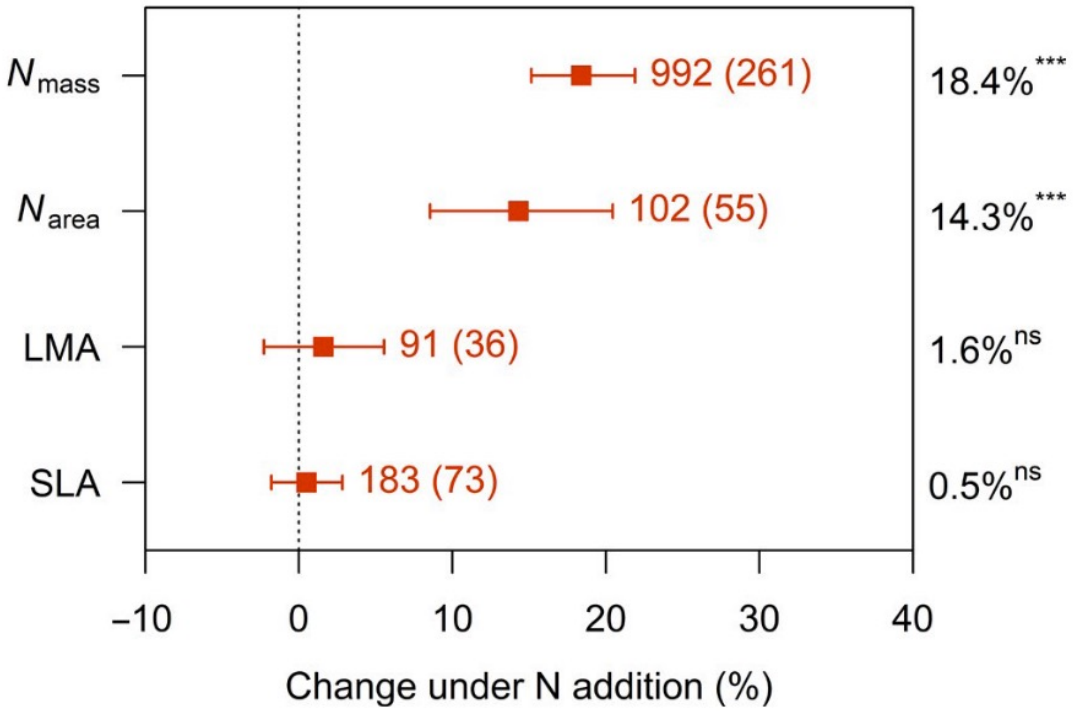
The cost of resource use for photosynthesis drives variance in leaf nitrogen content across a climate and soil resource availability gradient

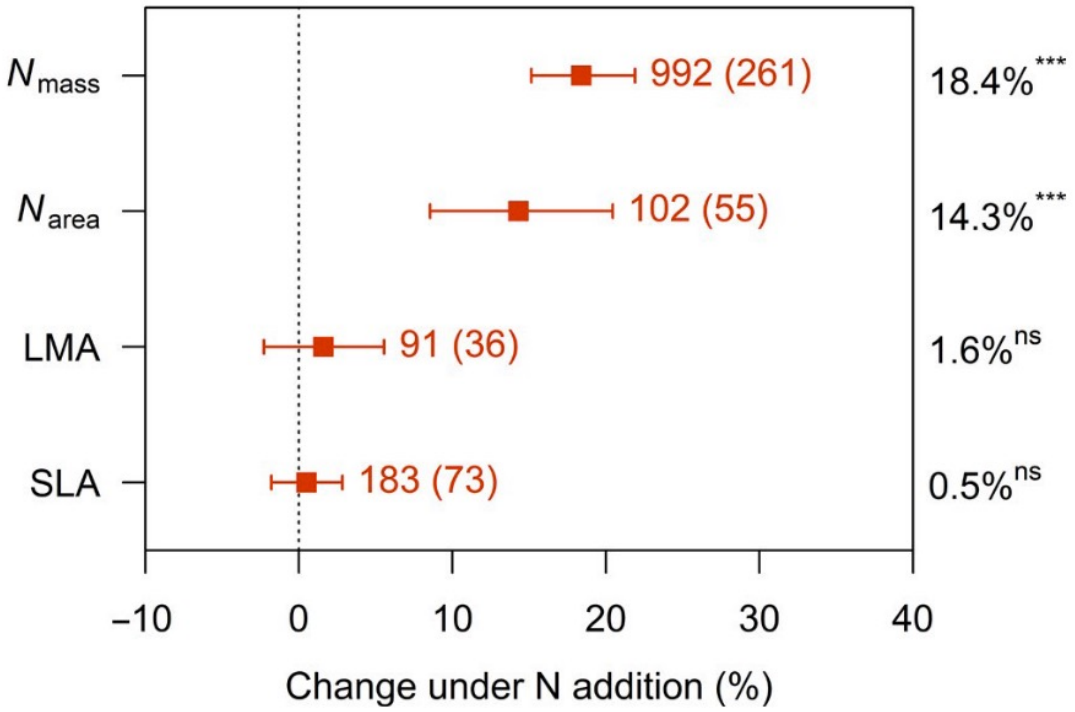
Evan A. Perkowski; Nicholas G. Smith

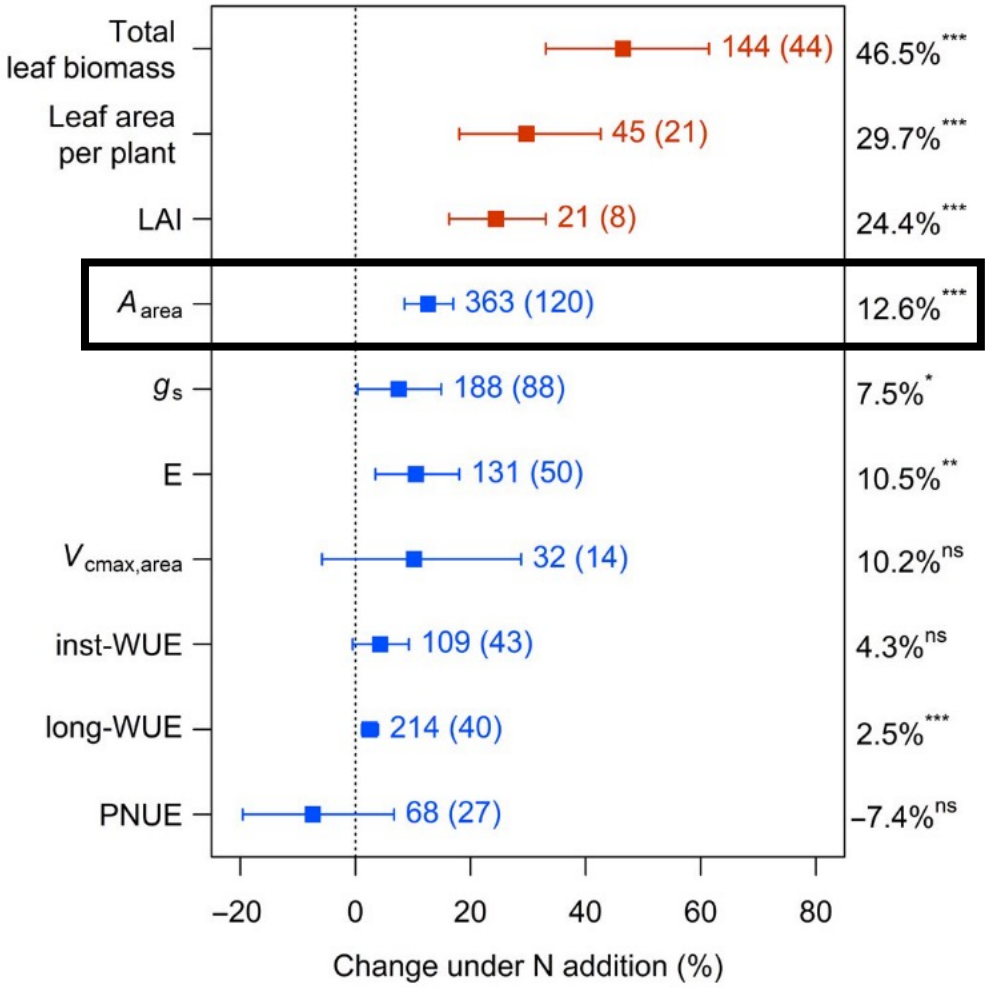
Soil nitrogen generally increases leaf nitrogen…



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

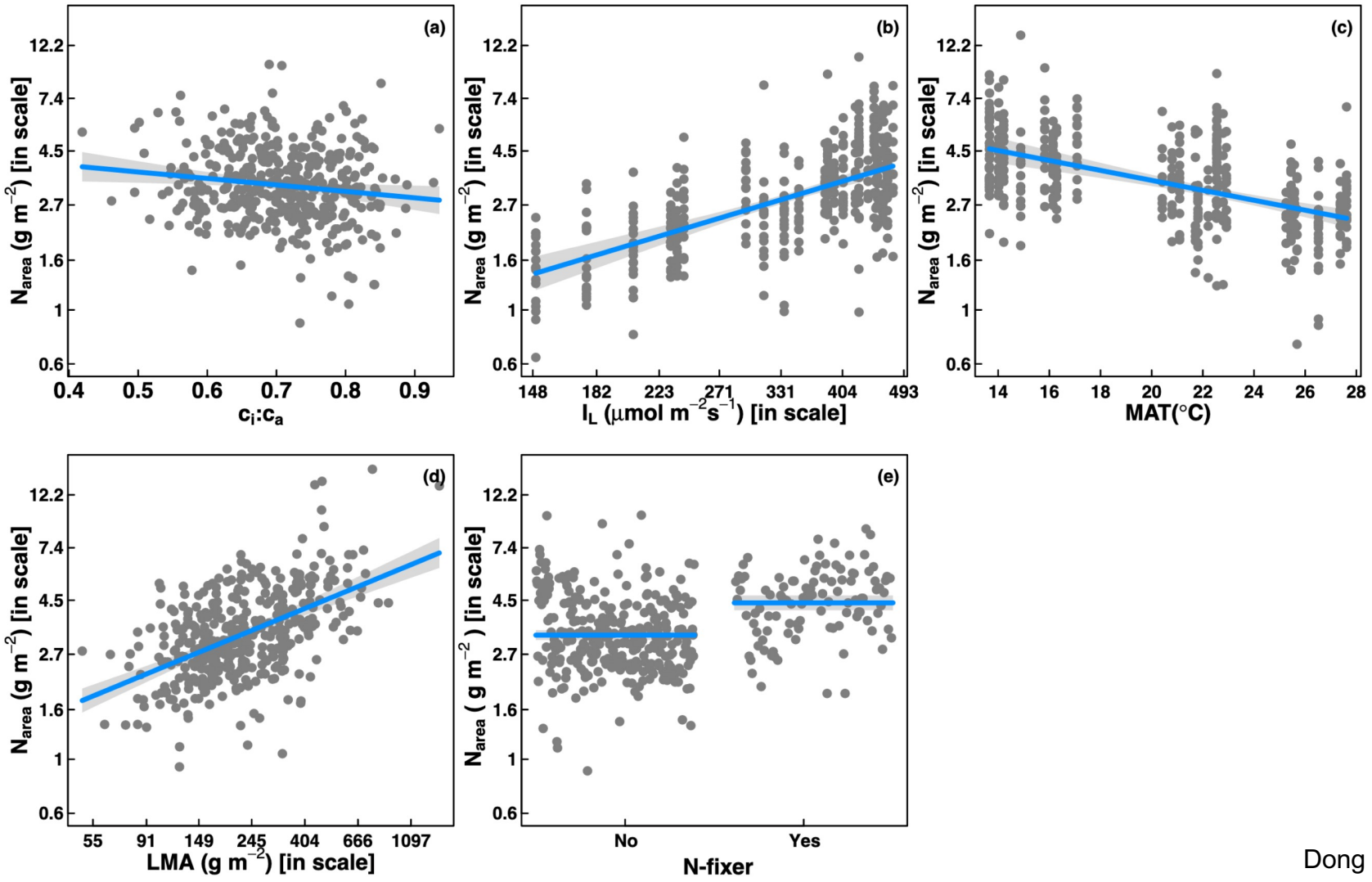
… which often corresponds with increased photosynthesis





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

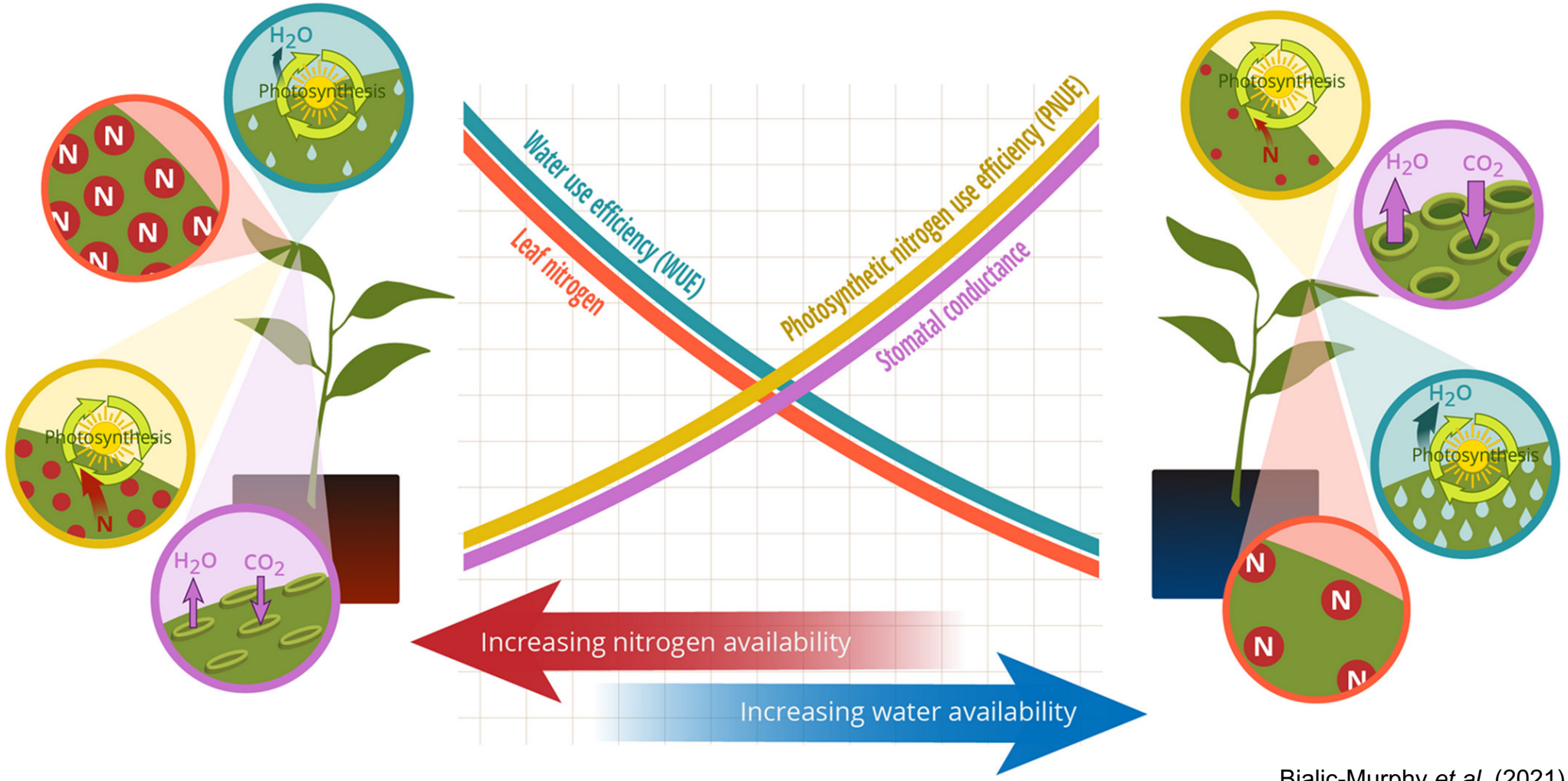
However, leaf nitrogen can be predicted independent of soil nitrogen



Dong et al. (2017) *Biogeosciences*

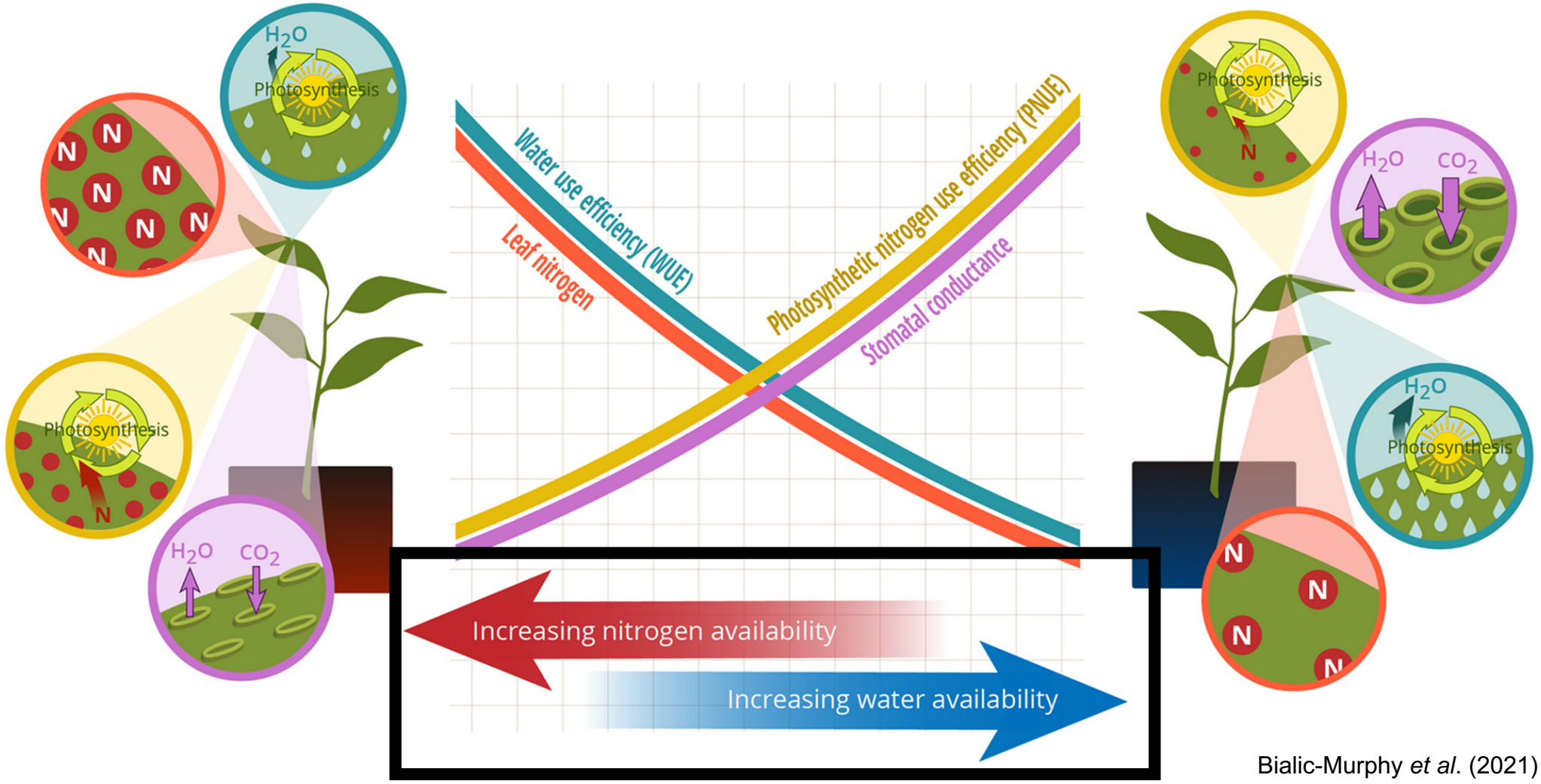
Leaf nitrogen is likely a product of interactions between climatic and edaphic factors

