

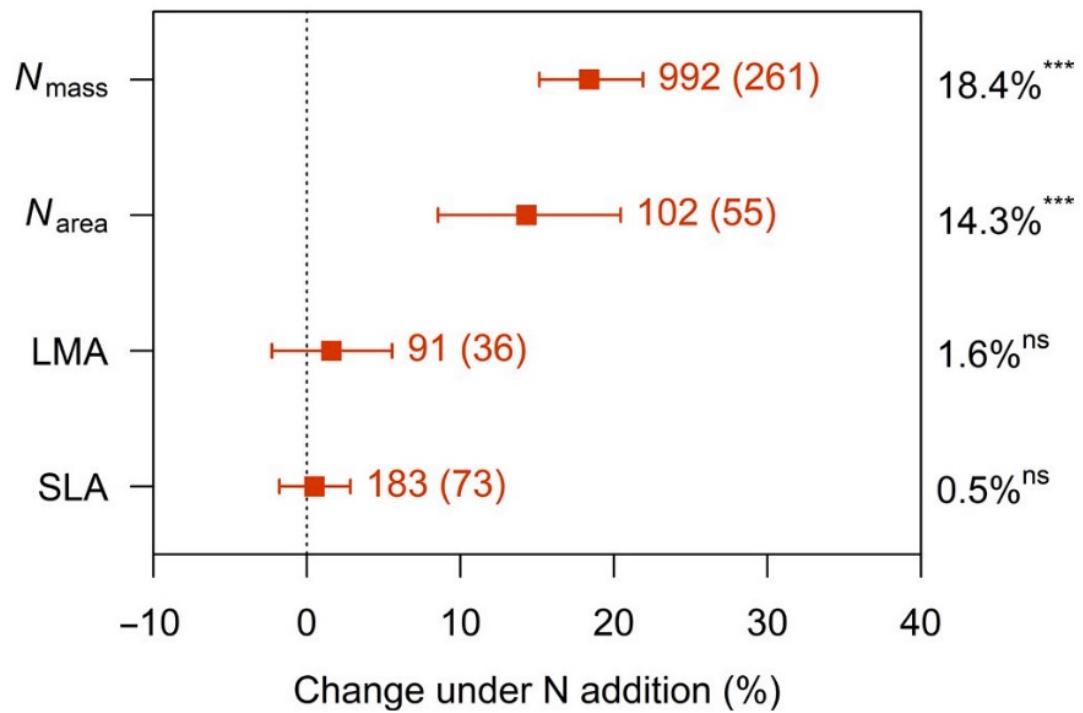


# The cost of resource use for photosynthesis drives variance in leaf nitrogen content across a climate and soil resource availability gradient

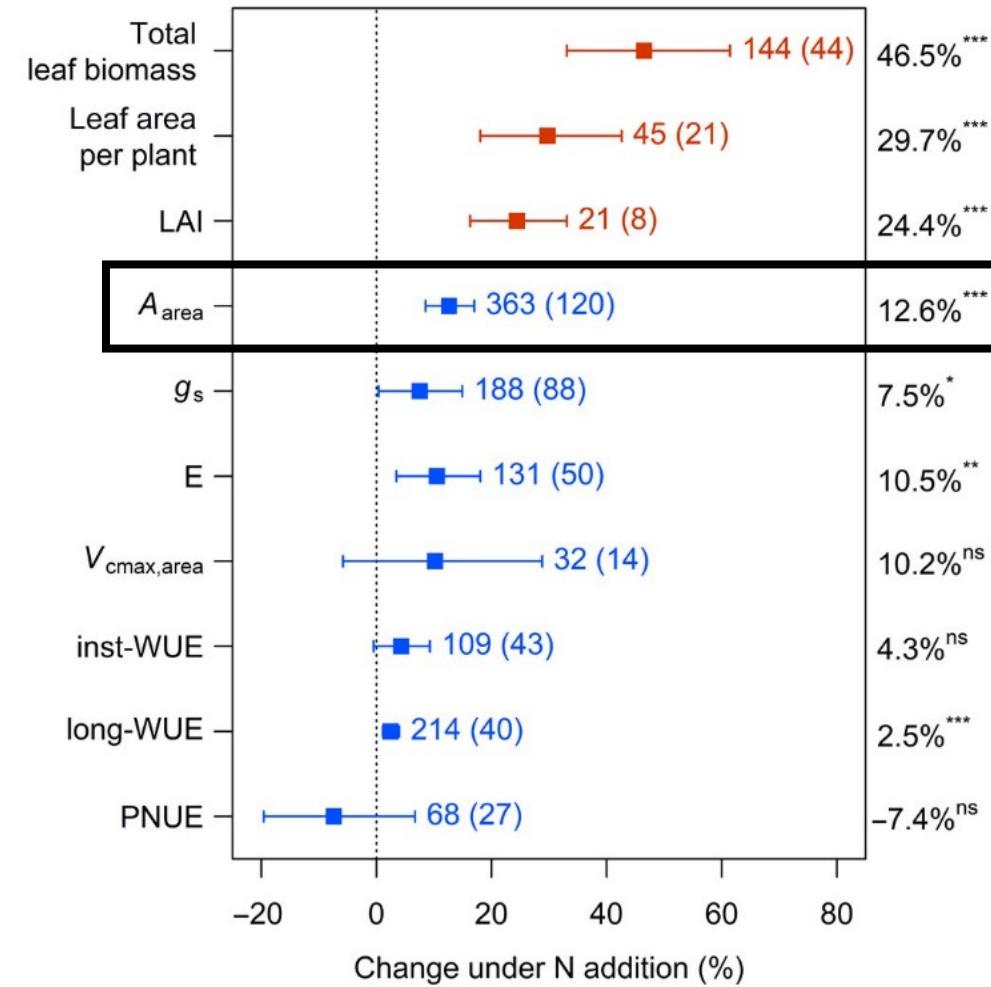
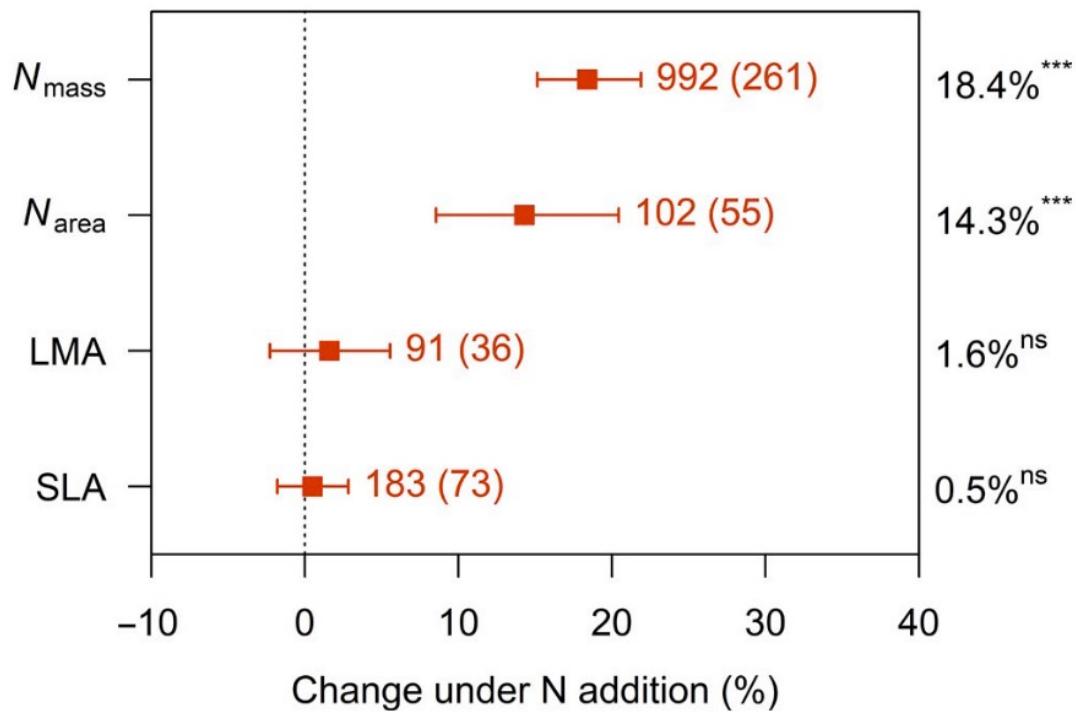
Evan A. Perkowski; Nicholas G. Smith



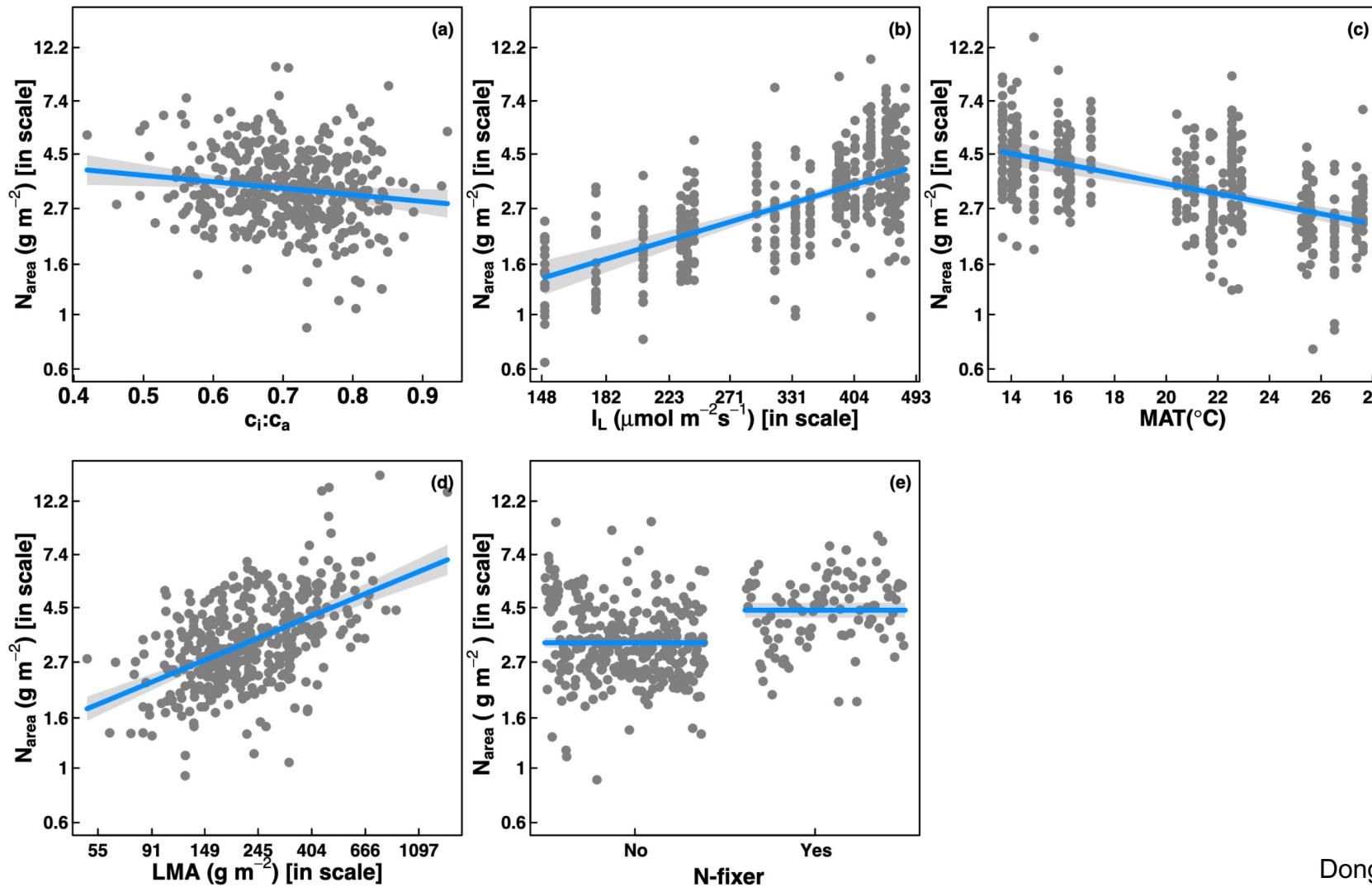
# Soil nitrogen generally increases leaf nitrogen...



