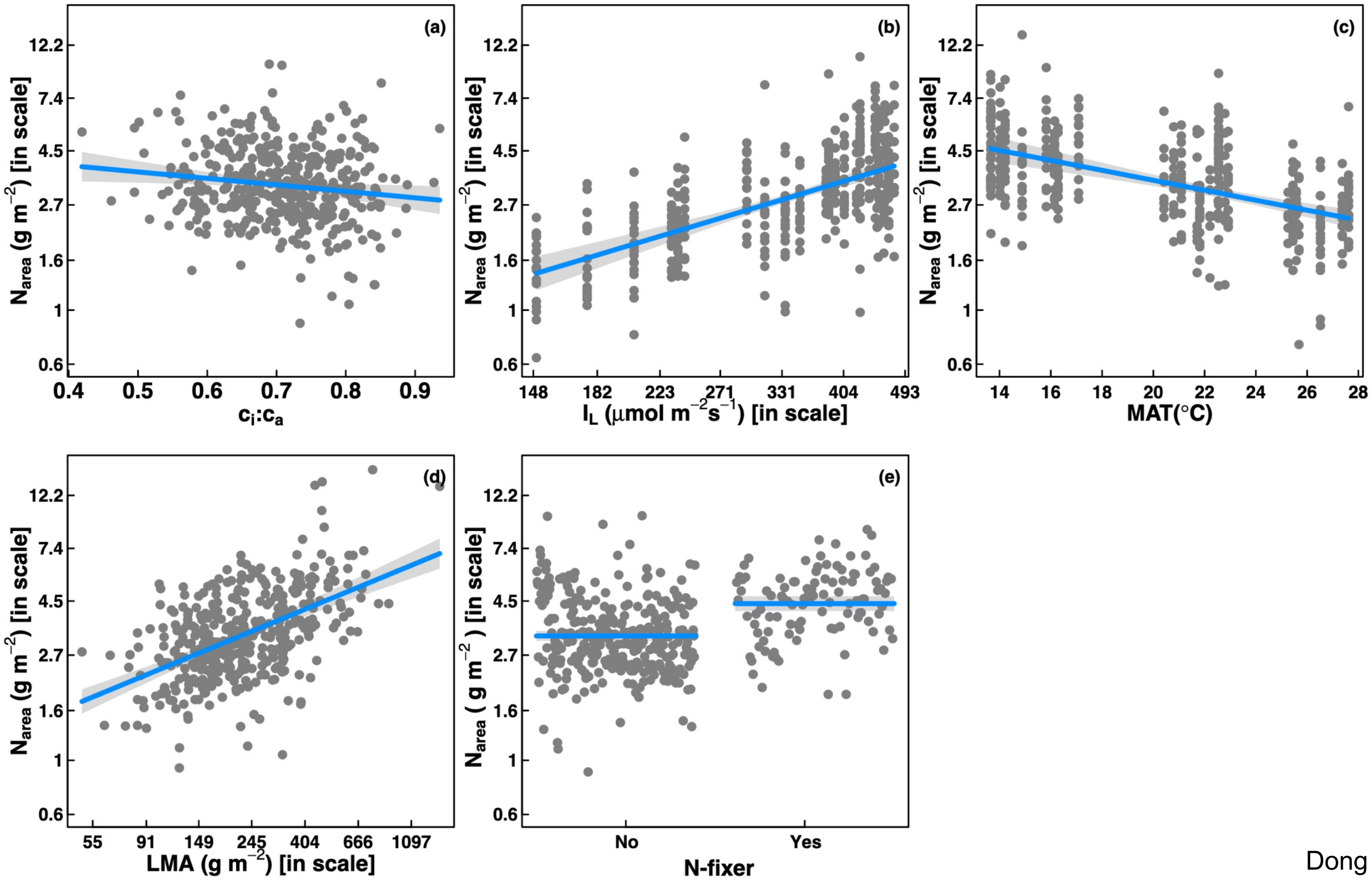
… which often corresponds with increased photosynthesis





Liang et al. (2020) *Global Change Biology*

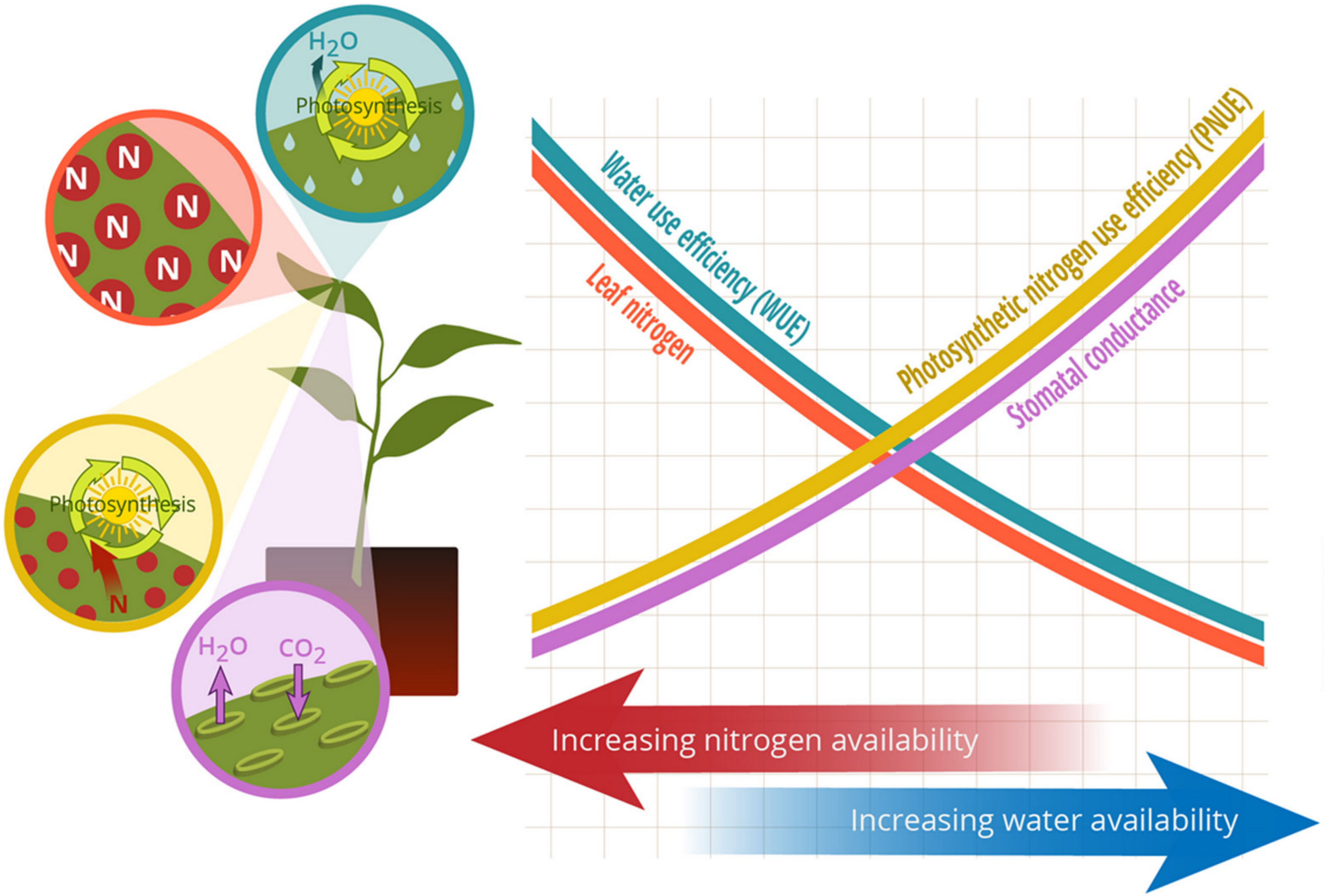
However, leaf nitrogen can be predicted independent of soil nitrogen



Dong et al. (2017) *Biogeosciences*

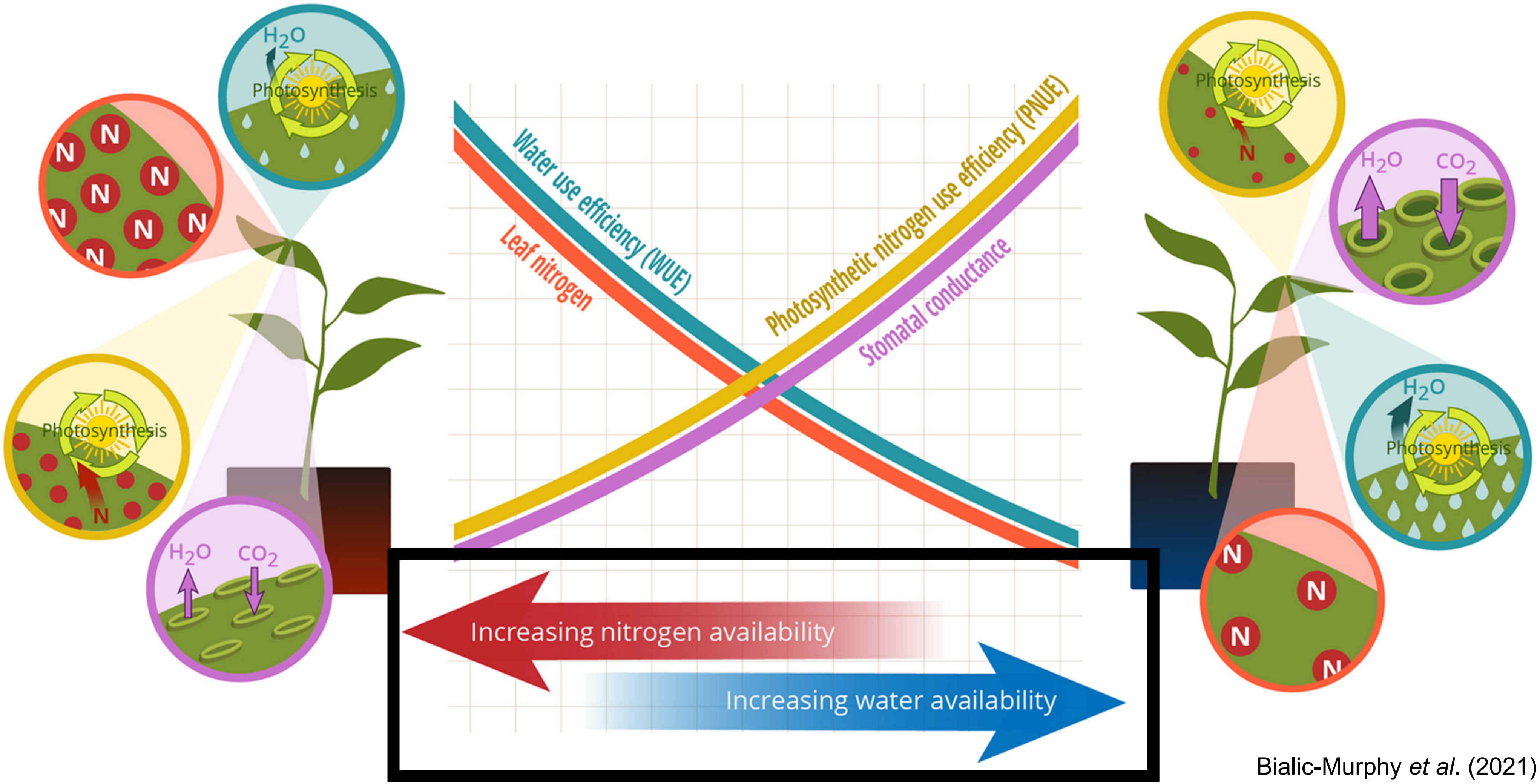
Leaf nitrogen is likely a product of interactions between climatic and edaphic factors

Photosynthetic least-cost theory



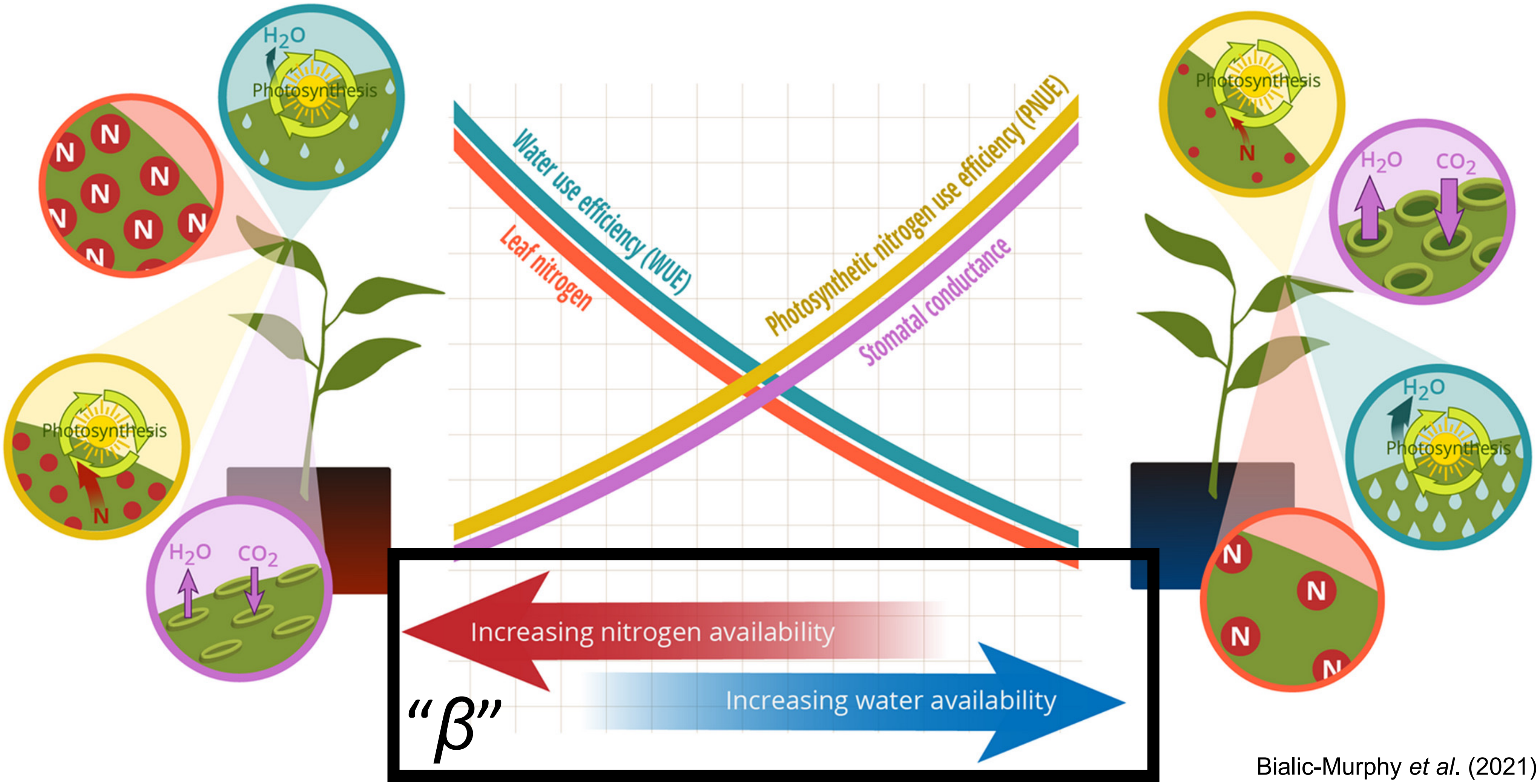
Bialic-Murphy *et al.* (2021) *Ecology Letters*