Photosynthetic least-cost theory



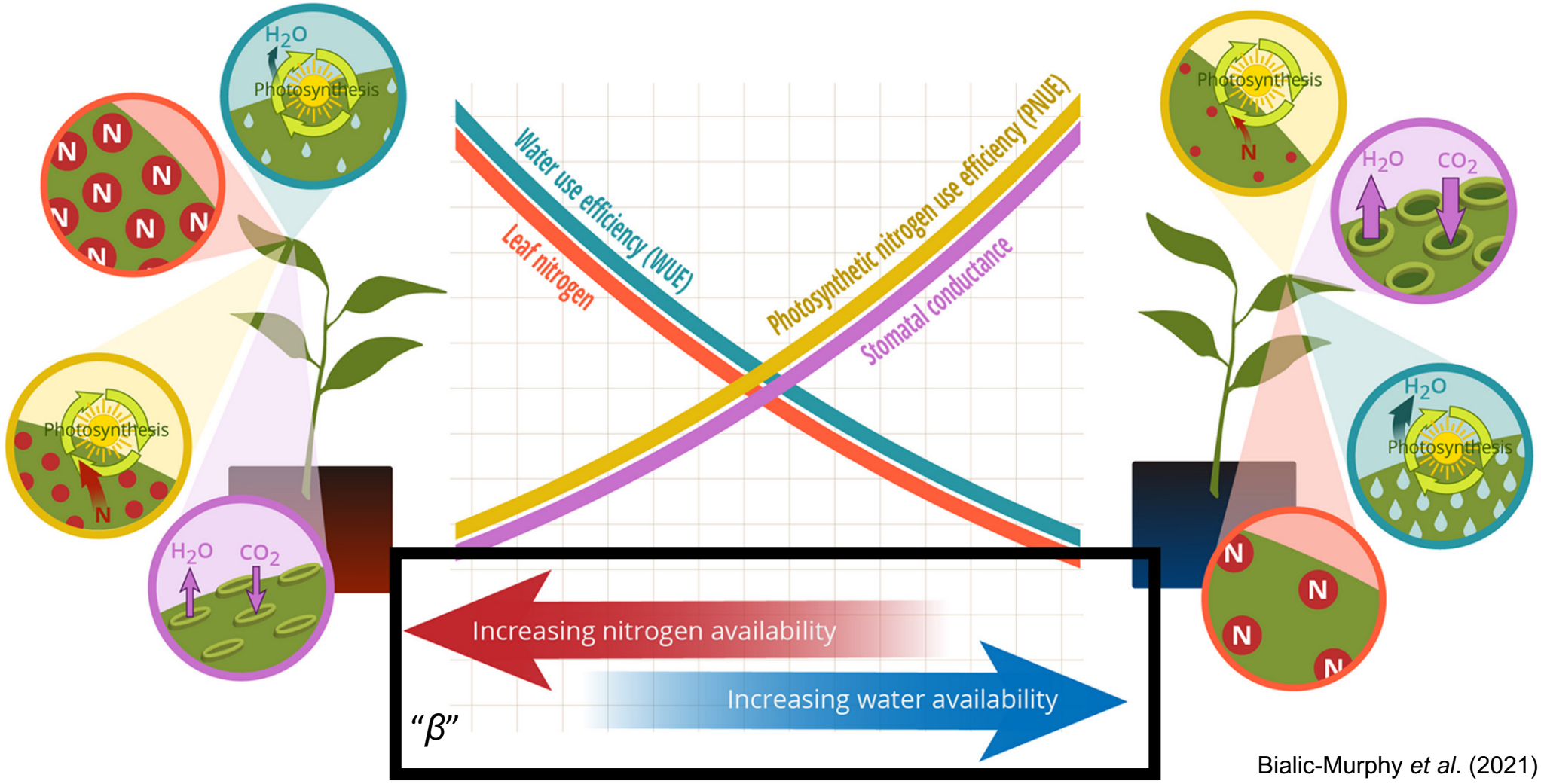
Bialic-Murphy *et al*. (2021) *Ecology Letters*

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



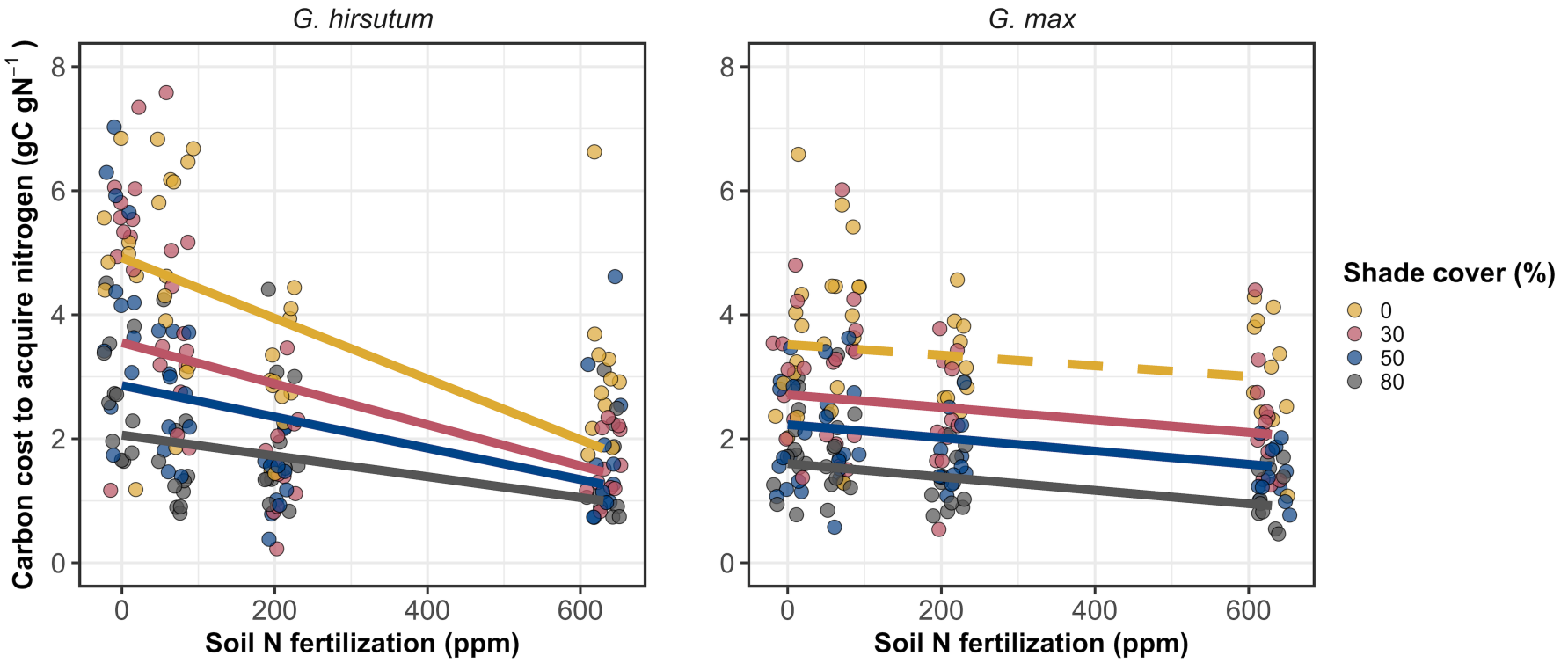
Bialic-Murphy *et al*. (2021) *Ecology Letters*

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



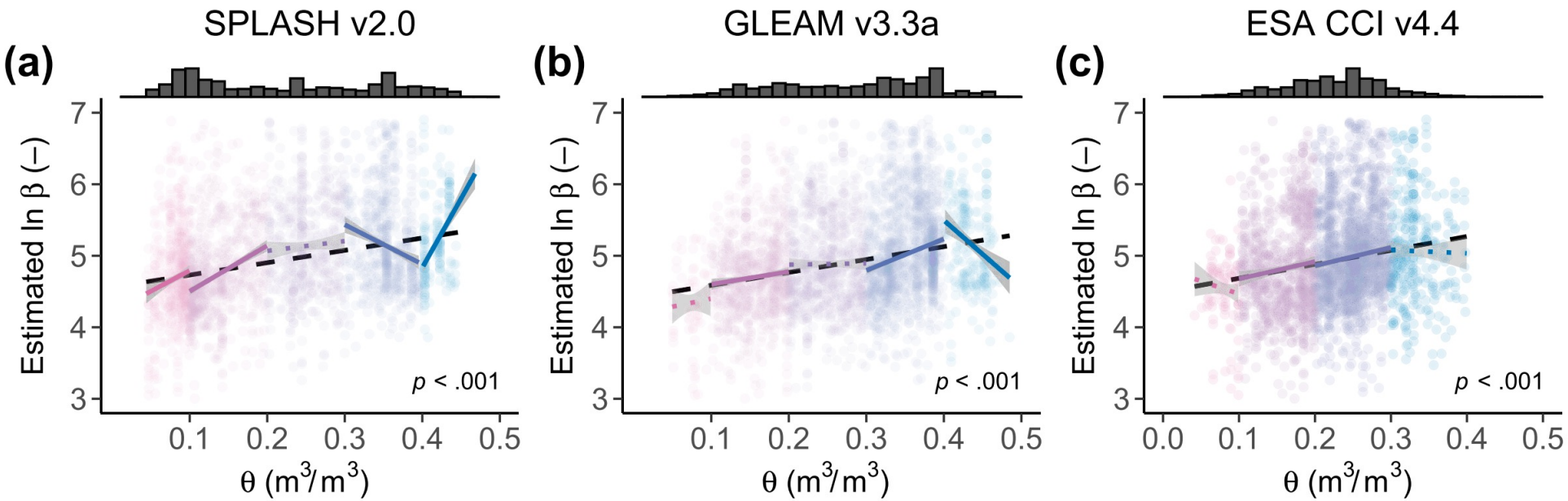
Bialic-Murphy *et al*. (2021) *Ecology Letters*

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



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

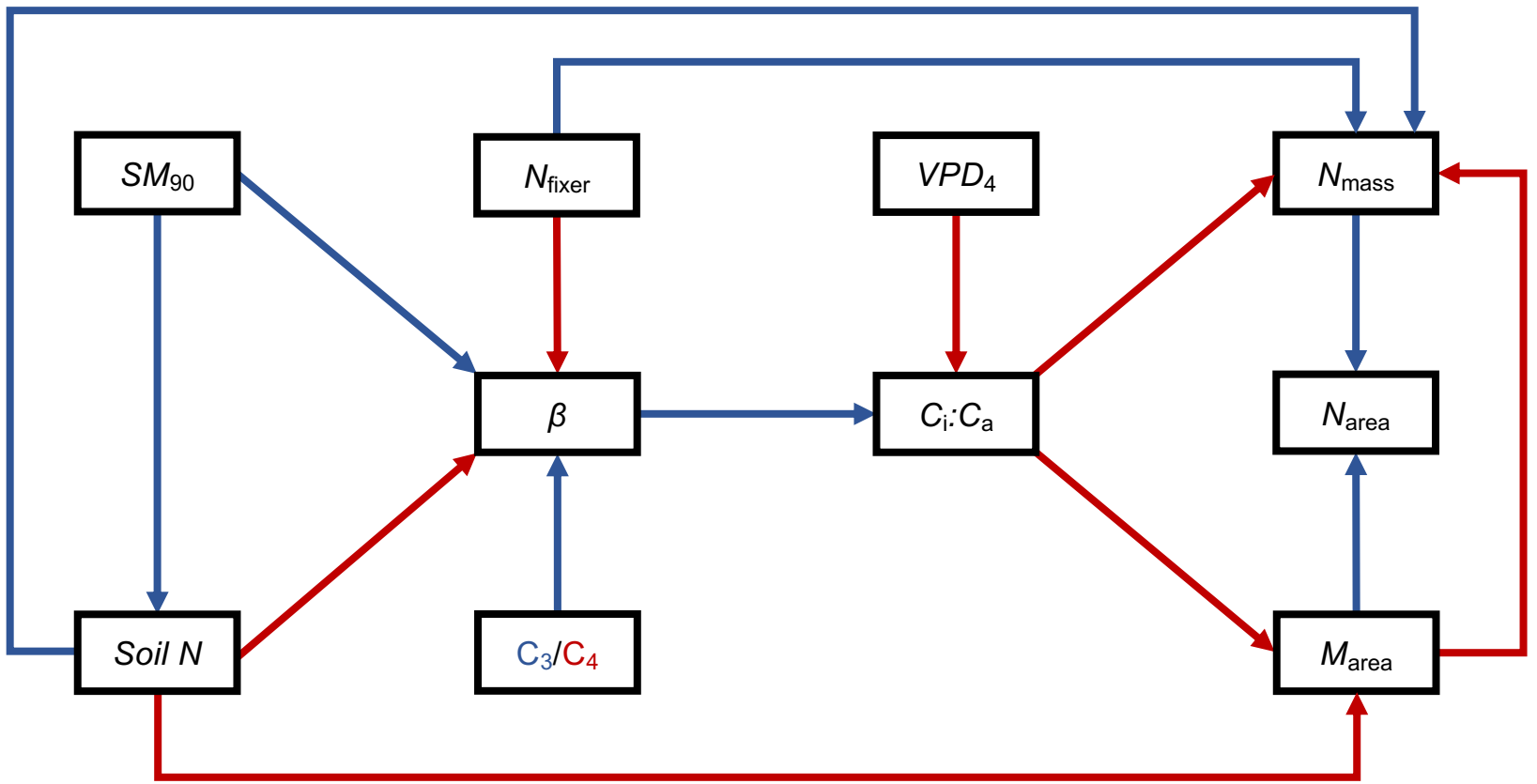
β is held constant in least-cost optimality models, but varies across environments