# ... which often corresponds with increased photosynthesis

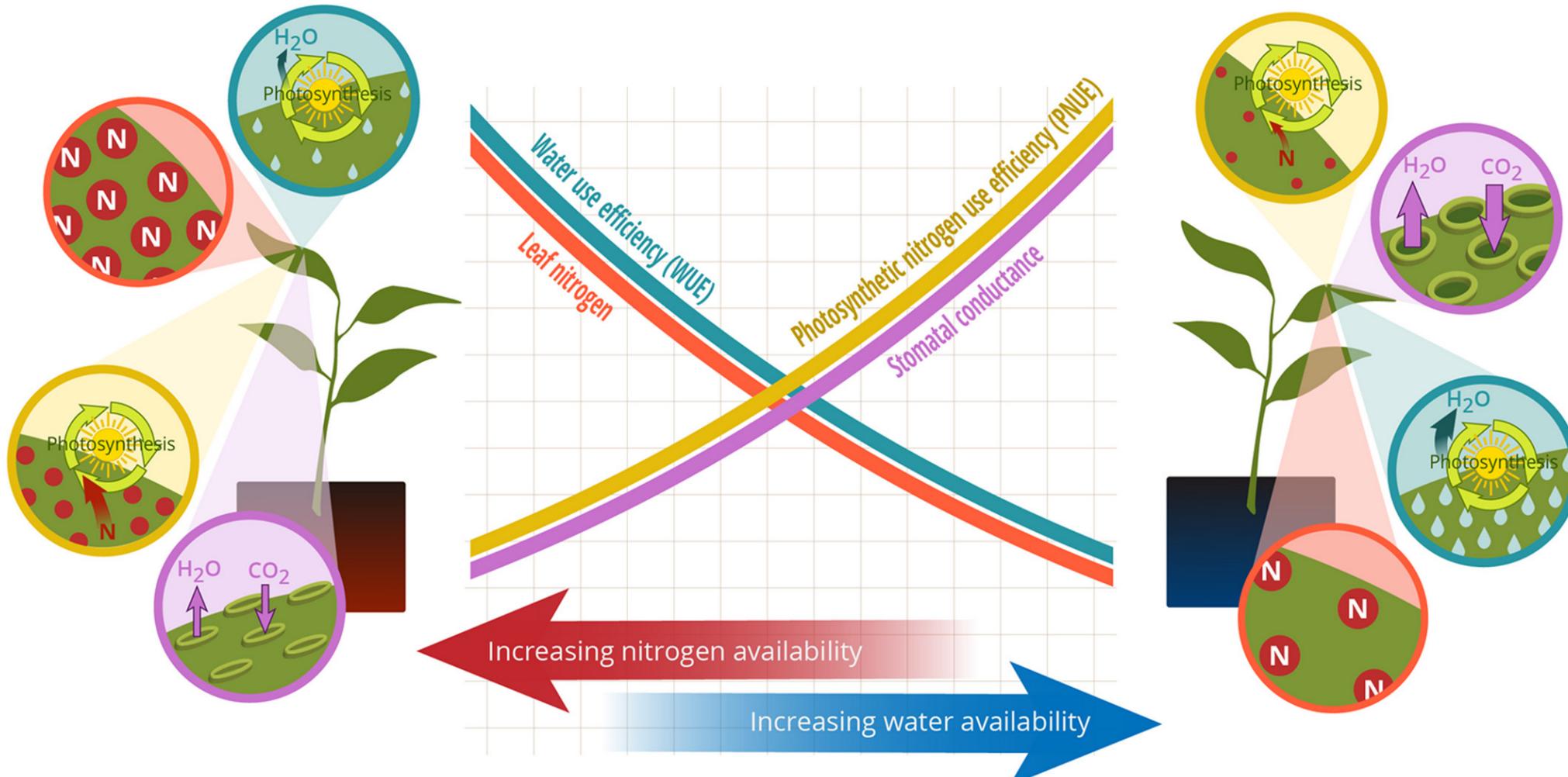


However, leaf nitrogen can be predicted independent of soil nitrogen

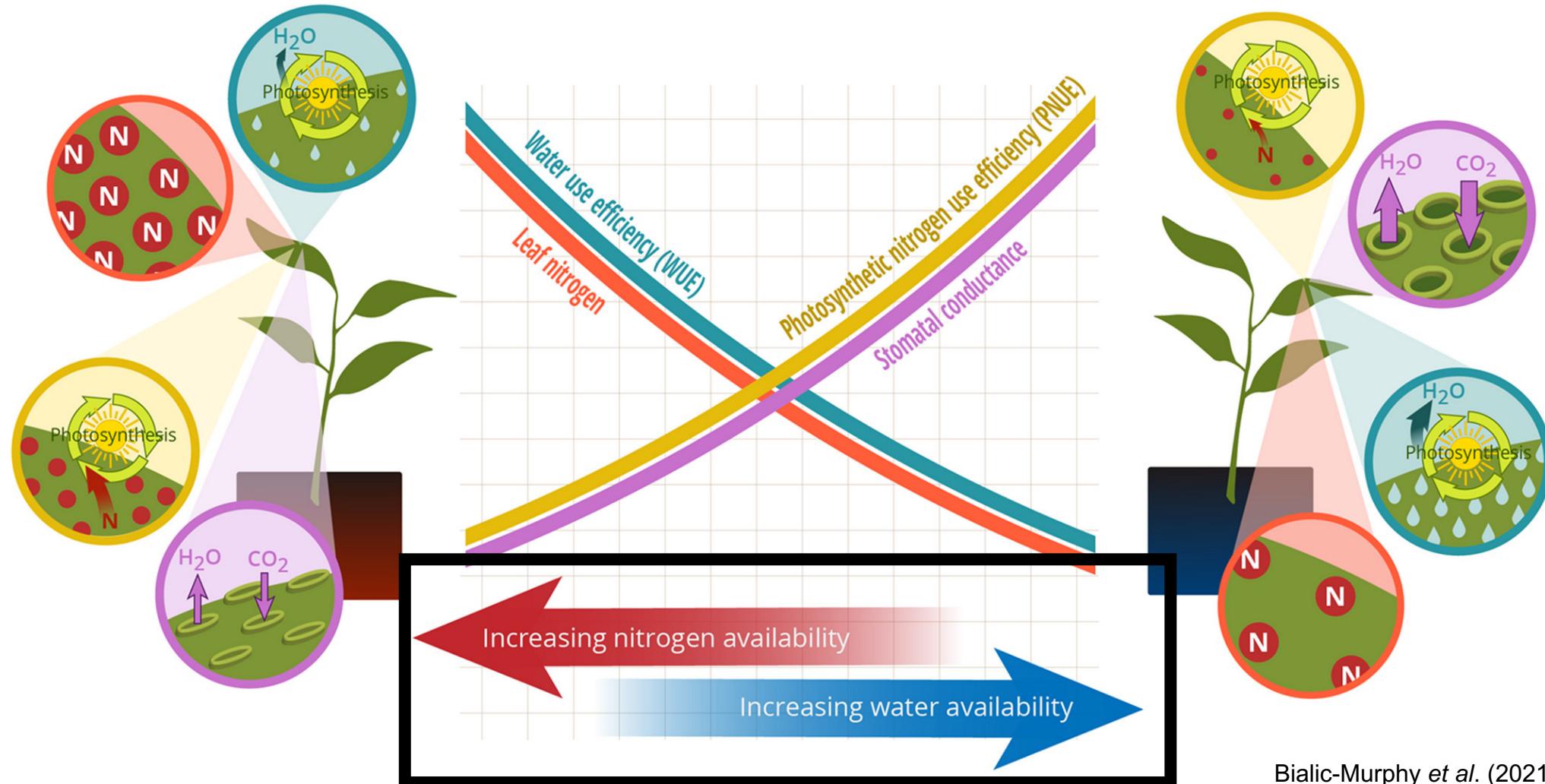


Leaf nitrogen is likely a product of interactions between climatic and edaphic factors

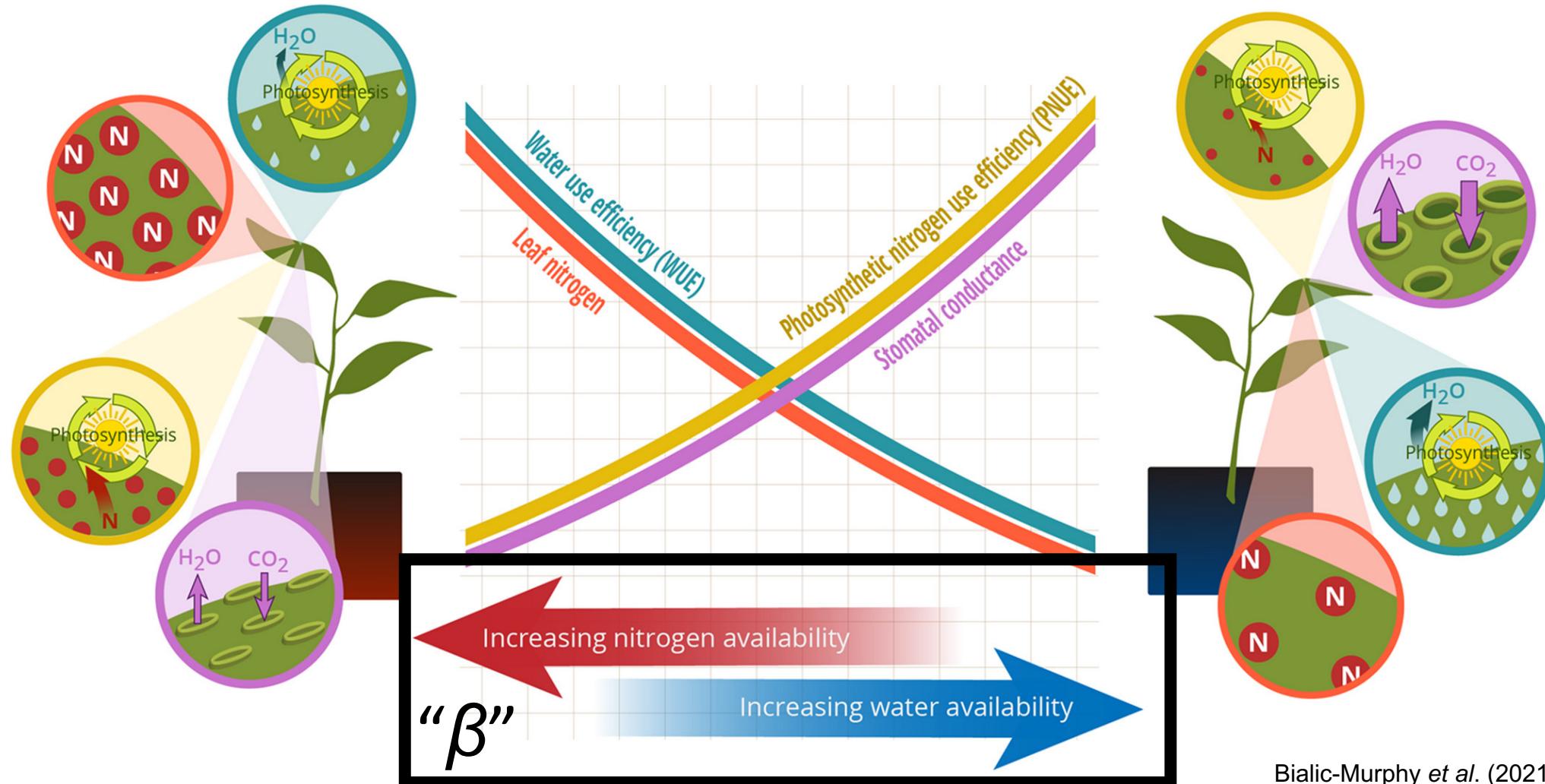
# Photosynthetic least-cost theory



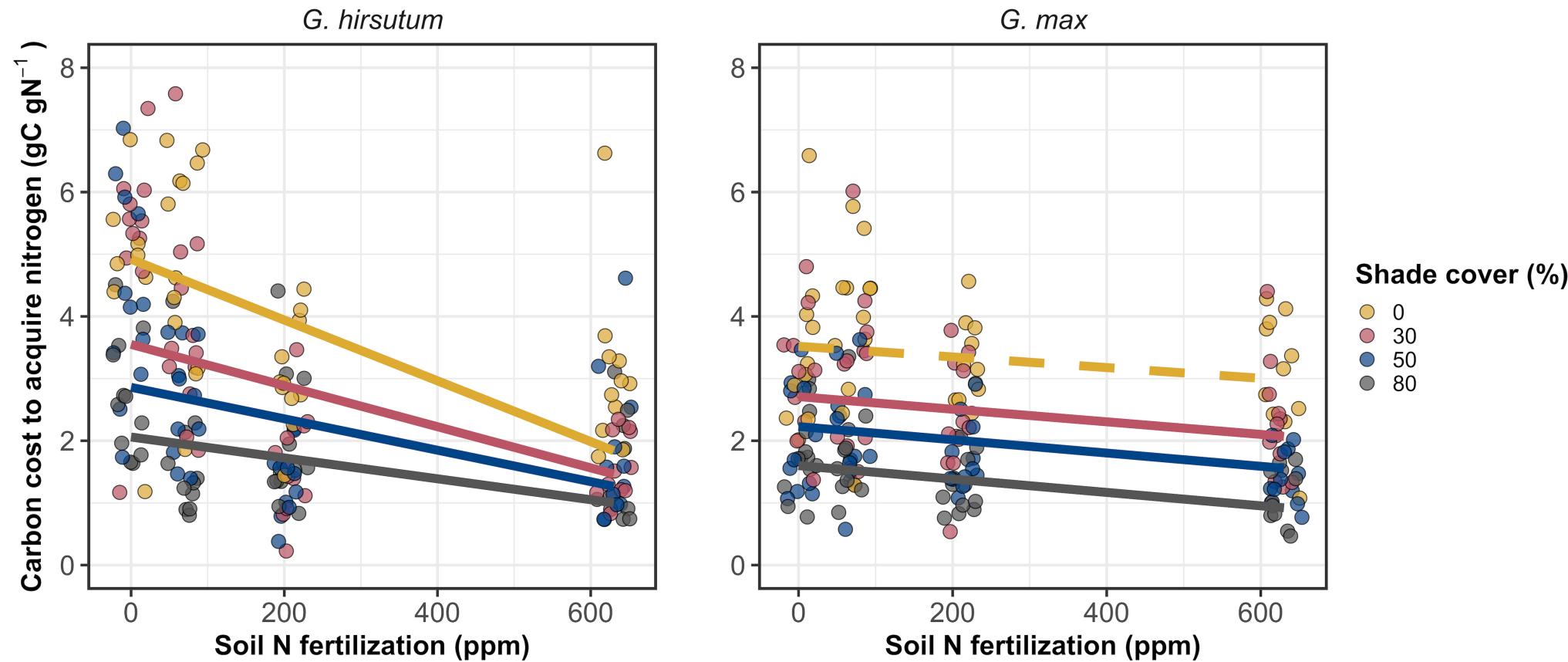
# Photosynthetic least-cost theory: leaves acclimate to changing climatic and edaphic environments via summed cost of resource use (nitrogen and water)



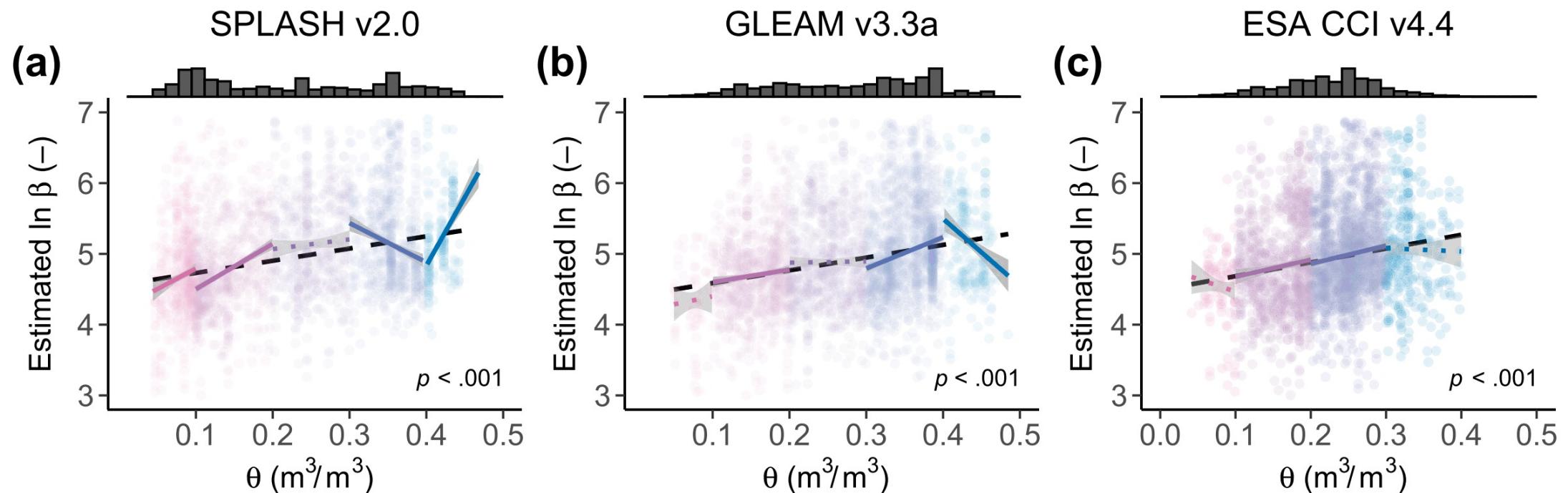
# Photosynthetic least-cost theory: leaves acclimate to changing climatic and edaphic environments via summed cost of resource use (nitrogen and water)