Photosynthetic least-cost theory: leaves acclimate to changing climatic and edaphic environments via summed cost of resource use (nitrogen and water)



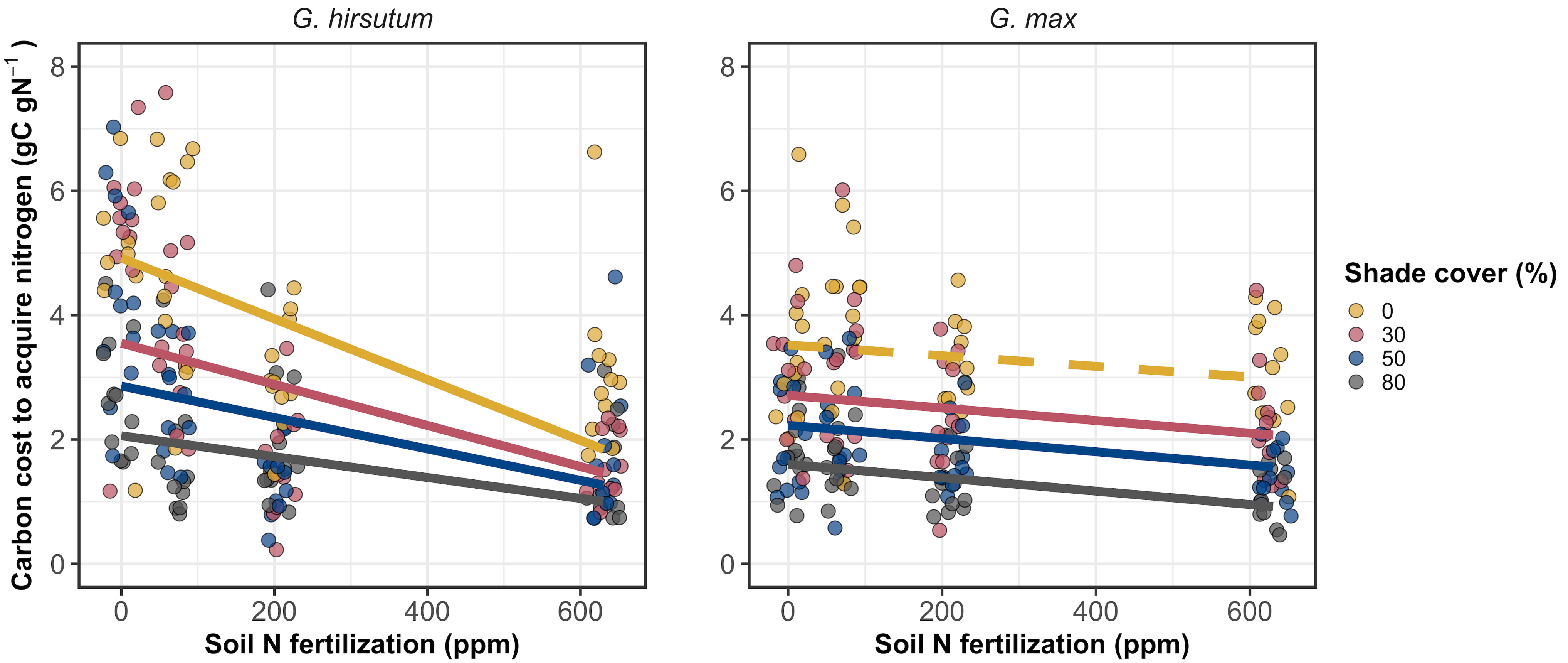
Bialic-Murphy *et al.* (2021) *Ecology Letters*

Photosynthetic least-cost theory: leaves acclimate to changing climatic and edaphic environments via summed cost of resource use (nitrogen and water)



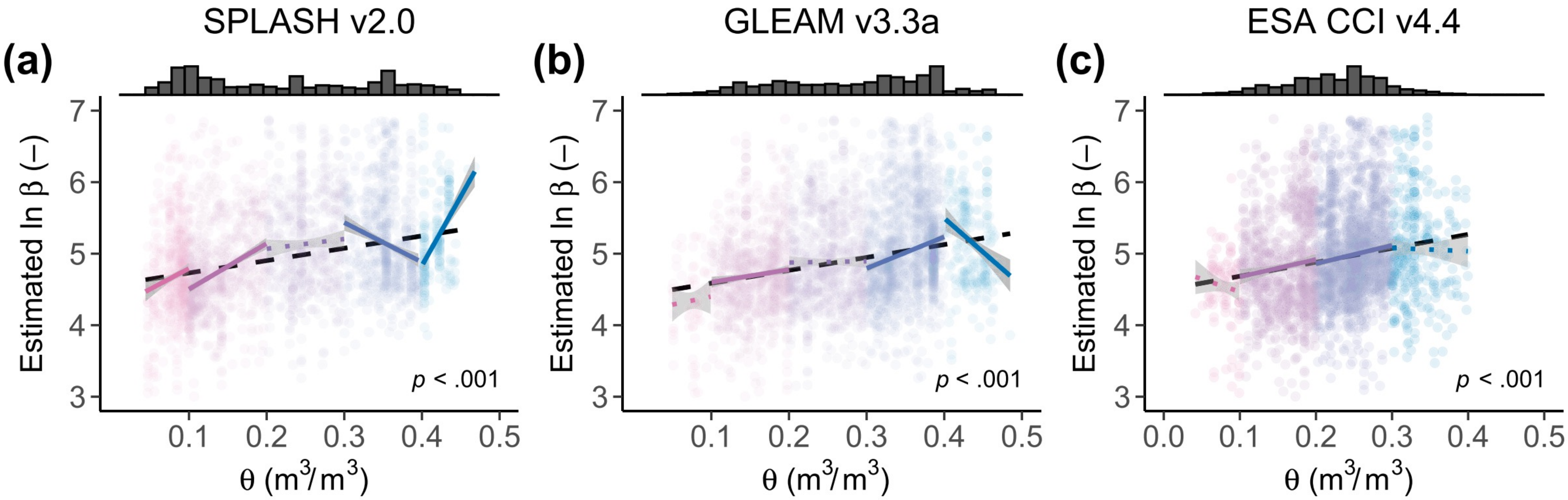
Bialic-Murphy *et al.* (2021) *Ecology Letters*

β is held constant in least-cost optimality models, but varies across environments



Perkowski et al. (2021) *Journal of Experimental Botany*

β is held constant in least-cost optimality models, but varies across environments



Lavergne et al. (2020) *Global Change Biology*

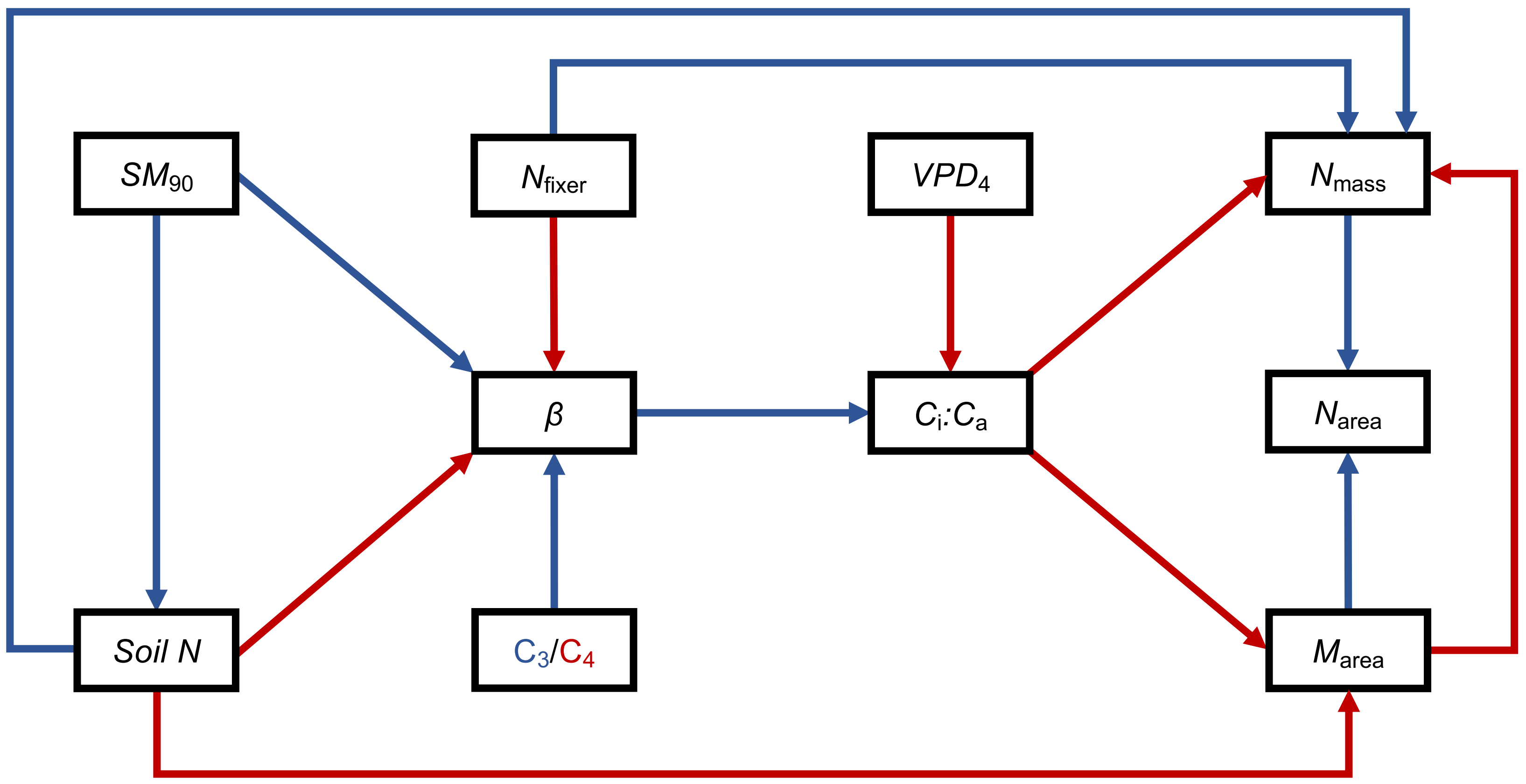
Open questions

- How dynamic are costs to acquire nitrogen relative to water across edaphic and climatic gradients?

- To what extent do costs to acquire nitrogen relative to water determine variance in leaf nitrogen content across environmental gradients?