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

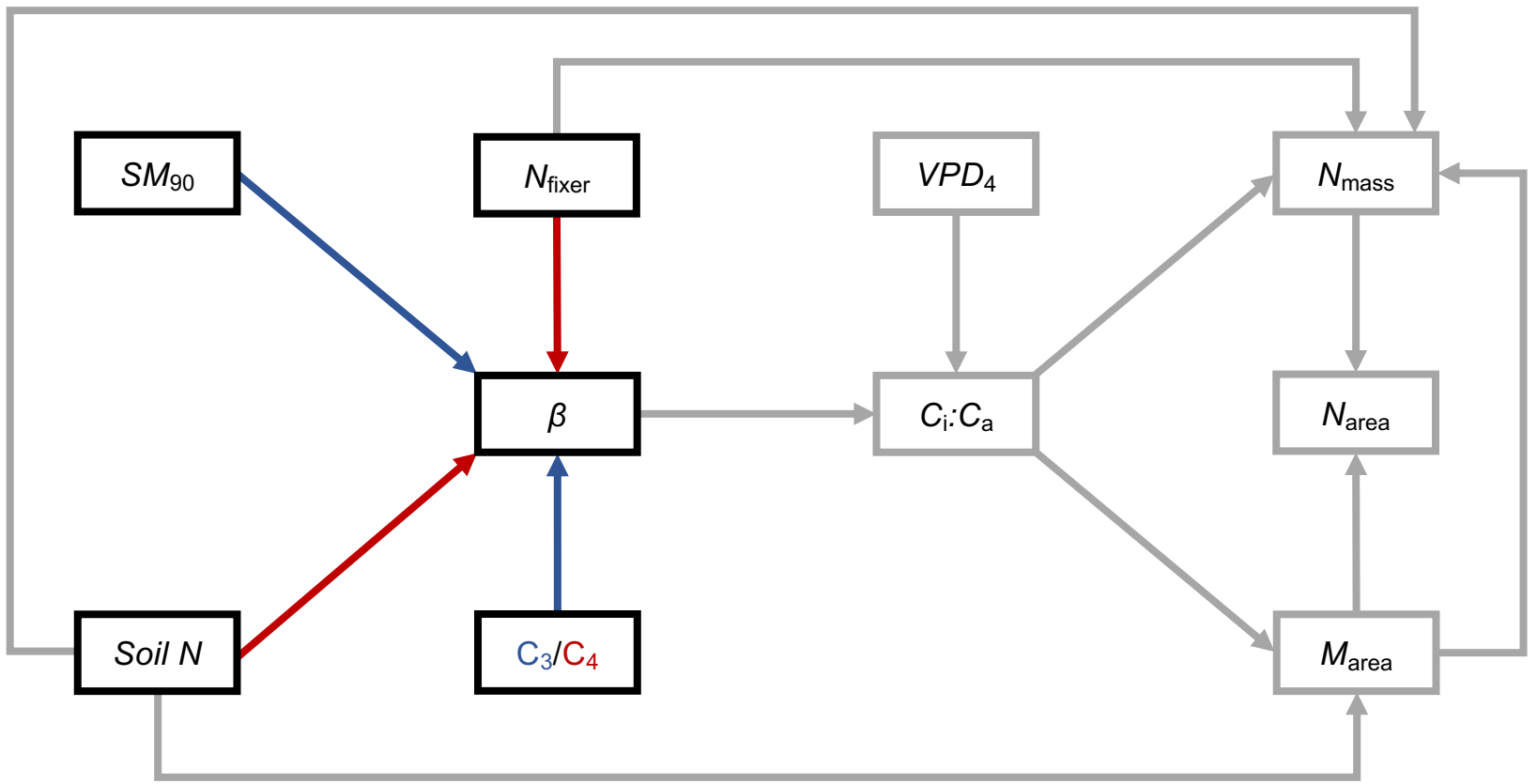
Open questions

Hypotheses



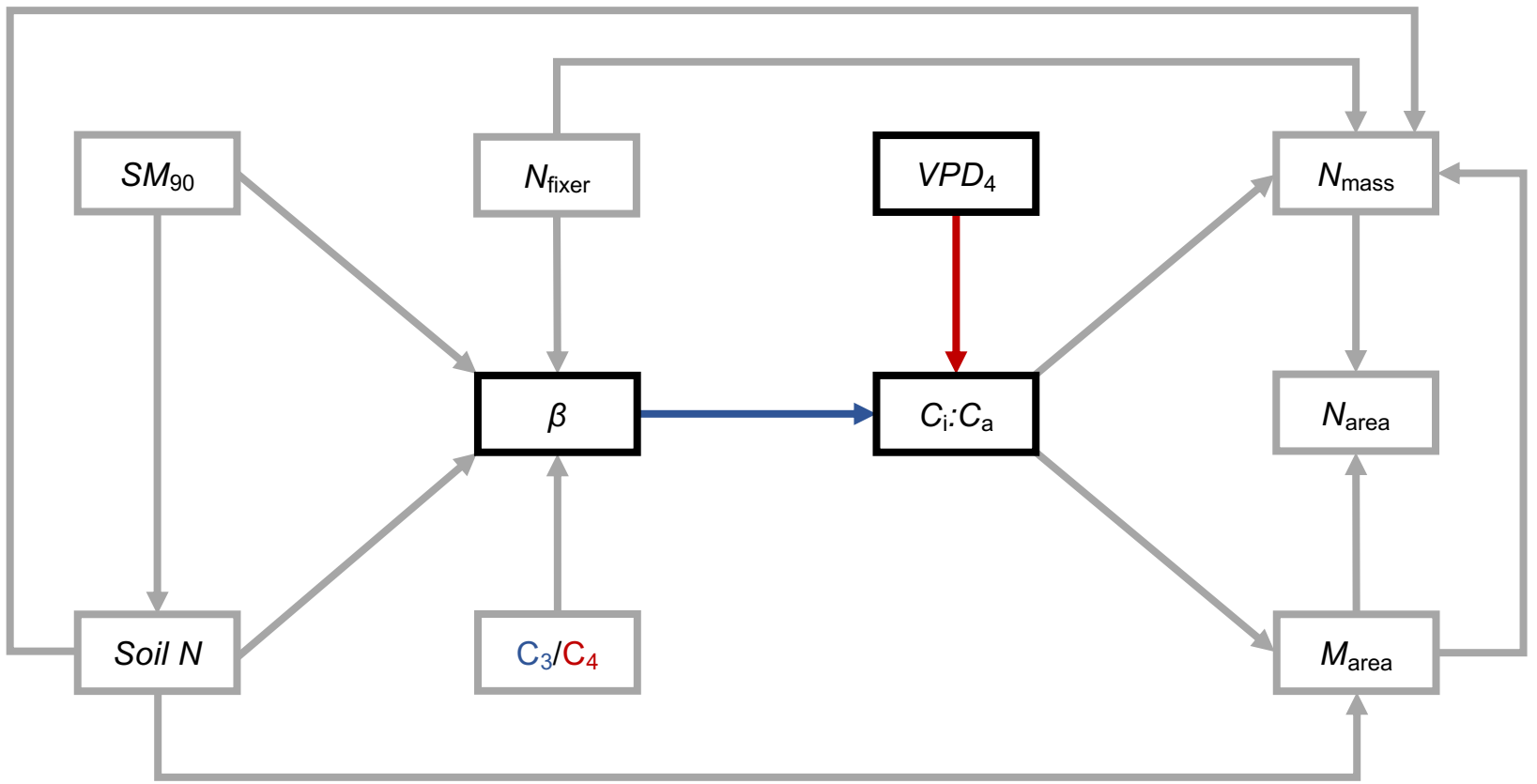
Positive
Negative

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



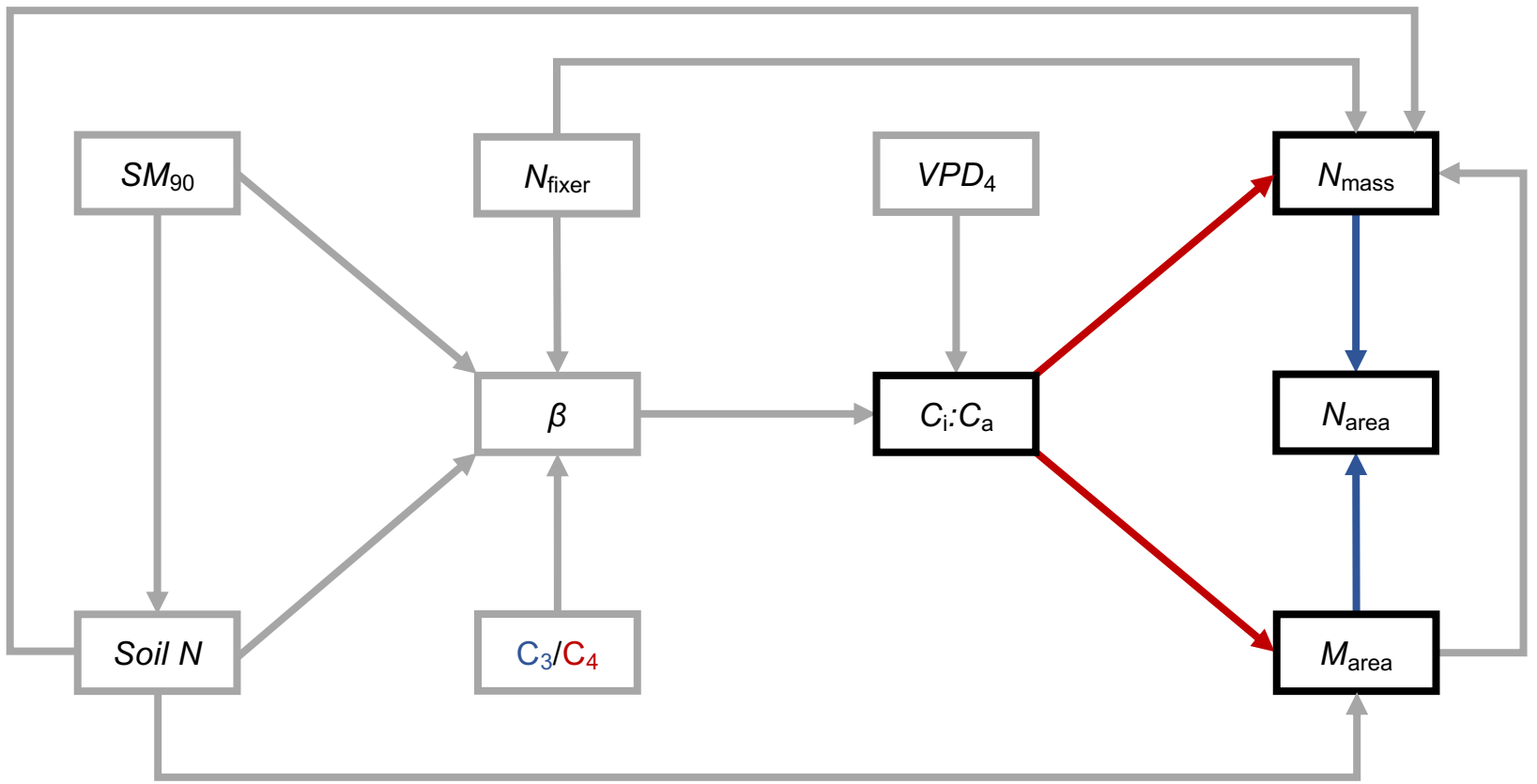
Positive
Negative

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



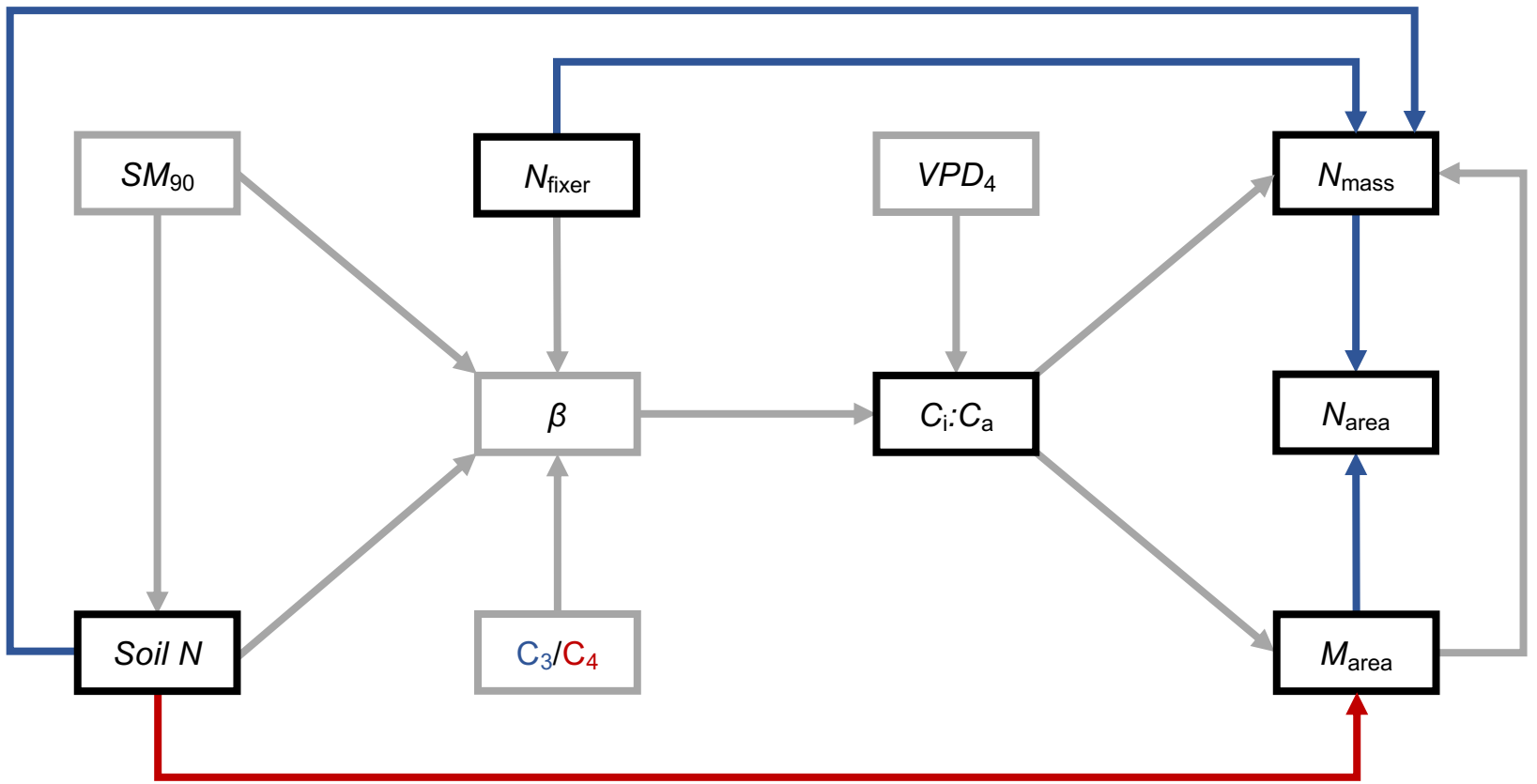
Positive
Negative

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



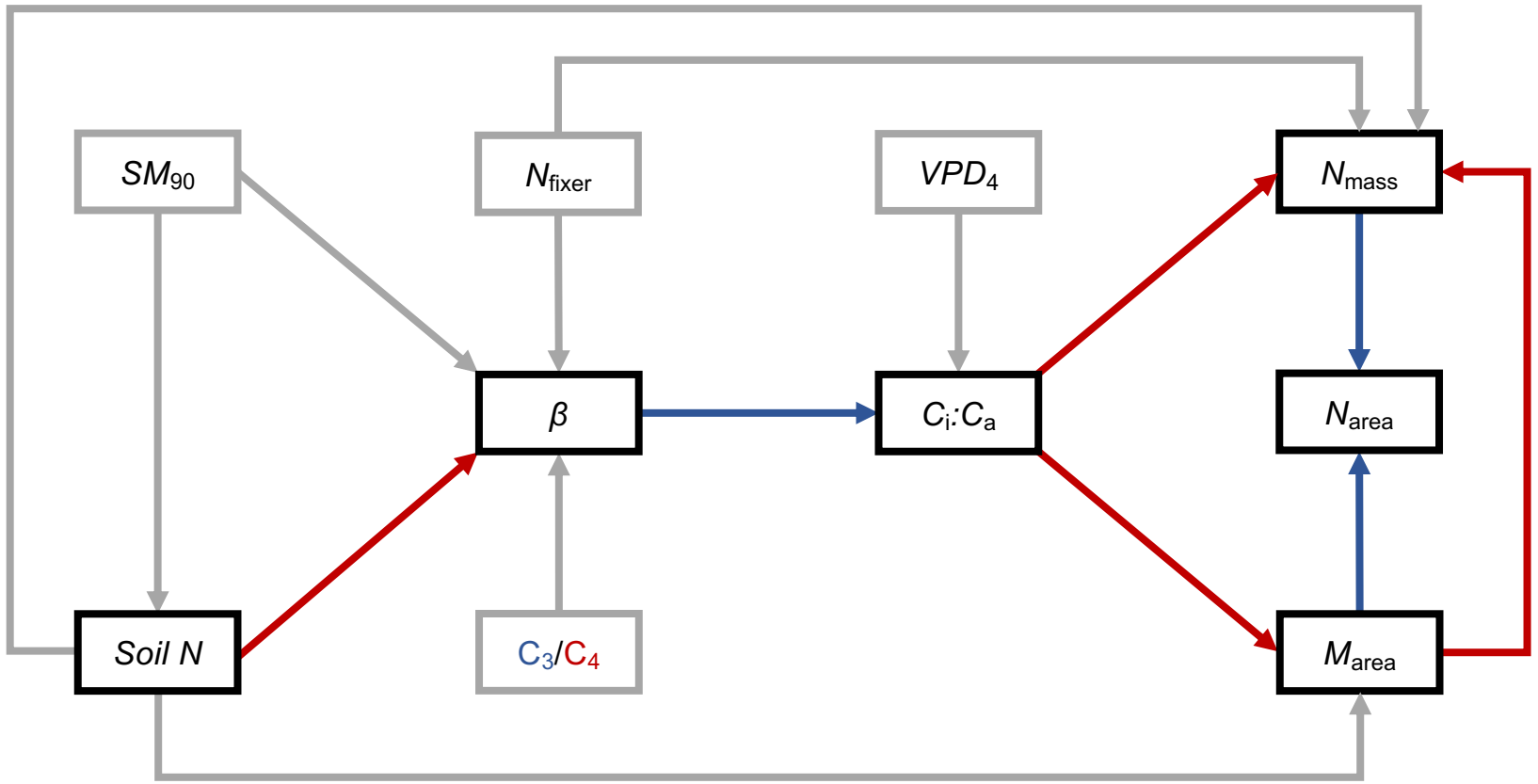
Positive
Negative

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



Positive
Negative

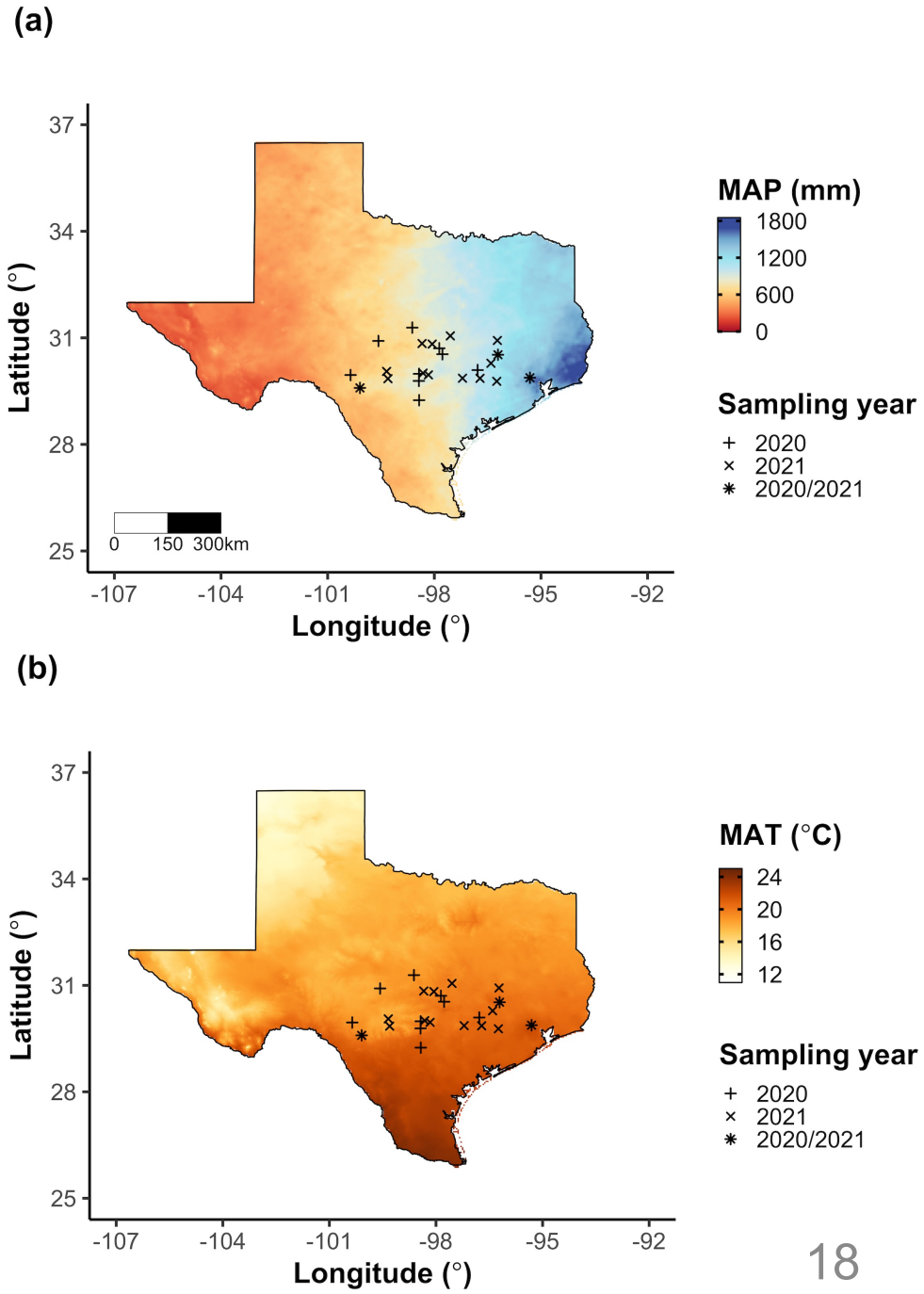
… or may indirectly **increase** N_{area} due to **reductions** in the cost of acquiring nitrogen



