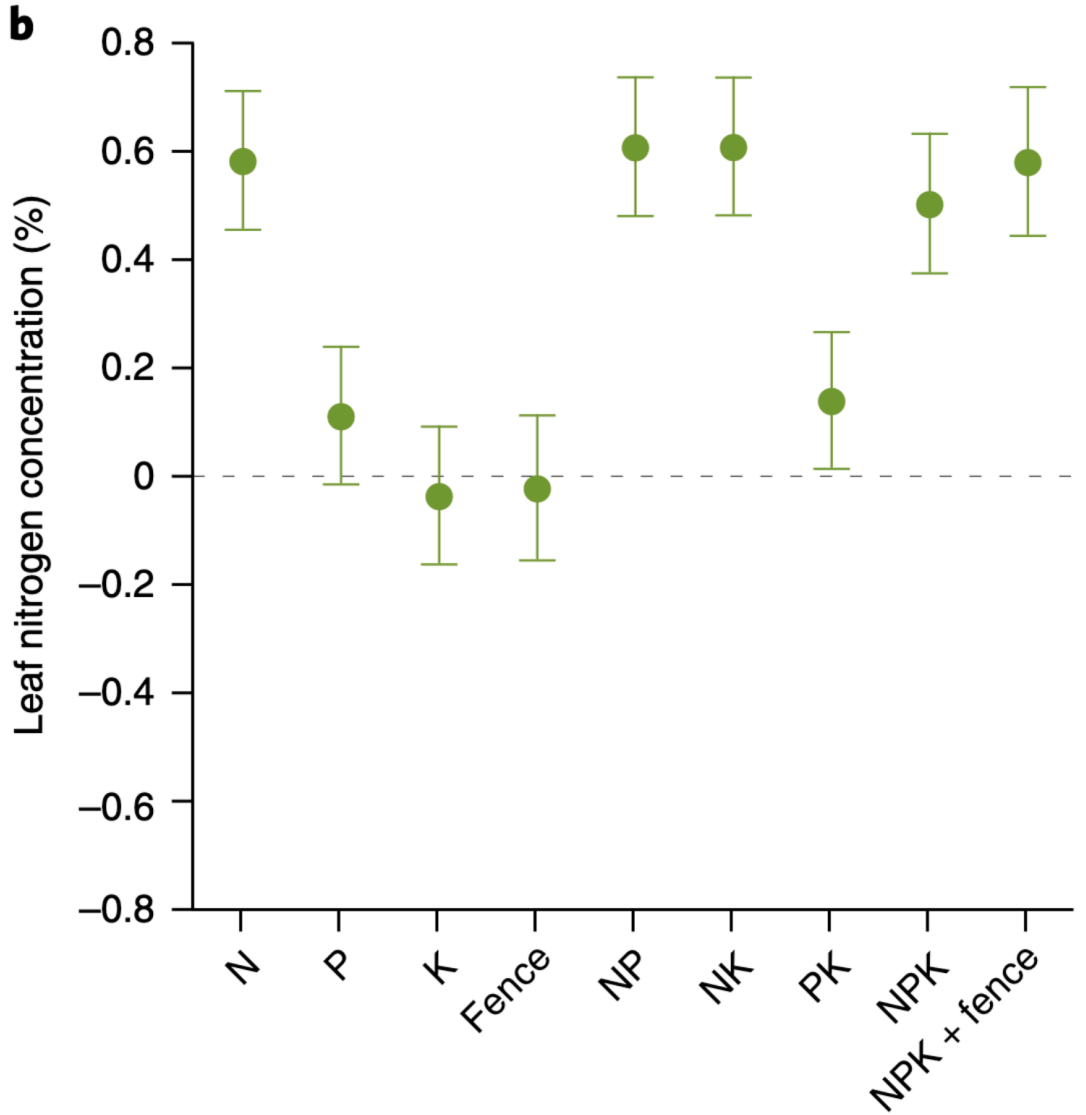
Leaf nitrogen is driven by the unit cost of nitrogen and water use in Texan grasslands