# $\beta$ is held constant in least-cost optimality models, but varies across environments



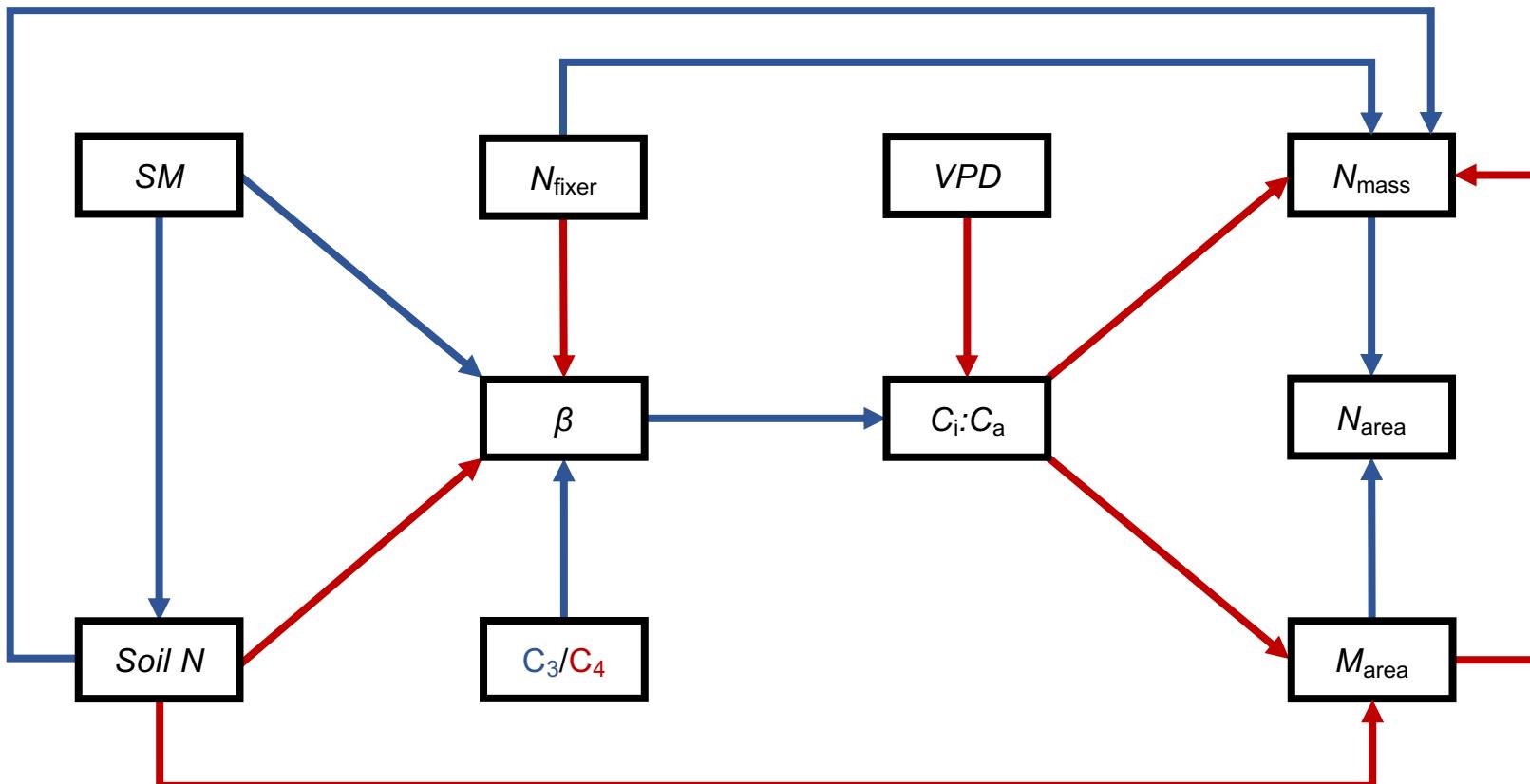
# $\beta$ is held constant in least-cost optimality models, but varies across environments



# Open questions

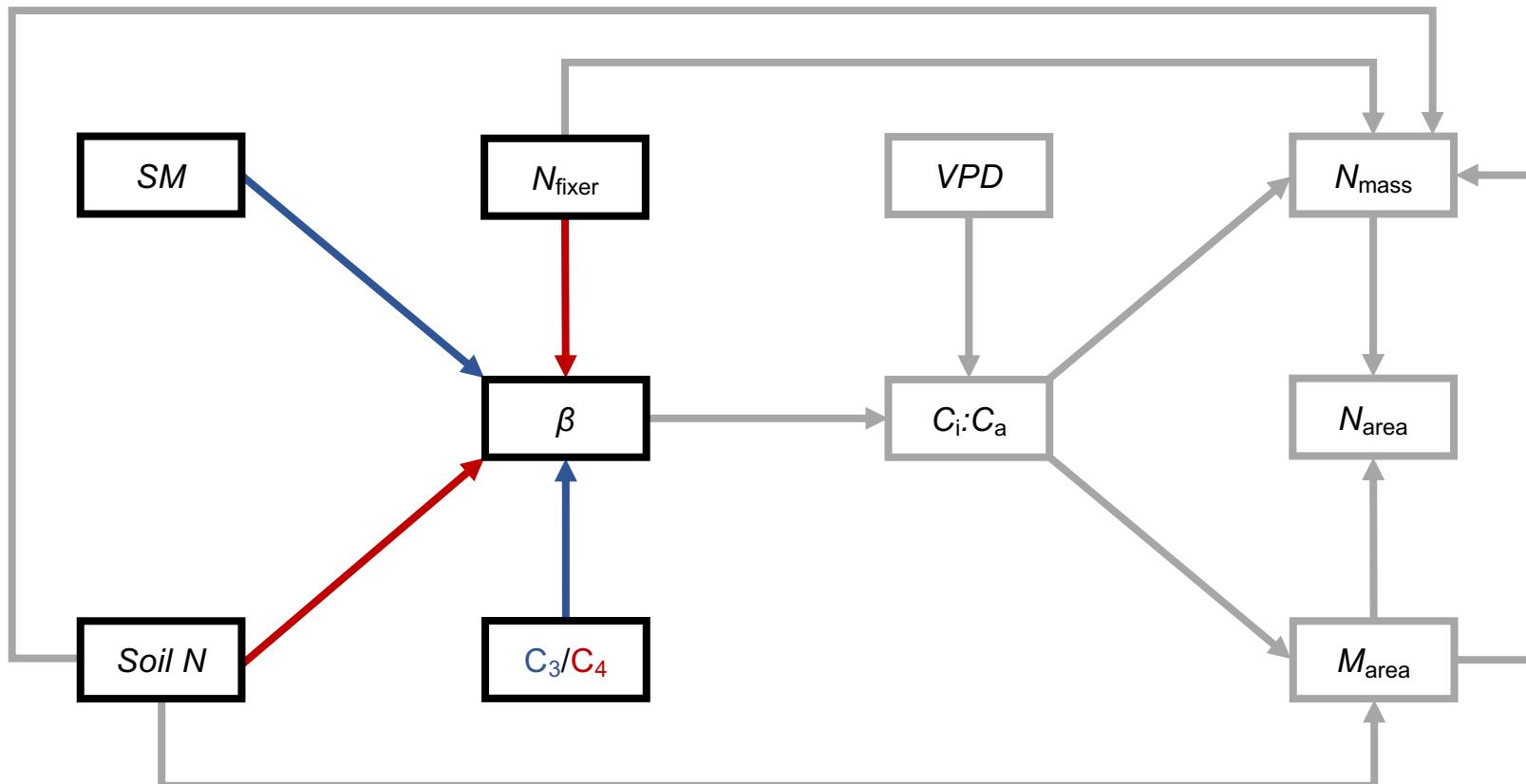
- How dynamic are costs to acquire nitrogen relative to water across edaphic and climatic gradients?
- To what extent do costs to acquire nitrogen relative to water determine variance in leaf nitrogen content across environmental gradients?
  - What is the underlying role of photosynthetic pathway or nitrogen acquisition strategy?