Positive
Negative

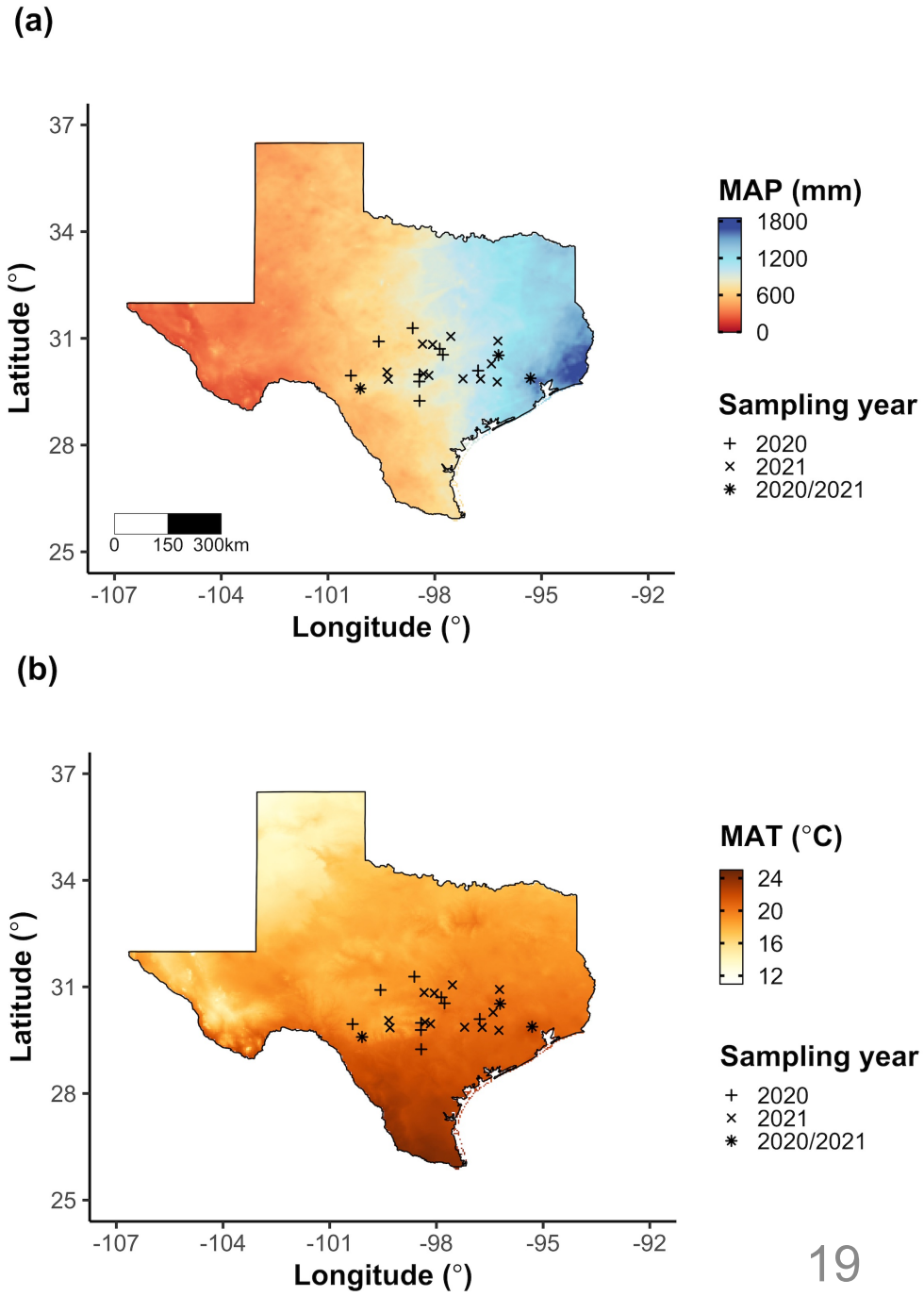
Field gradient experiment

- 24 sites
  - 12 visited in 2020
  - 15 visited 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
  - [NO_3-N]

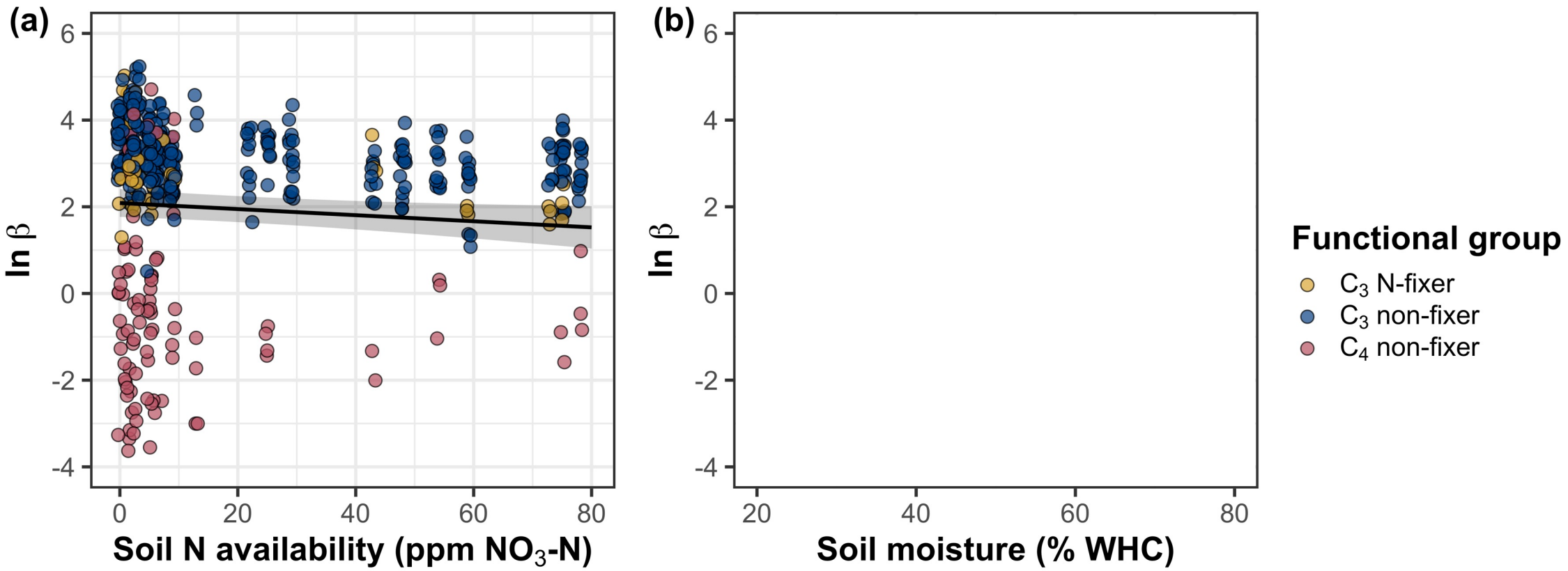


Climate and edaphic characteristics

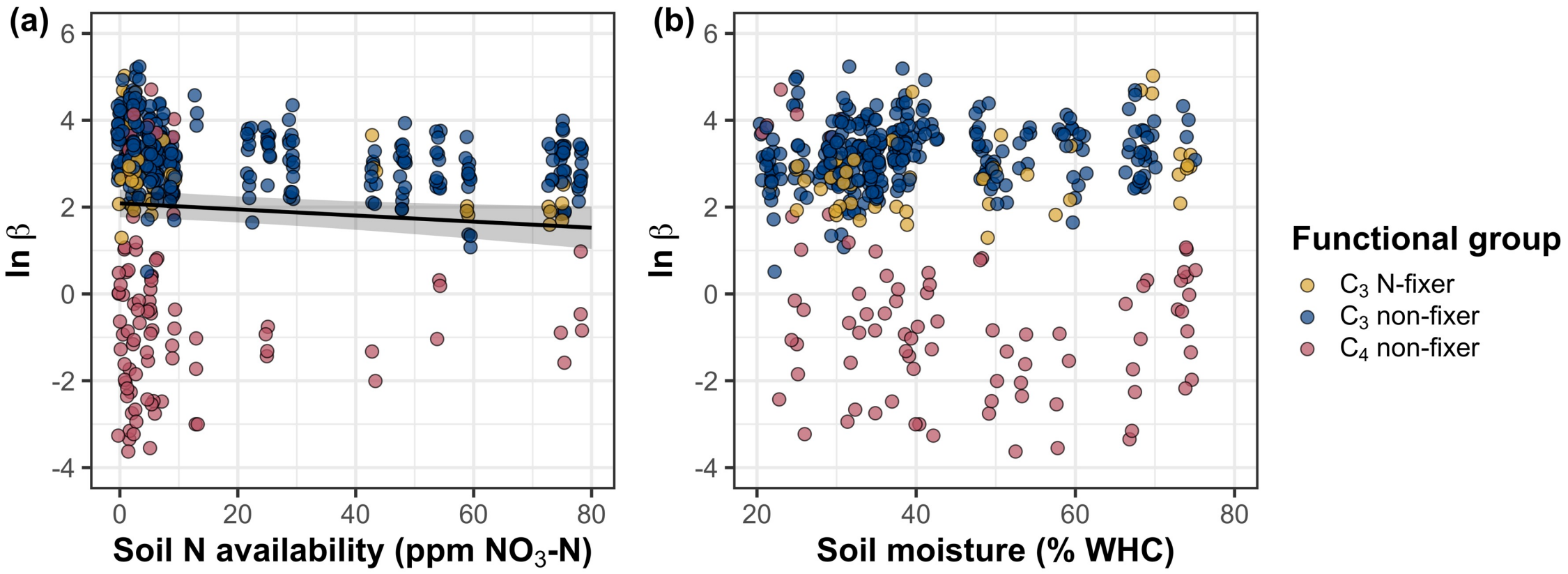
- PRISM data product (4-km grid across coterminous US)
  - Daily air temperature
  - Daily vapor pressure deficit
  - Daily precipitation
- Soil moisture derived from SPLASHv1.0 model
  - As function of water holding capacity



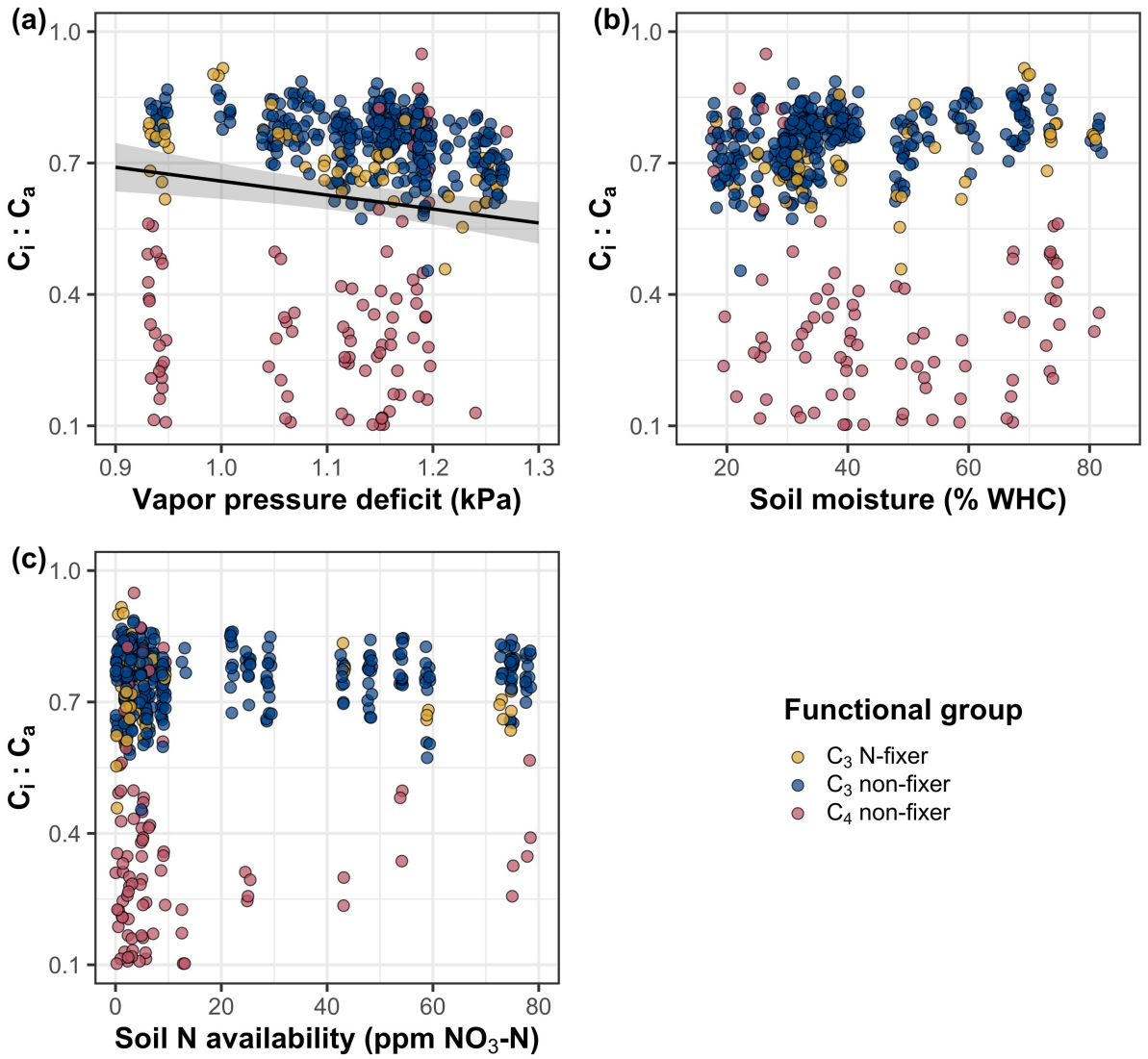
β **decreases** with increasing soil nitrogen



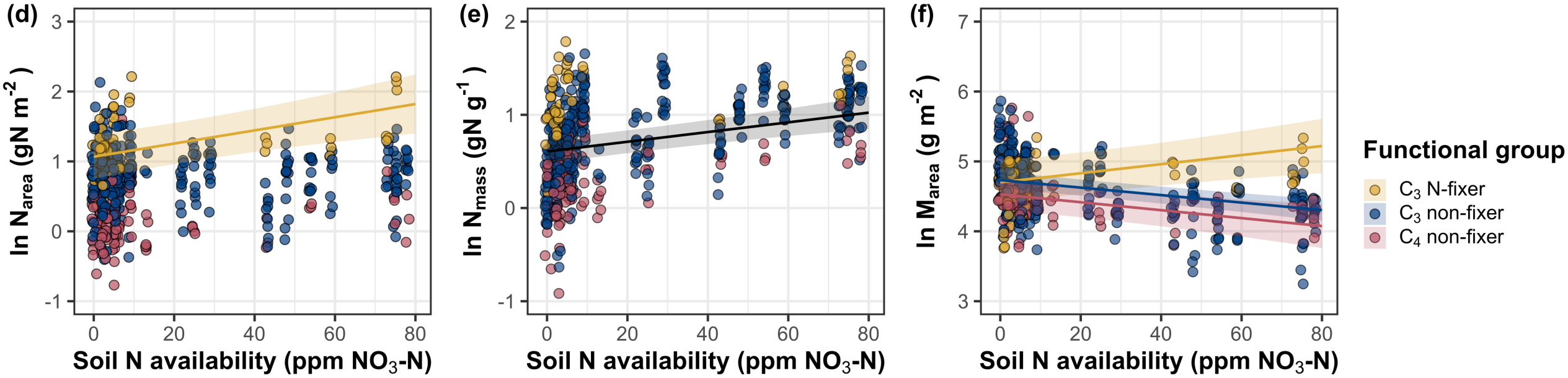
β **decreases** with increasing soil nitrogen, but is **not** modified by soil moisture



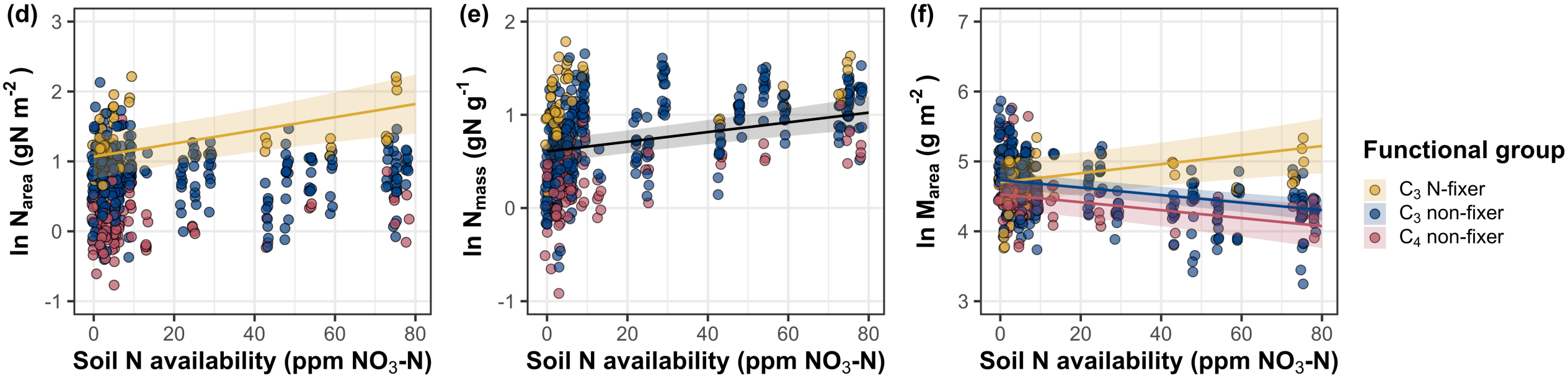
Leaf C_i:C_a **decreases** with increasing vapor pressure deficit, but is **not** modified by edaphic factors



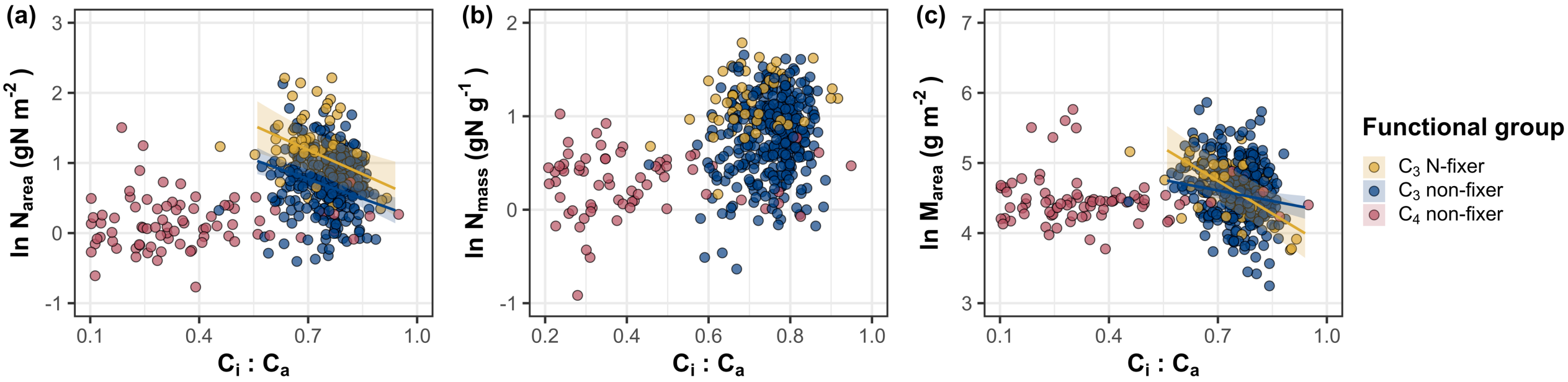
N_{area} **increases** with increasing soil nitrogen availability