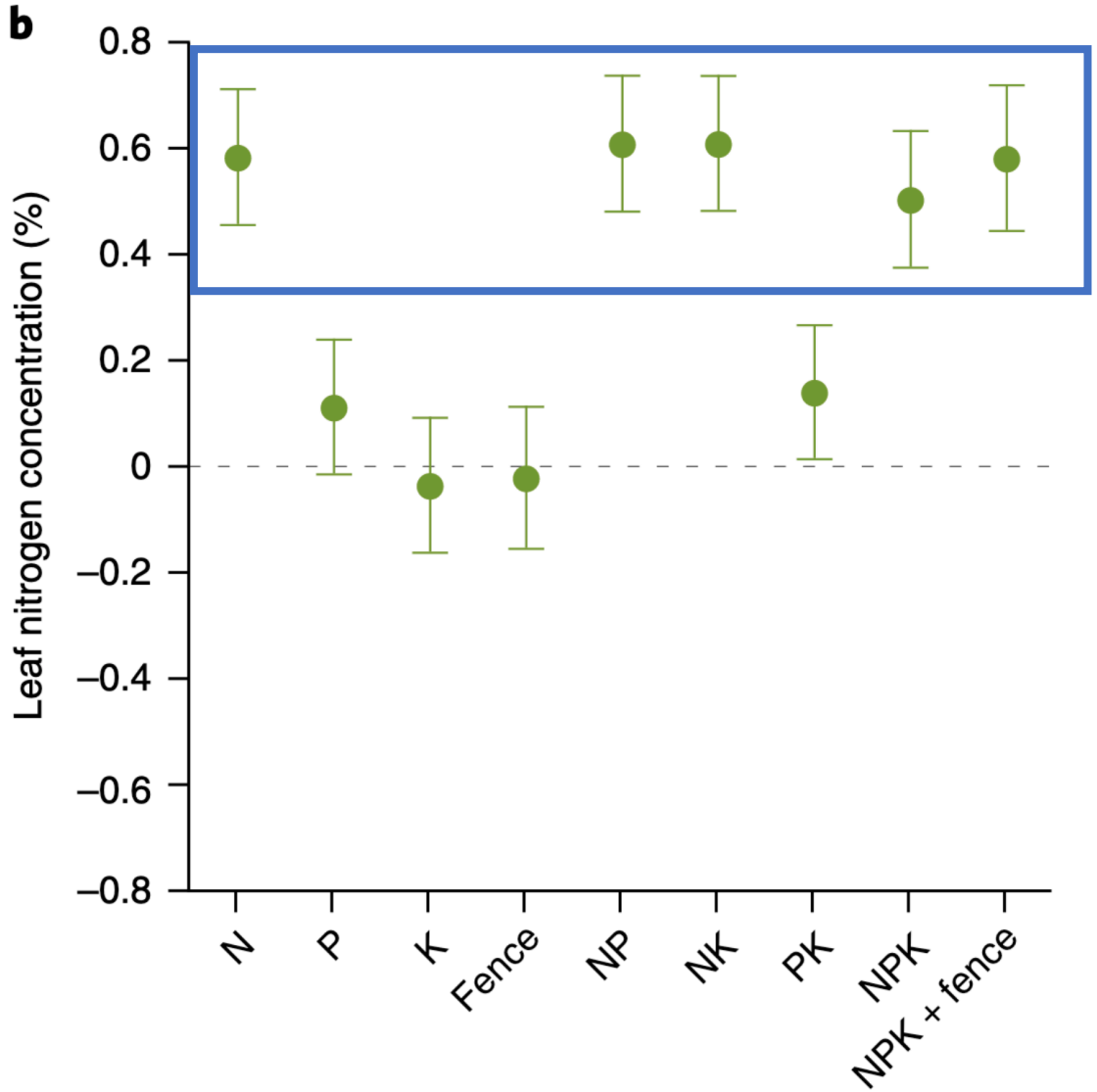
Evan A. Perkowski; Nicholas G. Smith

Soil nitrogen generally increases leaf nitrogen



Firn et al. (2019) *Nature*

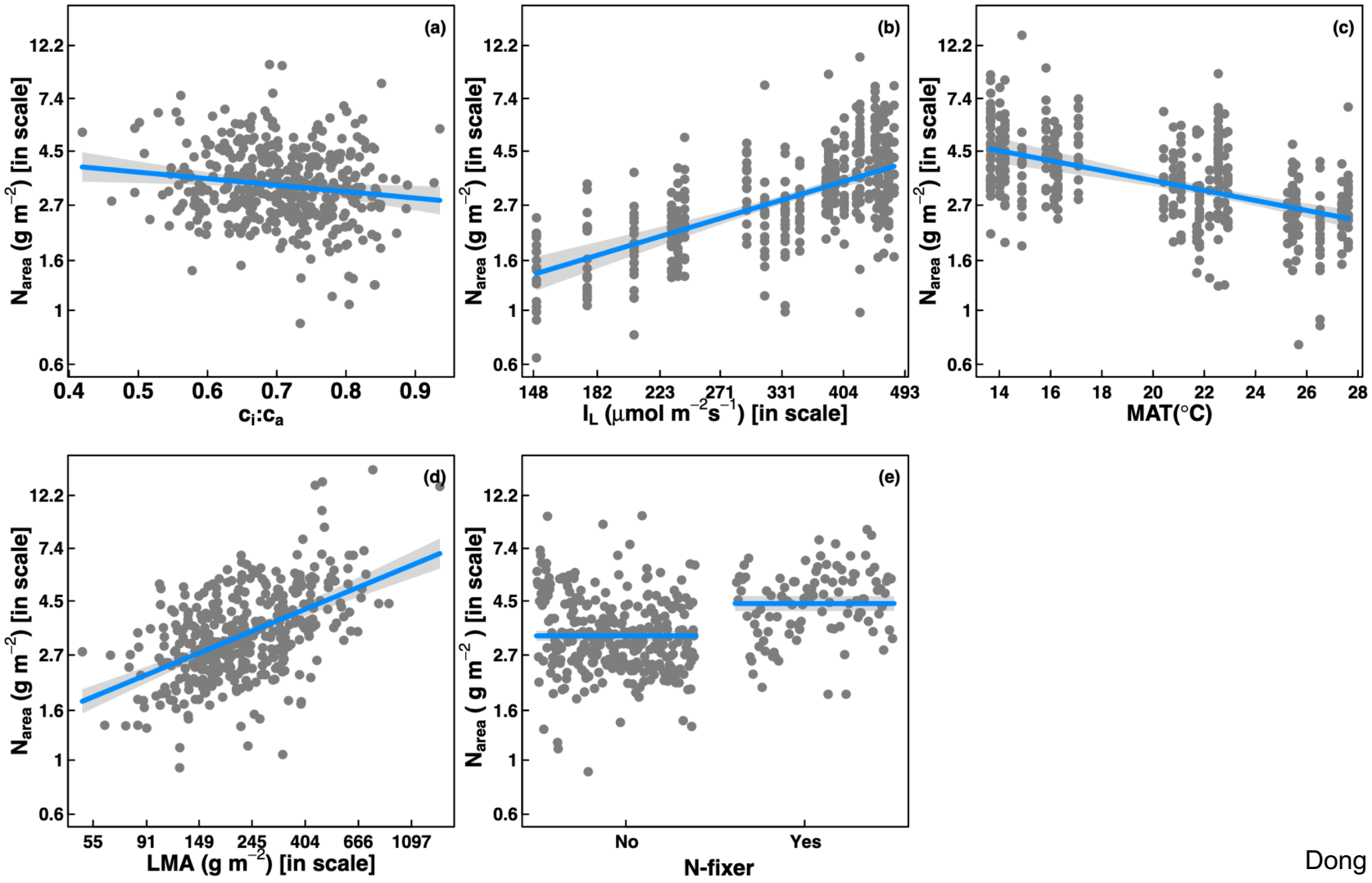
Soil nitrogen generally increases leaf nitrogen



Plots that receive nitrogen have higher leaf nitrogen content

Firn et al. (2019) *Nature*

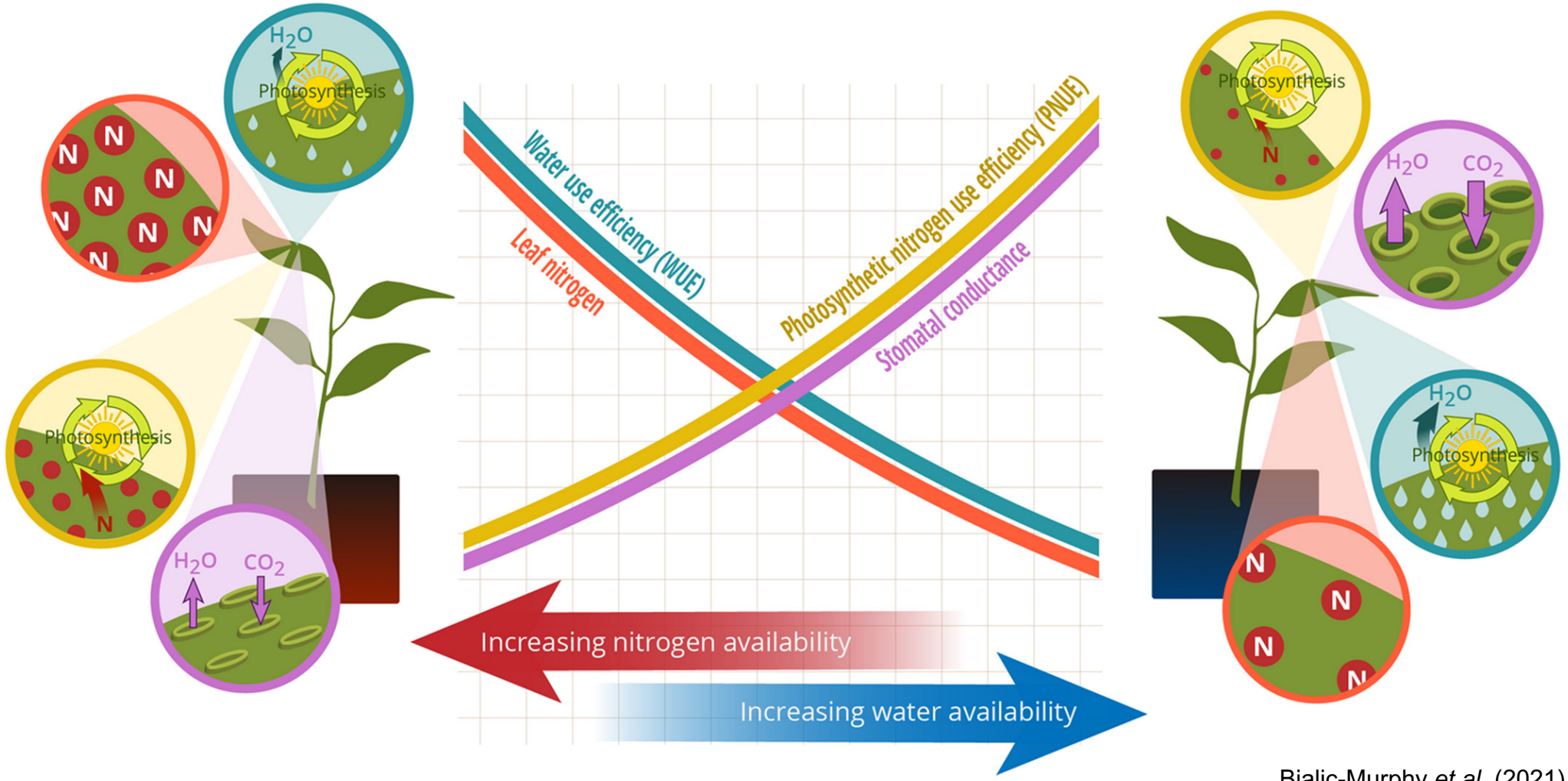
But, leaf nitrogen can be predicted independent of soil nitrogen



Dong et al. (2017) *Biogeosciences*

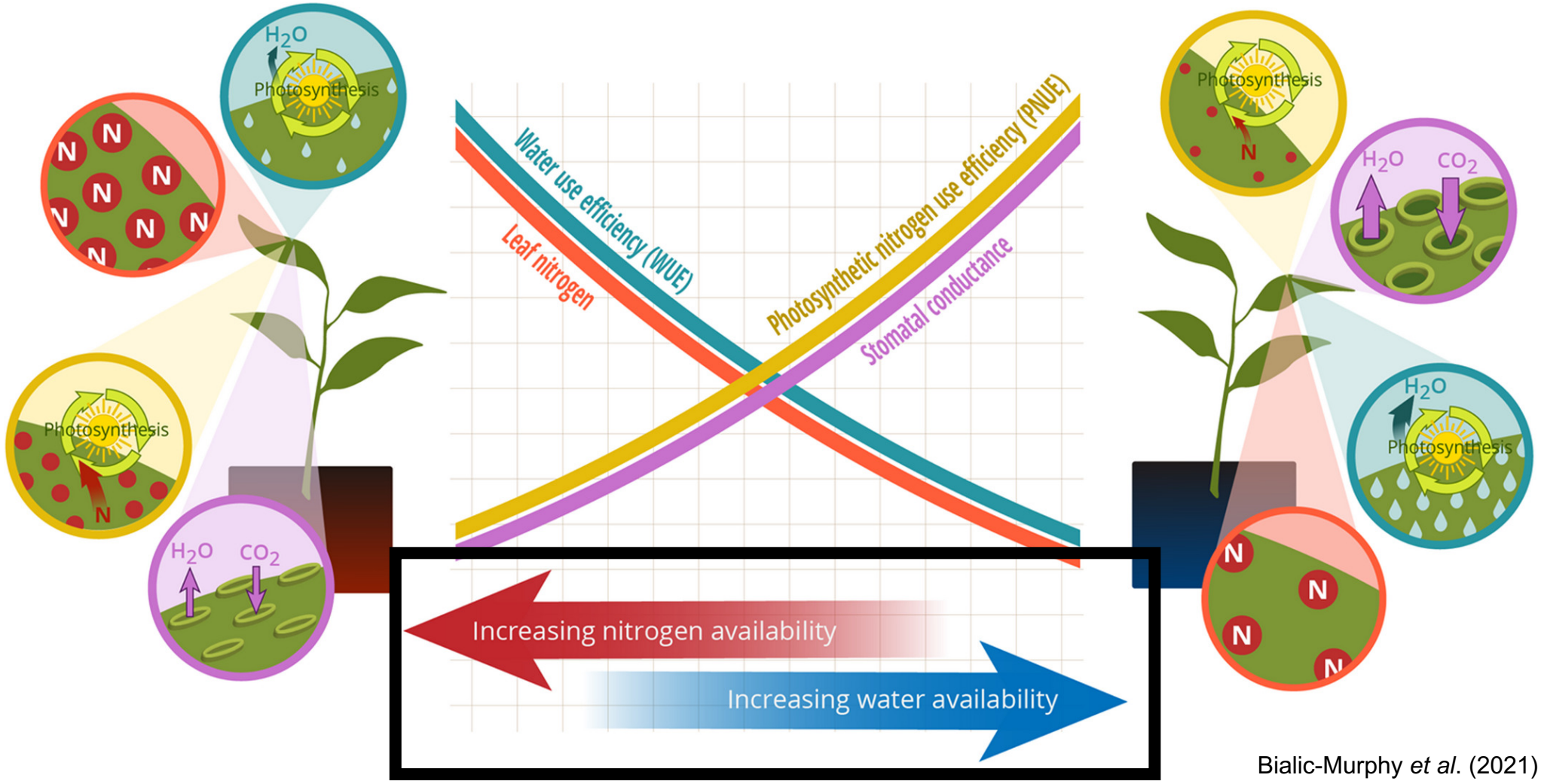
Leaf N is likely a product of interactions between climatic and edaphic factors