# Hypotheses



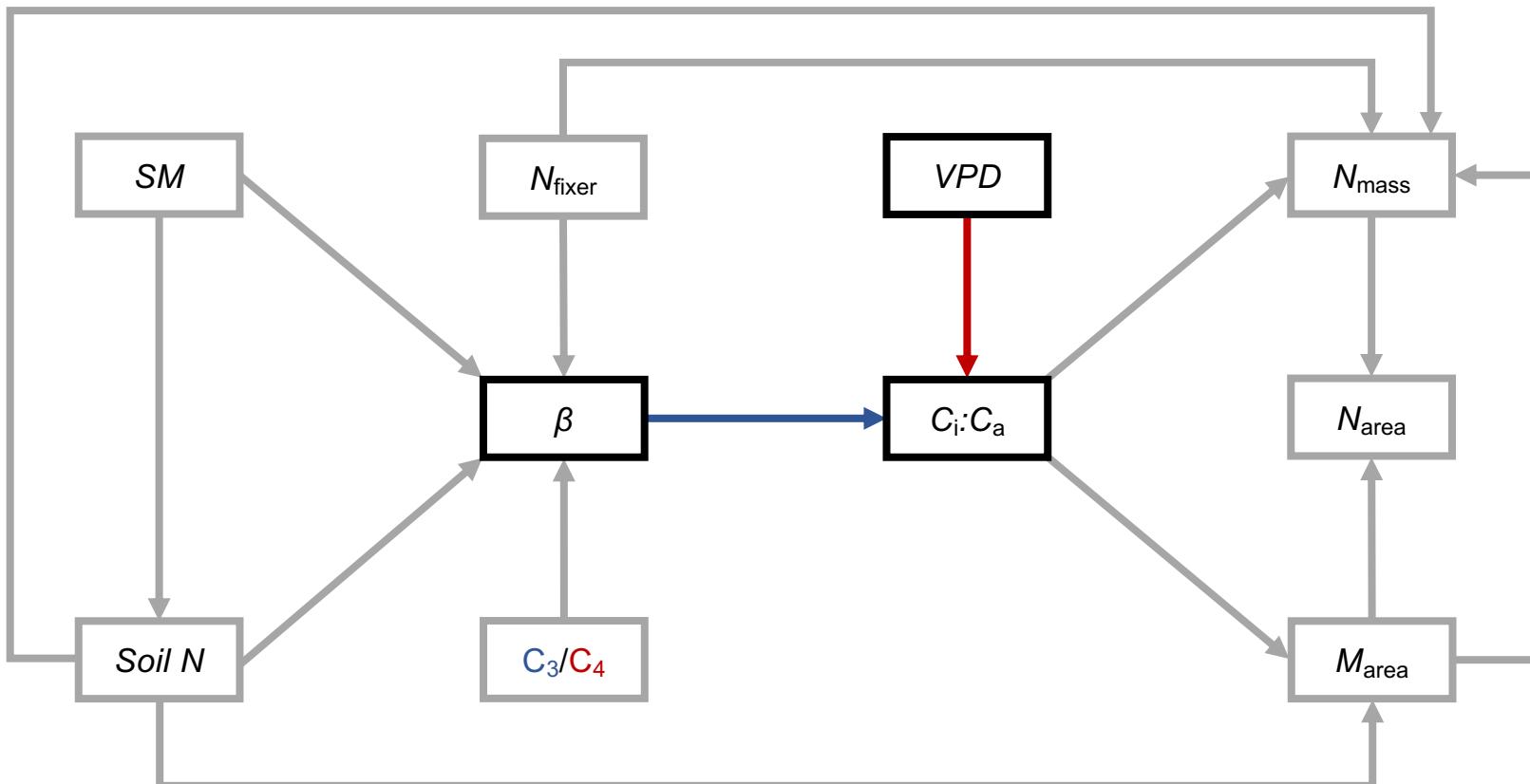
Positive  
Negative

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



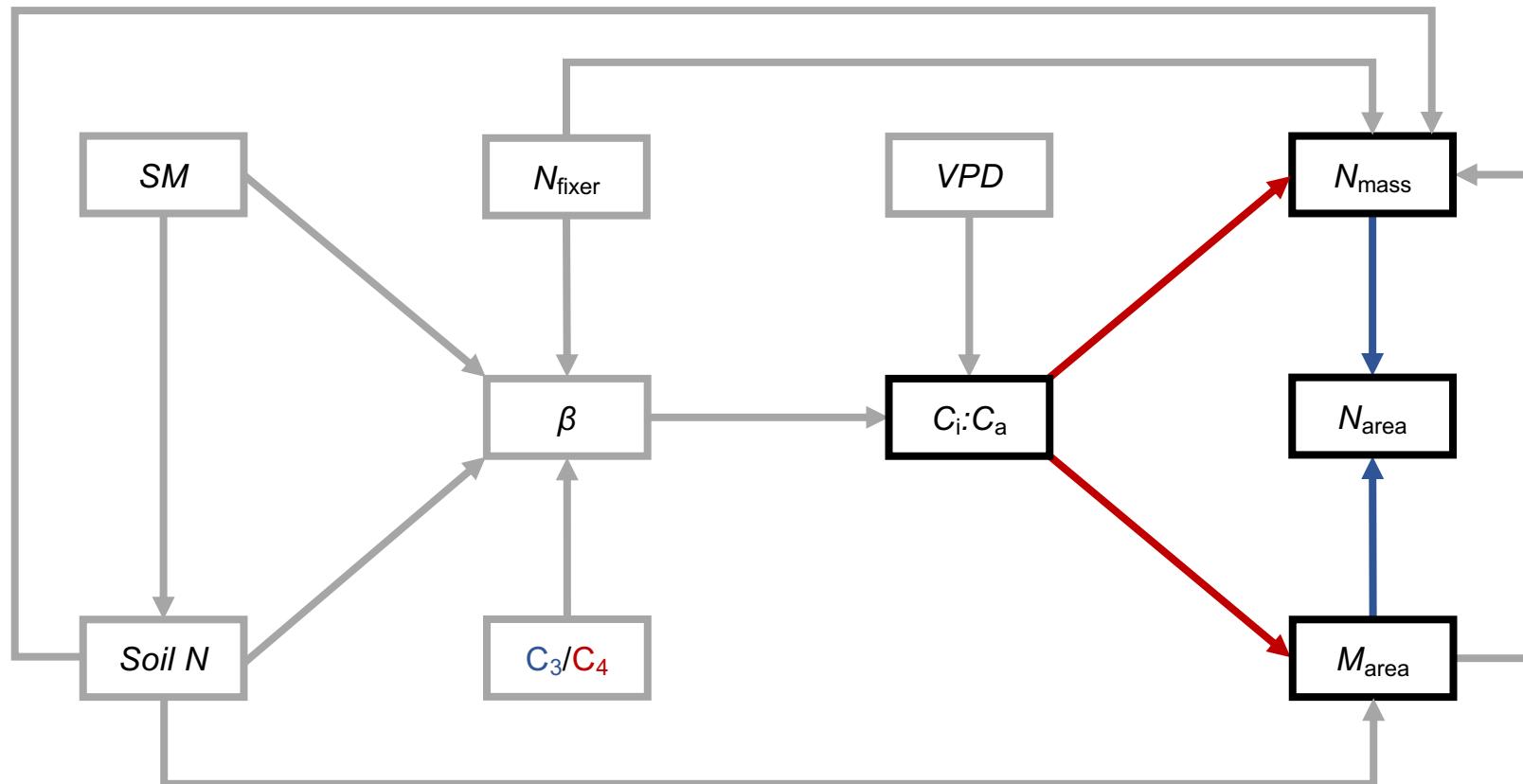
Positive  
Negative

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



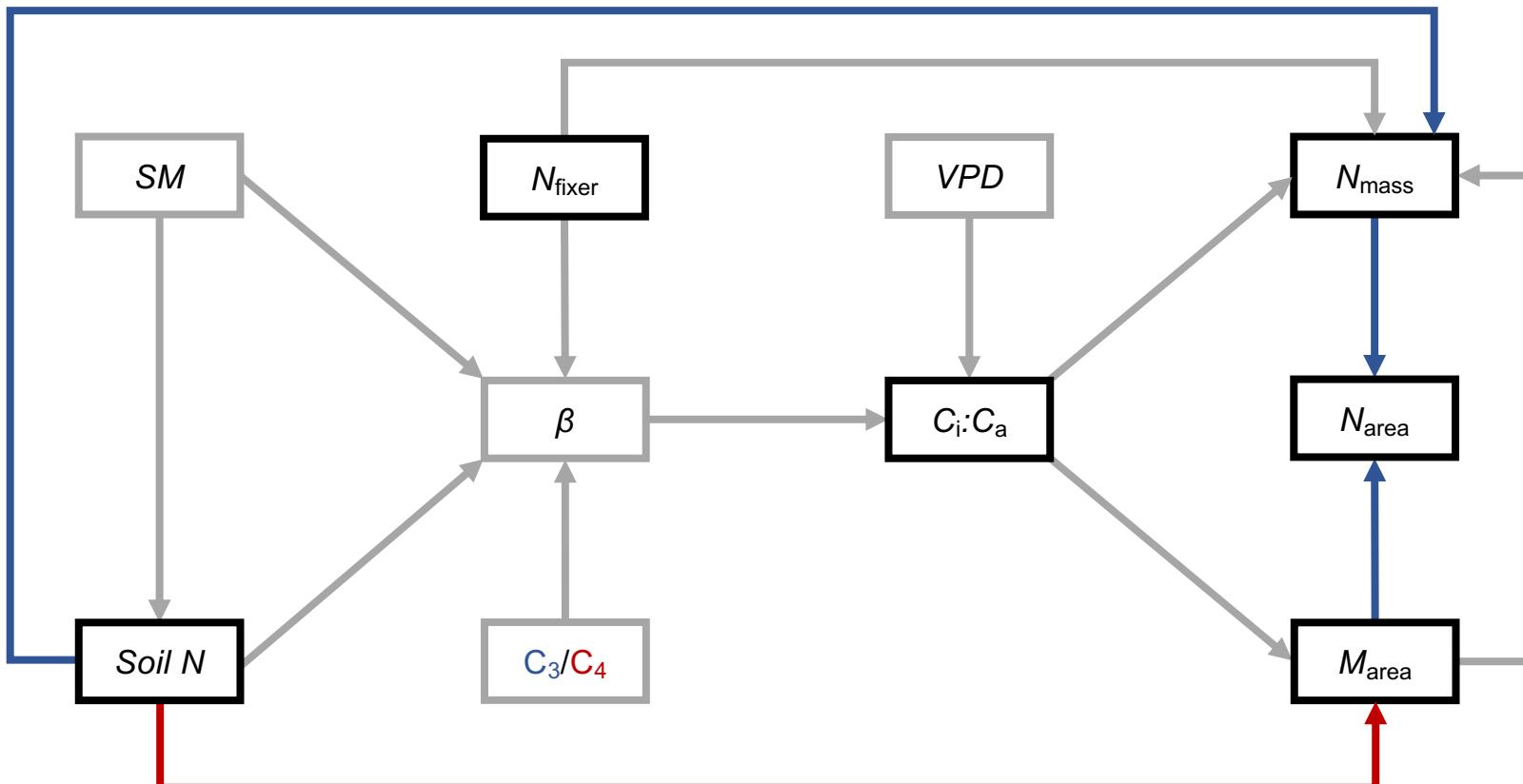
Positive  
Negative

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

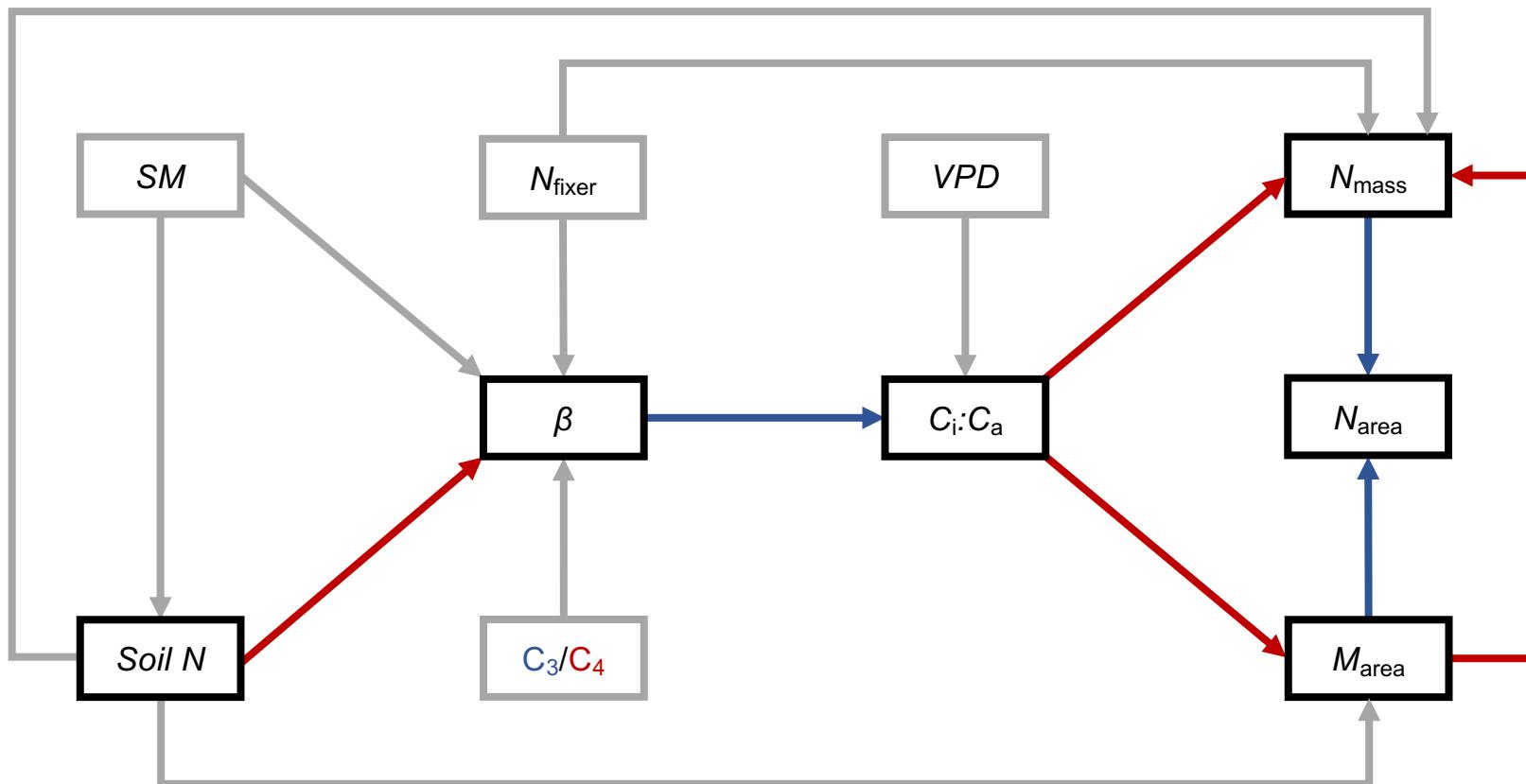


Positive  
Negative

Soil N may directly **increase**  $N_{\text{area}}$  due to increasing  $N_{\text{mass}} \dots$

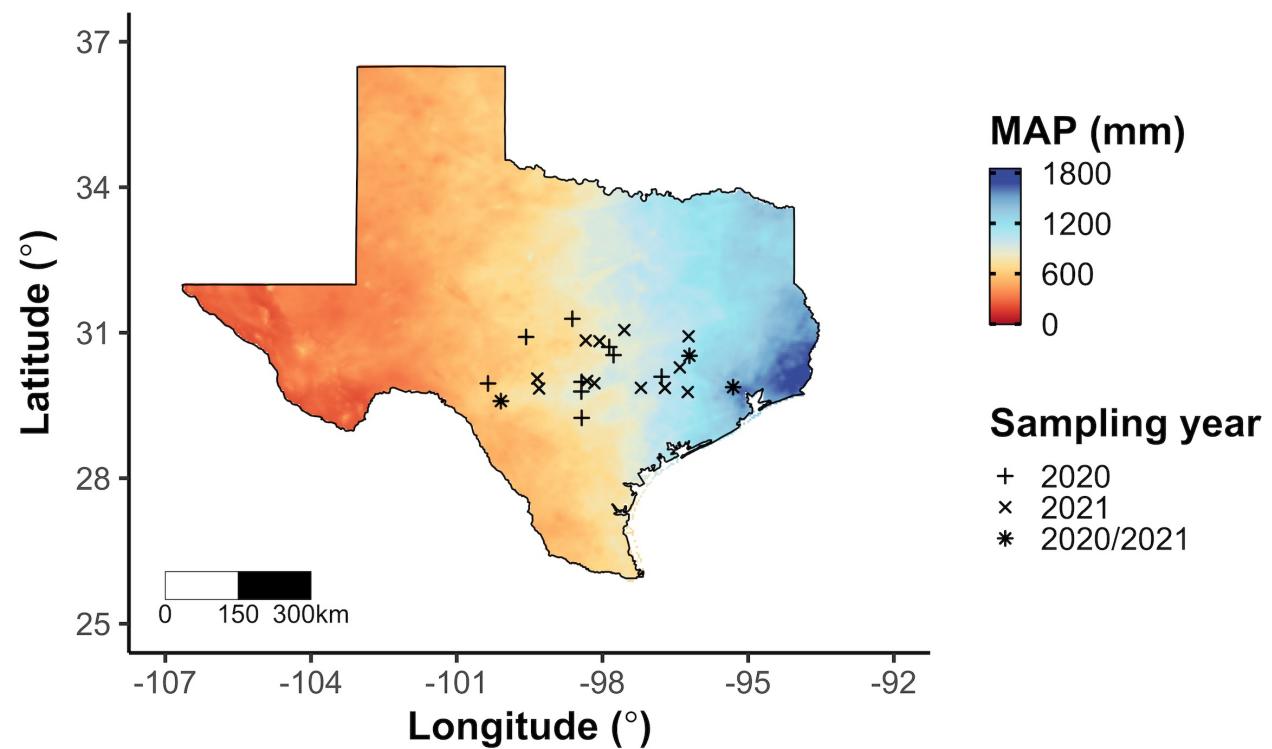


... or may indirectly **increase**  $N_{\text{area}}$  due to  
**reductions** in the cost of acquiring nitrogen



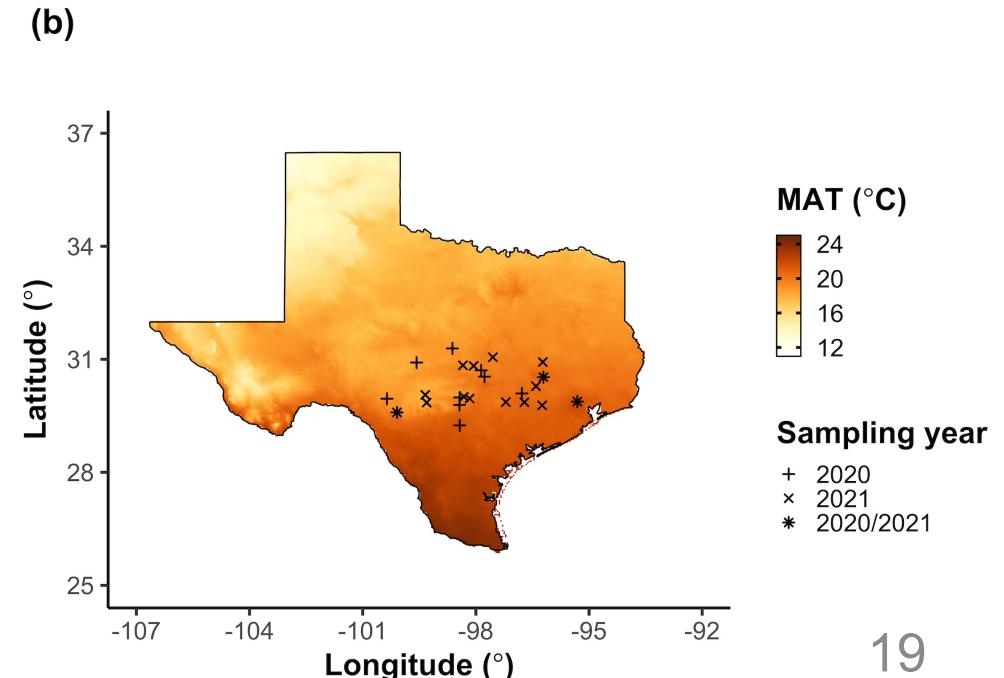
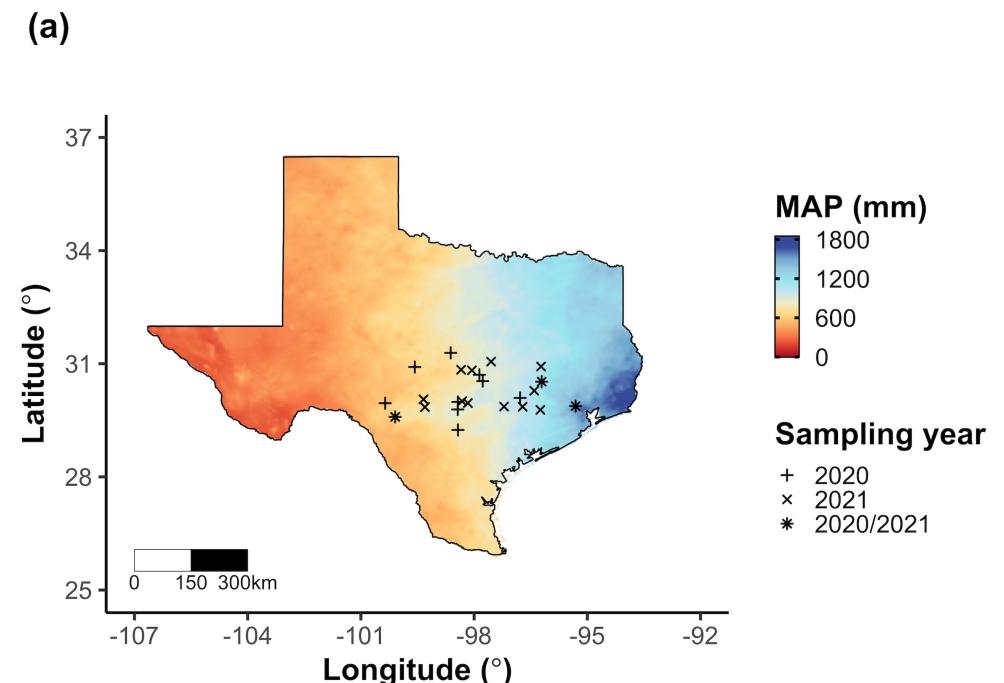
# Field gradient experiment

- 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<sub>i</sub>:C<sub>a</sub> ( $\delta^{13}\text{C}$ )
  - Cost of acquiring nitrogen relative to water ( $\beta$ )
- Composite soil sample