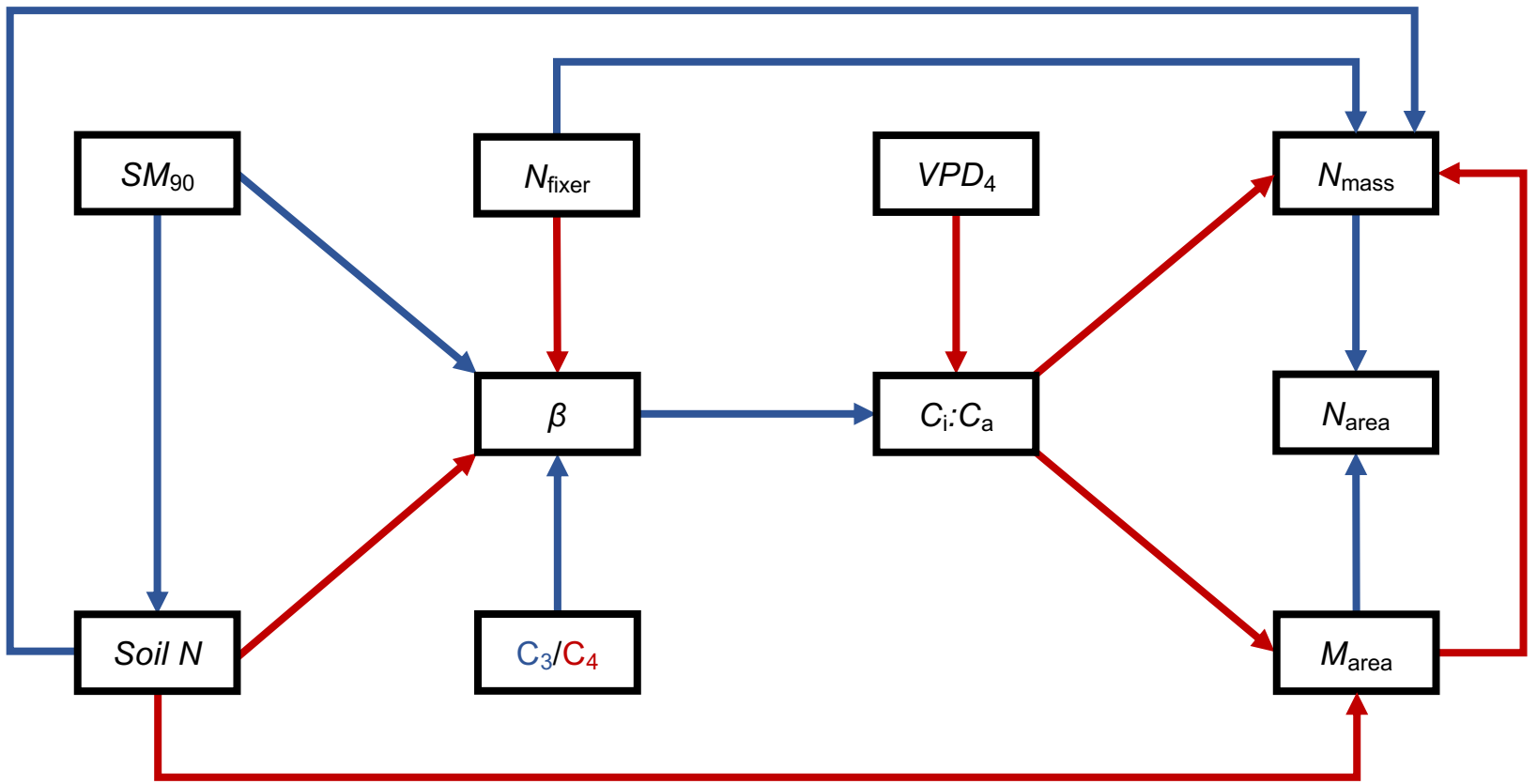


N_{area} **increases** with increasing soil nitrogen availability

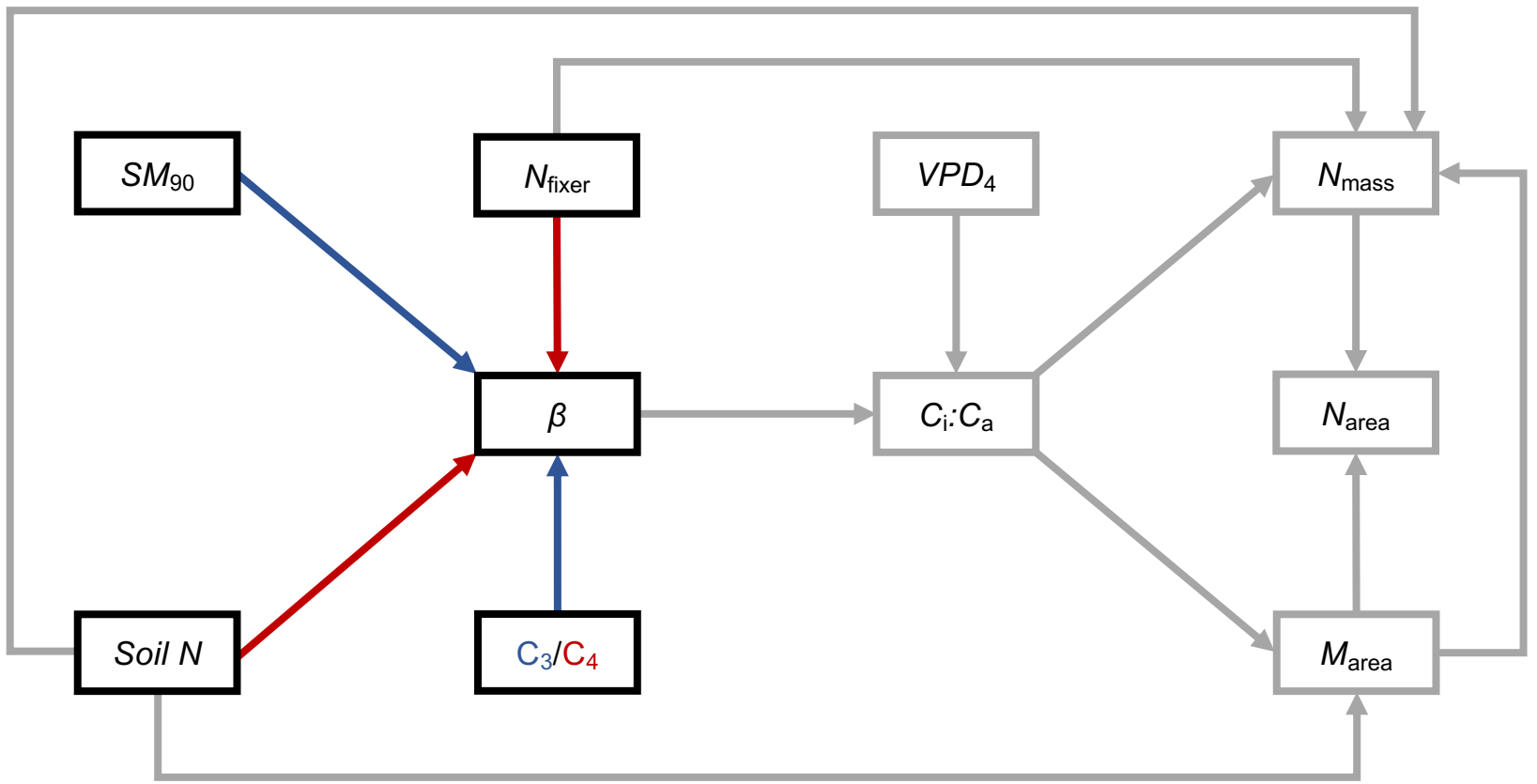


N_{area} is **negatively** associated with leaf C_i:C_a due to **reductions** in M_{area}