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)

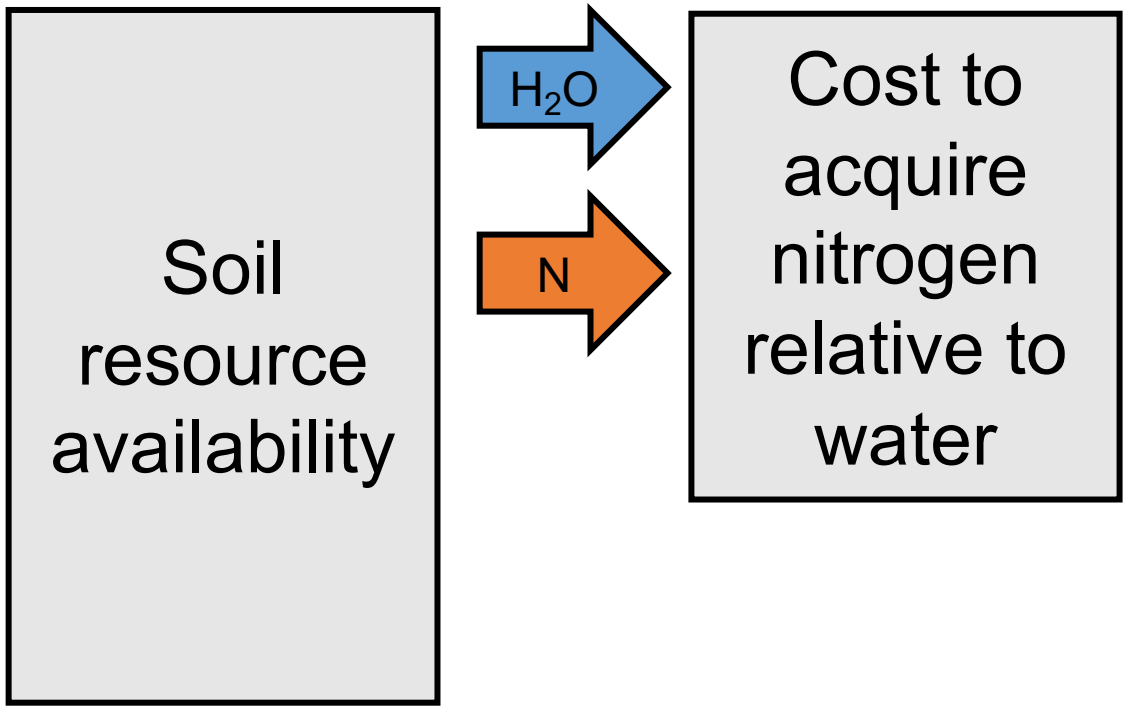


Bialic-Murphy *et al*. (2021) *Ecology Letters*

Positive effect

Negative effect

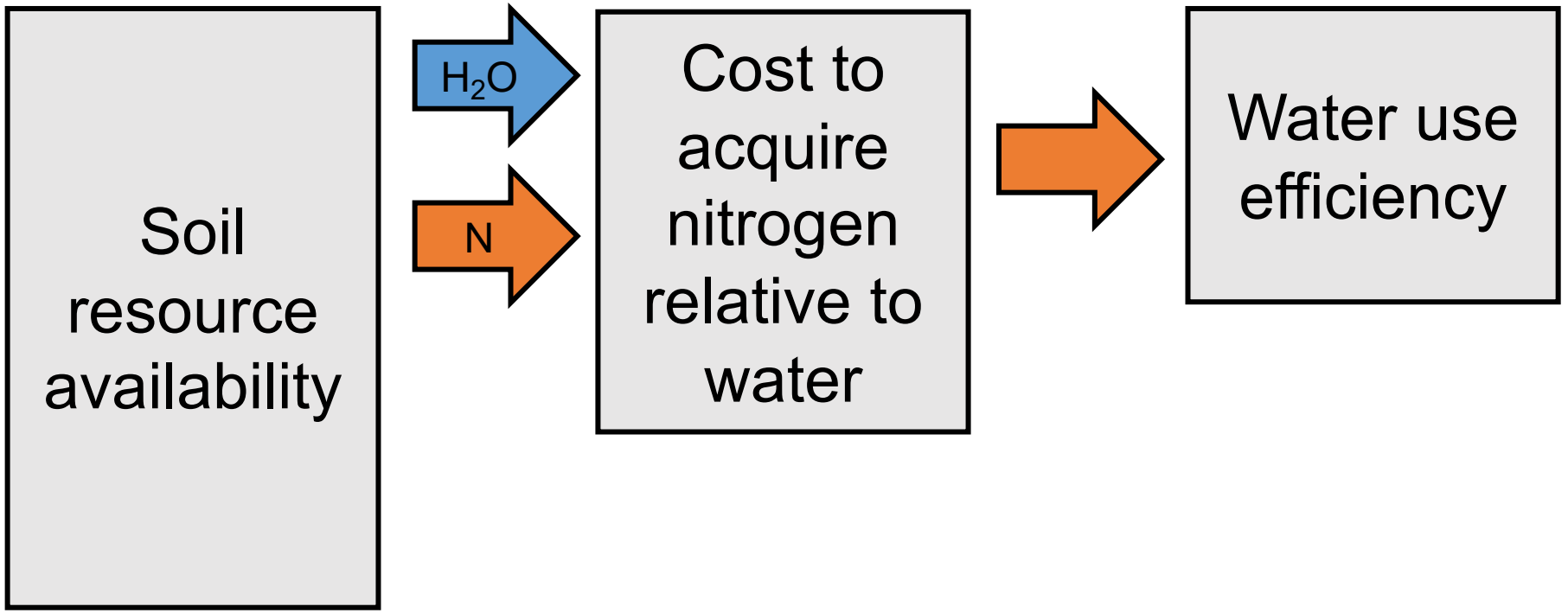
Soil N should **decrease**, and soil moisture should **increase** the cost of acquiring nitrogen relative to water



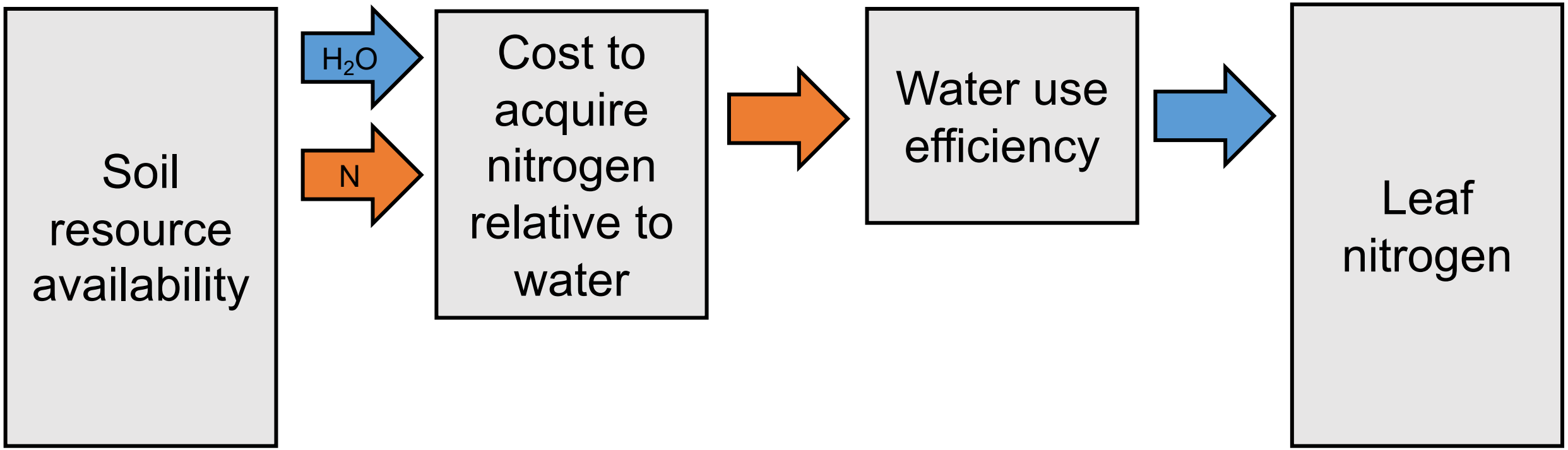
Increasing costs of acquiring nitrogen relative to water should **decrease** water use efficiency