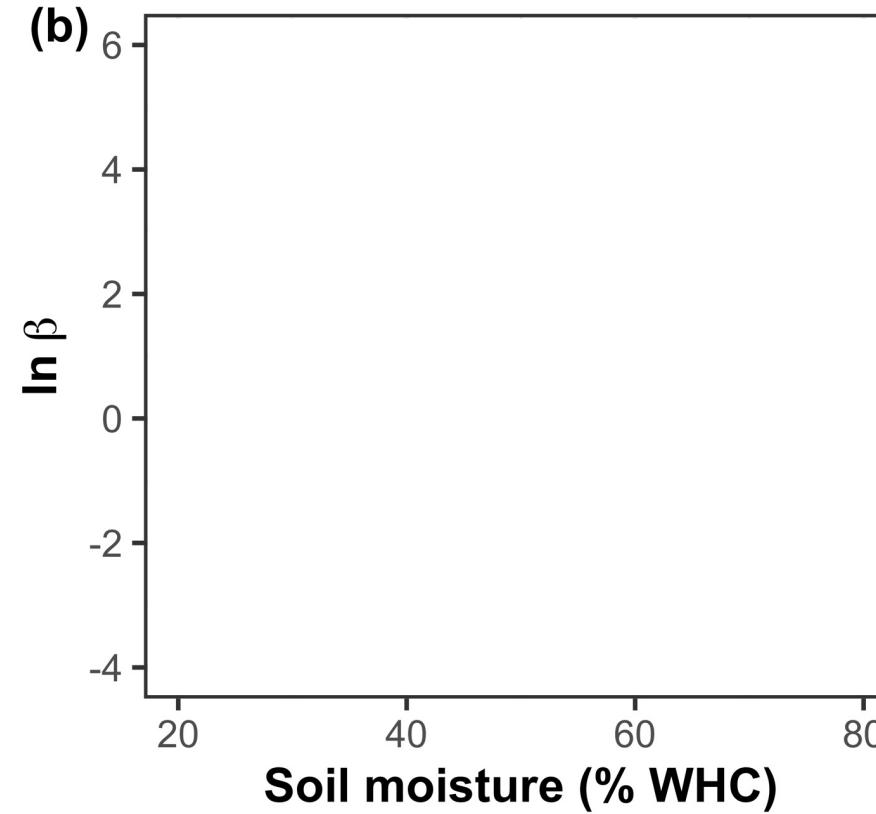
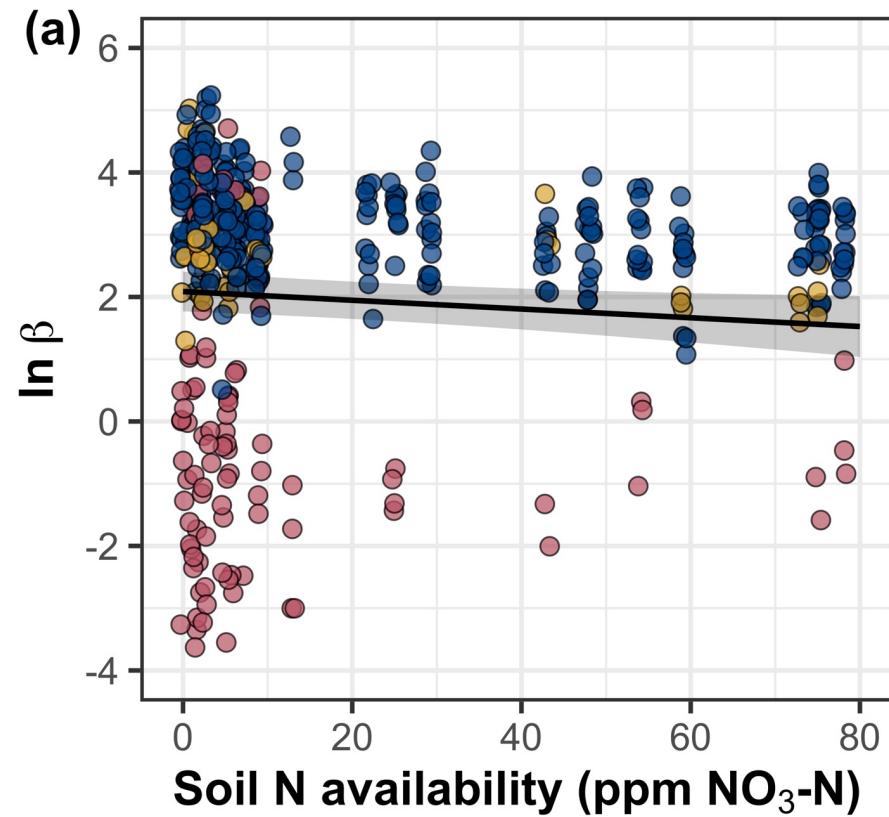


# Climate and edaphic characteristics

- Climate characteristics
  - Daily vapor pressure deficit
- Edaphic characteristics
  - Soil nitrogen availability ( $\text{NO}_3\text{-N}$ )
  - Soil moisture
- Timescales for VPD and soil moisture determined using model selection



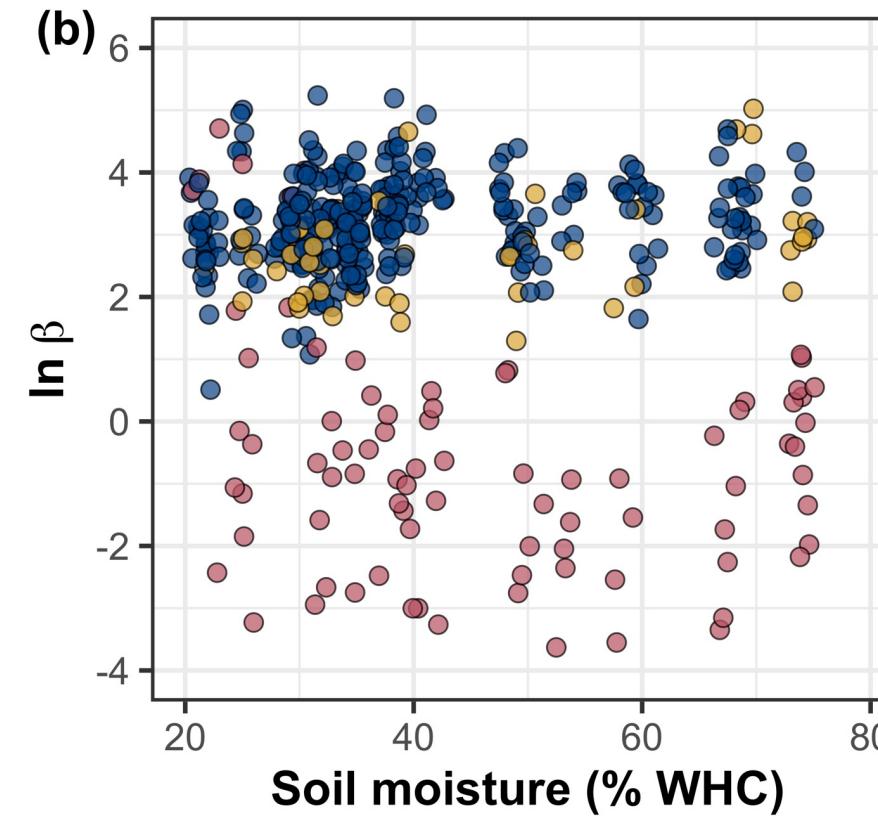
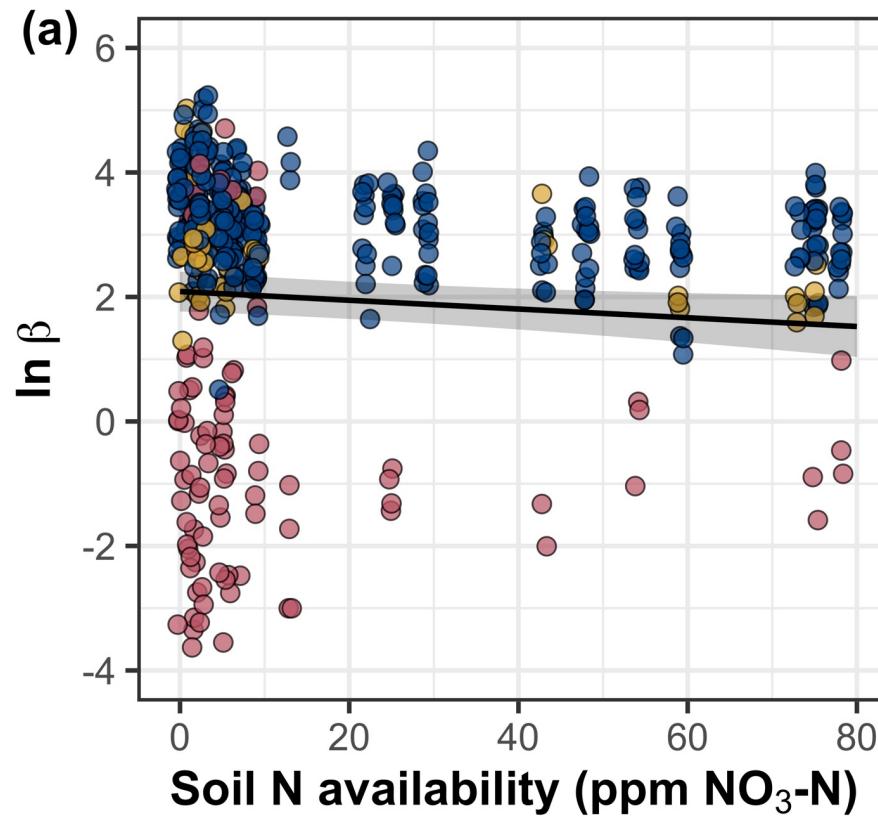
# $\beta$ decreases with increasing soil nitrogen



**Functional group**

- $\text{C}_3$  N-fixer
- $\text{C}_3$  non-fixer
- $\text{C}_4$  non-fixer

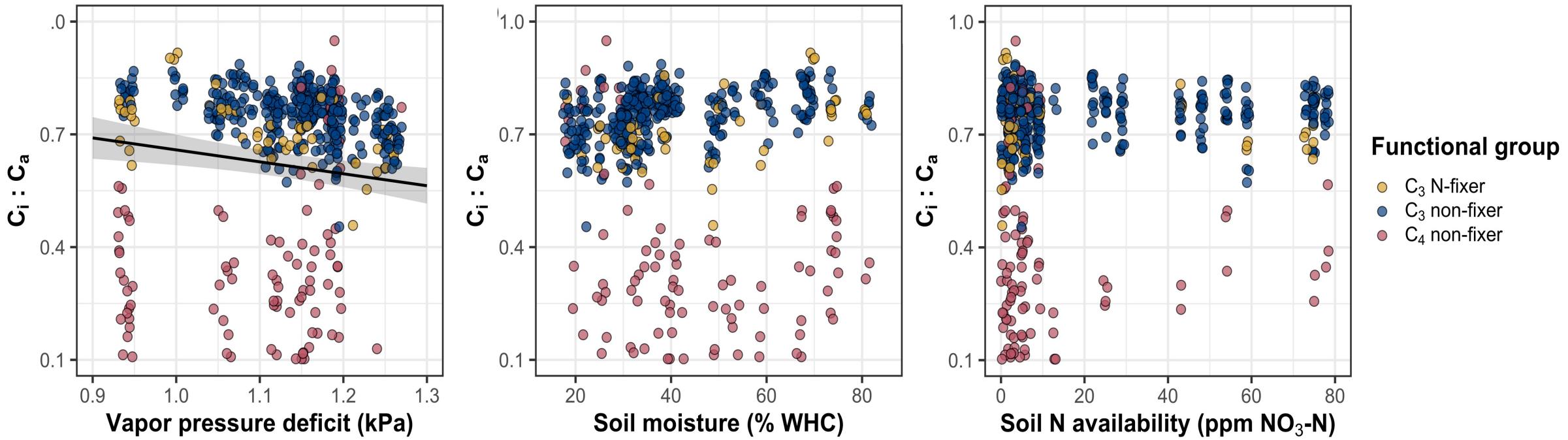
$\beta$  decreases with increasing soil nitrogen, but is not modified by soil moisture



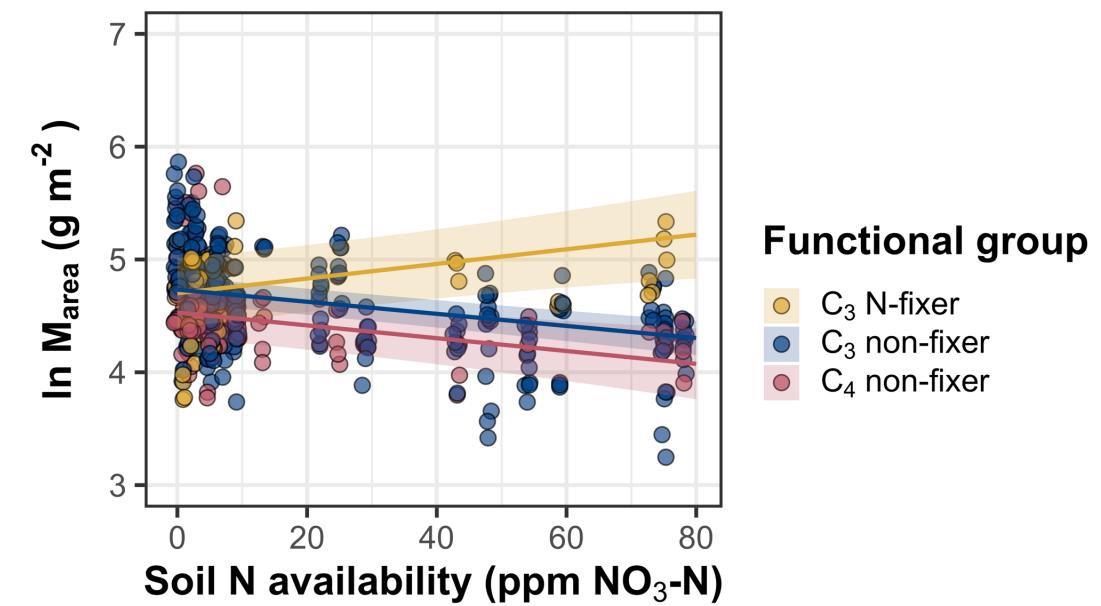
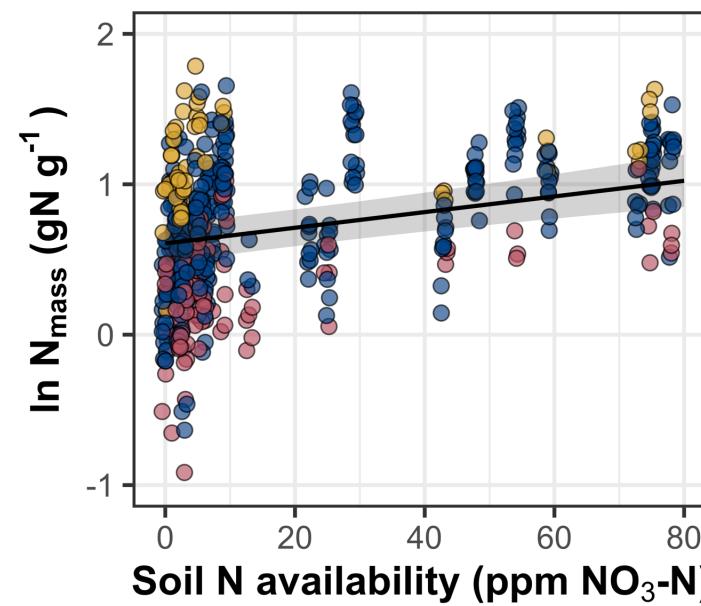
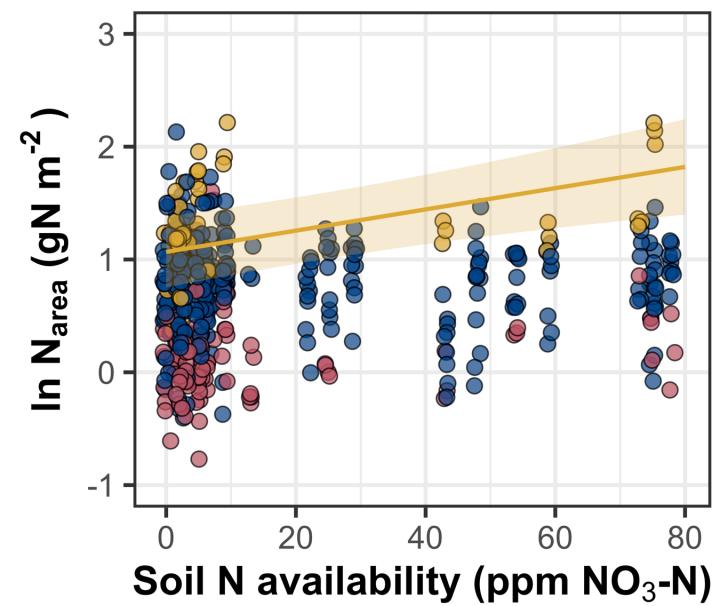
**Functional group**