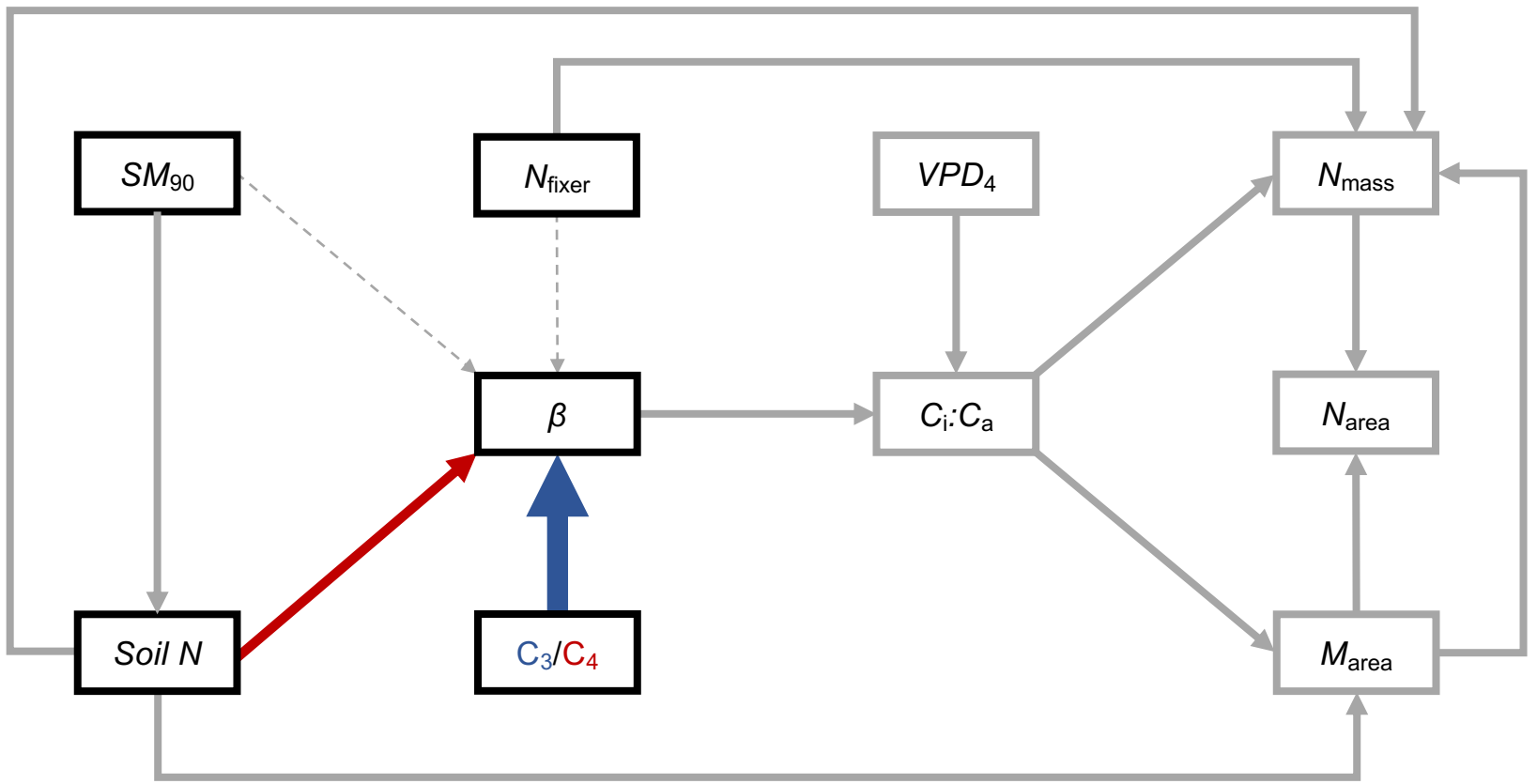


Positive
Negative

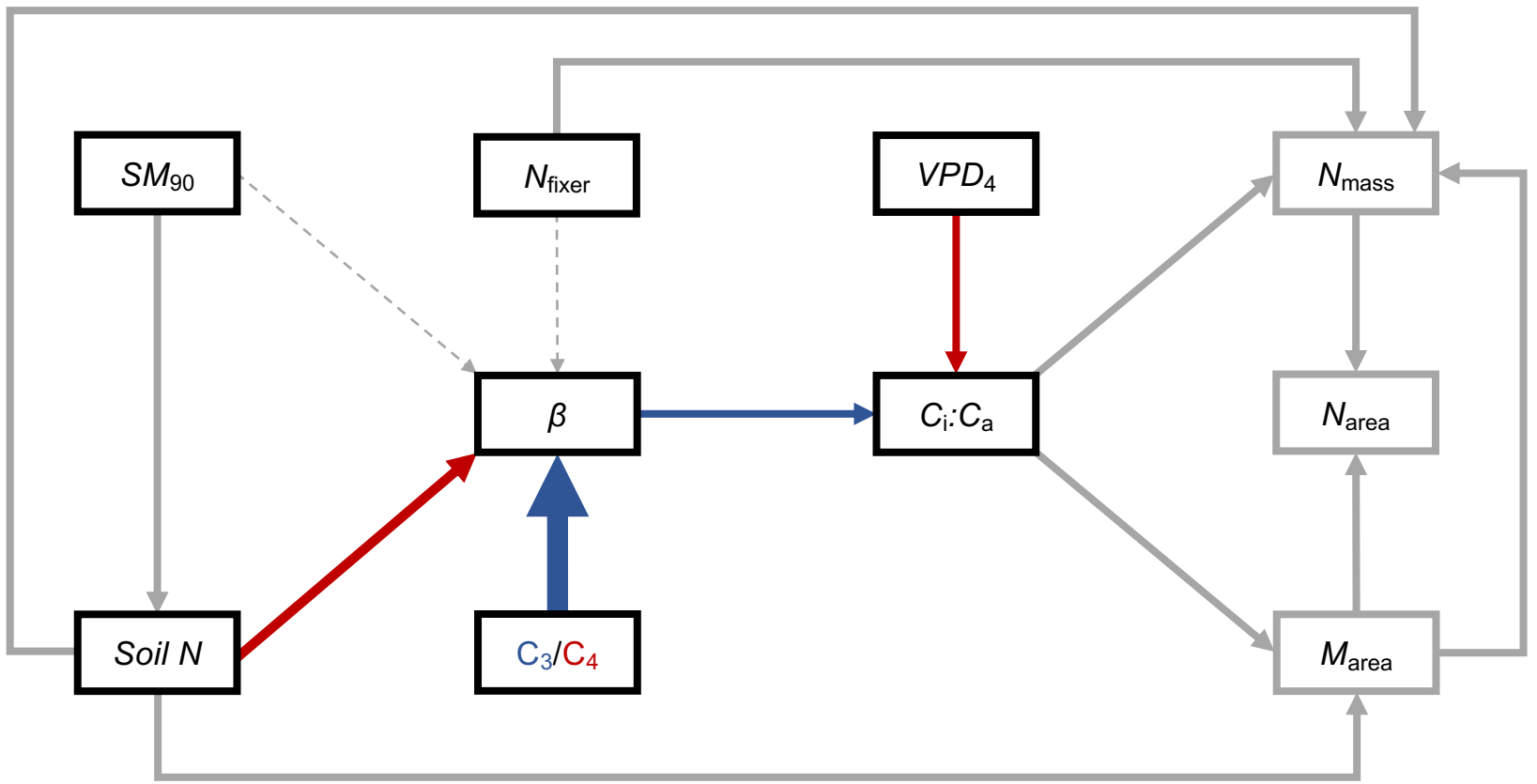


Positive
Negative

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

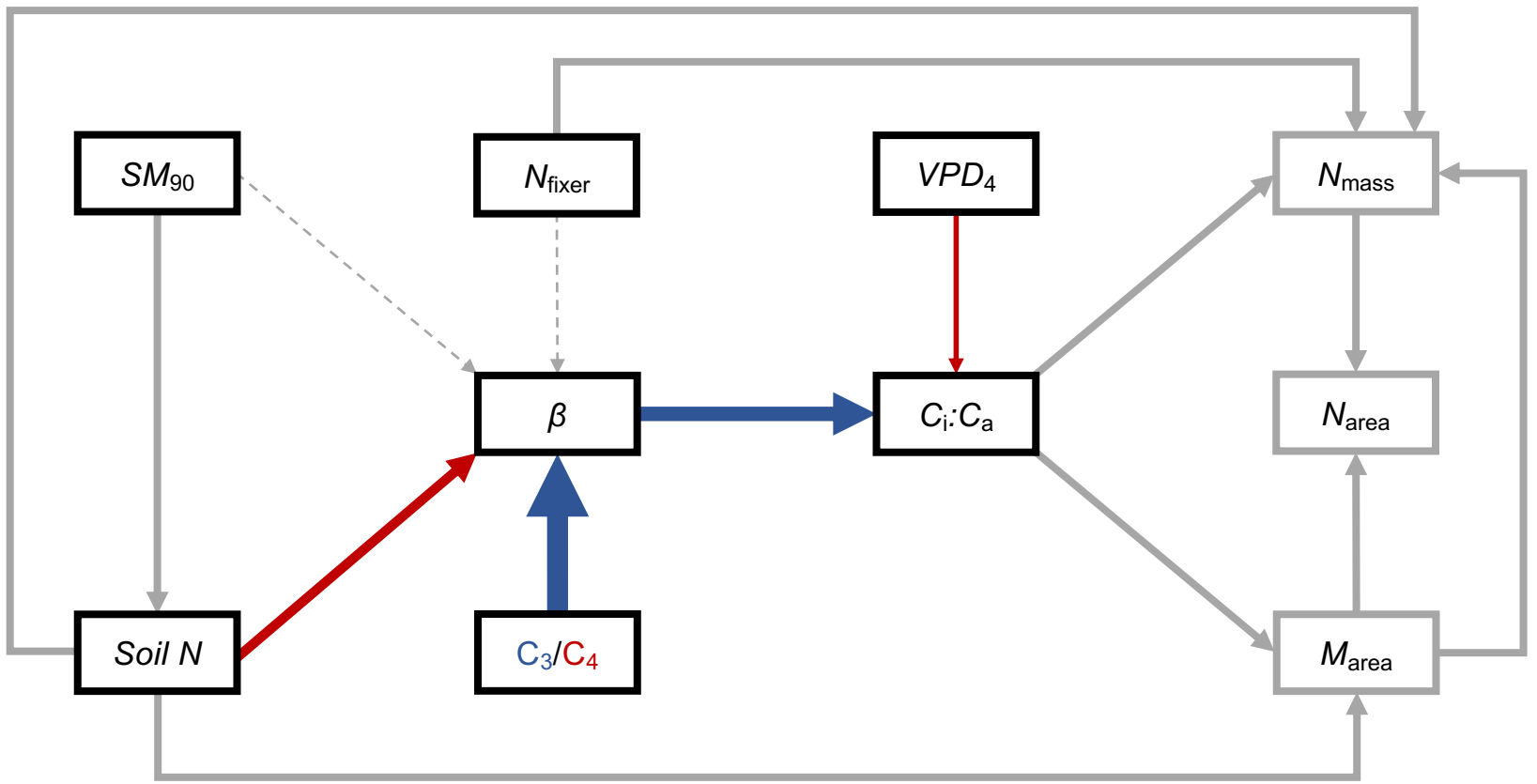


Positive
Negative

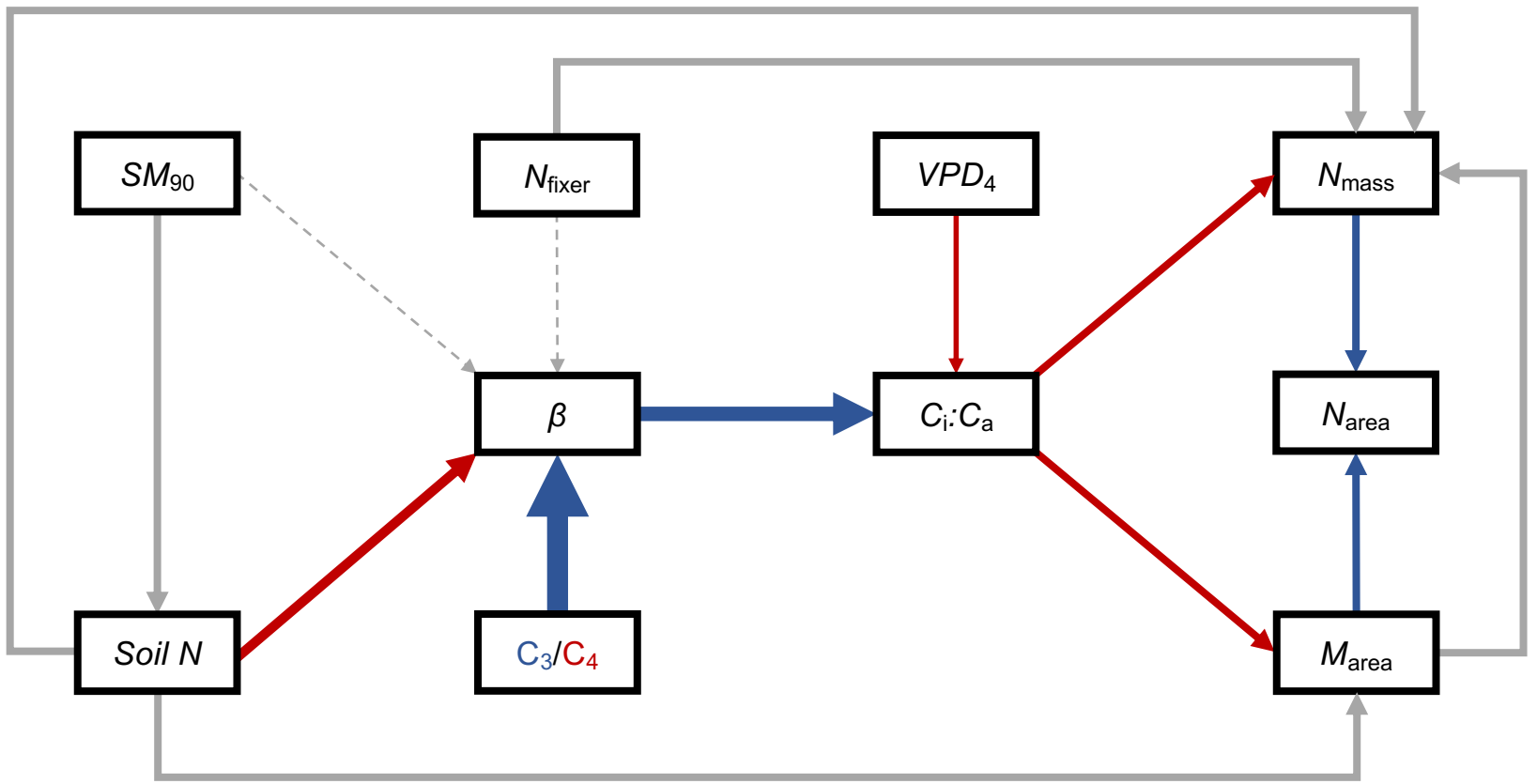


Positive
Negative

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

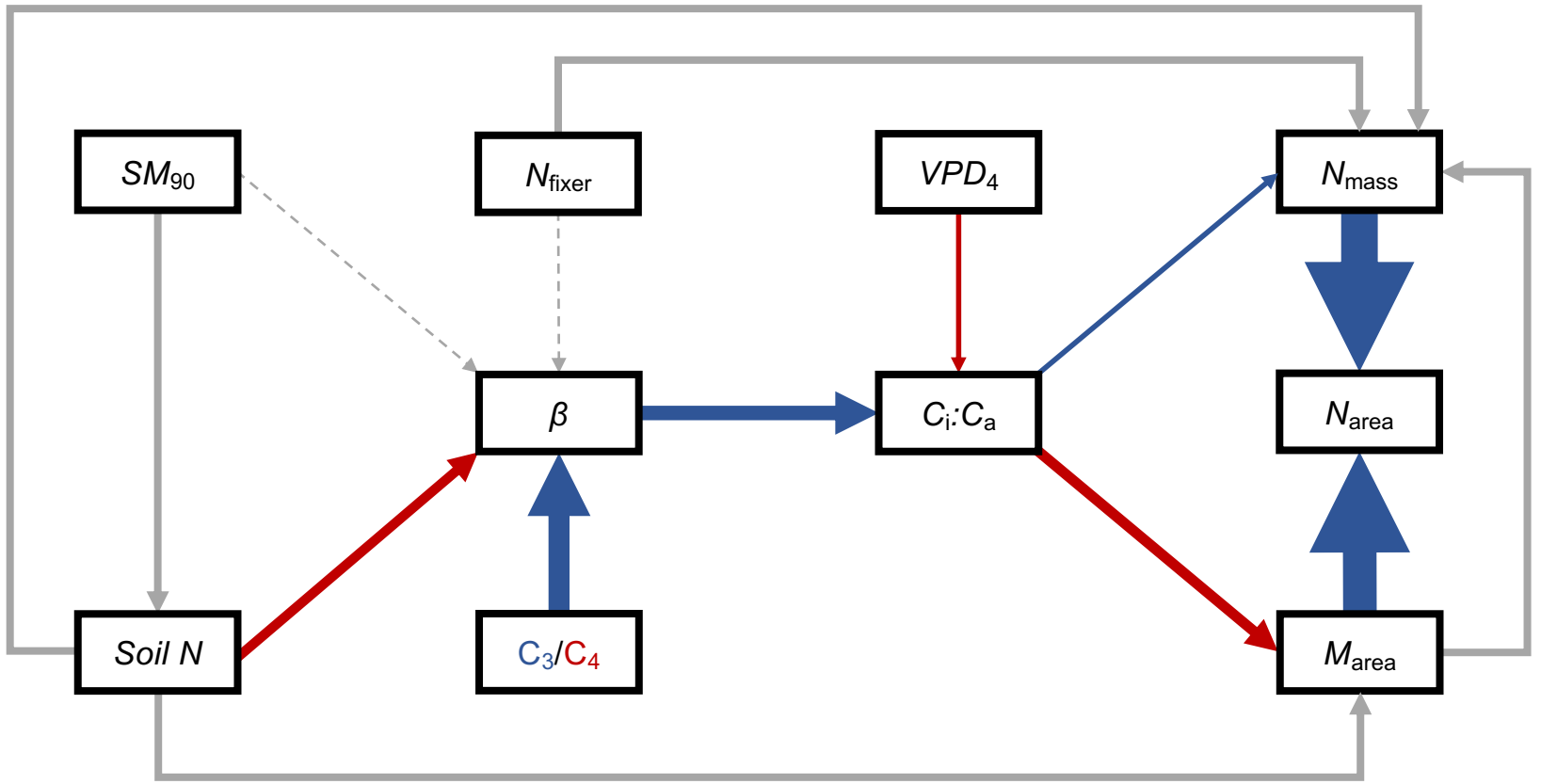


Positive
Negative

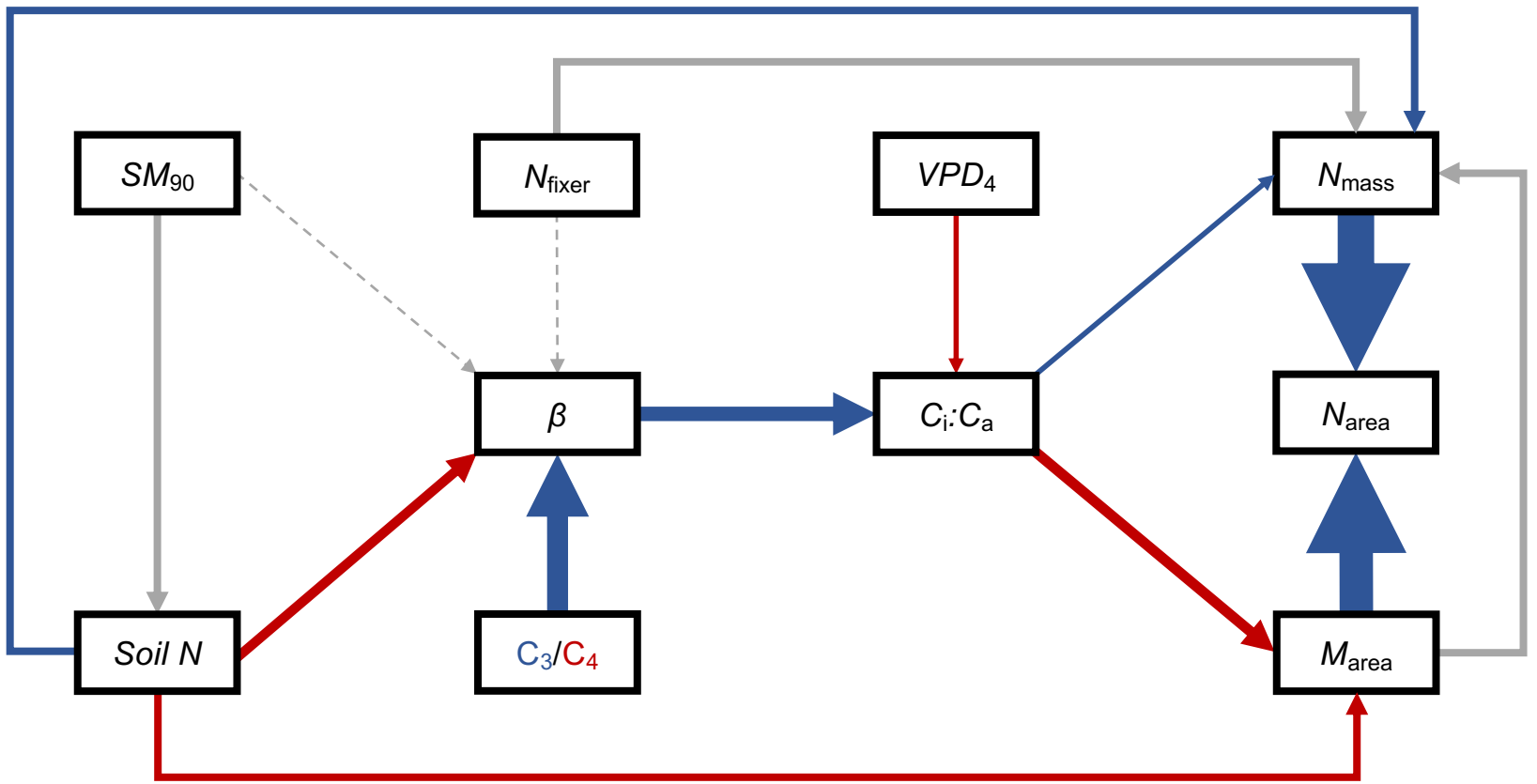


Positive
Negative

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

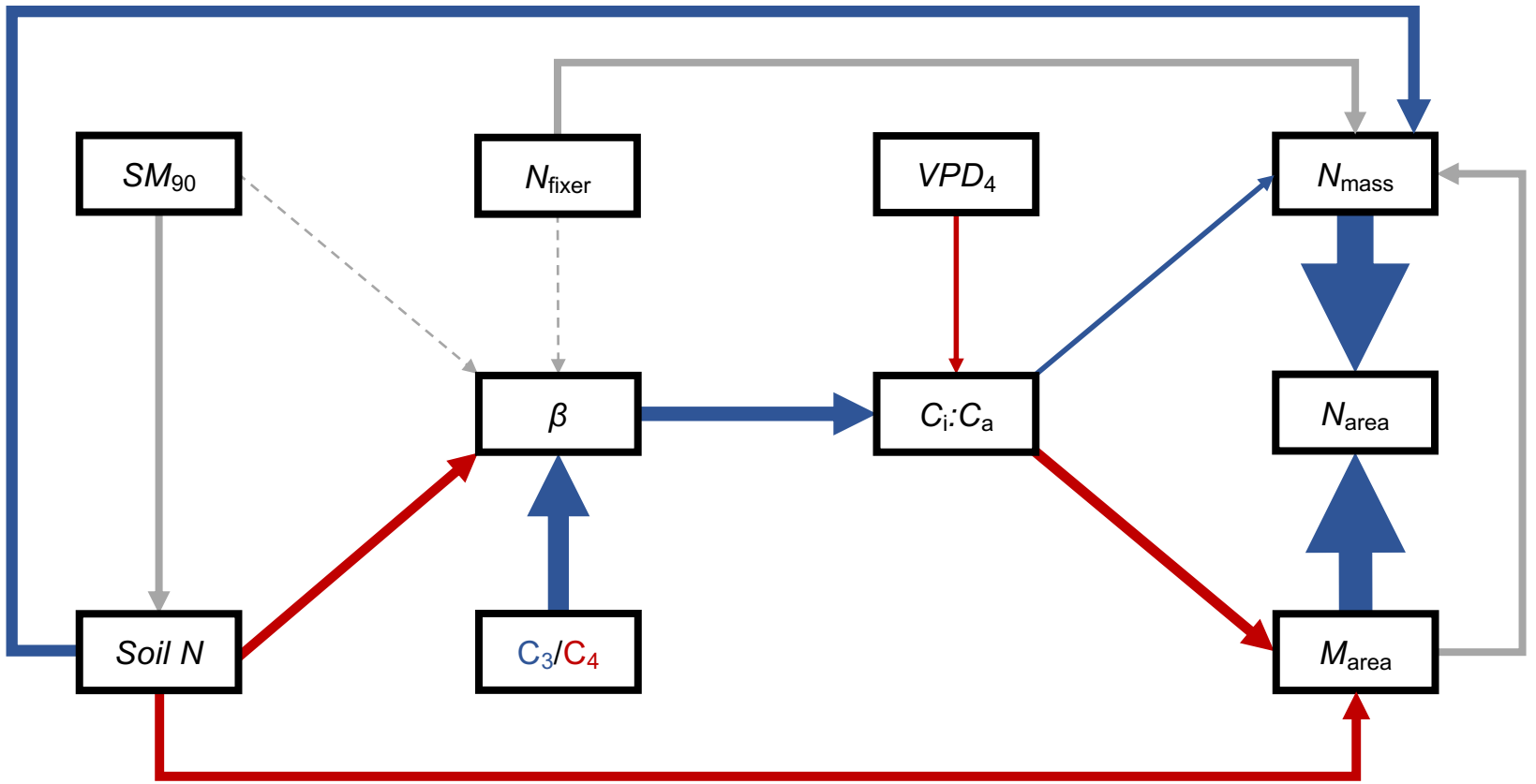


Positive
Negative

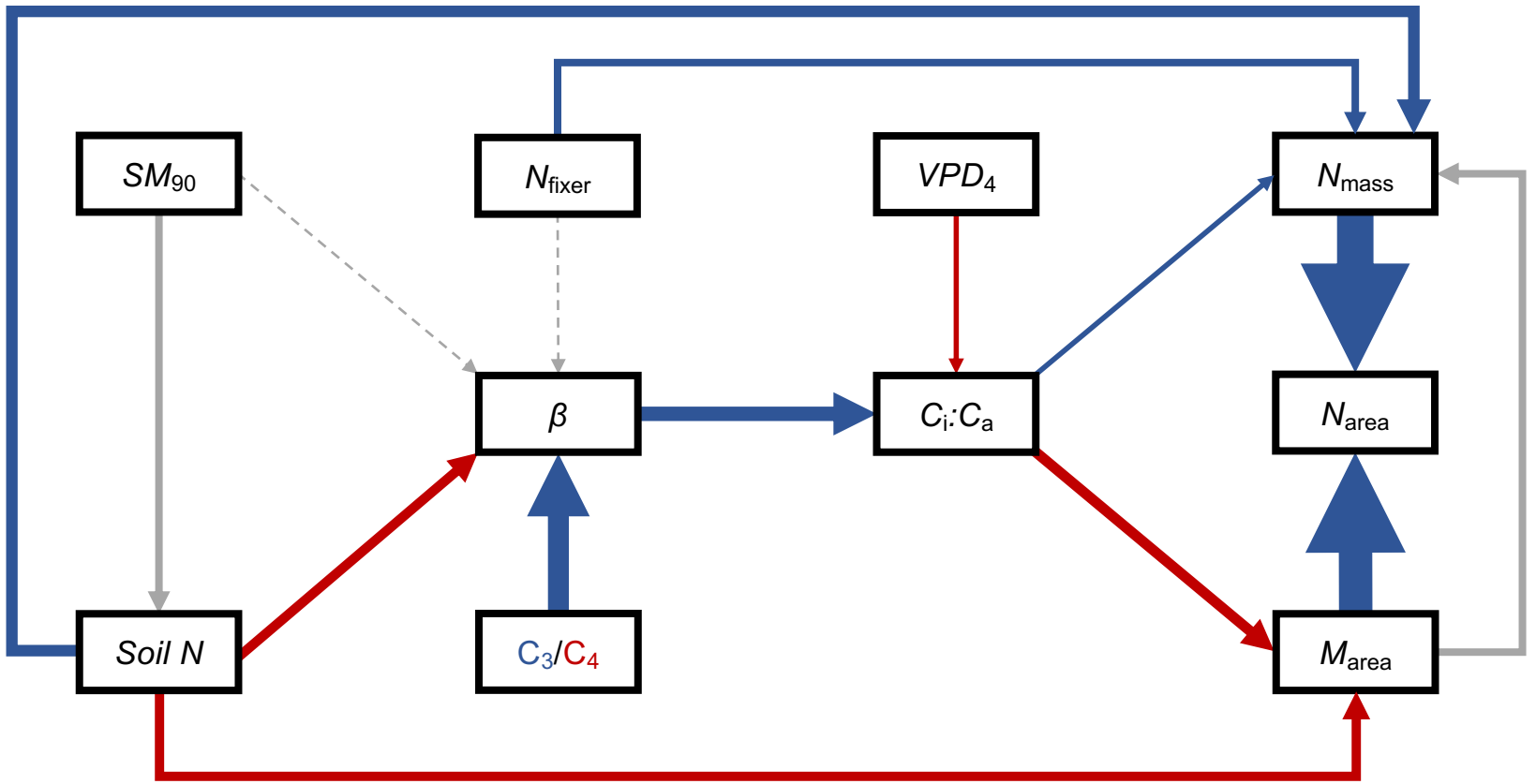


Positive
Negative

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