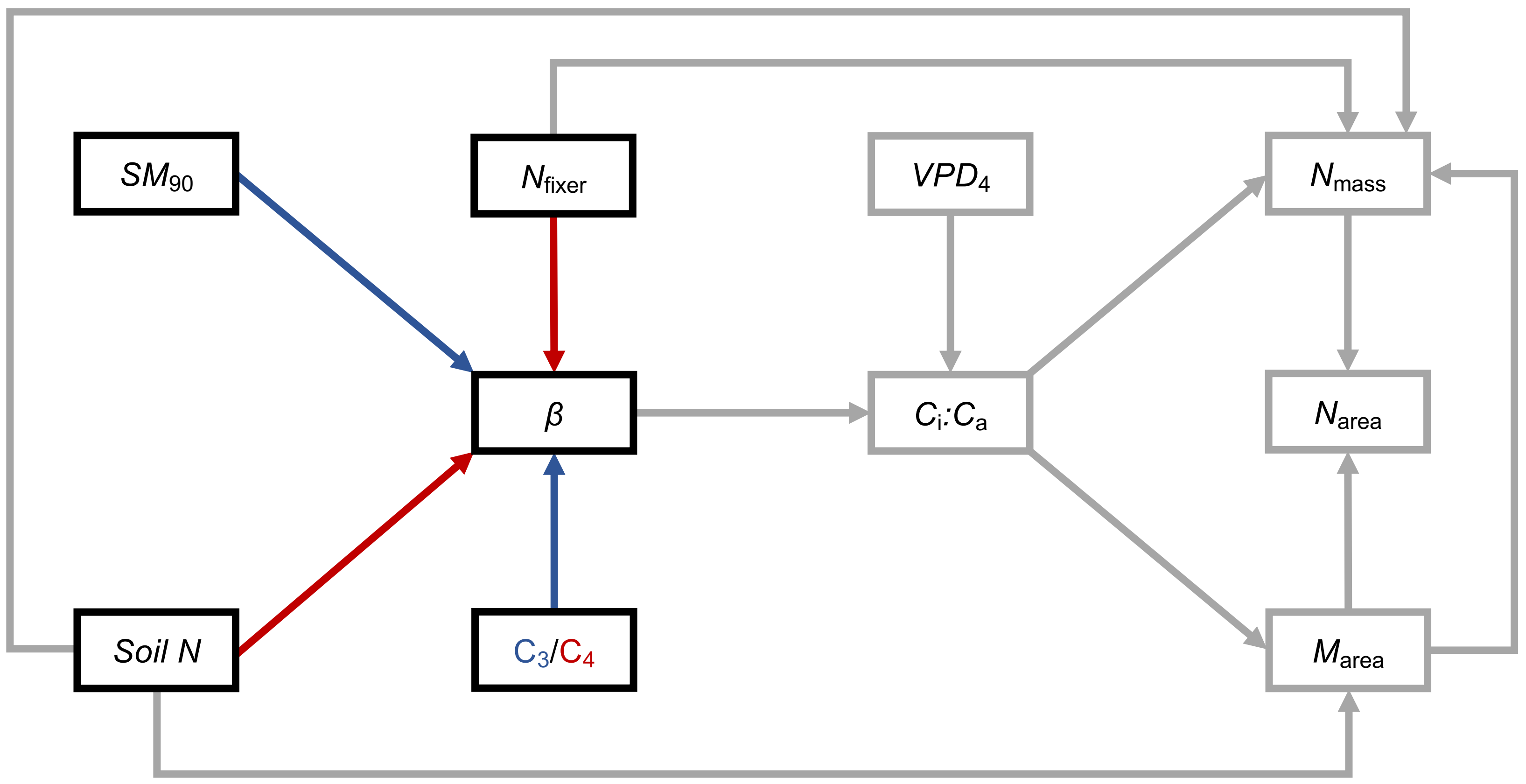
    - What is the underlying role of photosynthetic pathway or nitrogen acquisition strategy?

Hypotheses



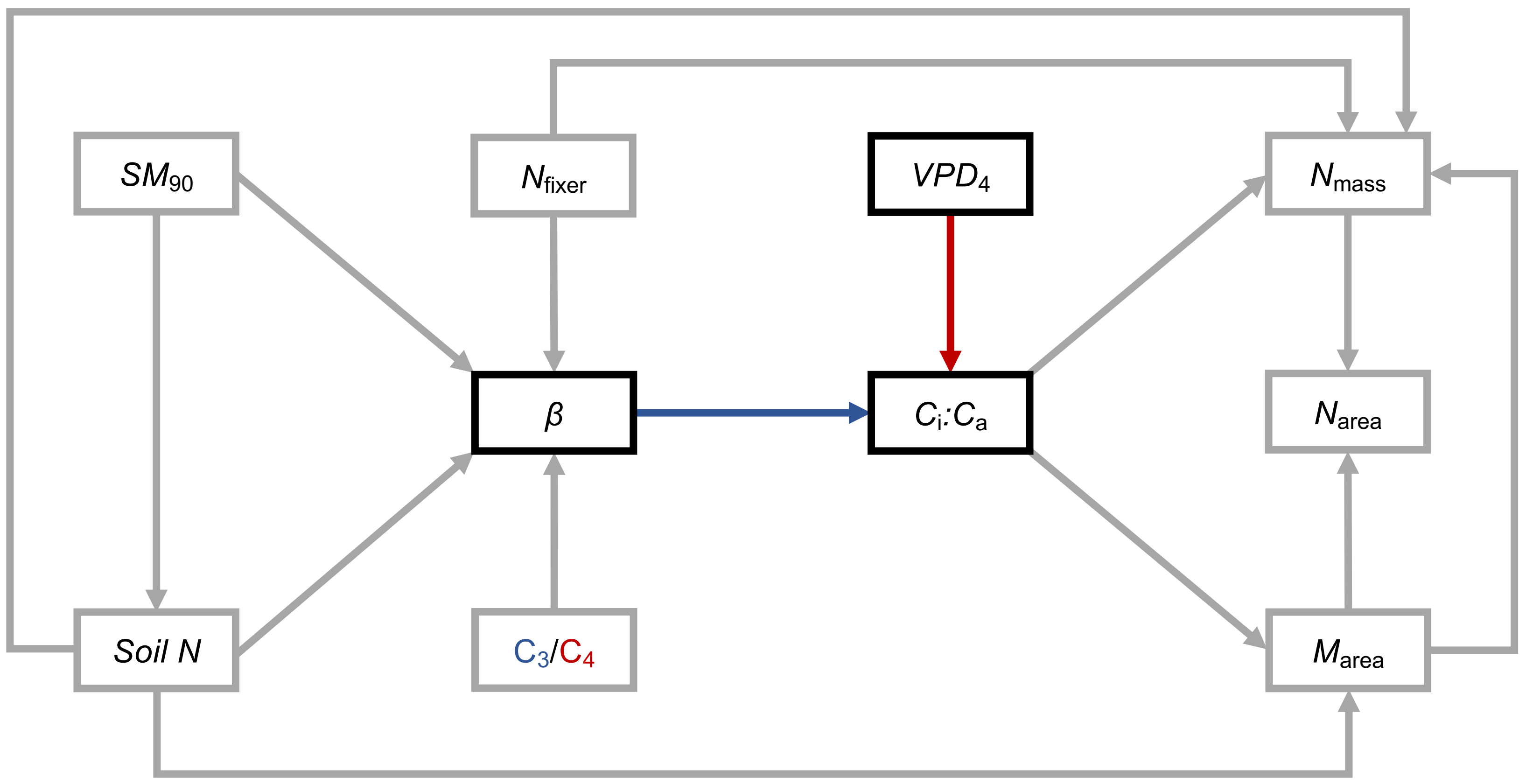
Positive
Negative

The cost of acquiring and using nutrients (β) will be modified by soil resources and species identity