- $C_3$  N-fixer
- $C_3$  non-fixer
- $C_4$  non-fixer

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



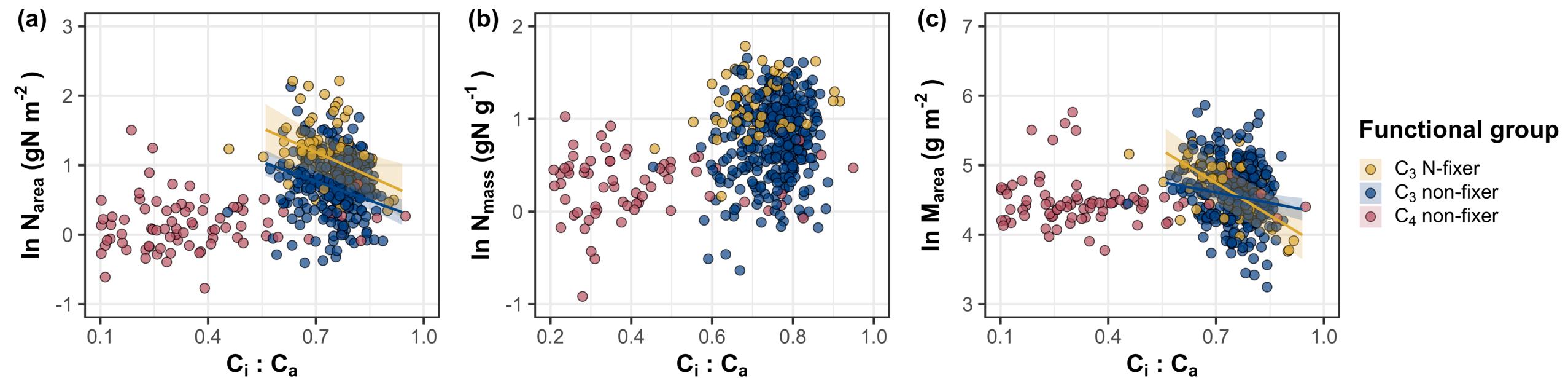
$N_{\text{area}}$  increases with increasing soil nitrogen availability



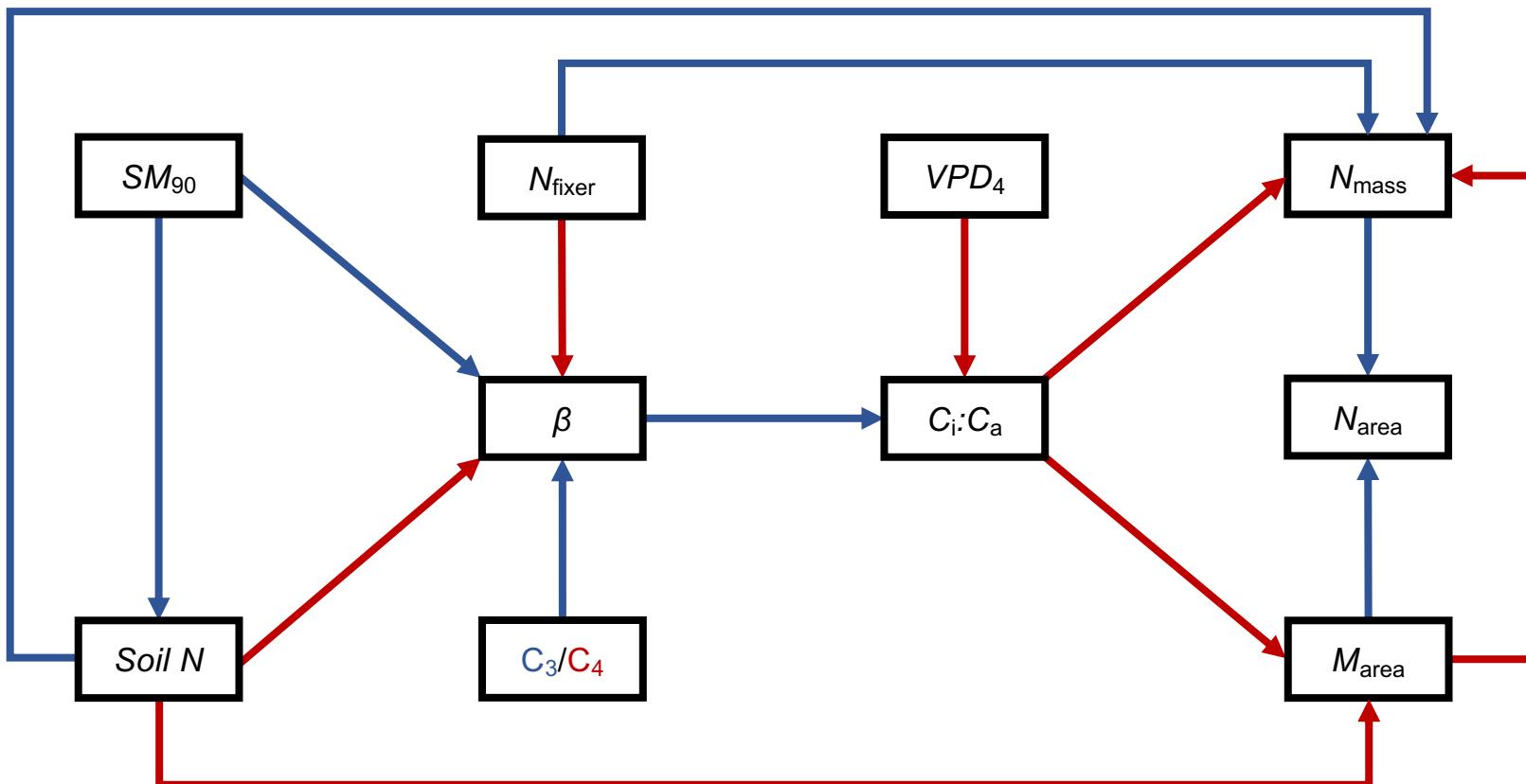
Functional group

- $C_3$  N-fixer
- $C_3$  non-fixer
- $C_4$  non-fixer

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

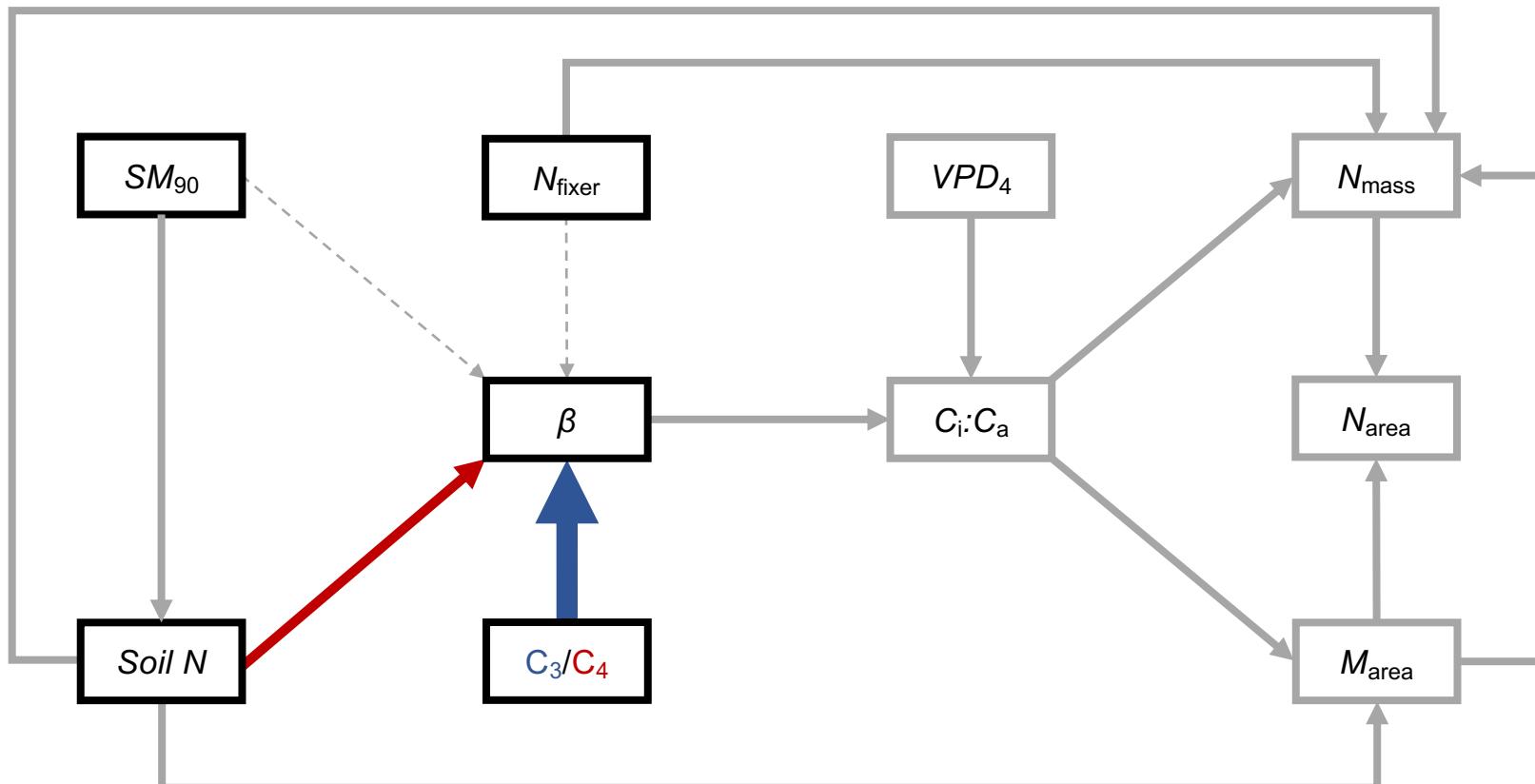


# Revisiting hypotheses



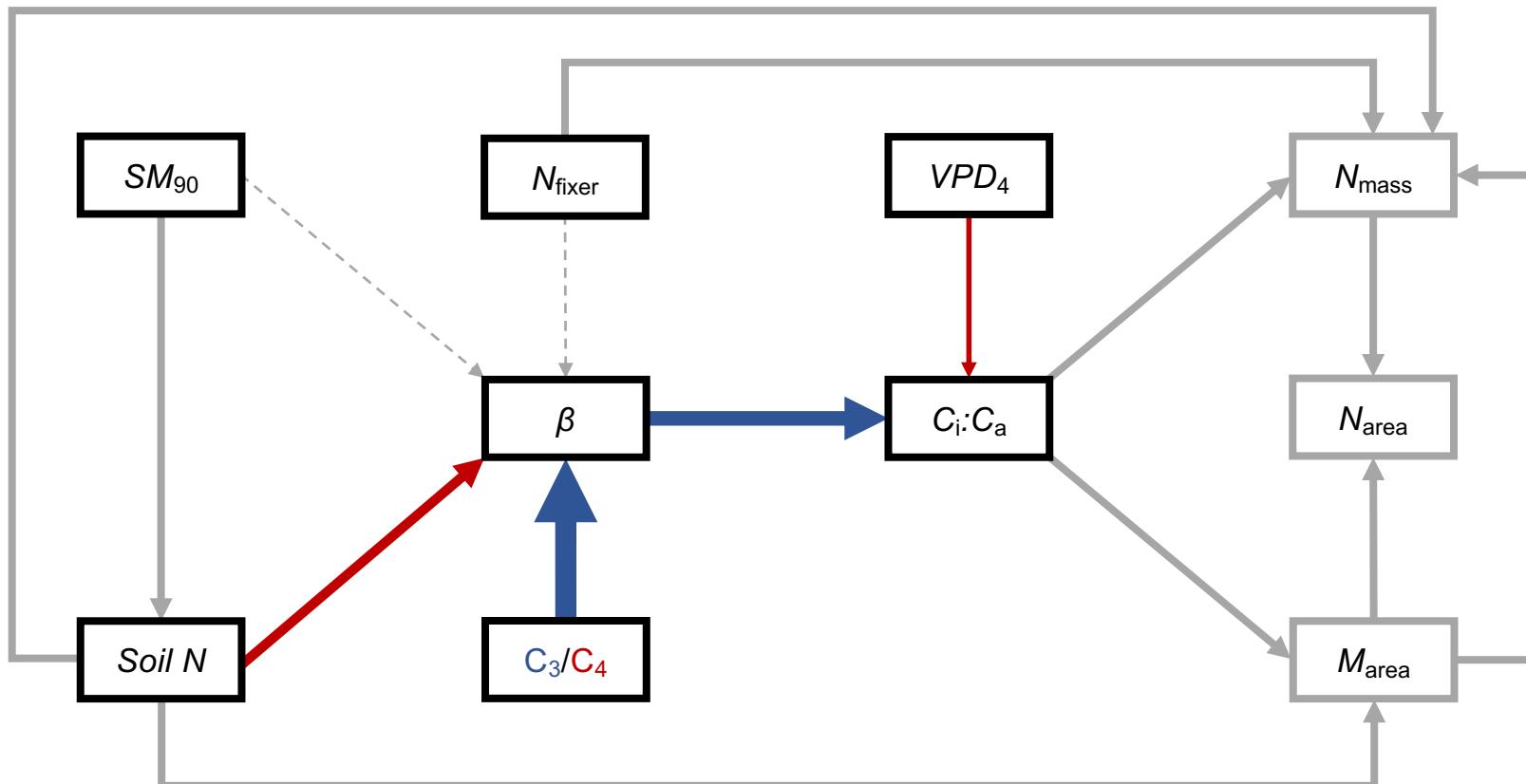
Positive  
Negative

$\beta$  is **negatively** associated with increasing soil nitrogen, and generally **lower** in C<sub>4</sub> species



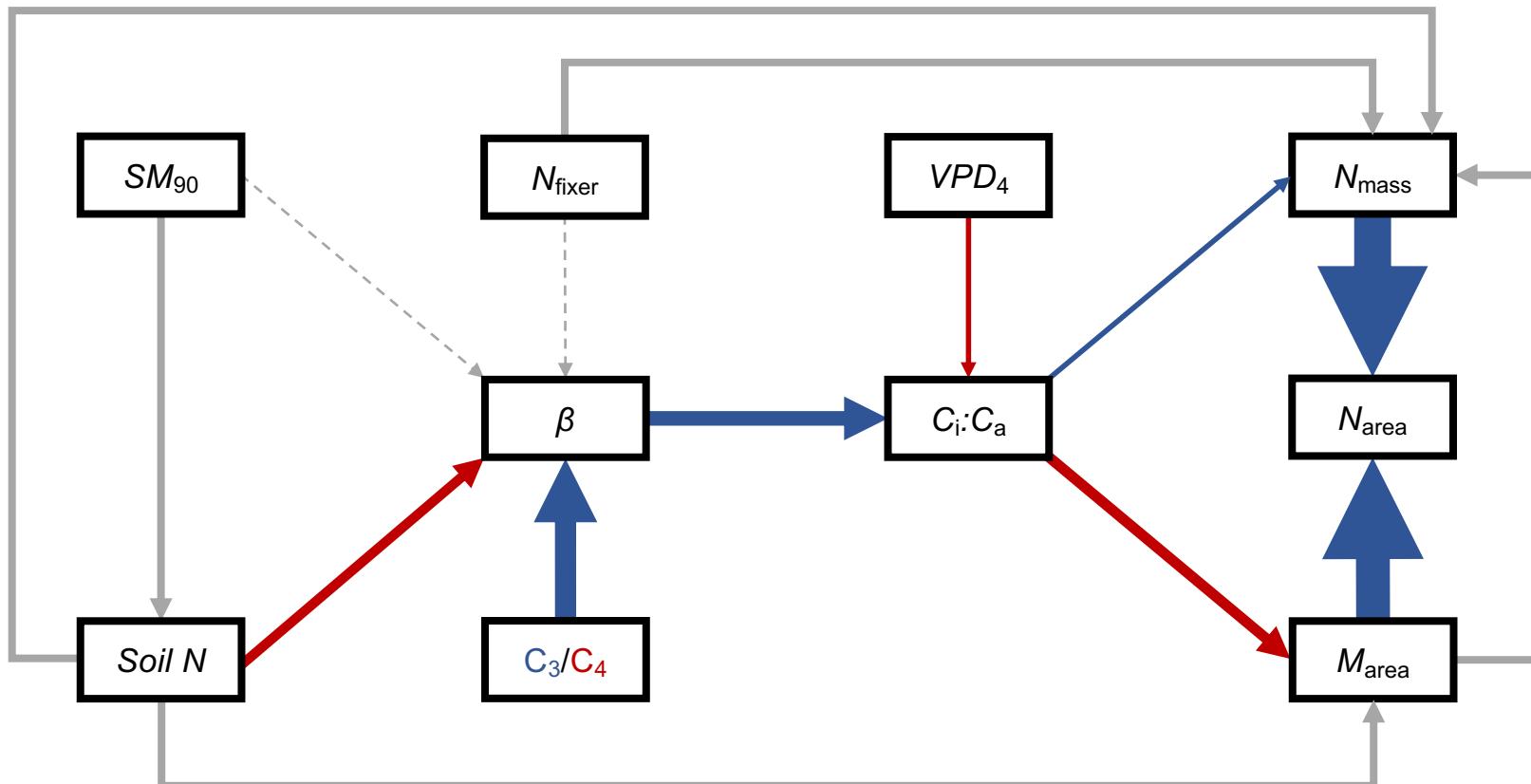
Positive  
Negative

Leaf  $C_i:C_a$  is **negatively** related to increasing vapor pressure deficit and **positively** related to  $\beta$