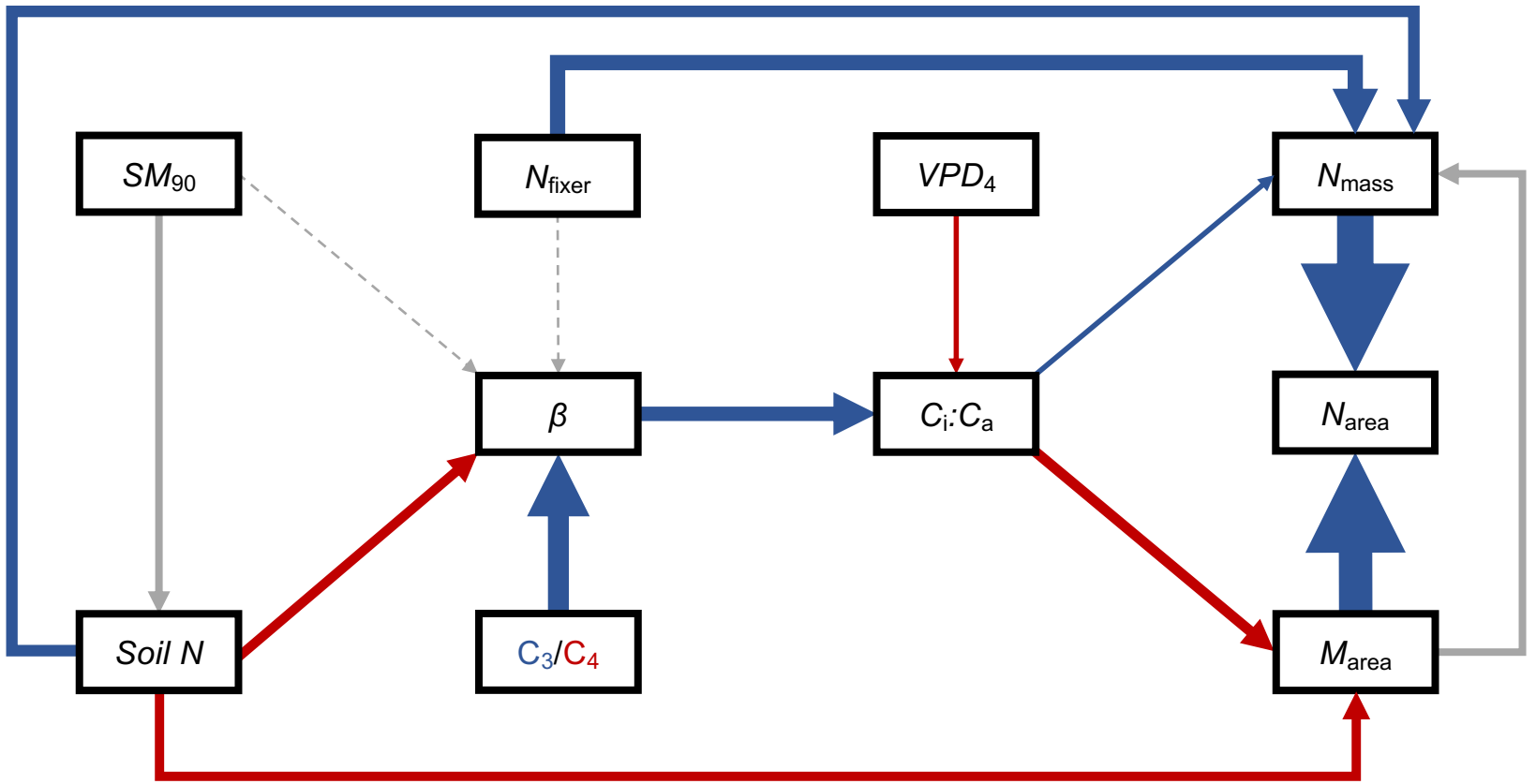


Positive
Negative

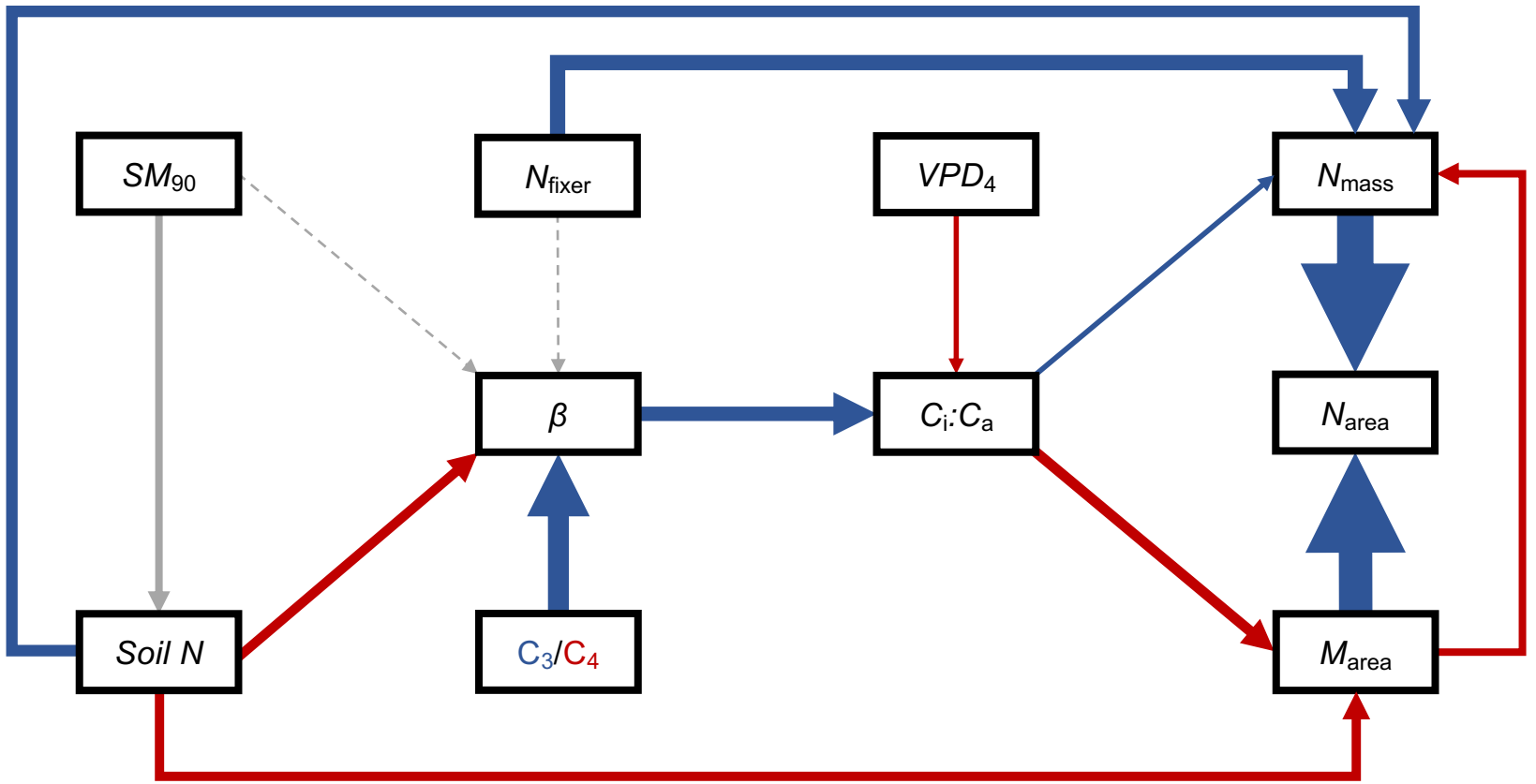


Positive
Negative

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

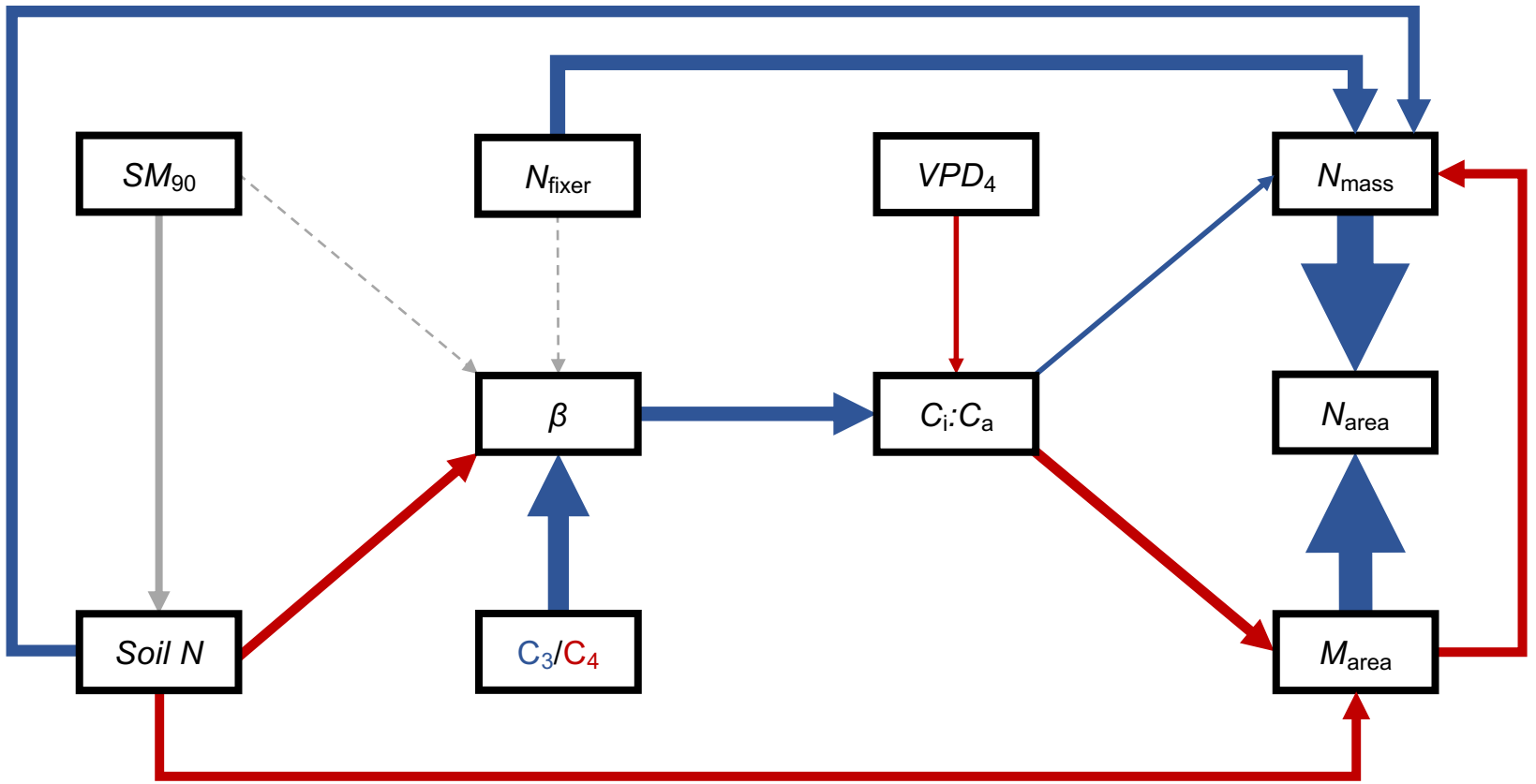


Positive
Negative

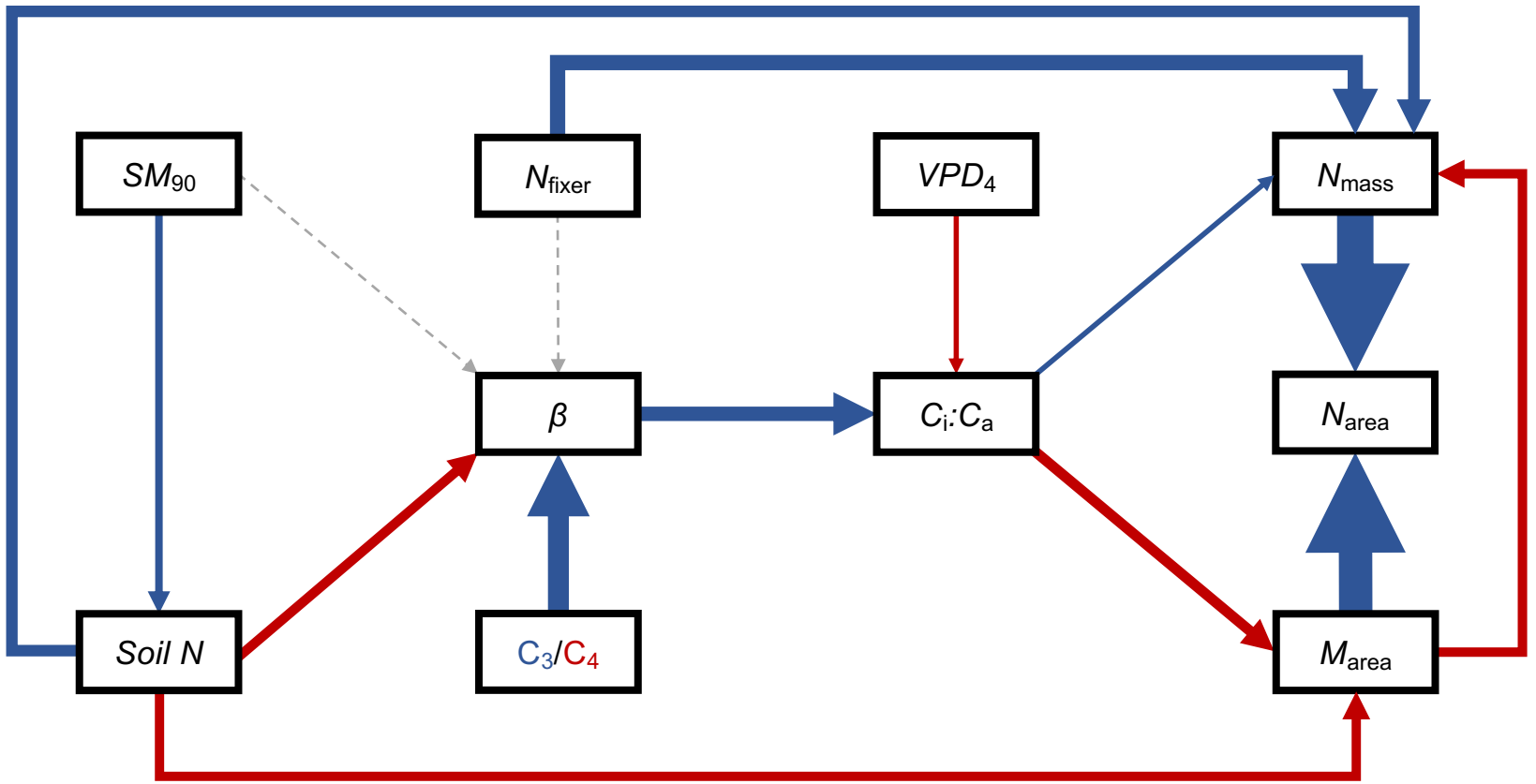


Positive
Negative

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

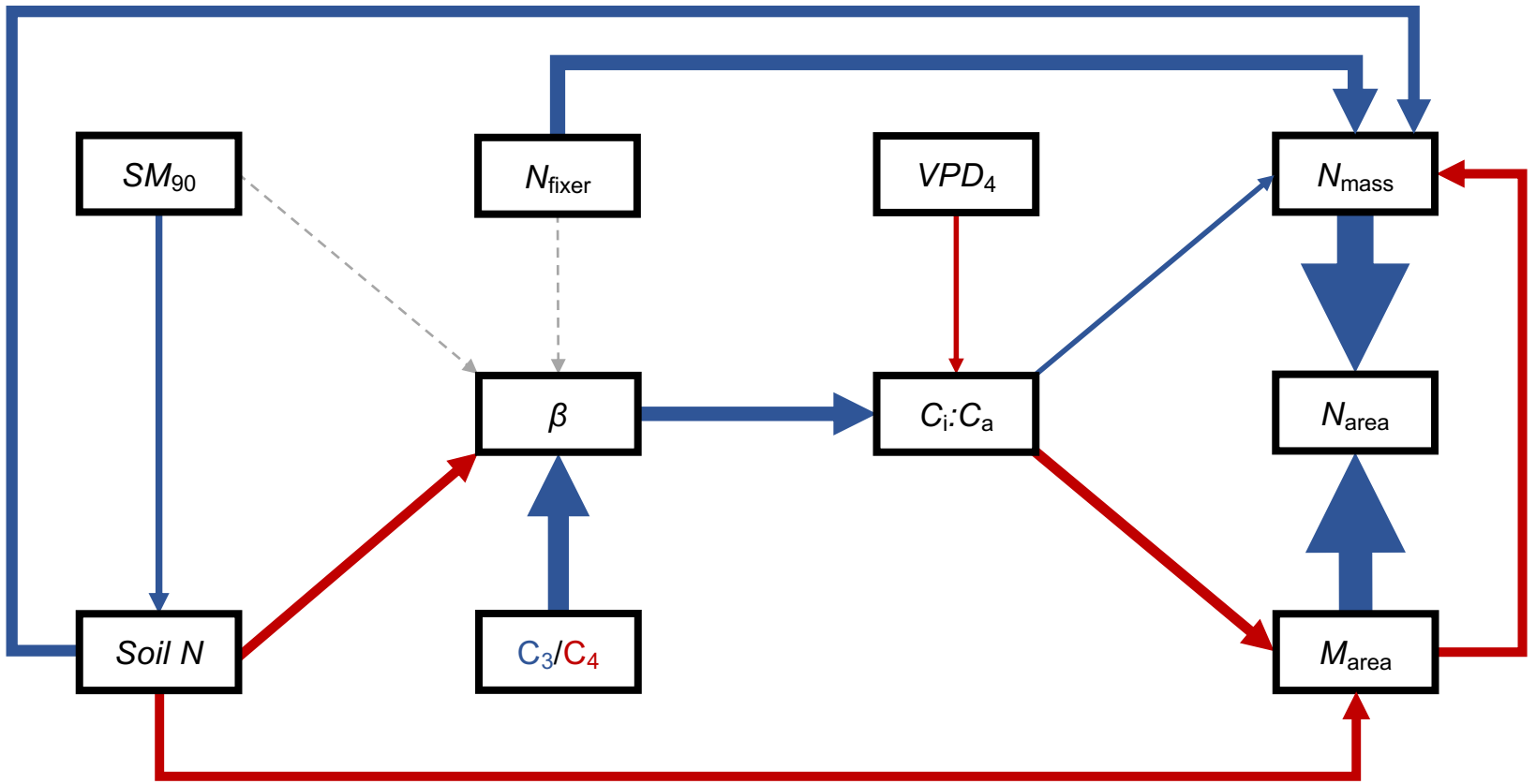


Positive
Negative

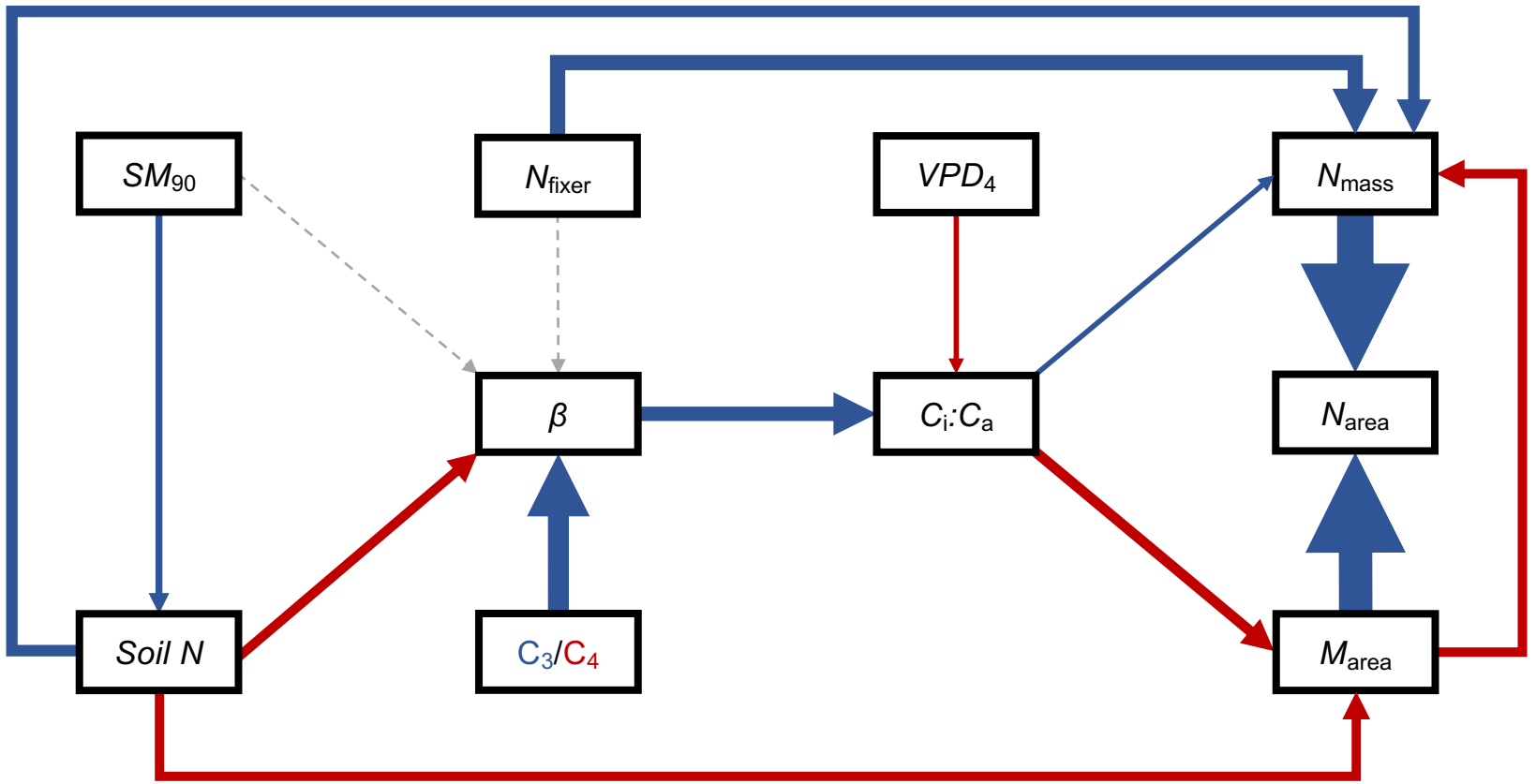


Positive
Negative

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

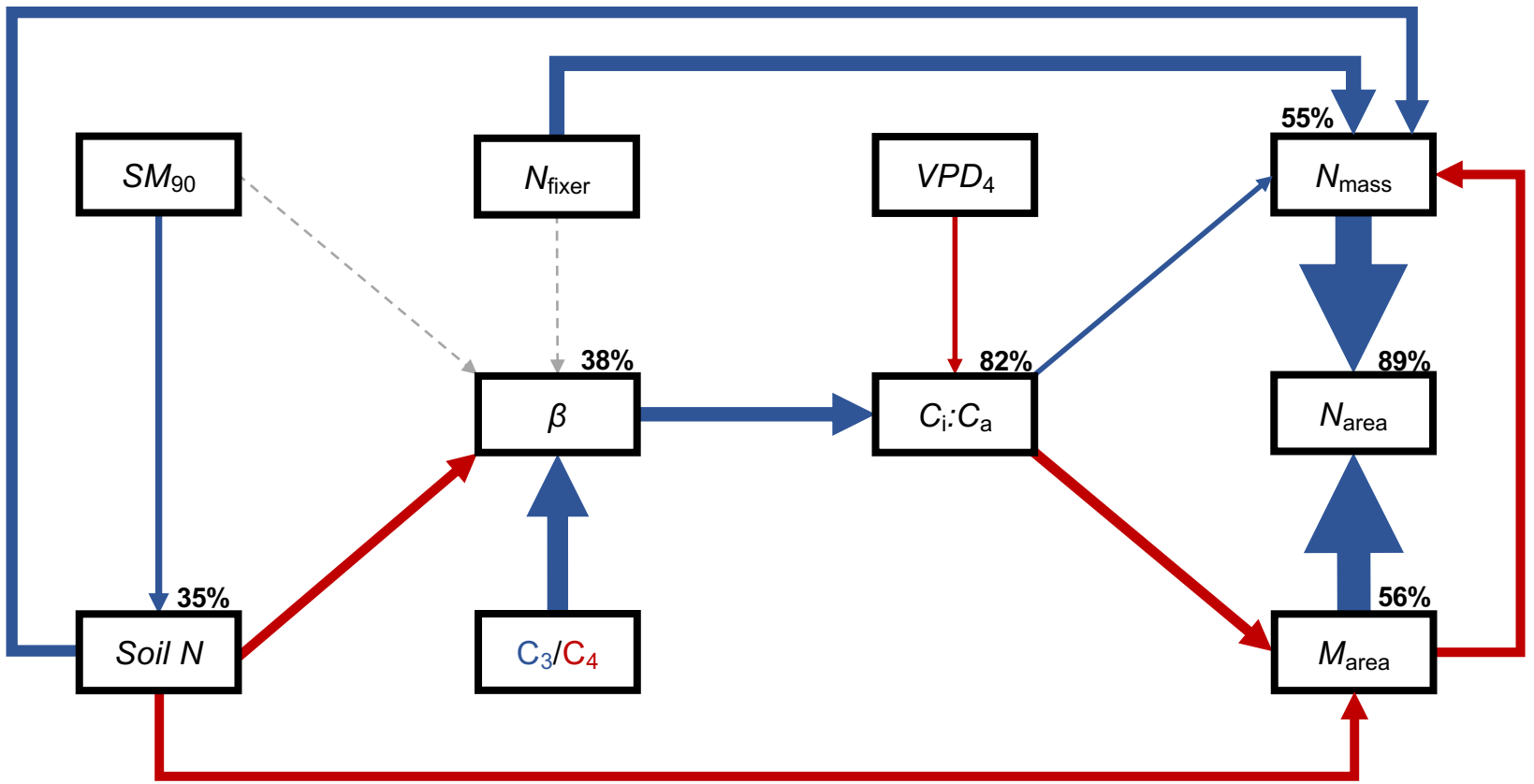


Positive
Negative



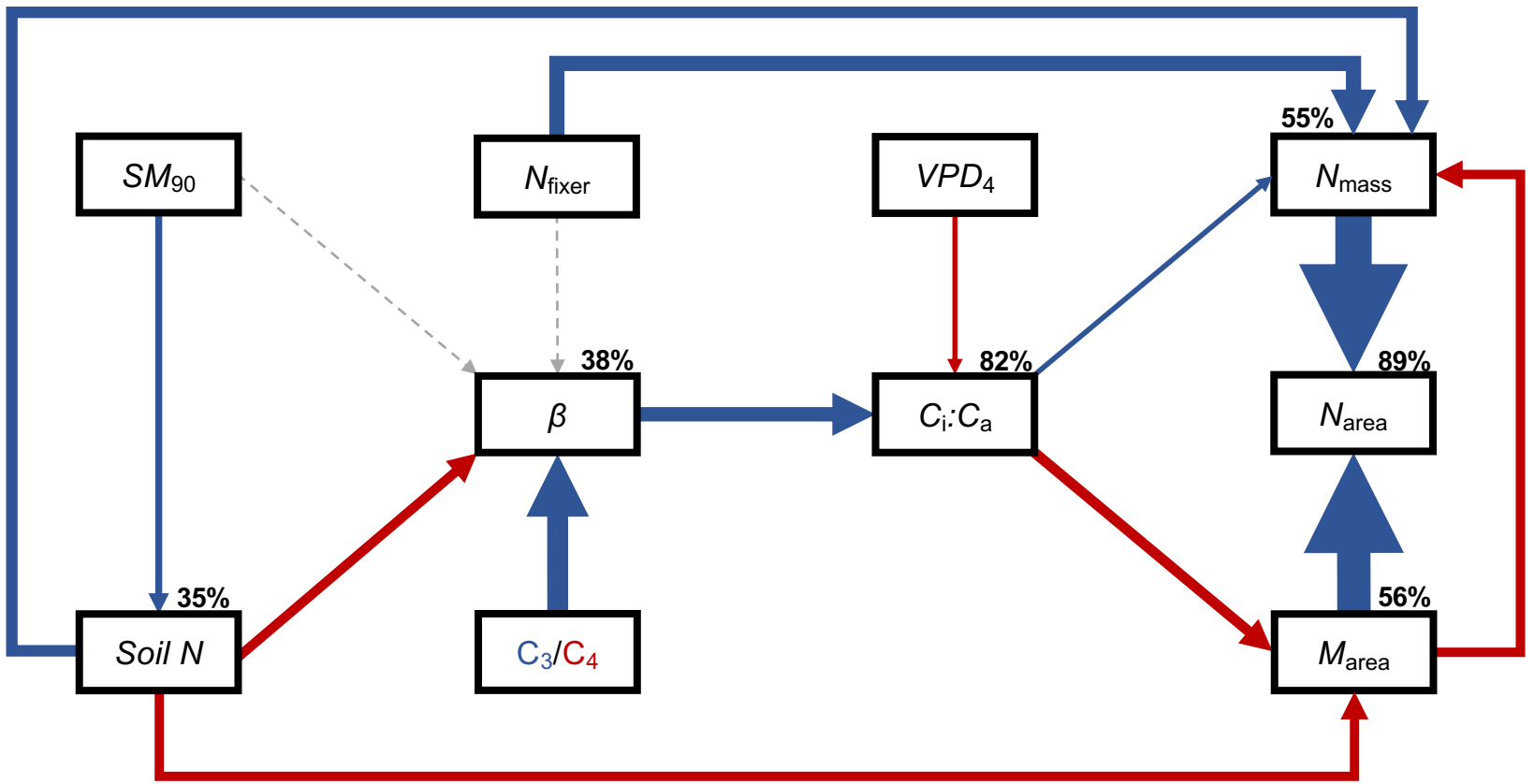
Positive
Negative