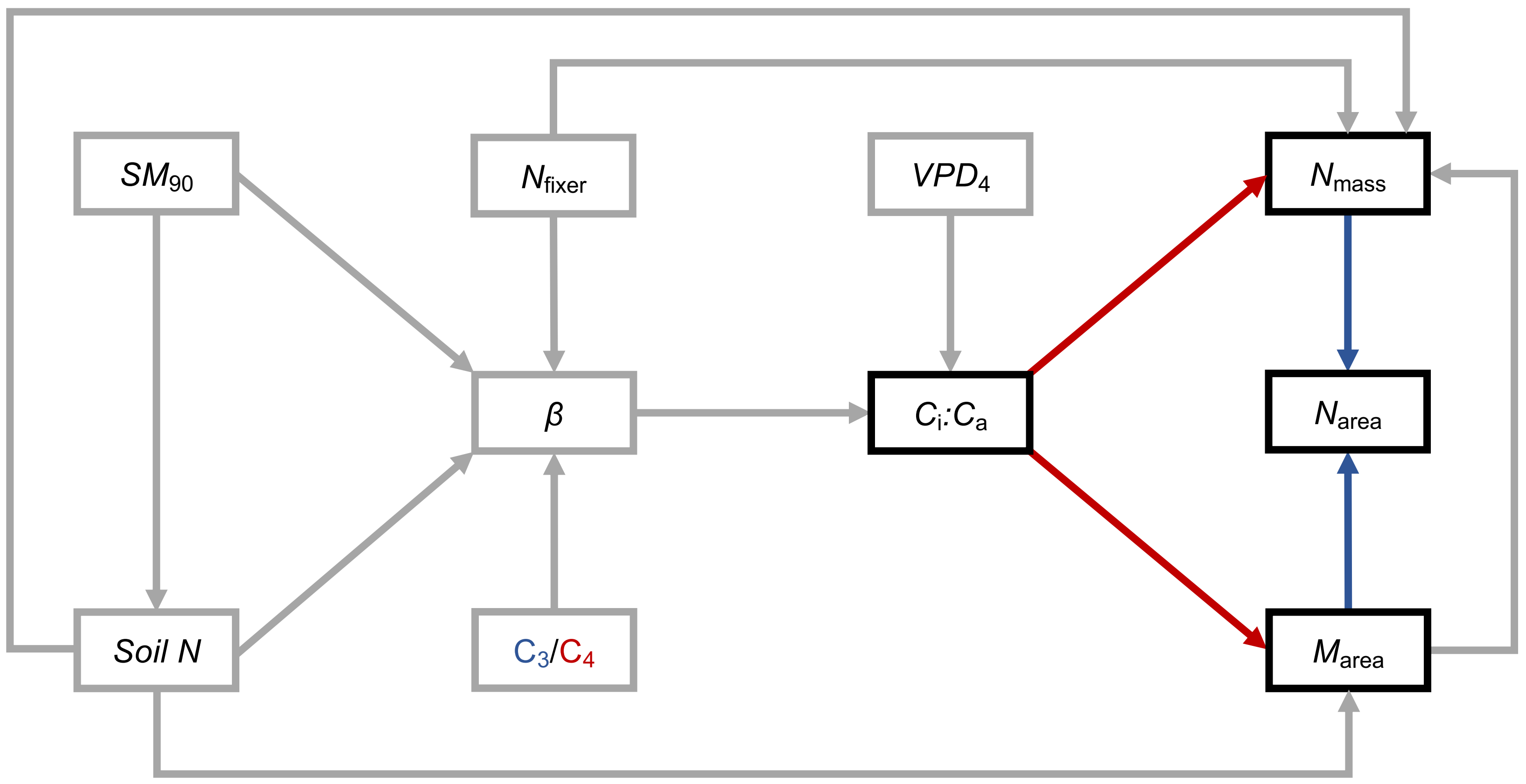
Positive
Negative

Leaf C_i:C_a will be modified by costs of resource use and aboveground climate



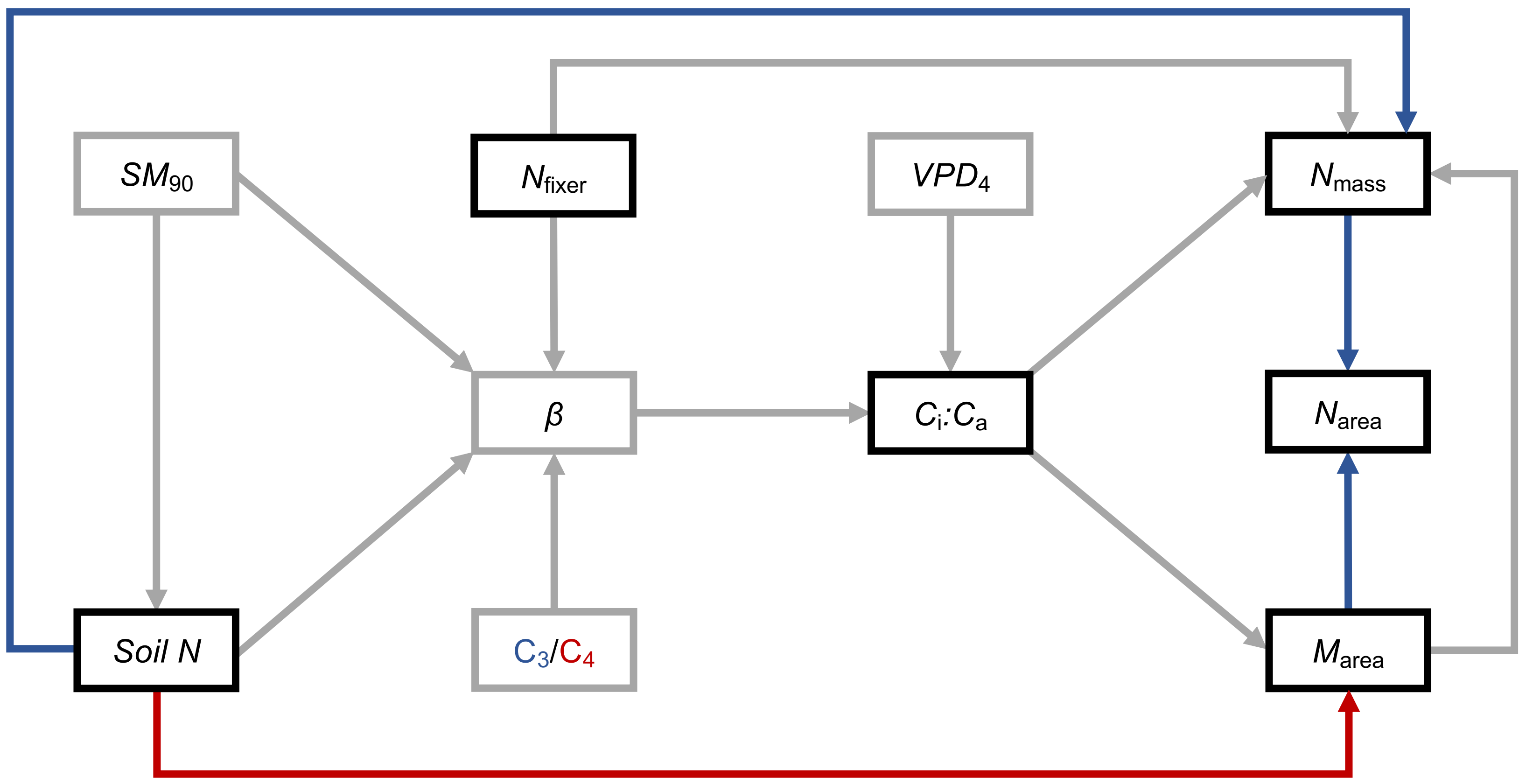
Positive
Negative

Leaf nitrogen content will be **negatively** related to leaf C_i:C_a



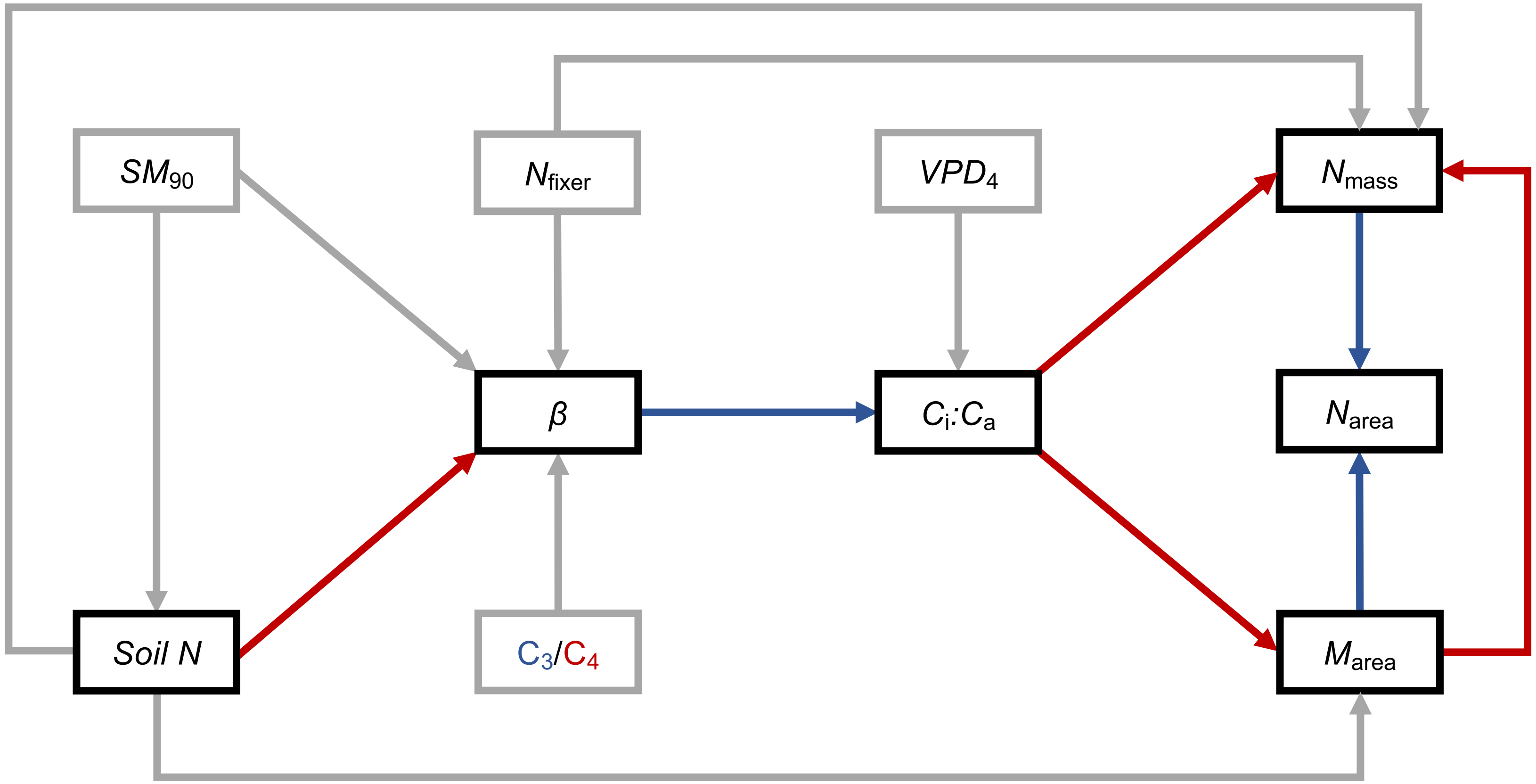
Positive
Negative

Soil N may directly **increase** N_{area} due to increasing N_{mass}…



Positive
Negative

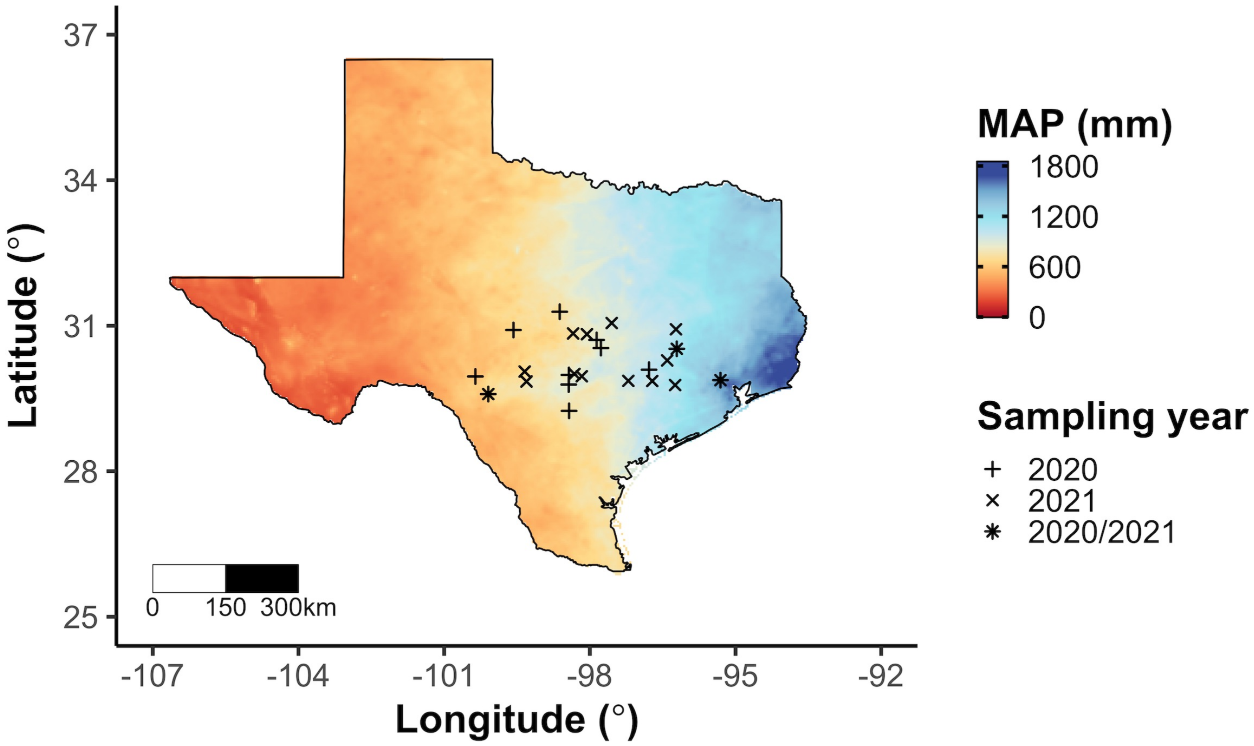
… or may indirectly **increase** N_{area} due to **reductions** in the cost of acquiring nitrogen



Positive
Negative

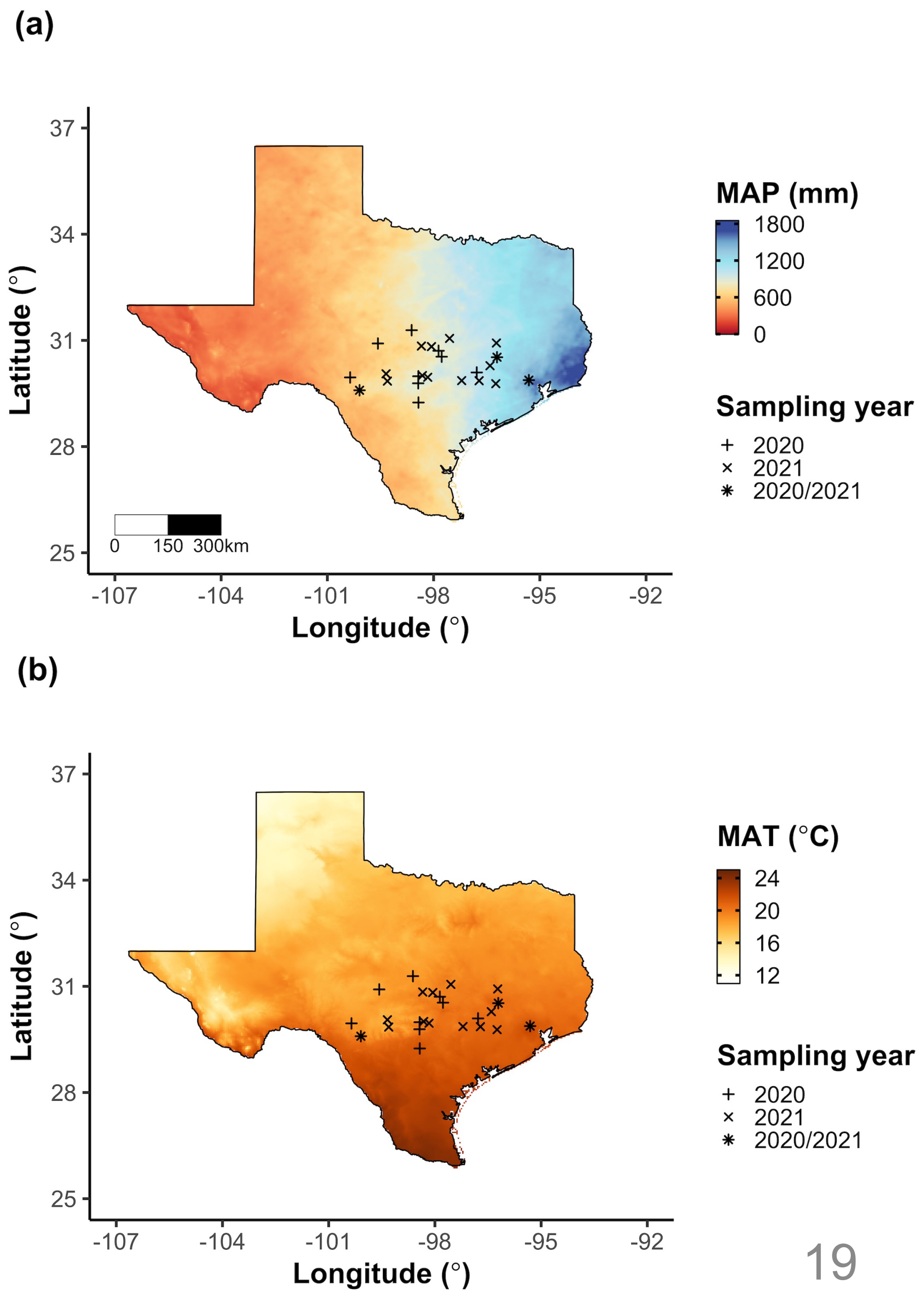
Field gradient experiment

- 24 sites
  - 12 in 2020
  - 15 in 2021 (3 from 2020)
- 3 leaves of 5 most dominant species at each site
  - Leaf nitrogen content
  - Leaf C_i:C_a ($\delta^{13}C$)
  - Cost of acquiring nitrogen relative to water (β)
- Composite soil sample