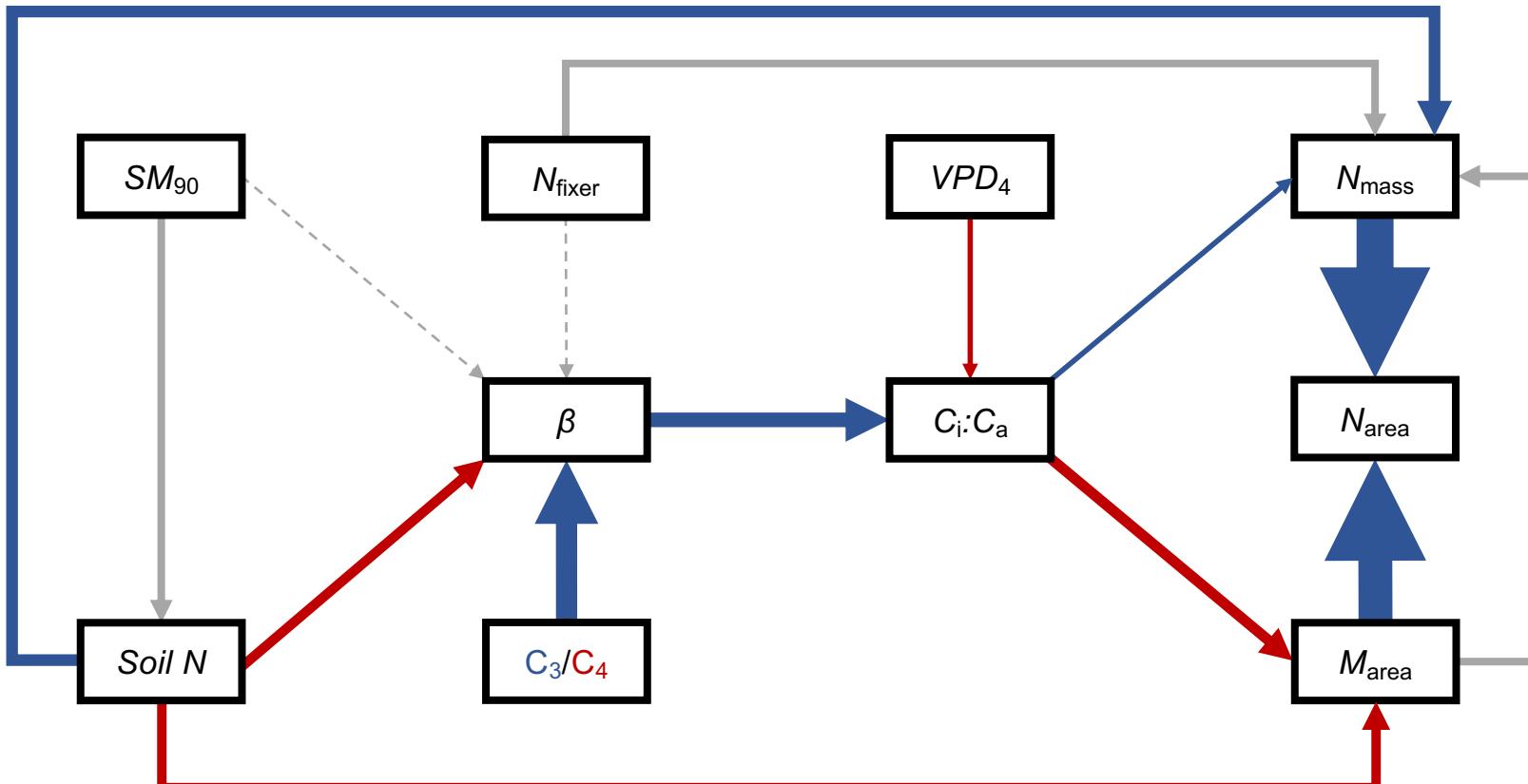
Positive  
Negative

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



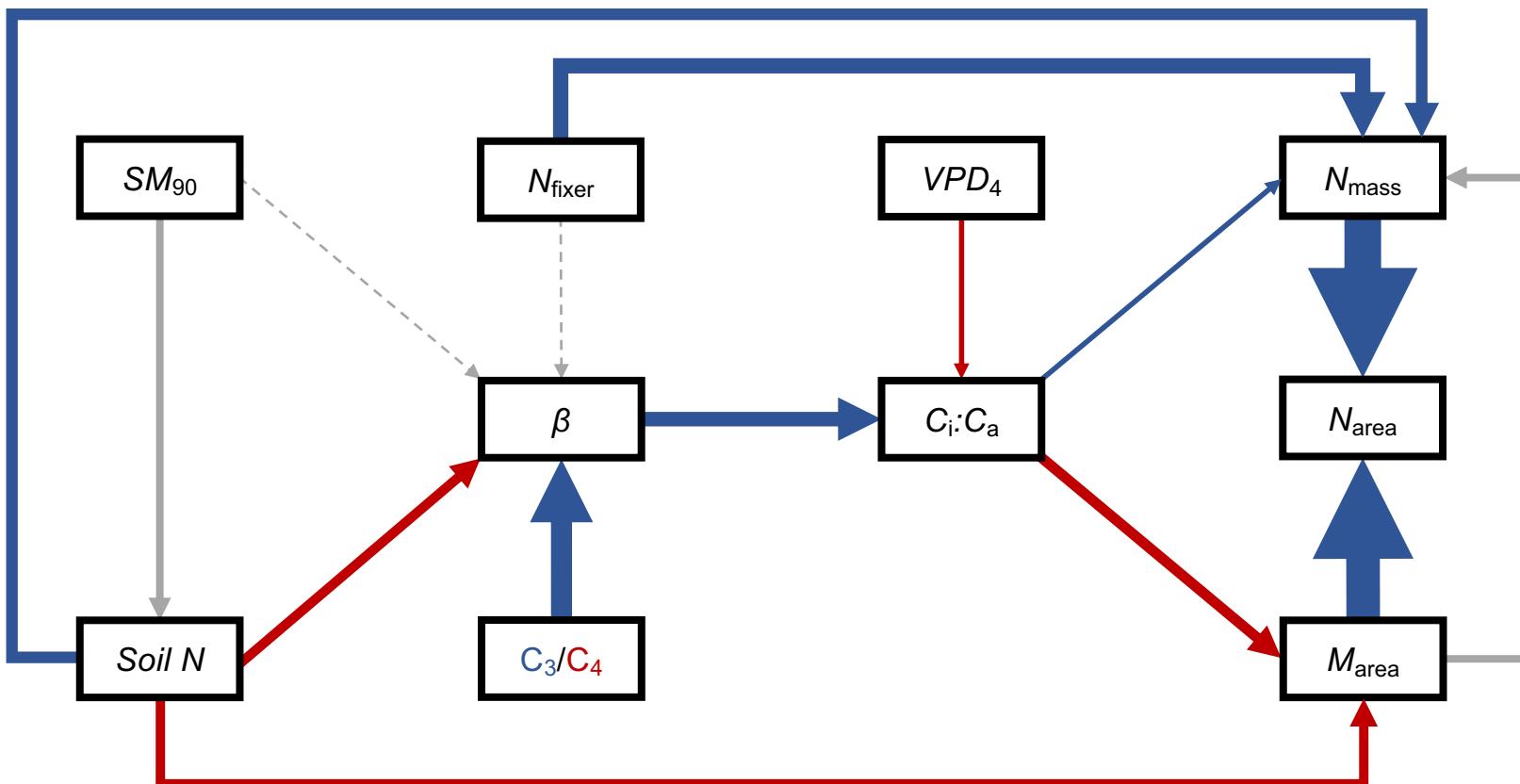
Positive  
Negative

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



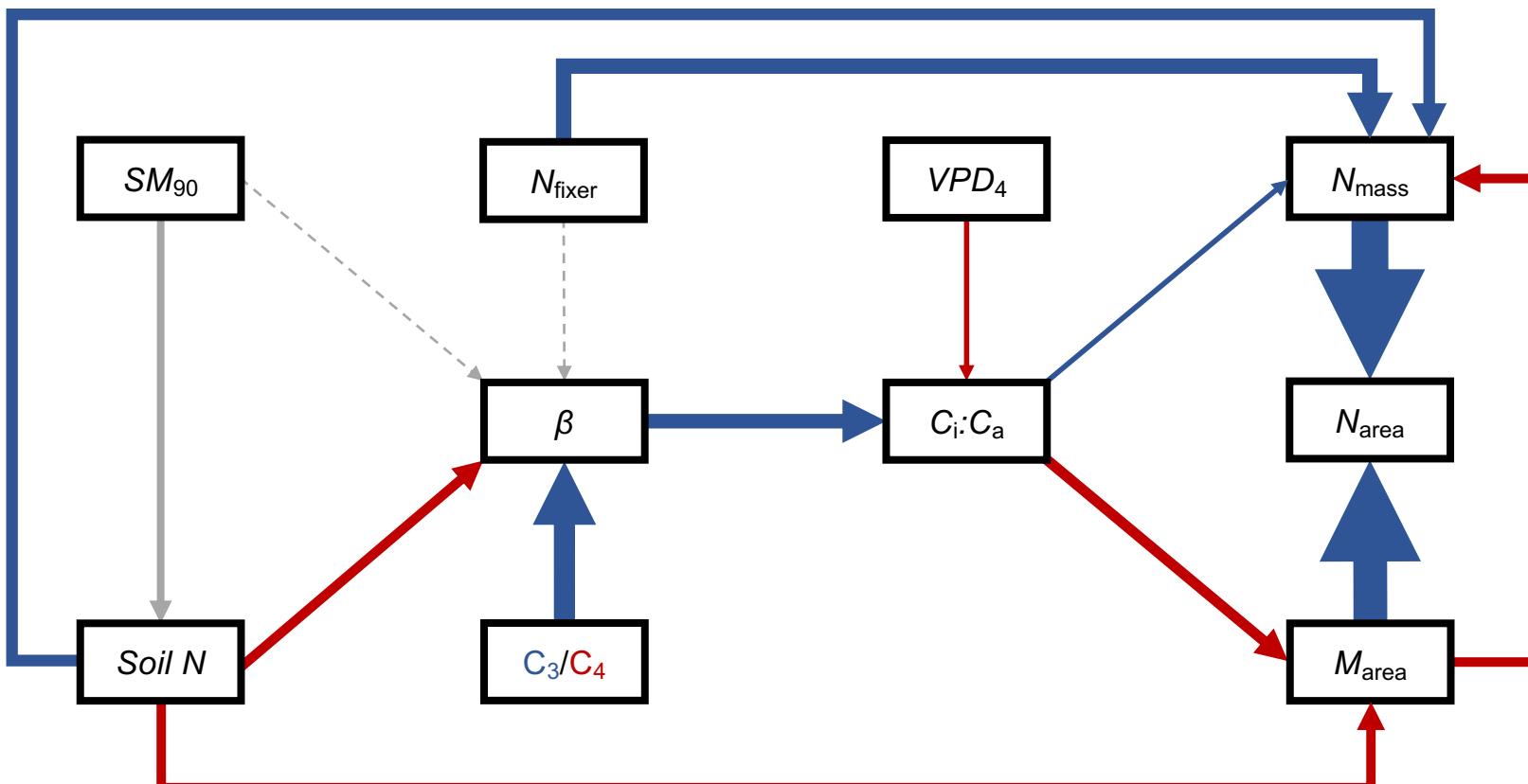
Positive  
Negative

# N-fixation ability directly increases $N_{\text{mass}}$

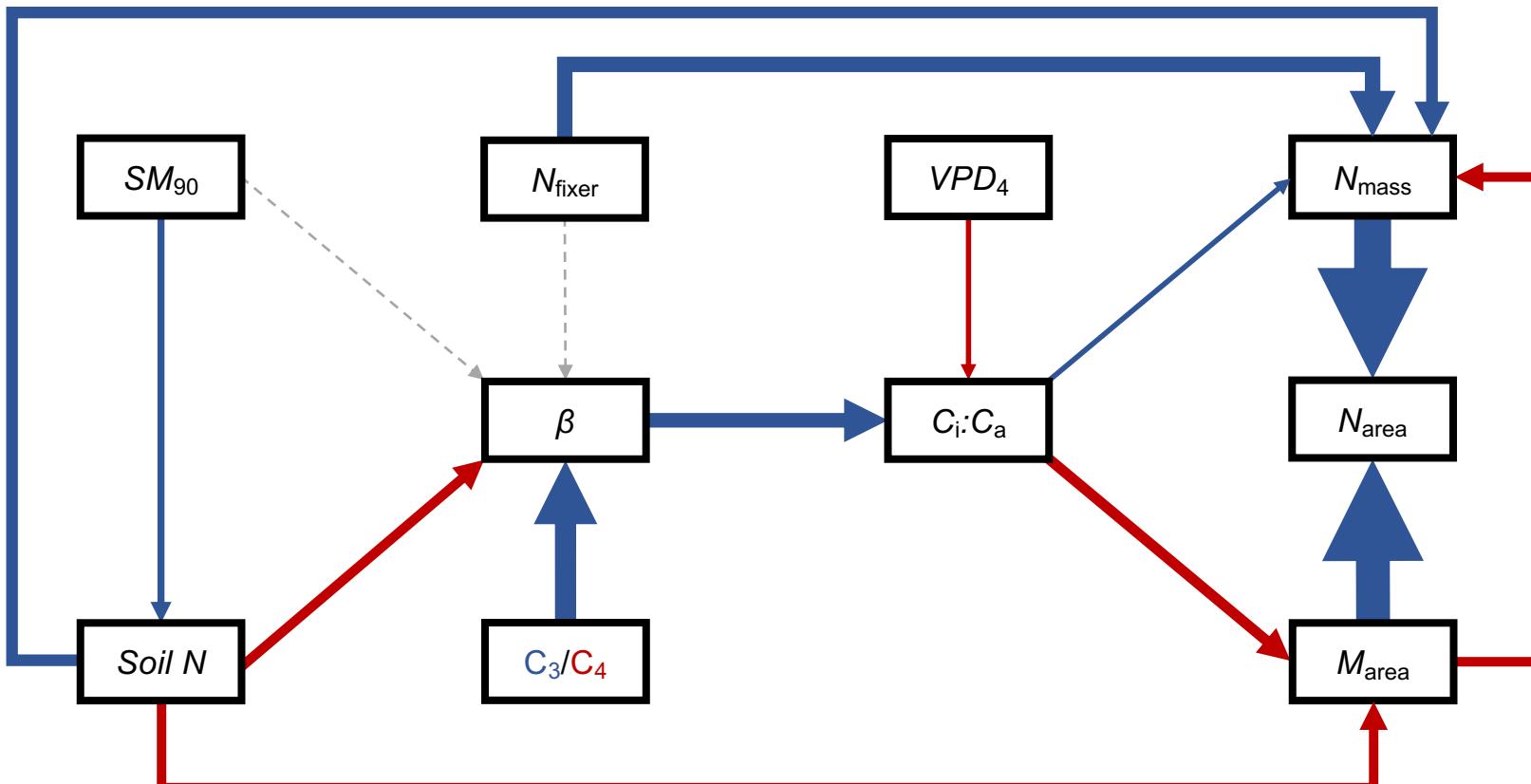


Positive  
Negative

$M_{\text{area}}$  is **negatively** associated with  $N_{\text{mass}}$

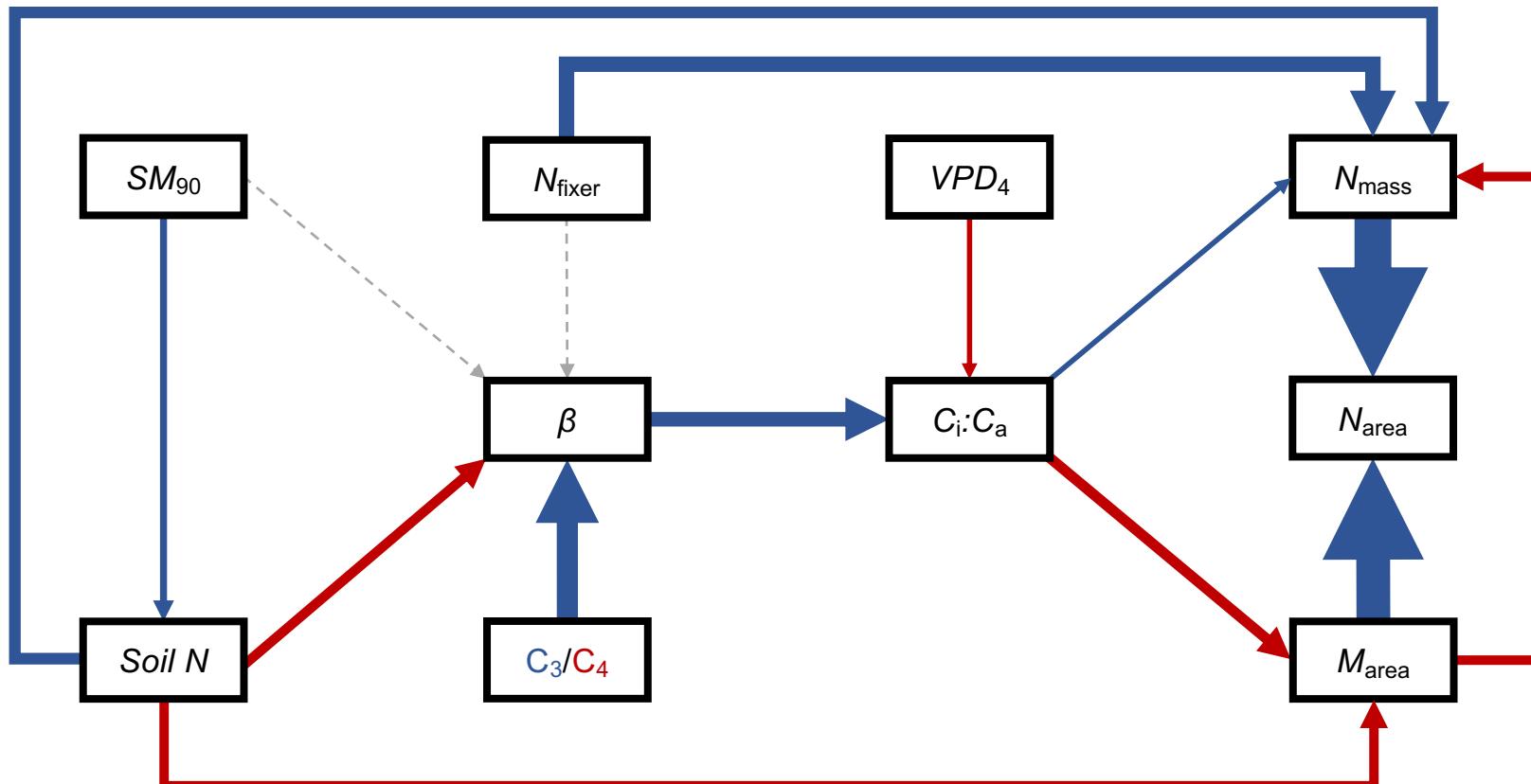


Soil moisture was **positively** associated with soil nitrogen availability



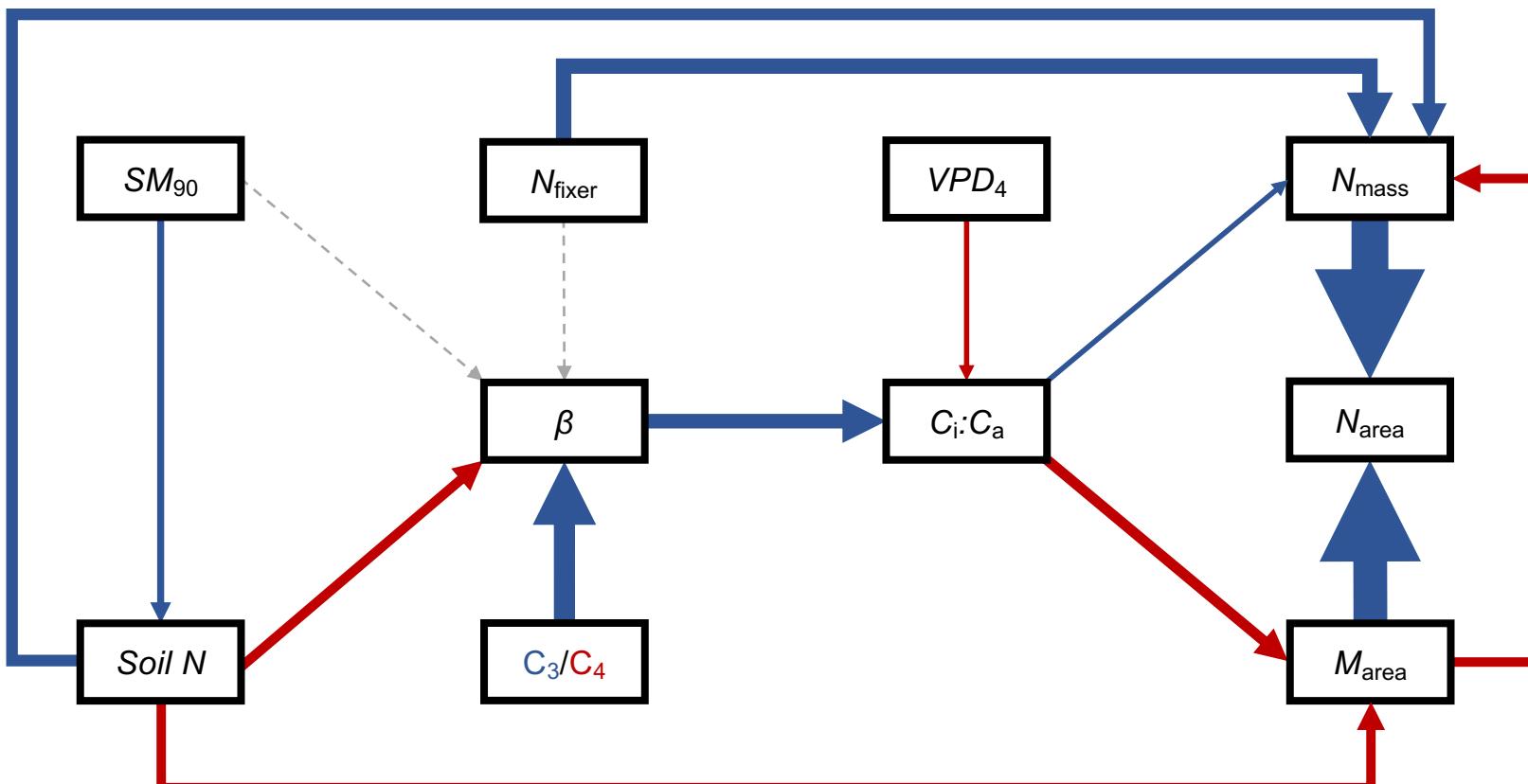
Positive  
Negative

Soil N directly increased  $N_{\text{area}}$  due to changes in  $N_{\text{mass}} \dots$



Positive  
Negative

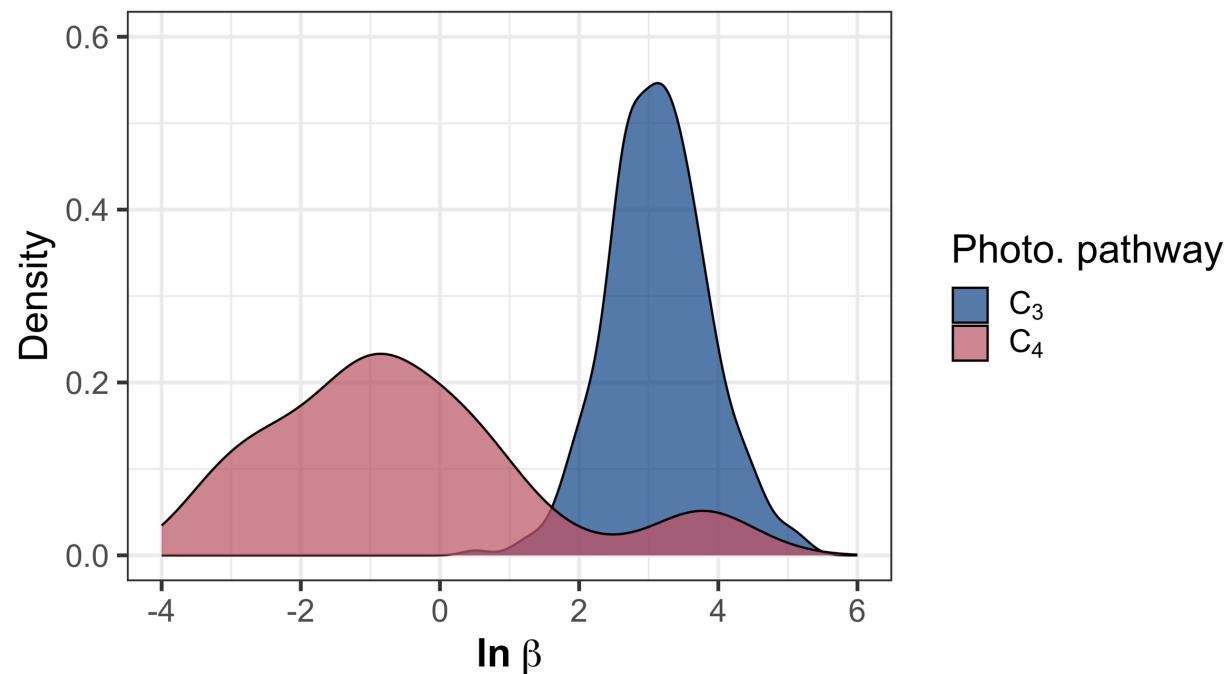
... and indirectly increased  $N_{\text{area}}$  through  
**reductions** in  $\beta$



Positive  