Positive effect

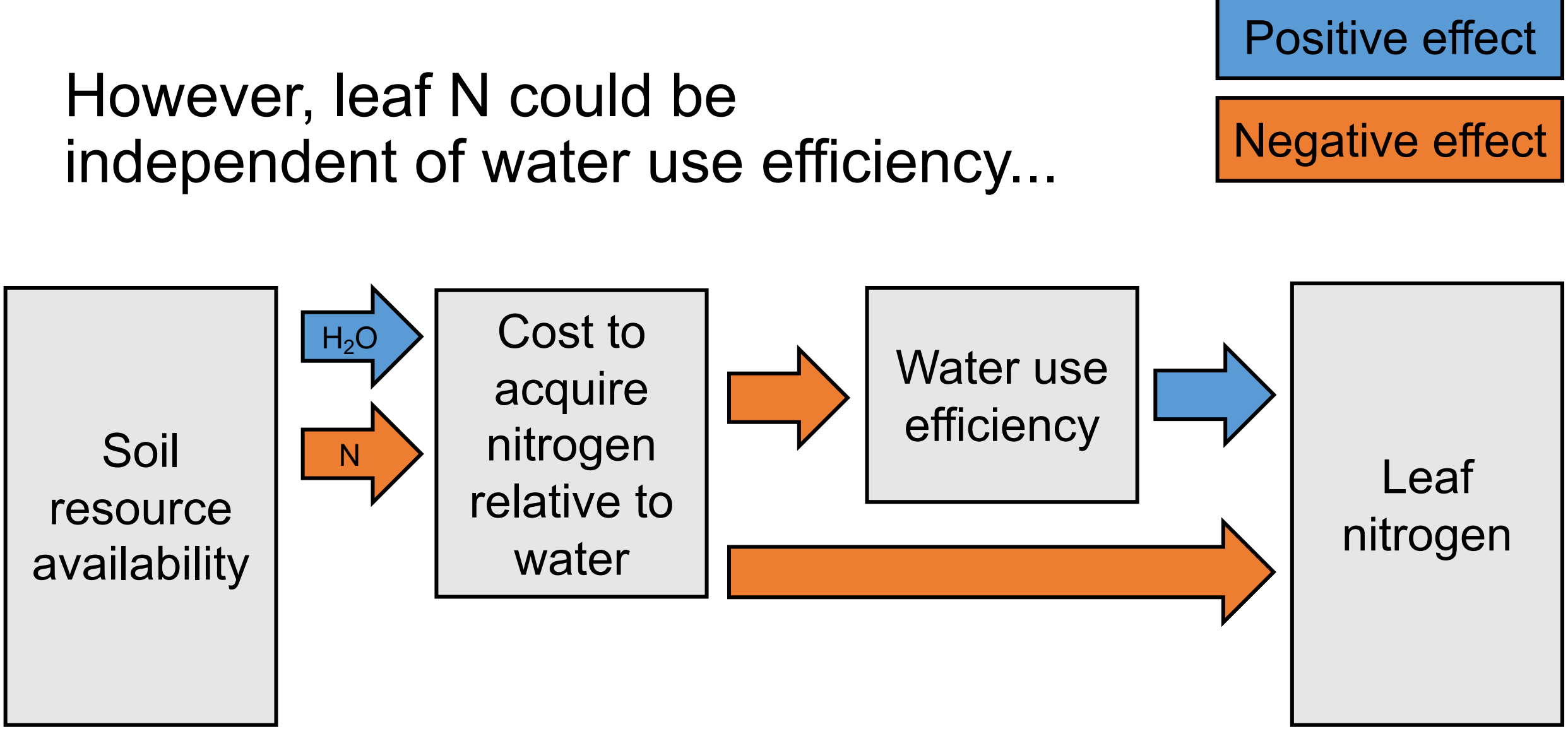
Negative effect



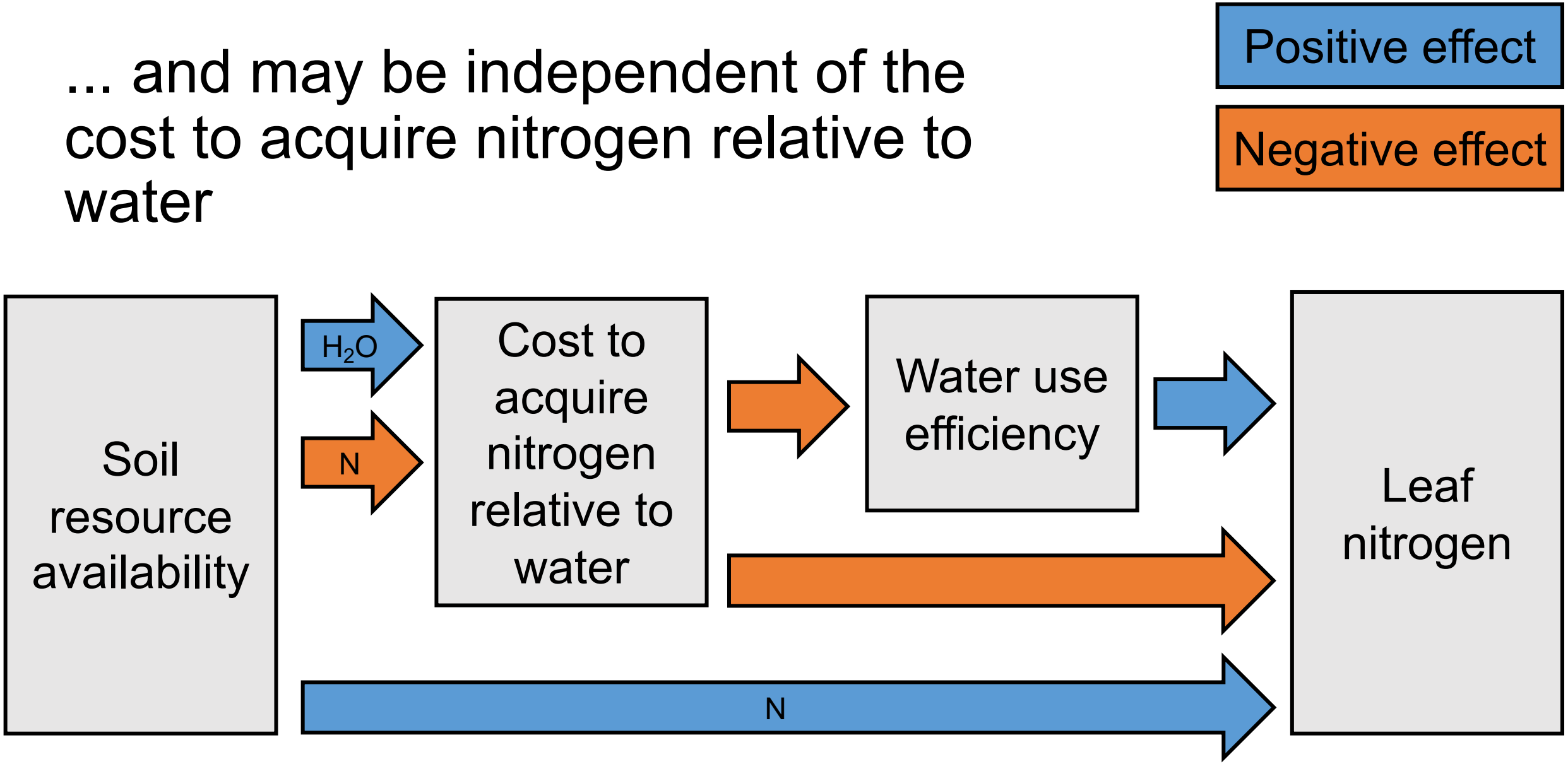
Increasing water use efficiency should **increase** leaf N



However, leaf N could be independent of water use efficiency...