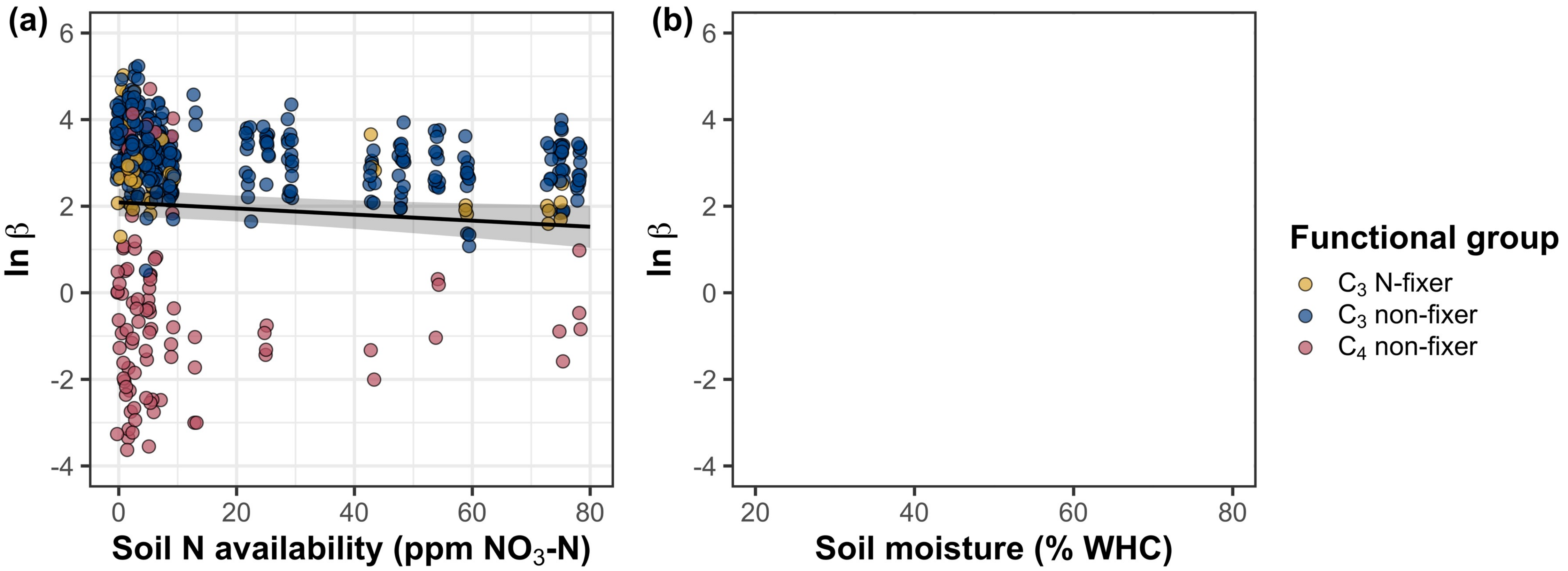


Climate and edaphic characteristics

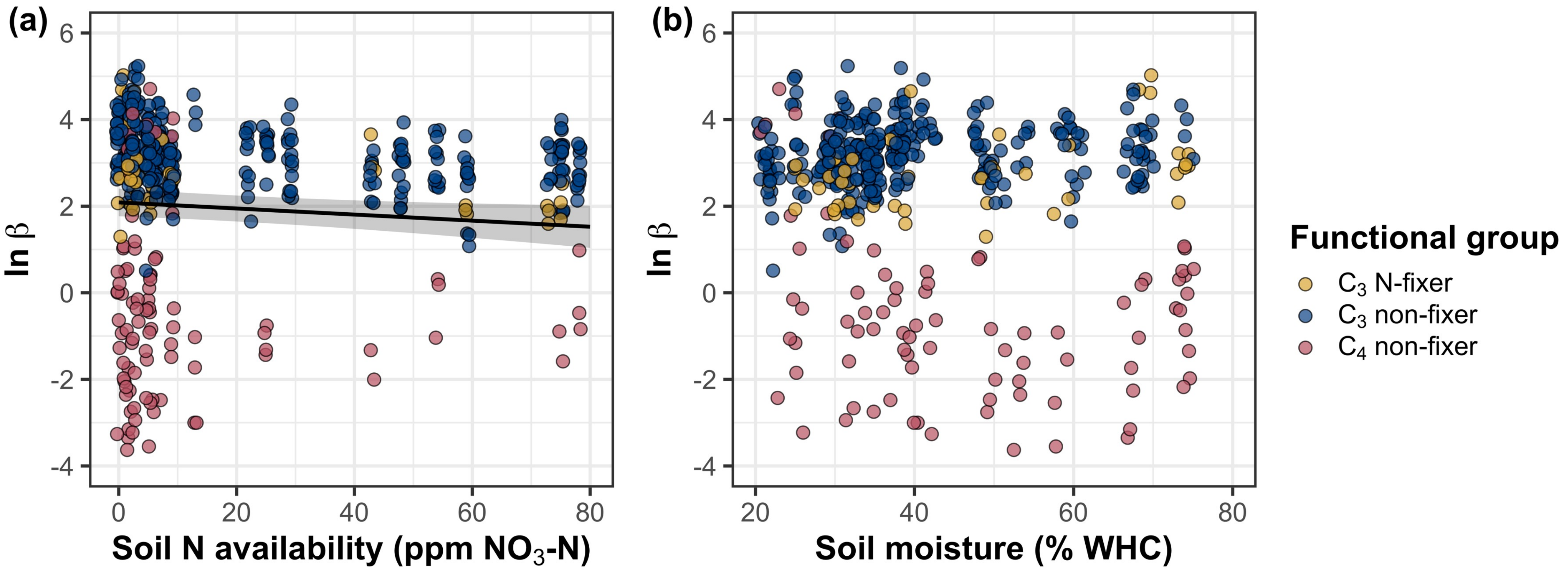
- Climate characteristics
  - Daily vapor pressure deficit
- Edaphic characteristics
  - Soil nitrogen availability (NO_3-N)
  - Soil moisture
- Timescales for VPD and soil moisture determined using model selection



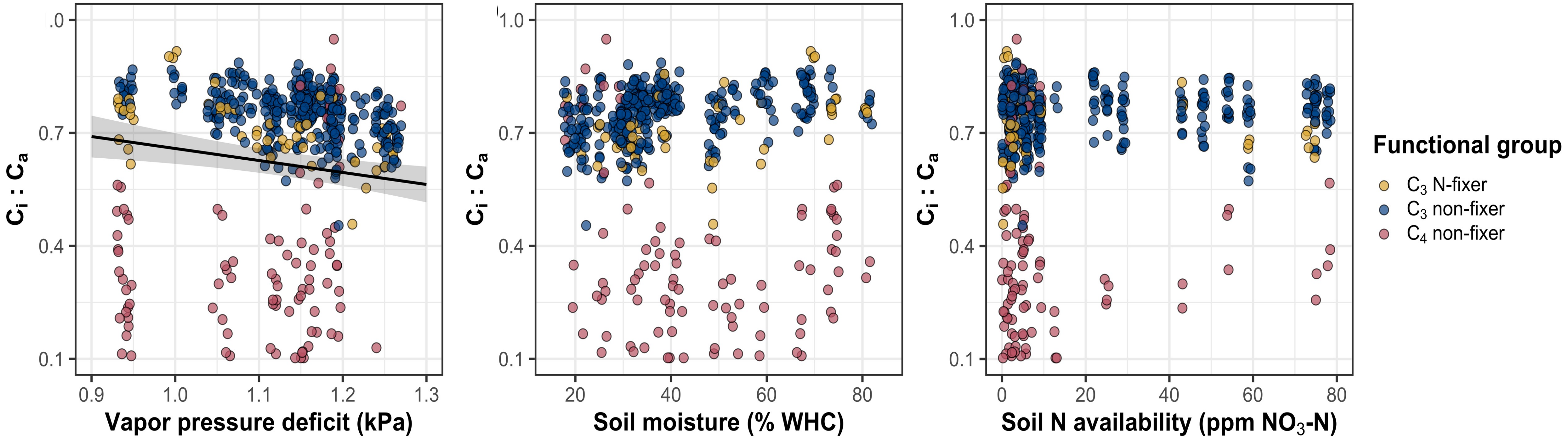
β **decreases** with increasing soil nitrogen



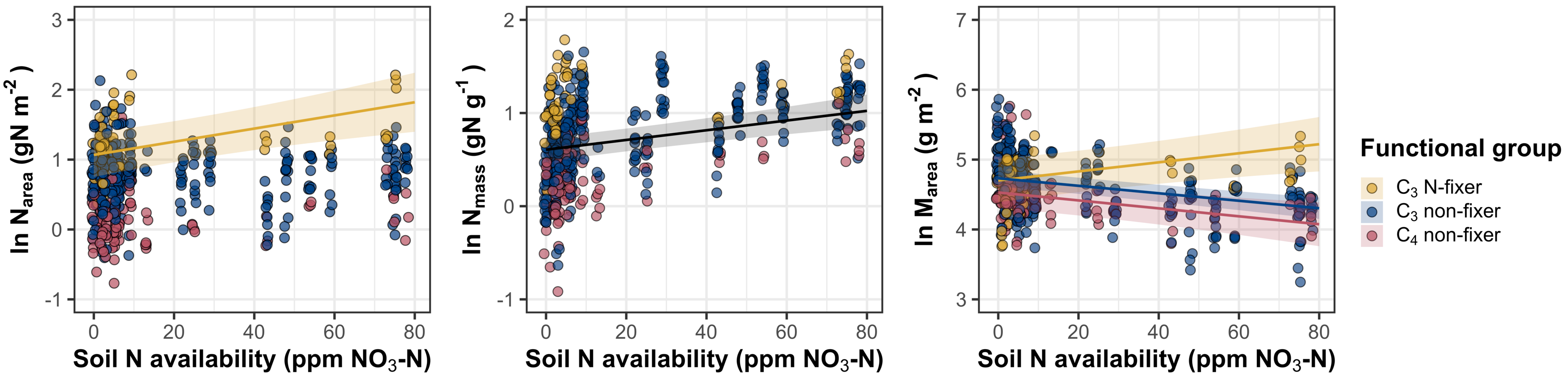
β **decreases** with increasing soil nitrogen, but is **not** modified by soil moisture



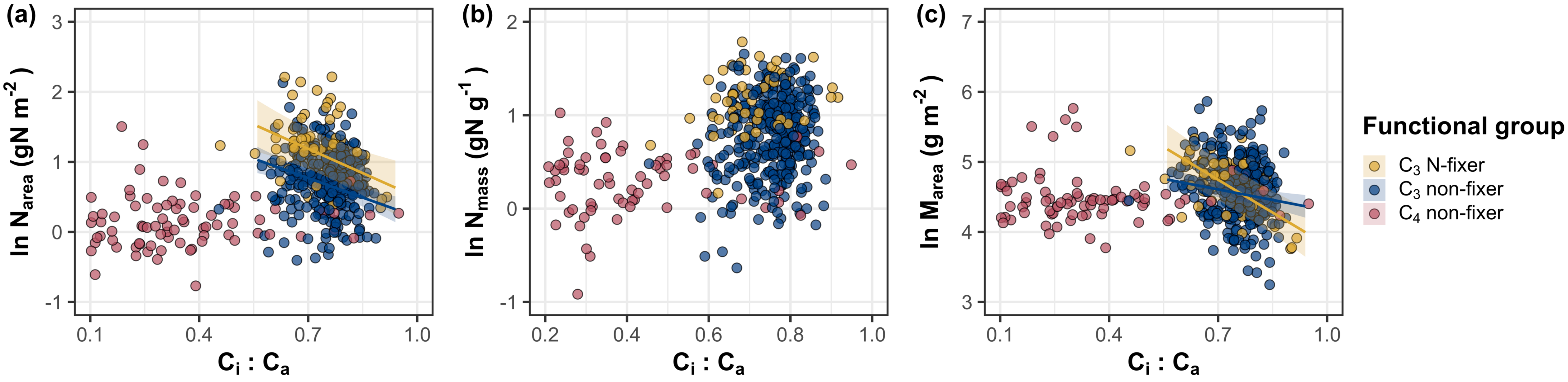
Leaf C_i:C_a **decreases** with increasing vapor pressure deficit, but is **not** modified by soil resource availability



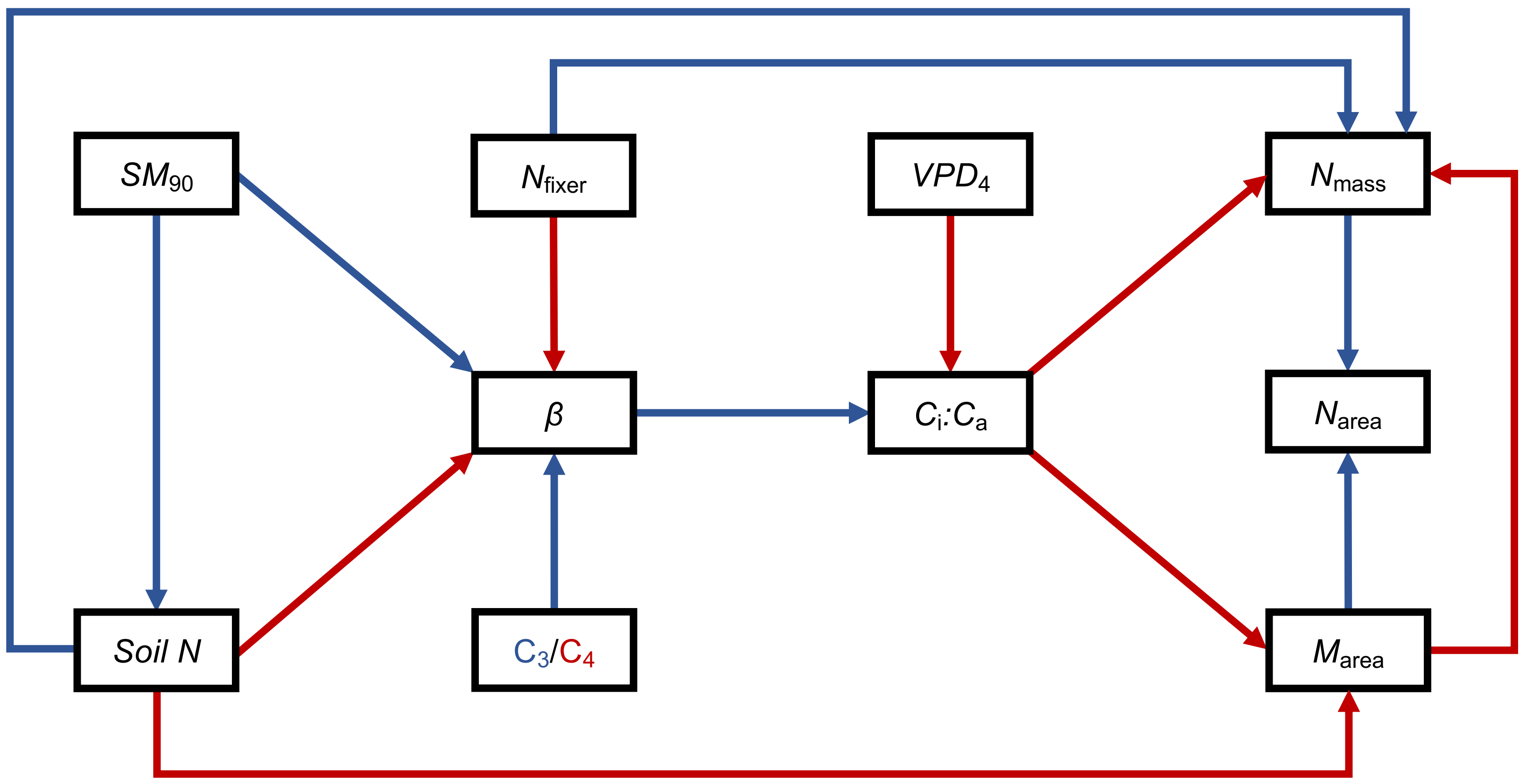
N_{area} **increases** with increasing soil nitrogen availability



N_{area} is **negatively** associated with leaf C_i:C_a due to **reductions** in M_{area}