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



Positive
Negative

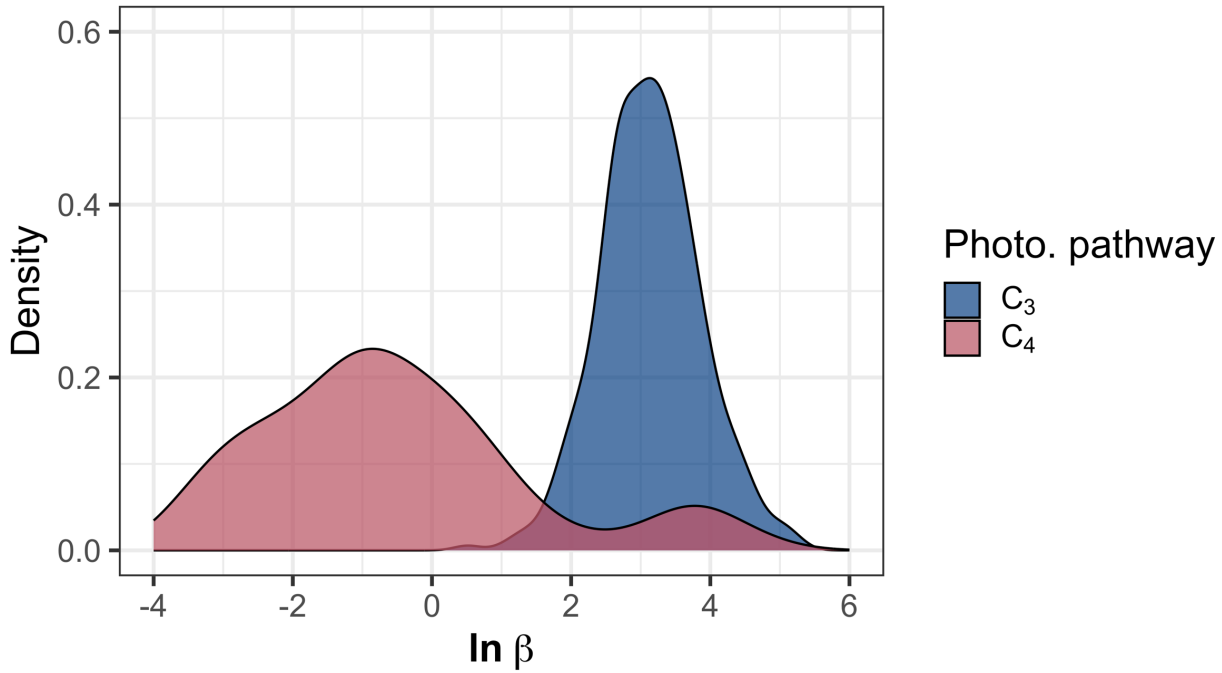
… and indirectly **increased** N_{area} due to **reductions** in β



Positive
Negative

Conclusions

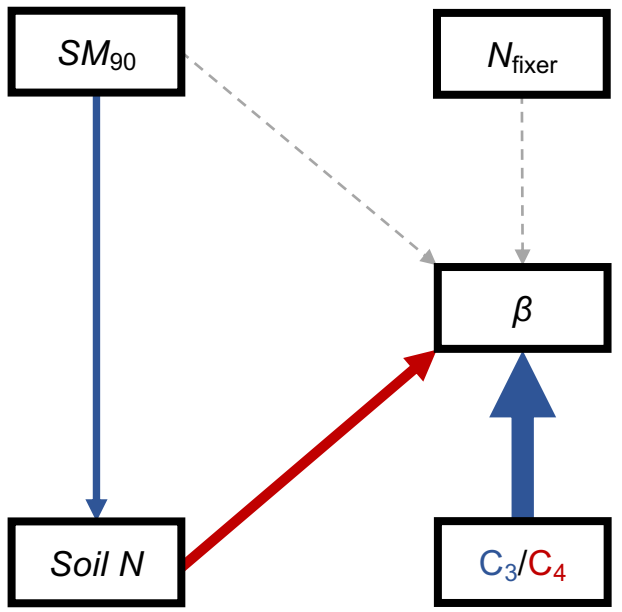
- β dynamically changes across environments



Conclusions

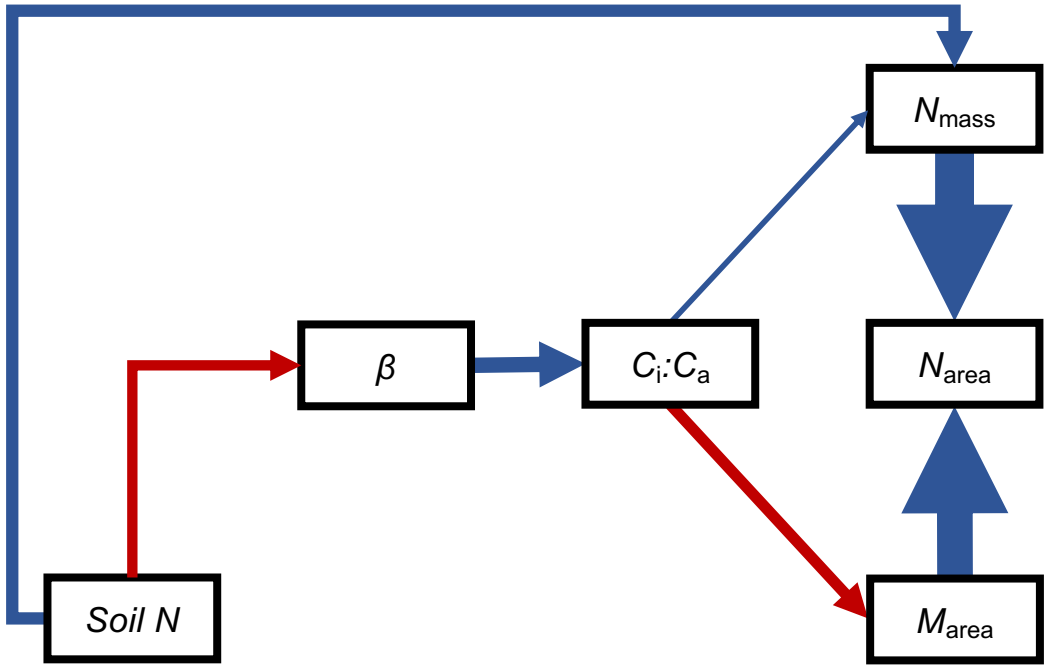
- β dynamically changes across environments

- 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
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- Christine Vanginault*
- Abigail Bell*
- Jose Villeda*
- Hannah German*
- Avery Schoenherr*

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)

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