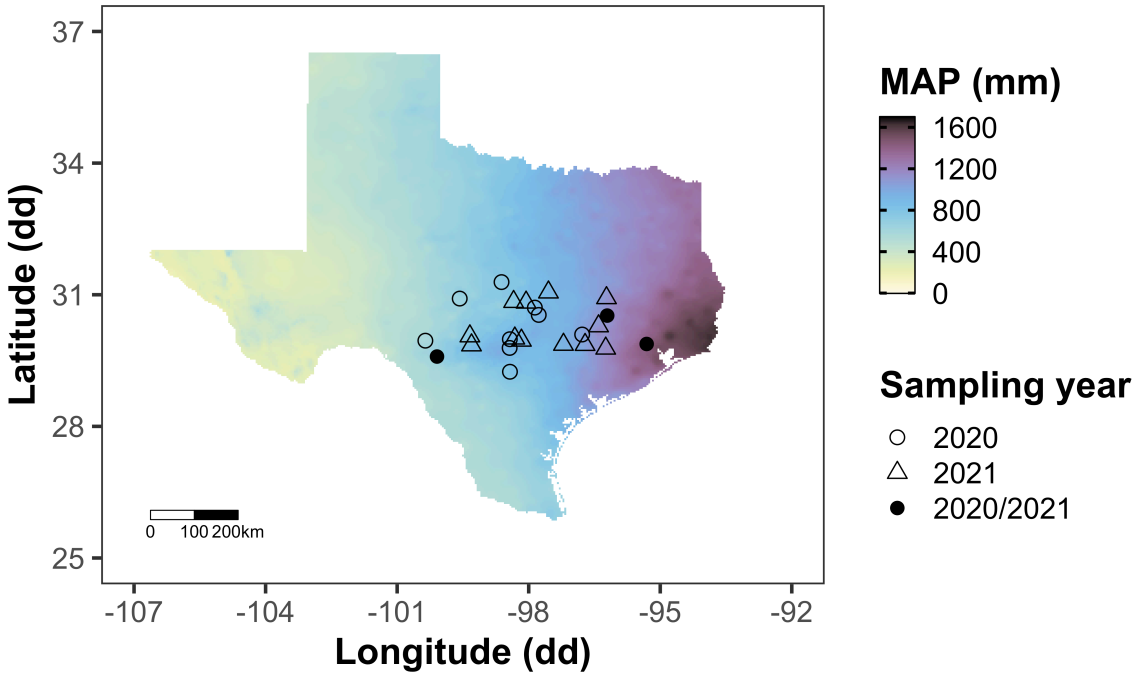
... and may be independent of the cost to acquire nitrogen relative to water

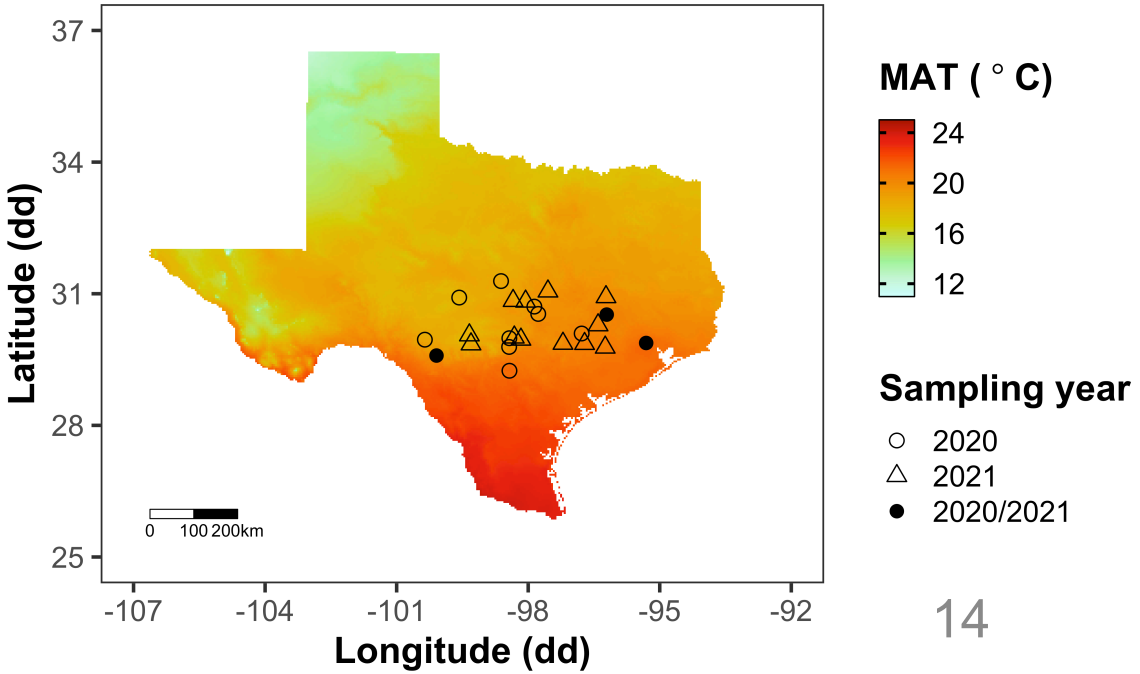


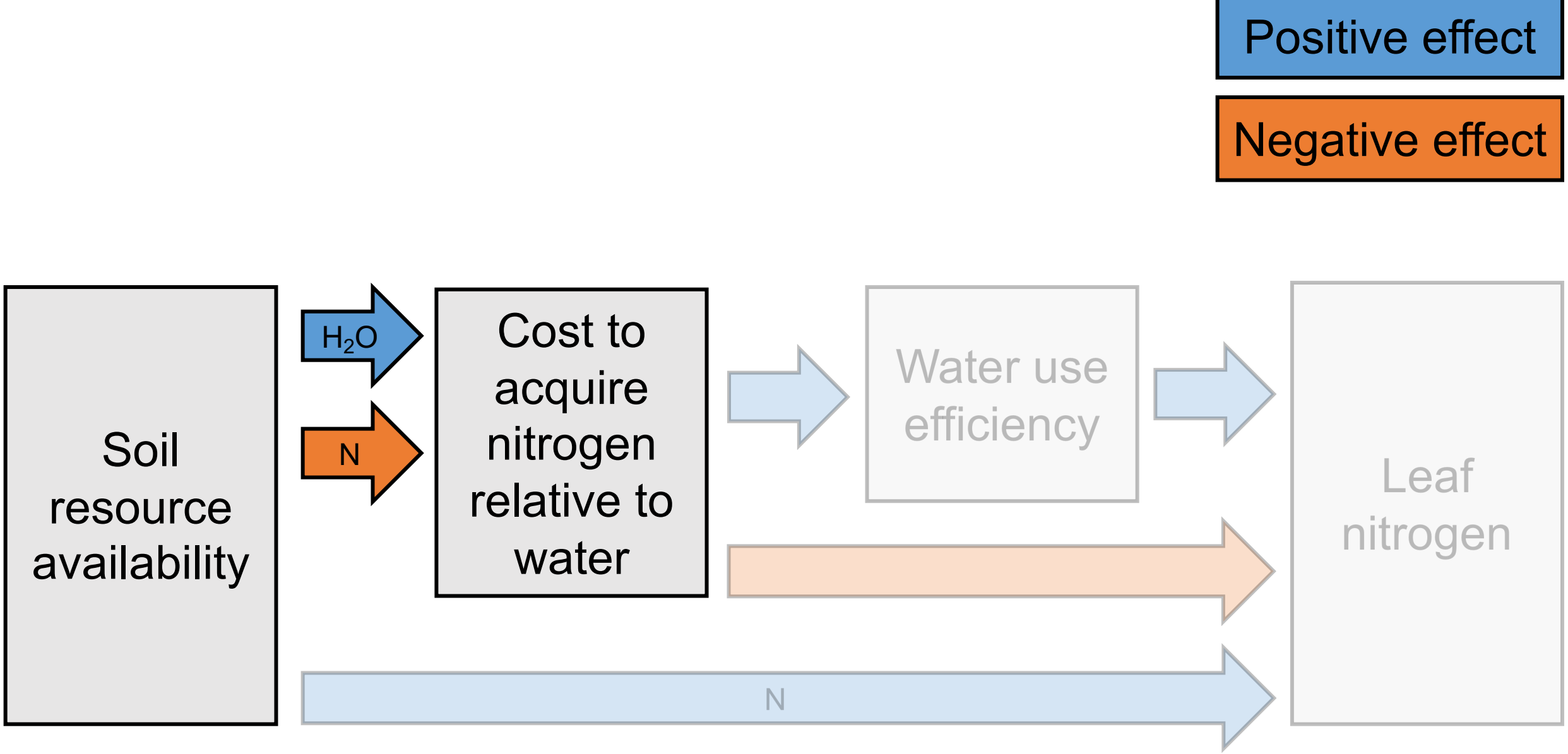
We currently lack empirical studies that directly test patterns expected from photosynthetic least-cost theory

Study sites, collection methods, traits

- 24 sites
  - 12 in 2020
  - 15 in 2021 (3 same from 2020)
- 3 leaves of 5 most dominant species at each site
  - Leaf N
  - Leaf water use efficiency ($\delta^{13}C$)
- Composite soil sample
  - [NO_3-N]