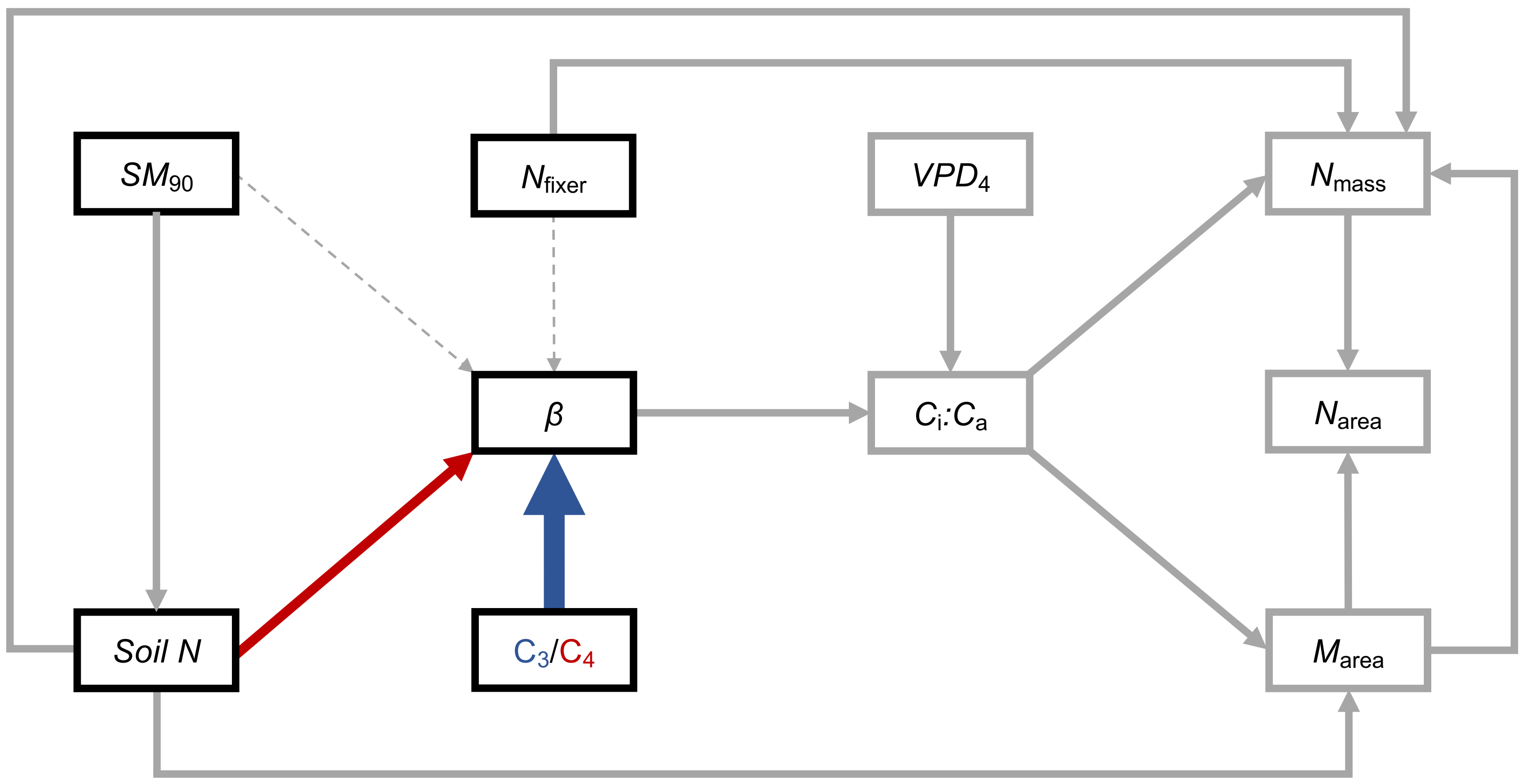


Revisiting hypotheses



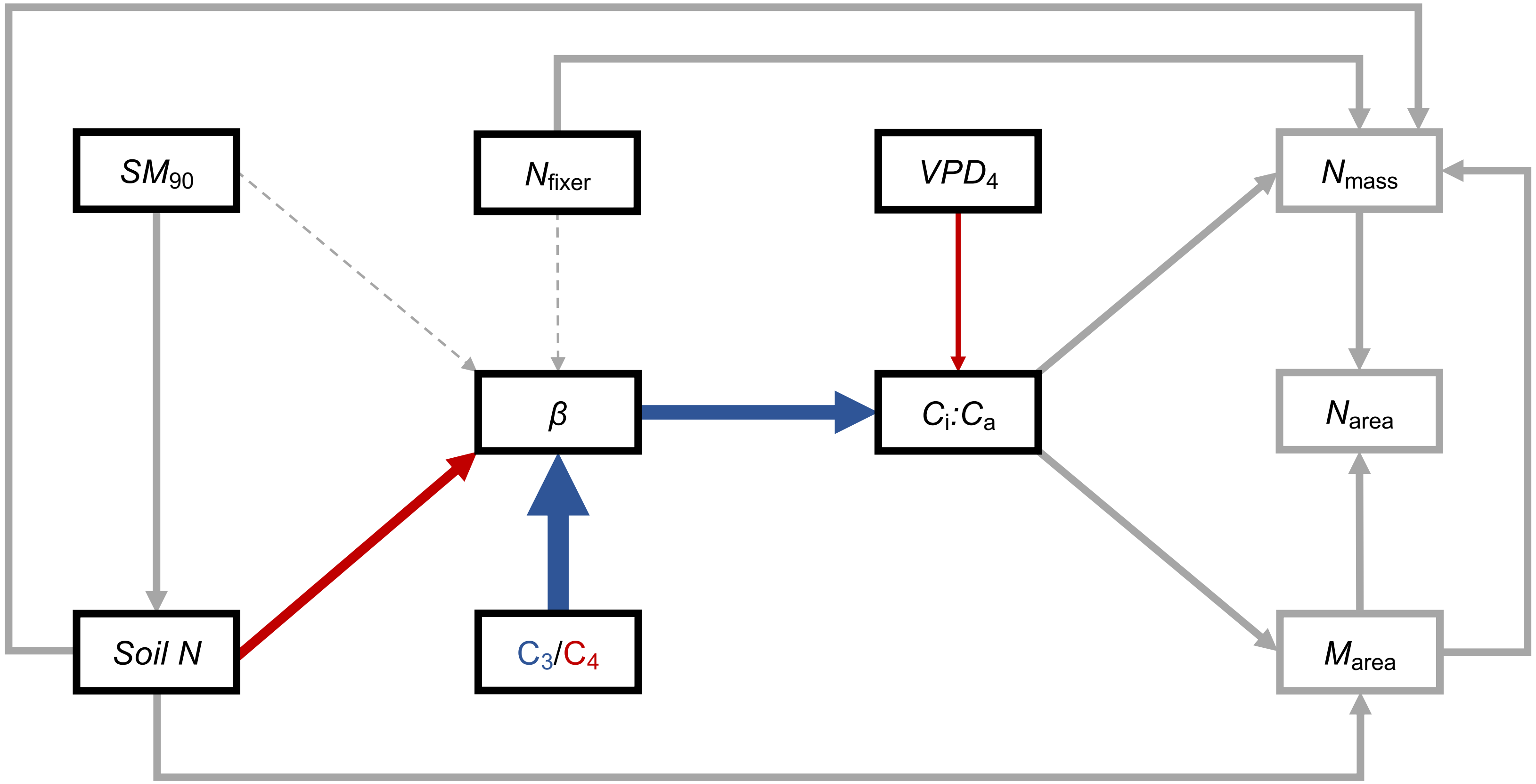
Positive
Negative

β is **negatively** associated with increasing soil nitrogen, and generally **lower** in C_4 species



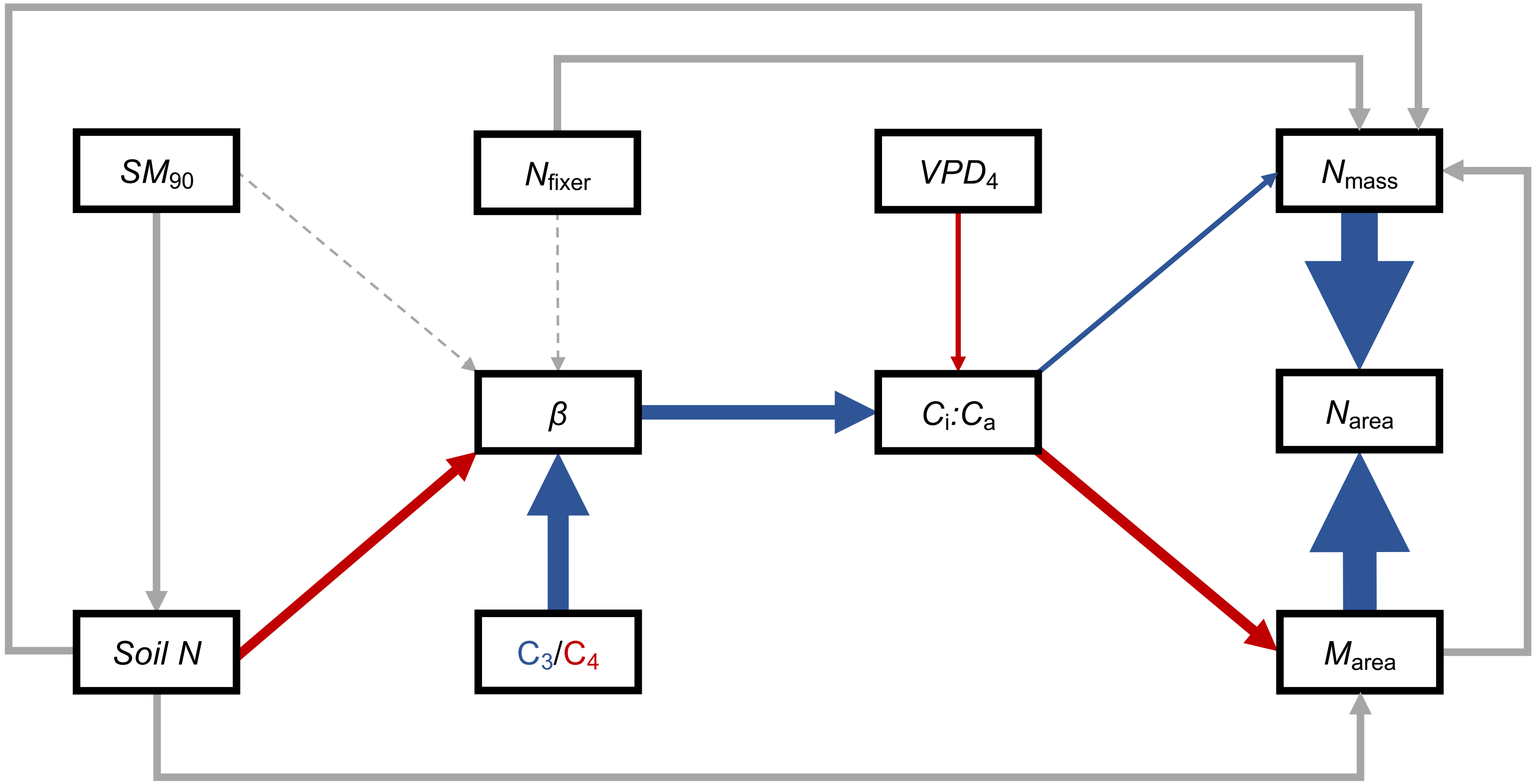
Positive
Negative

Leaf C_i:C_a is **negatively** related to increasing vapor pressure deficit and **positively** related to β



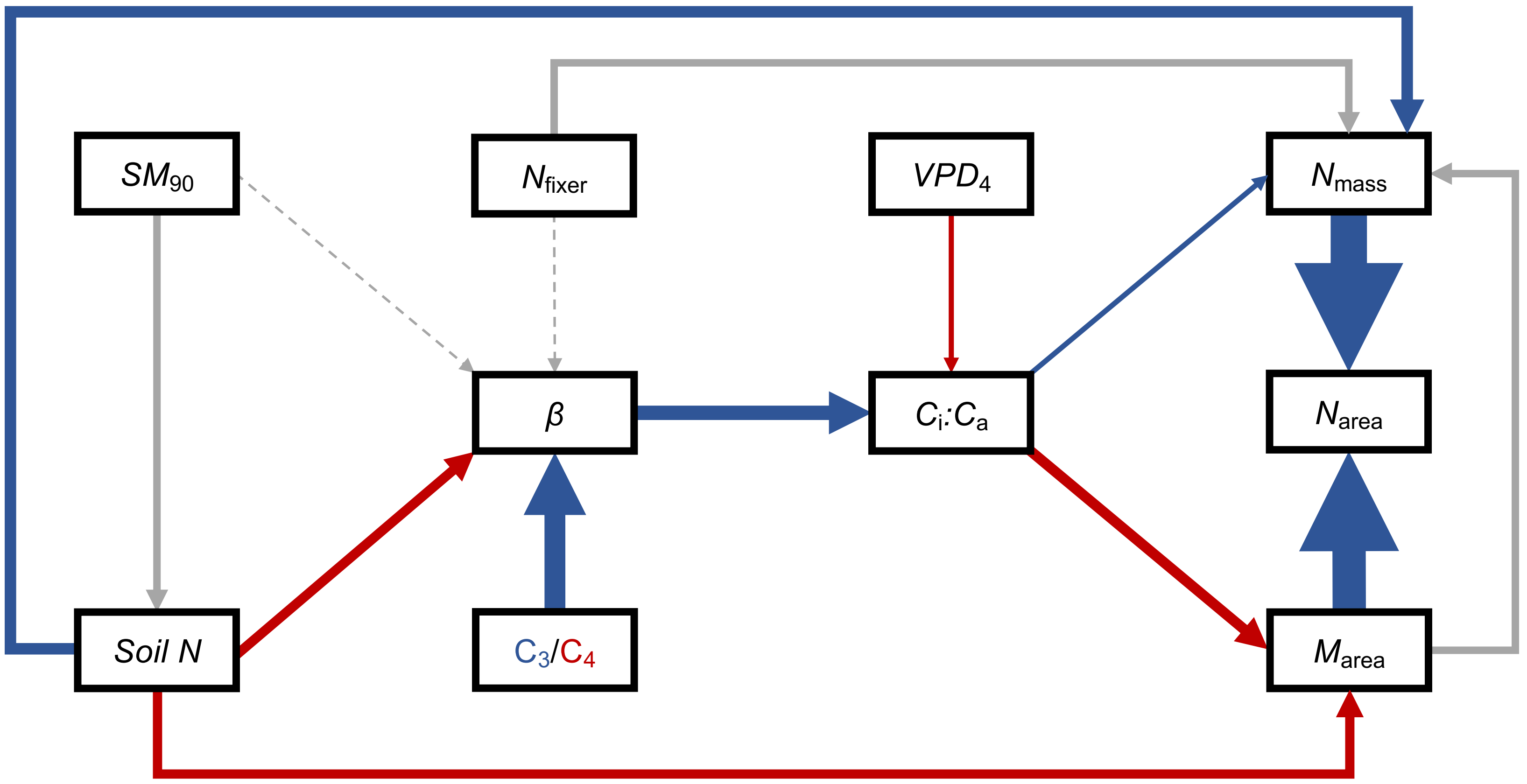
Positive
Negative

M_{area} is **negatively** related to leaf C_i:C_a, while N_{mass} is **positively** related to leaf C_i:C_a