Negative

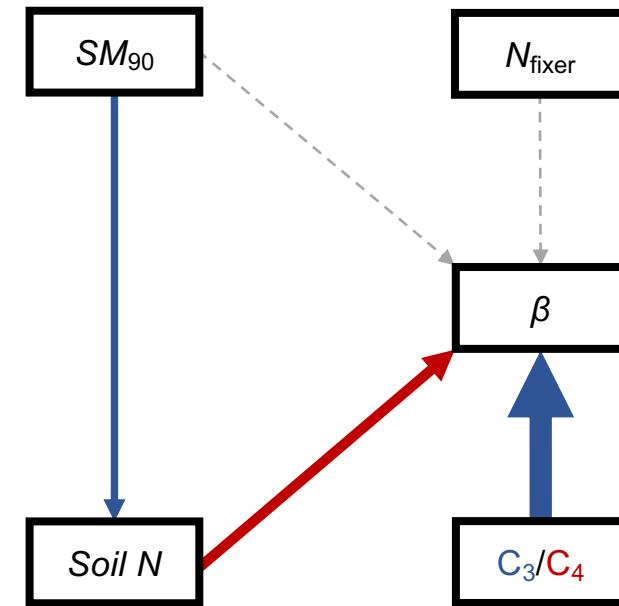
# Conclusions

- $\beta$  dynamically changes across environments



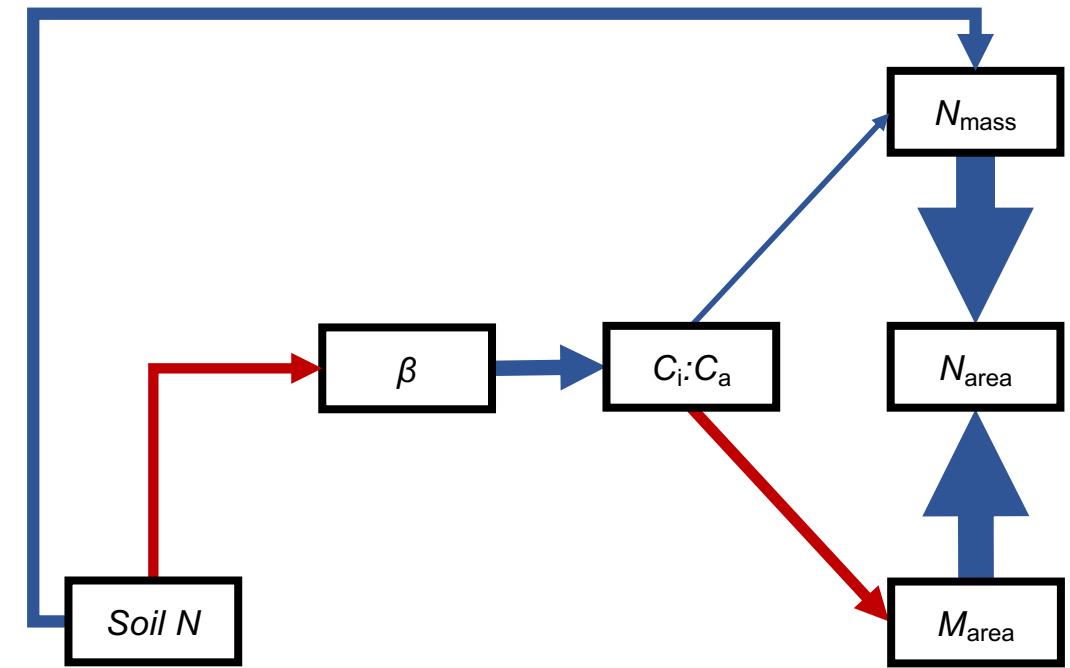
# Conclusions

- $\beta$  dynamically changes across environments
- Soil N is more important for determining variance in  $\beta$  than soil moisture



# Conclusions

- $\beta$  dynamically changes across environments
- Soil N is more important for determining variance in  $\beta$  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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- Hannah German\*
- Avery Schoenherr\*



Texas Ecological Laboratory





# Extra slides

# Resource unit cost ratio ( $\beta$ )

cost of acquiring and using N

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

cost of acquiring and using H<sub>2</sub>O

# Resource unit cost ratio ( $\beta$ )

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