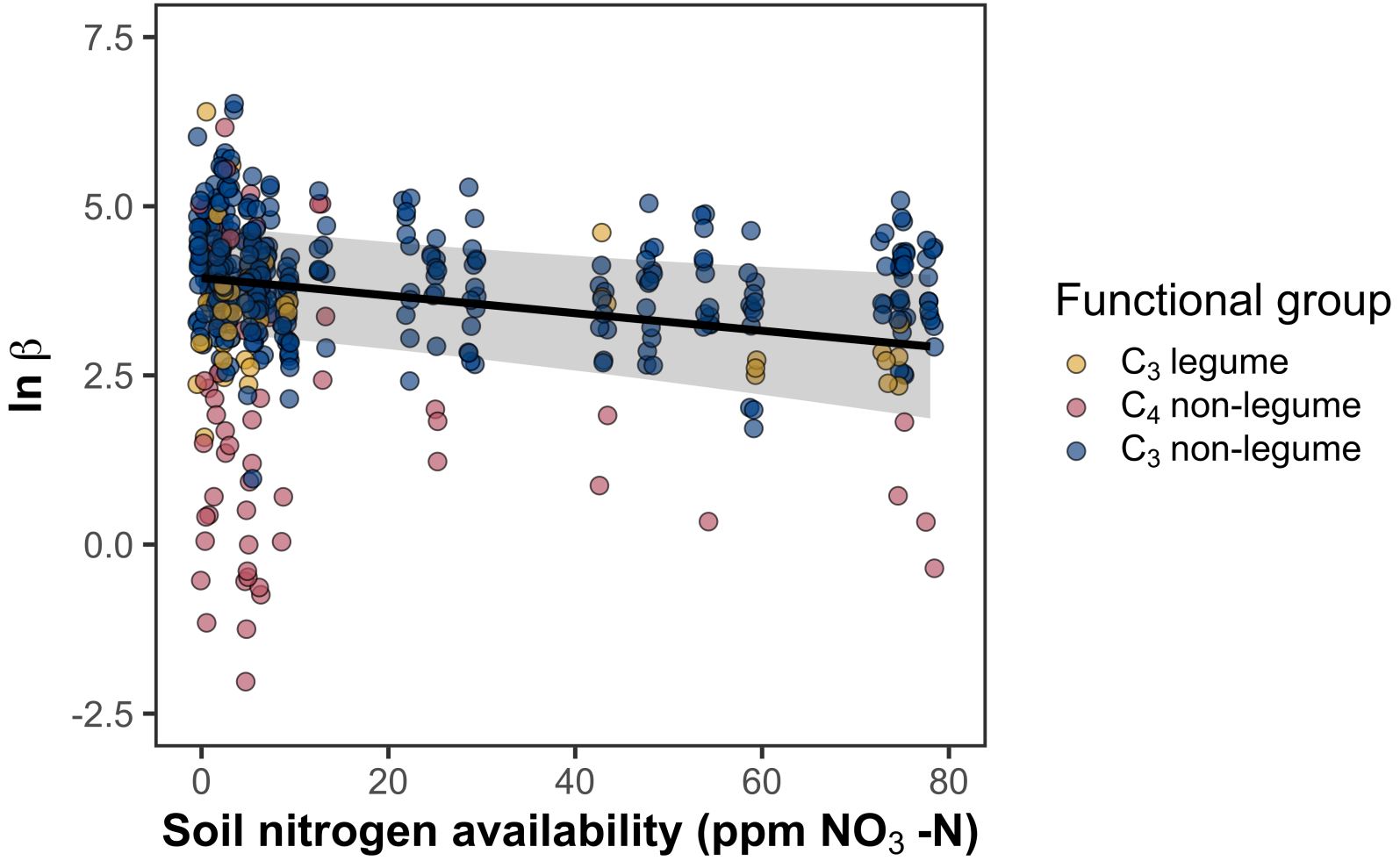





Positive effect
Negative effect
Soil resource availability
H_2O
N
Cost to acquire nitrogen relative to water
Water use efficiency
Leaf nitrogen
N

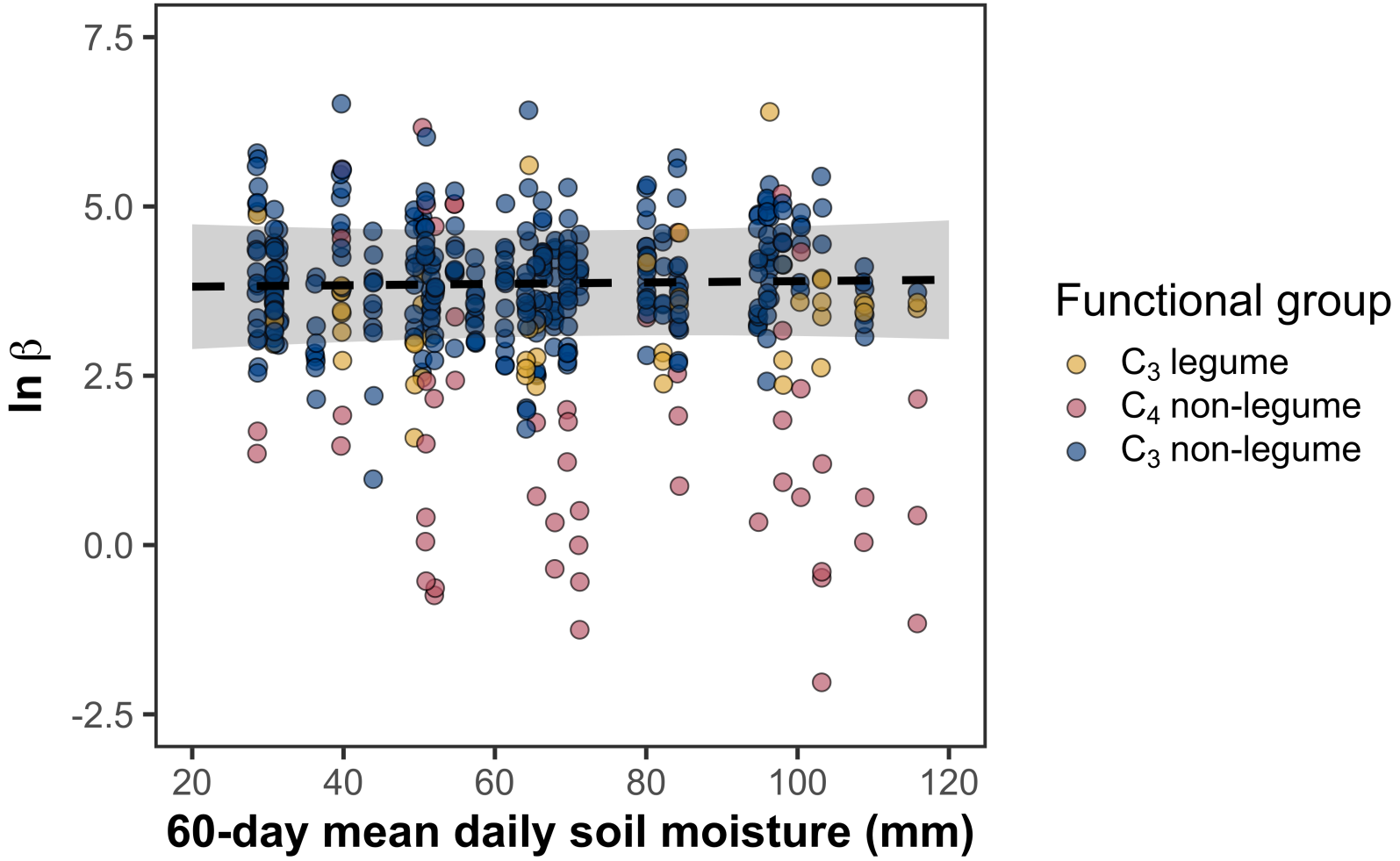
Soil nitrogen availability **decreases** the cost of acquiring nitrogen relative to water