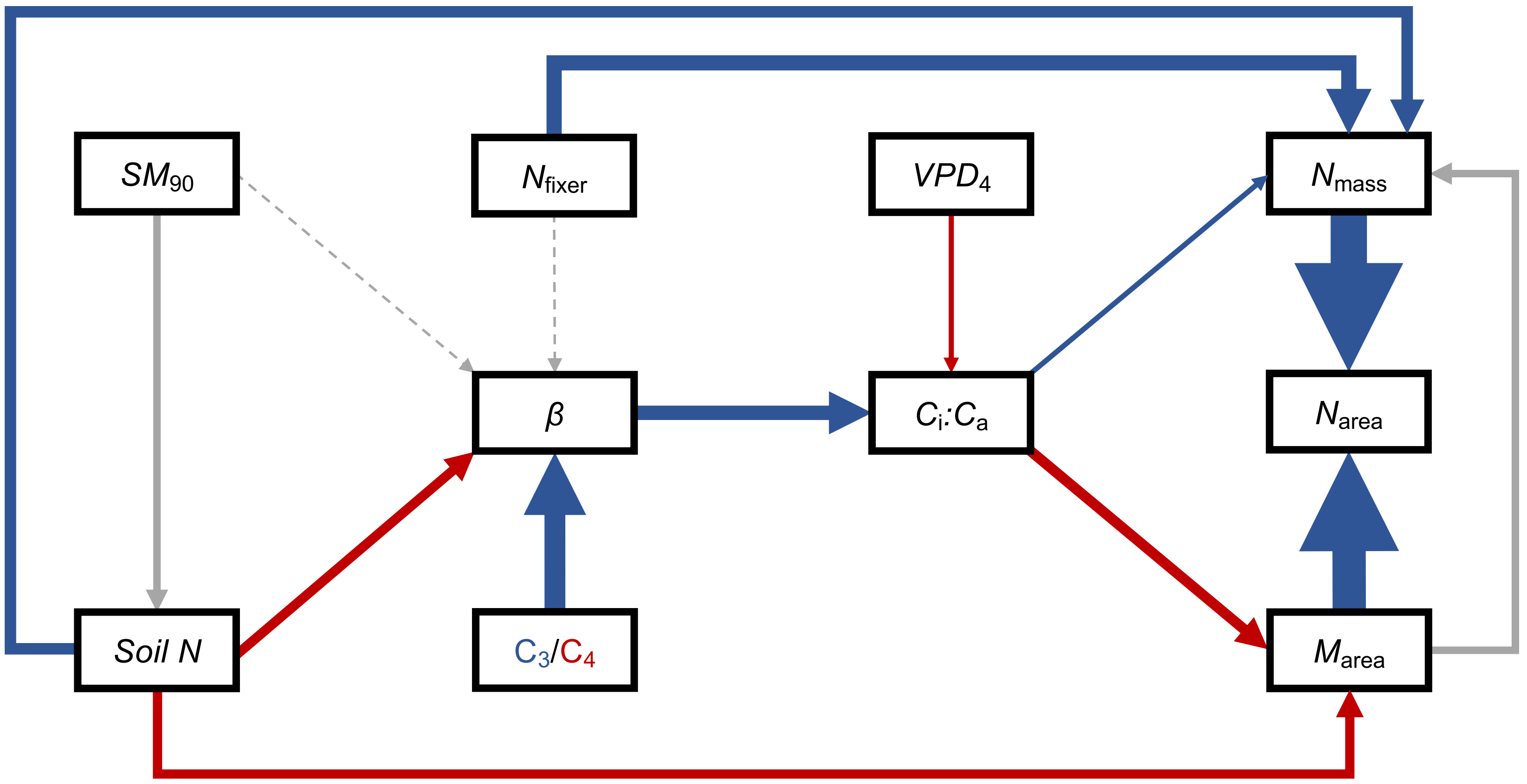
Positive
Negative

Increasing soil nitrogen availability directly **increases** N_{mass} and **decreases** M_{area}