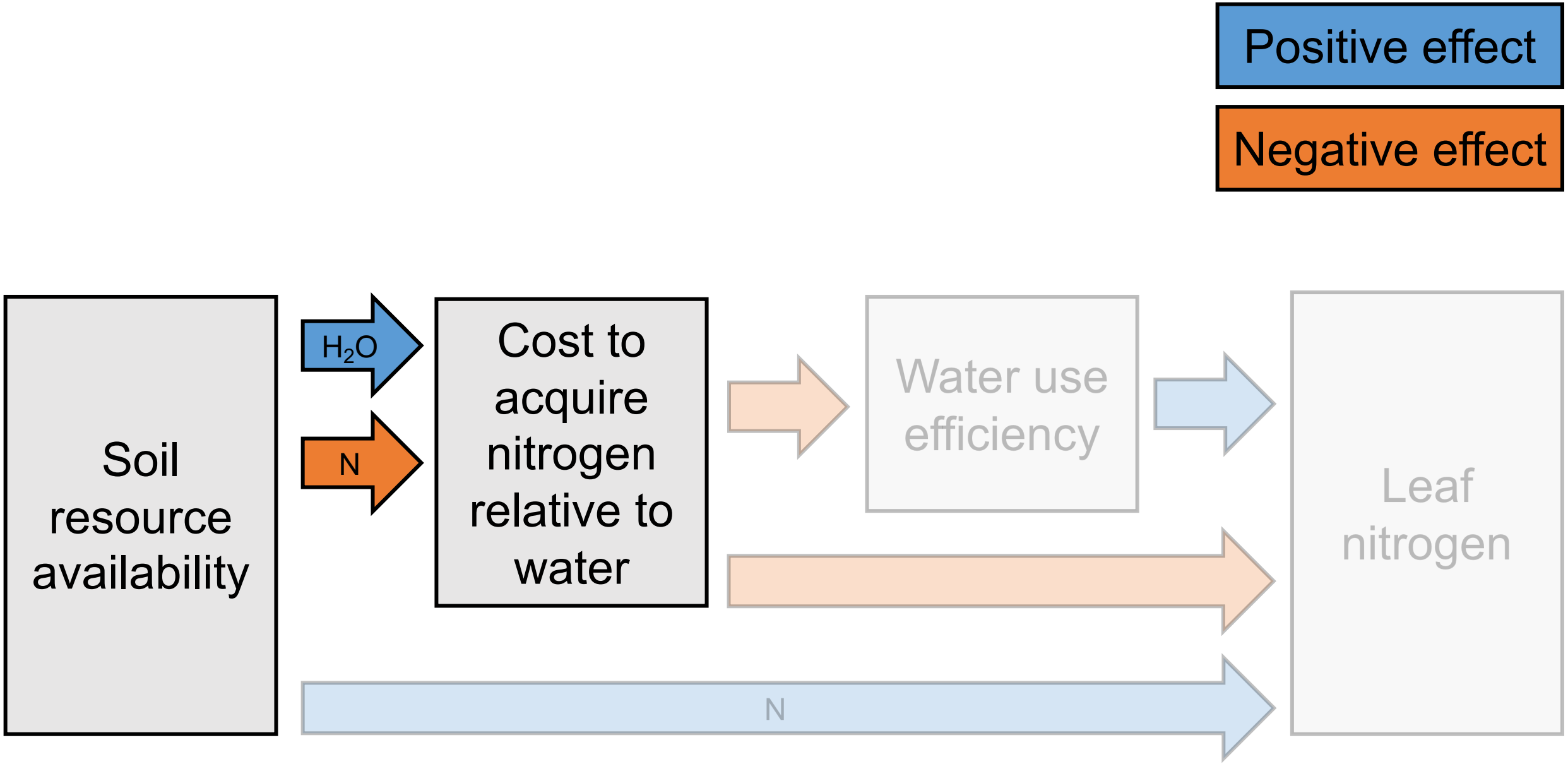
Cost of acquiring nitrogen relative to water

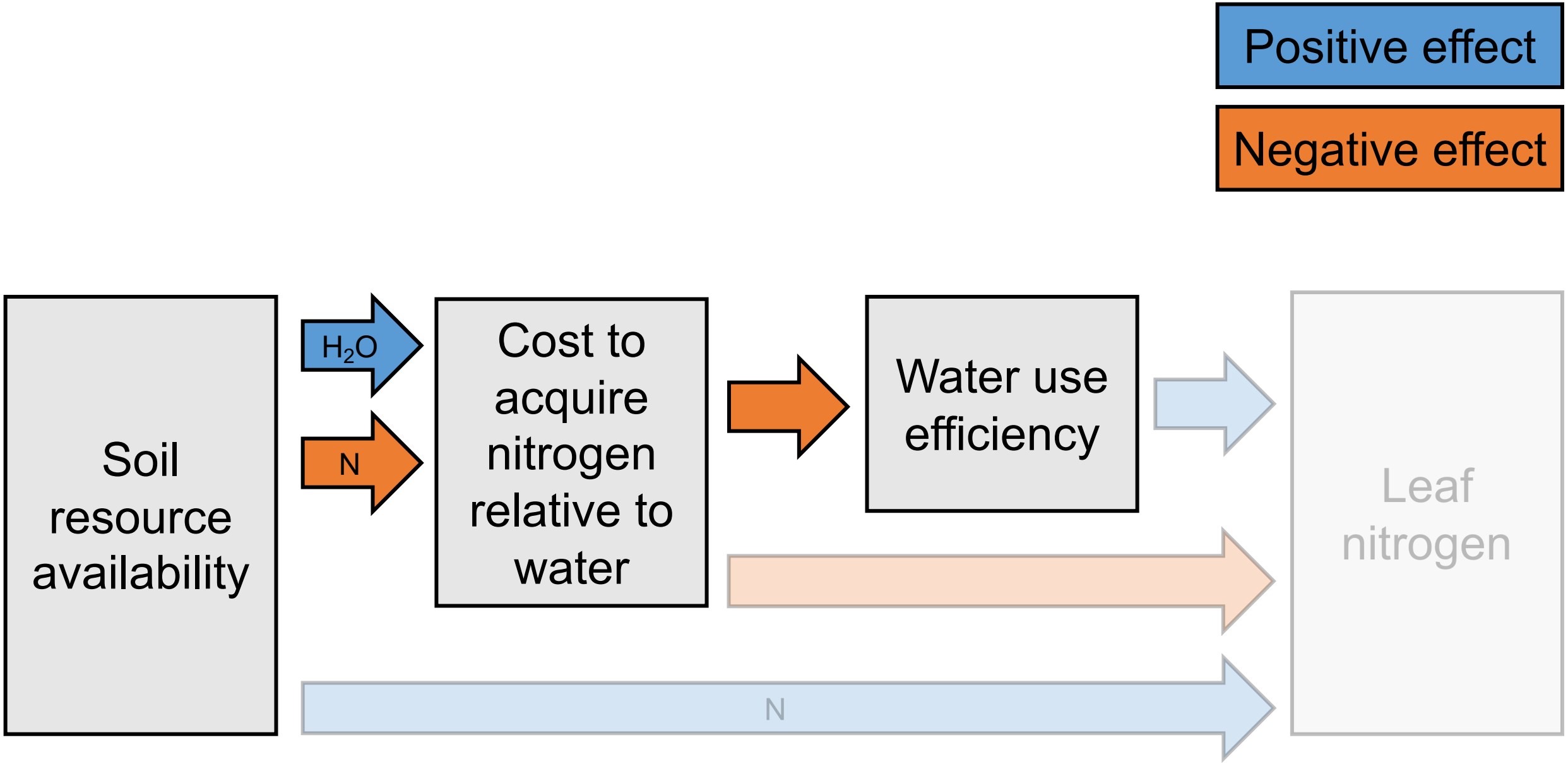


Soil moisture **does not change** the cost of acquiring nitrogen relative to water

Cost of acquiring nitrogen relative to water

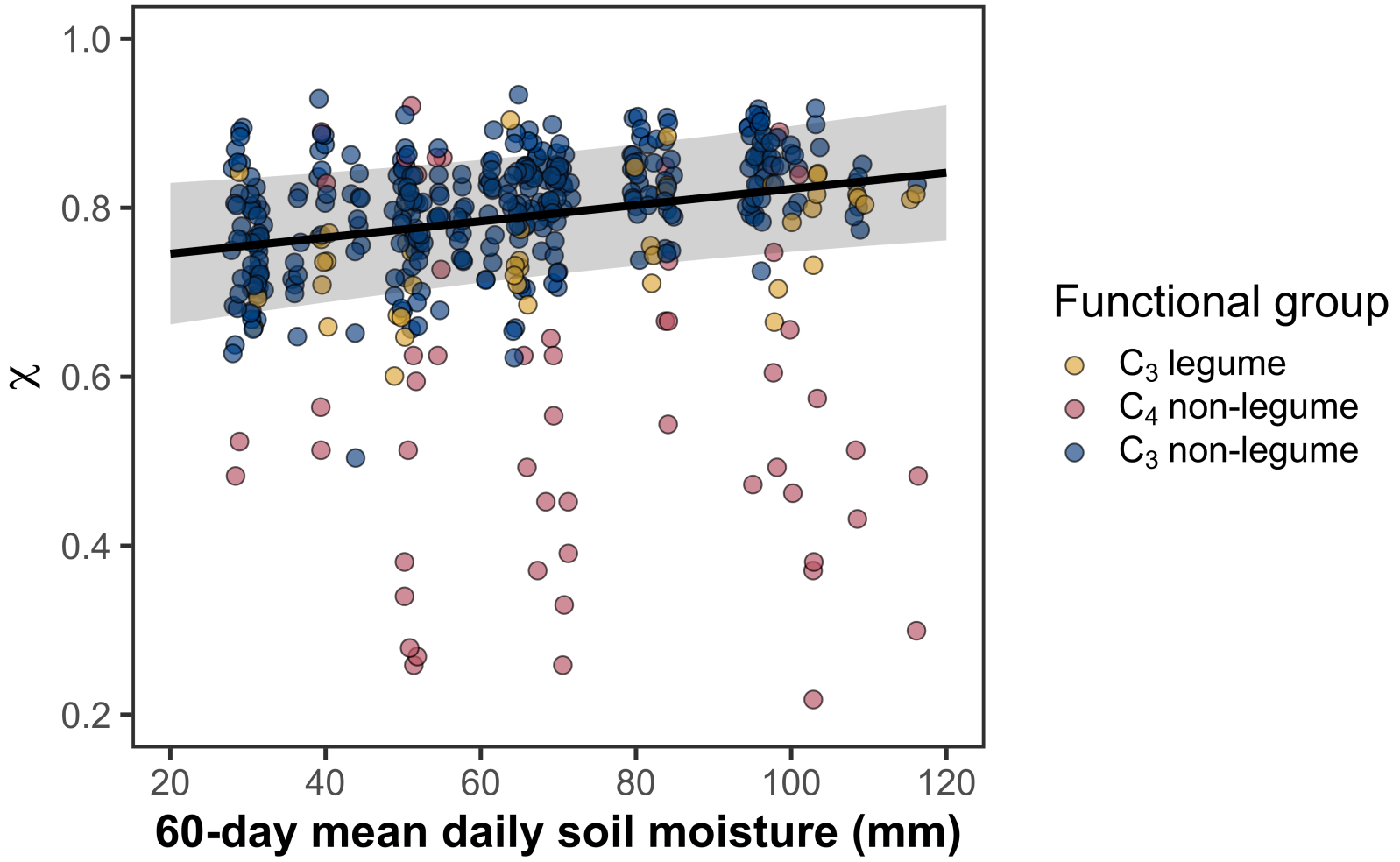



Positive effect
Negative effect
Soil resource availability
H_2O
N
Cost to acquire nitrogen relative to water
Water use efficiency
Leaf nitrogen
N