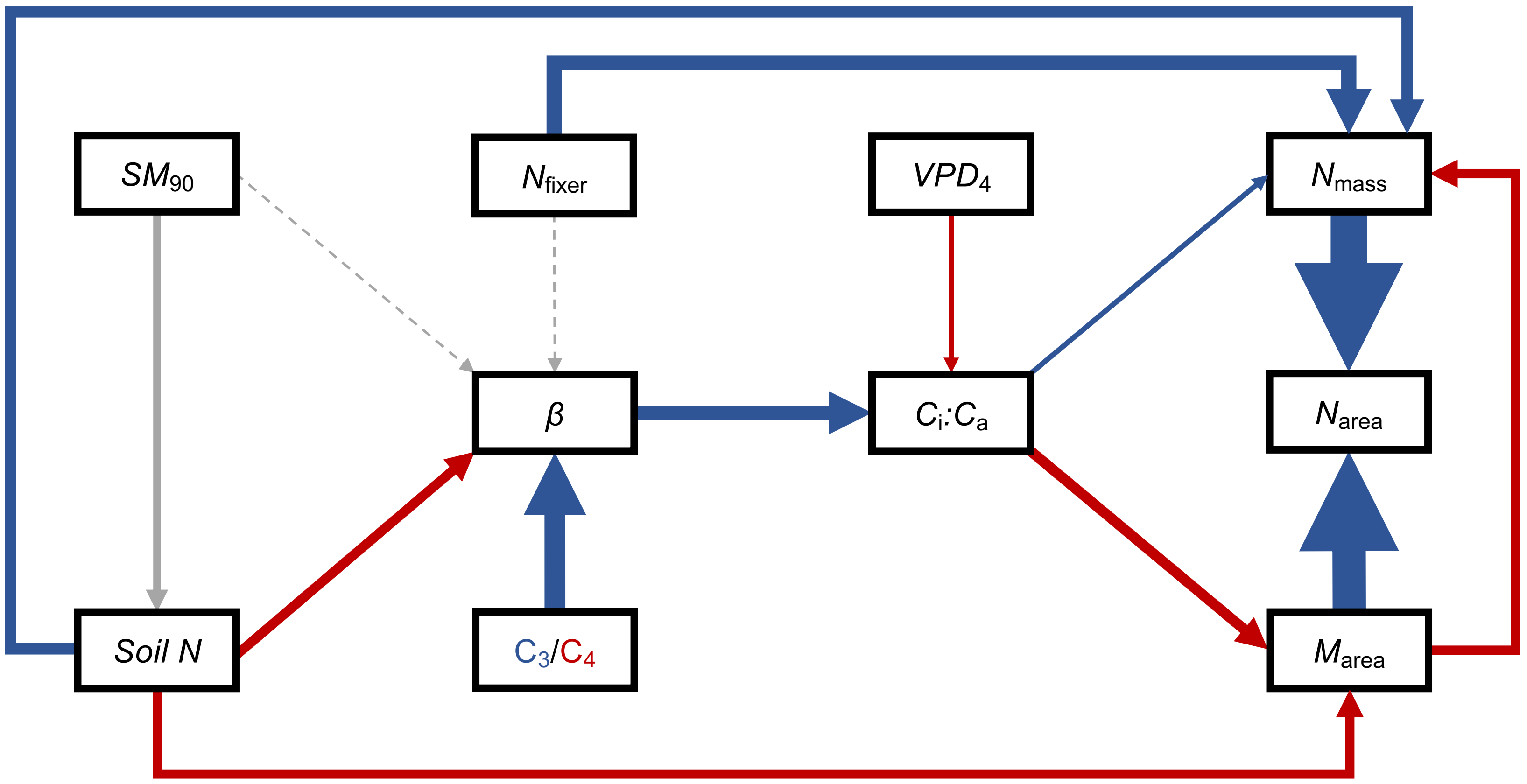
Positive
Negative

N-fixation ability directly **increases** N_{mass}



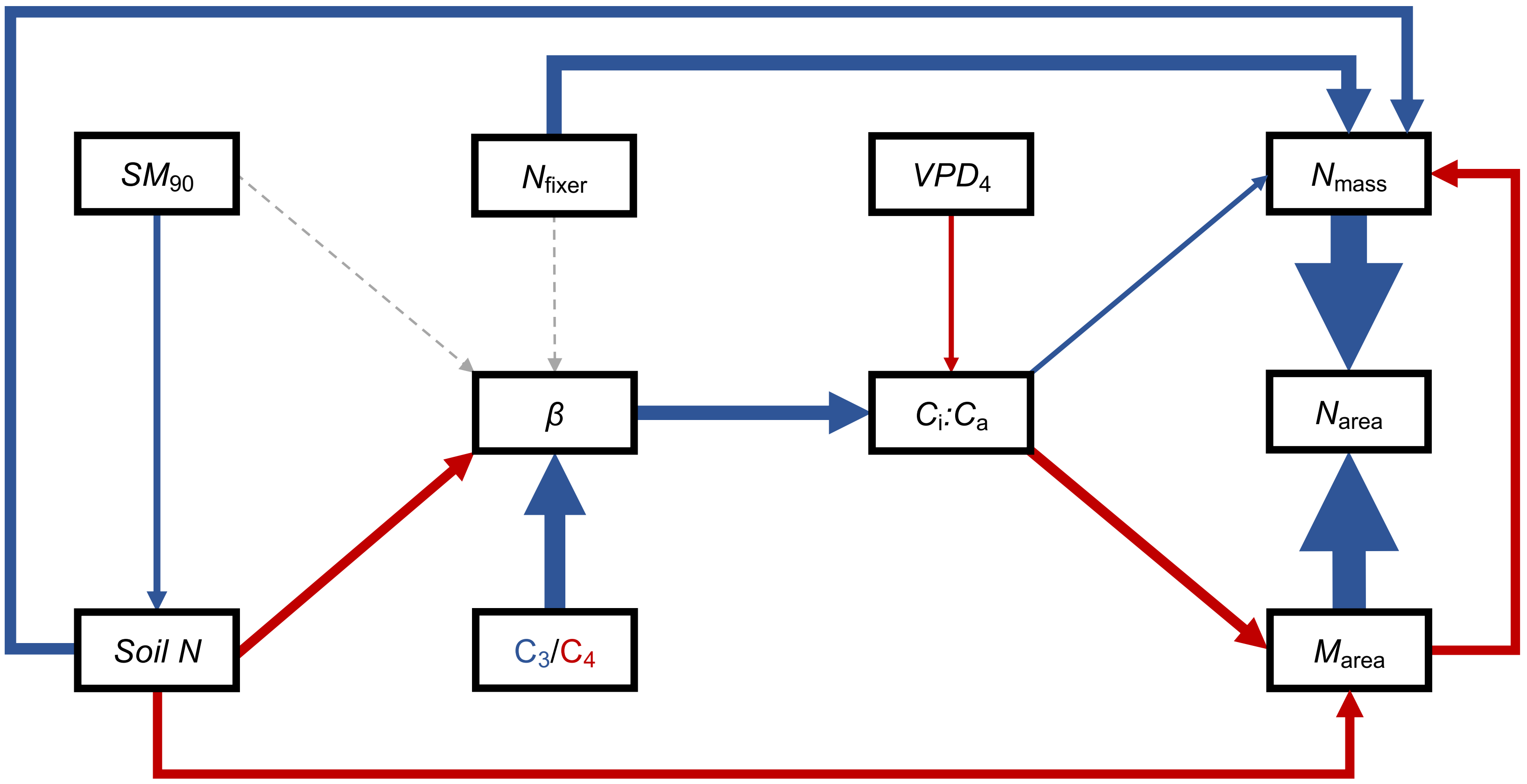
Positive
Negative

M_{area} is **negatively** associated with N_{mass}



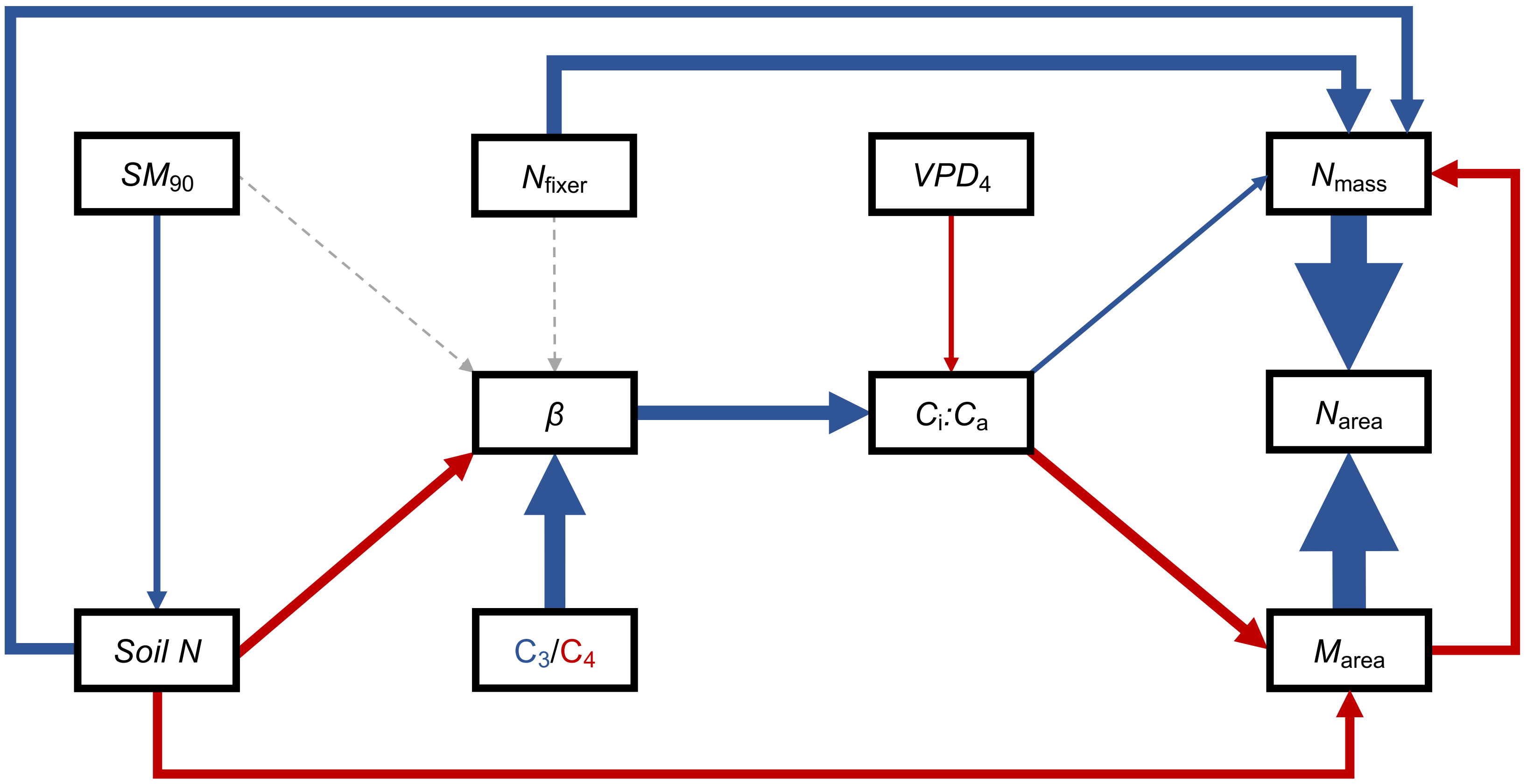
Positive
Negative

Soil moisture was **positively** associated with soil nitrogen availability



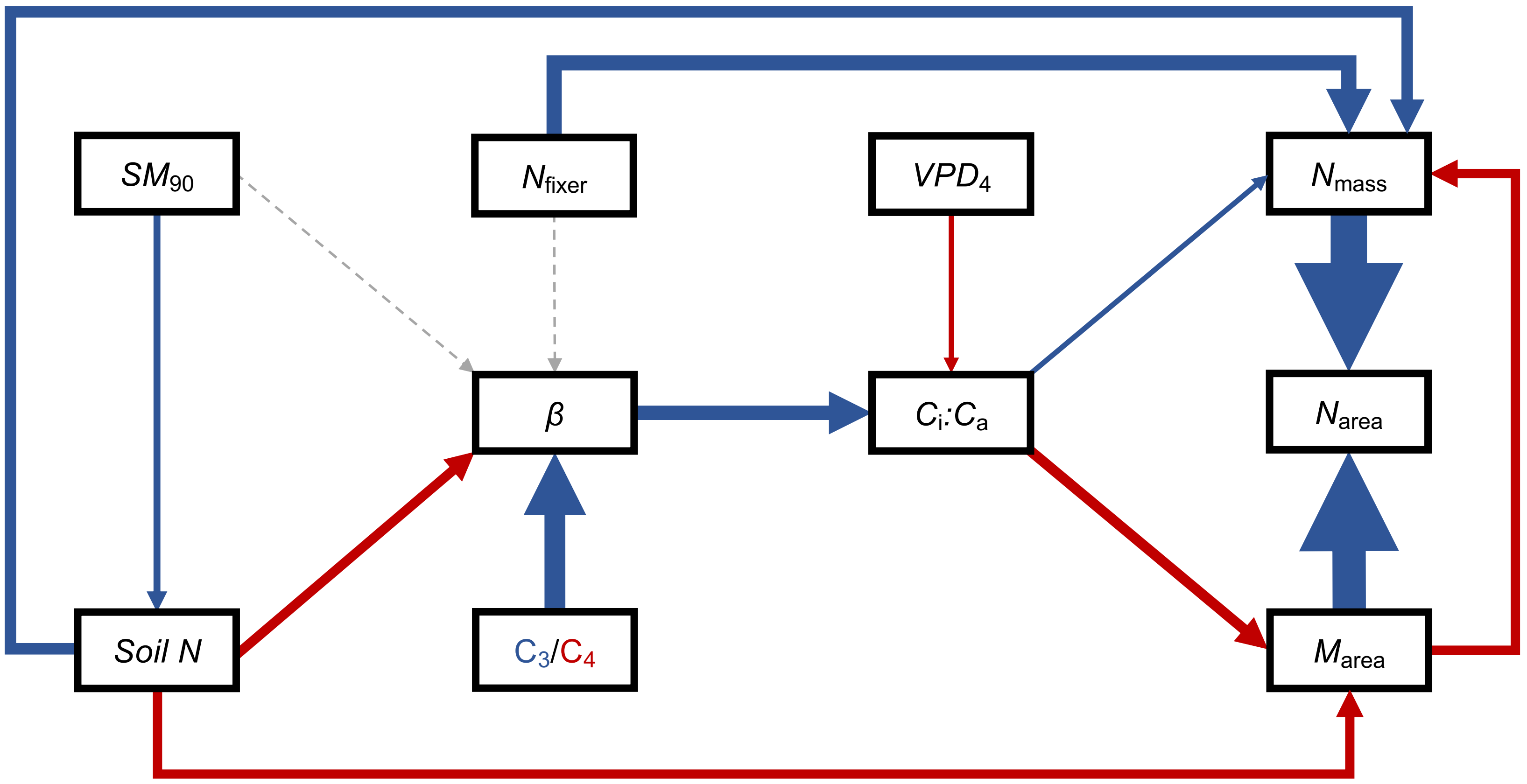
Positive
Negative

Soil N directly **increased** N_{area} due to changes in N_{mass}…



Positive
Negative

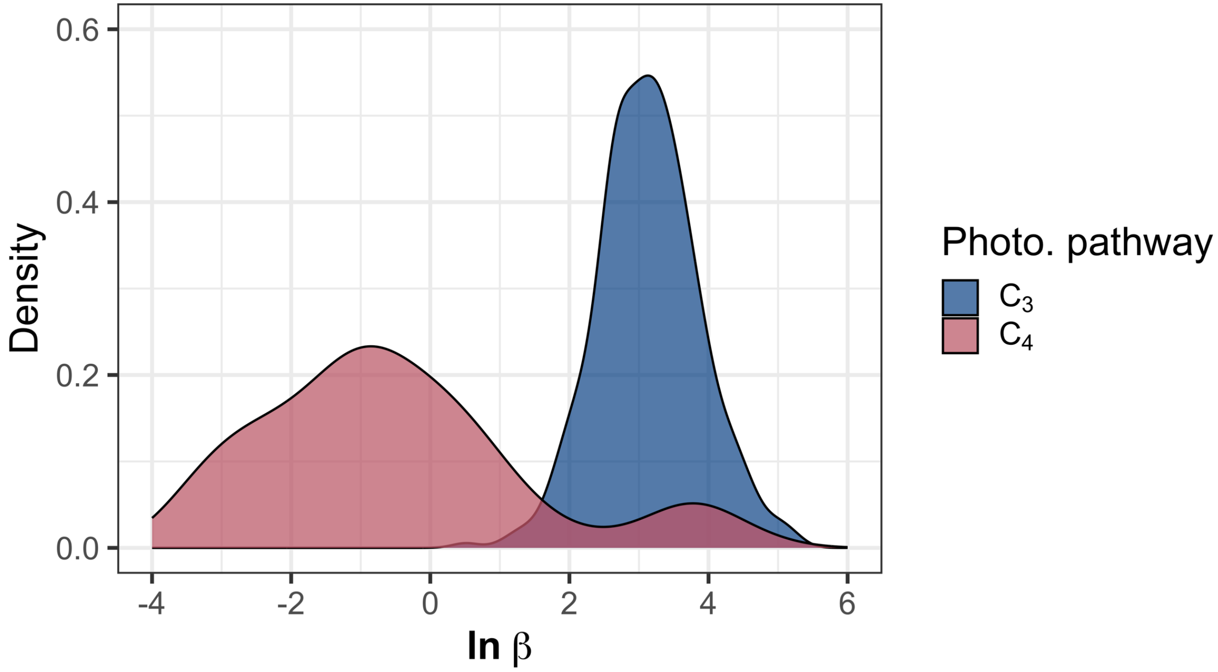
… and indirectly **increased** N_{area} through **reductions** in β



Positive
Negative

Conclusions

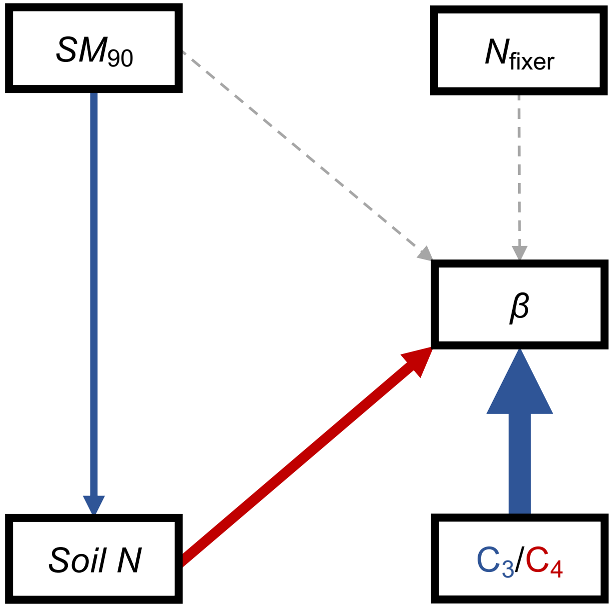
- β dynamically changes across environments



Conclusions

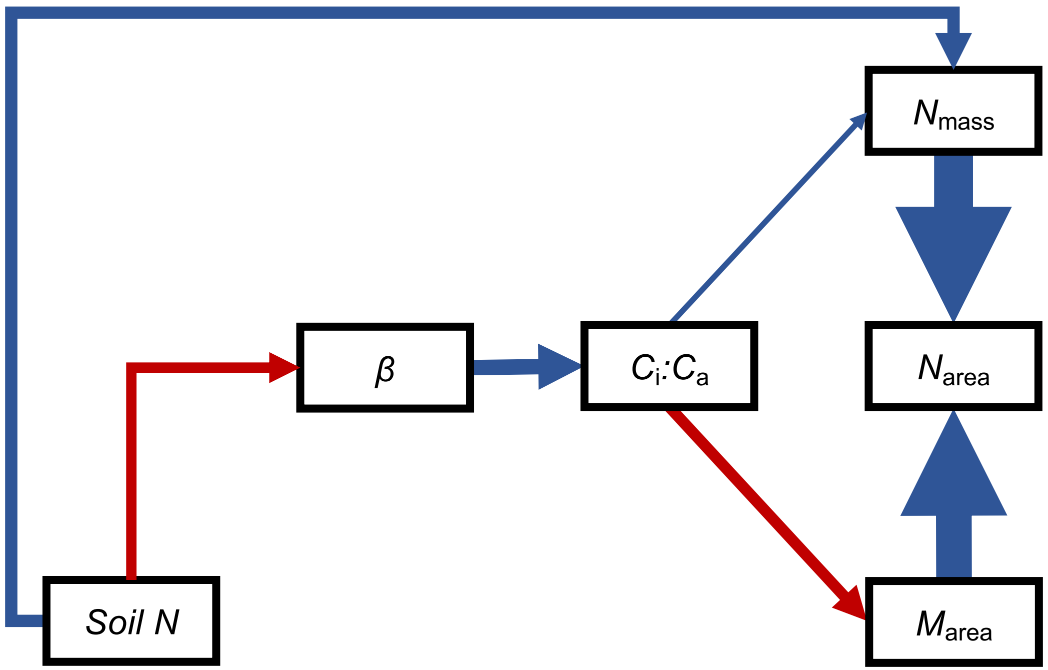
- β dynamically changes across environments

- Soil N is more important for determining variance in β than soil moisture



Conclusions

- *β* dynamically changes across environments
- Soil N is more important for determining variance in *β* than soil moisture
- Leaf N is both a direct and indirect product of soil N availability



Acknowledgements

Field and lab assistance (*UG mentees)

- Risa McNellis
- Jorge Ochoa*
- Peter Eludini
- Christine Vanginault*
- Abigail Bell*
- Jose Villeda*
- Hannah German*
- Avery Schoenherr*

BRAUN & GRESHAM
ATTORNEYS AT LAW
We are advocates for you and your land.

Texas Ecological Laboratory

SCHMIDT FUTURES

Extra slides

Resource unit cost ratio (β)

cost of acquiring and using N

$$\beta = \frac{b}{a}$$

cost of acquiring and using H_2O

Resource unit cost ratio (β)

$$\beta = \frac{b}{a} = 1.6\eta^{*}\mathrm{D}\frac{\left(\chi_{leaf} - \frac{\Gamma^{*}}{\mathrm{C}_{a}}\right)}{\left(1 - \chi_{leaf}\right)^{2} * (\mathrm{K} + \Gamma^{*})}$$