Positive effect
Negative effect
Soil resource availability
H_2O
N
Cost to acquire nitrogen relative to water
Water use efficiency
Leaf nitrogen
N

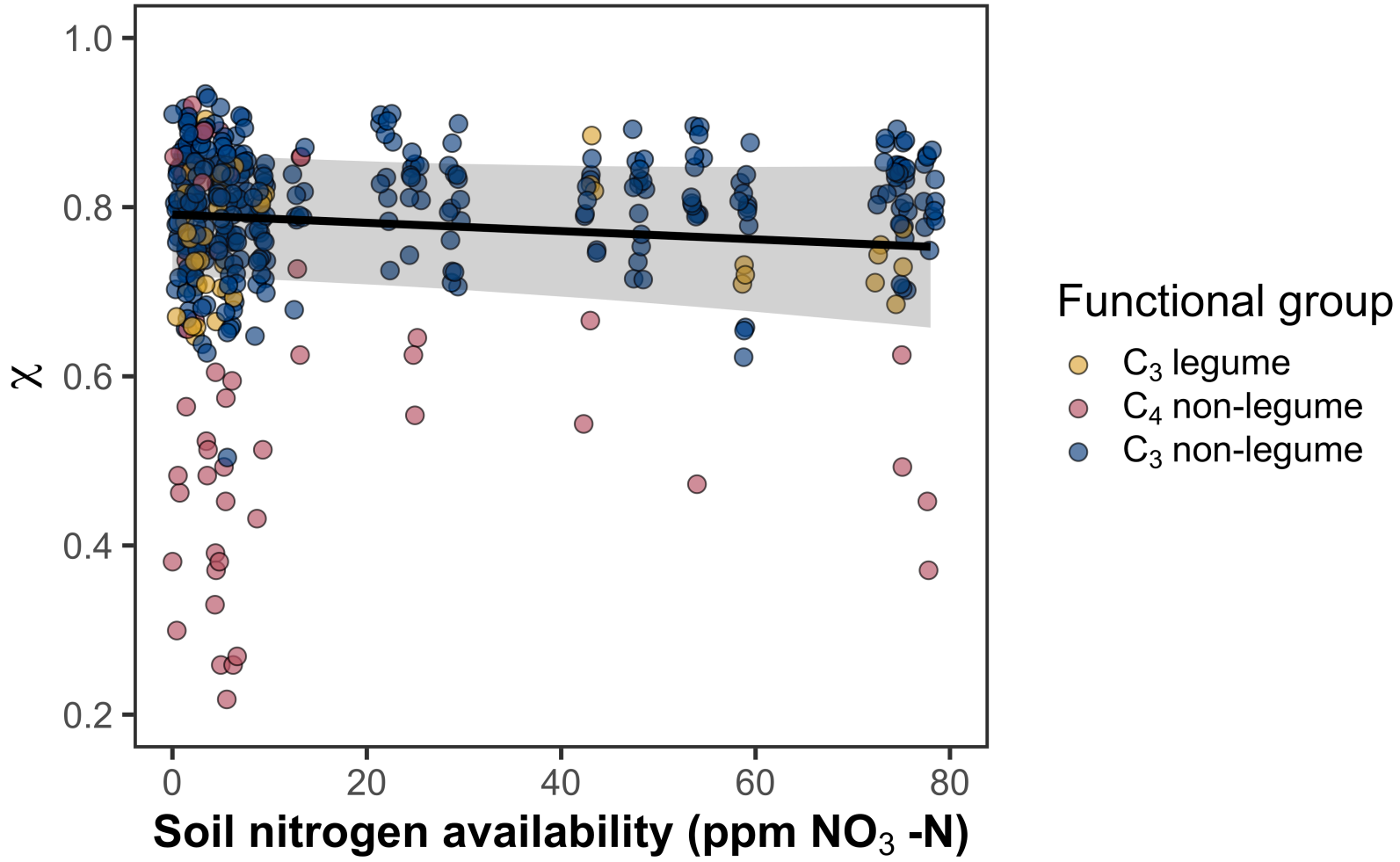
Soil moisture **decreases** water use efficiency

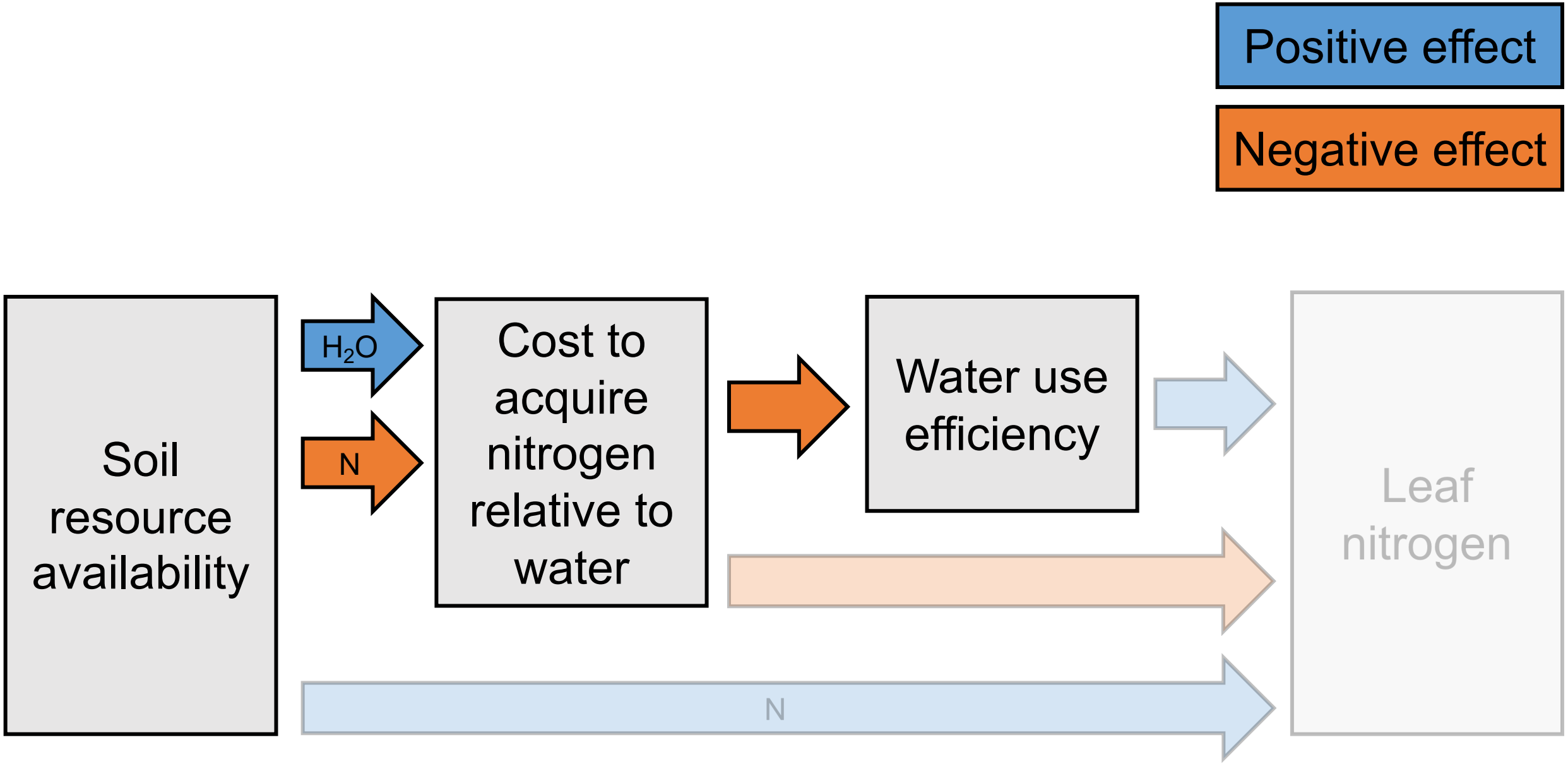
Increasing WUE



Soil nitrogen availability **increases** water use efficiency

Increasing WUE




Positive effect
Negative effect
Soil resource availability
H_2O
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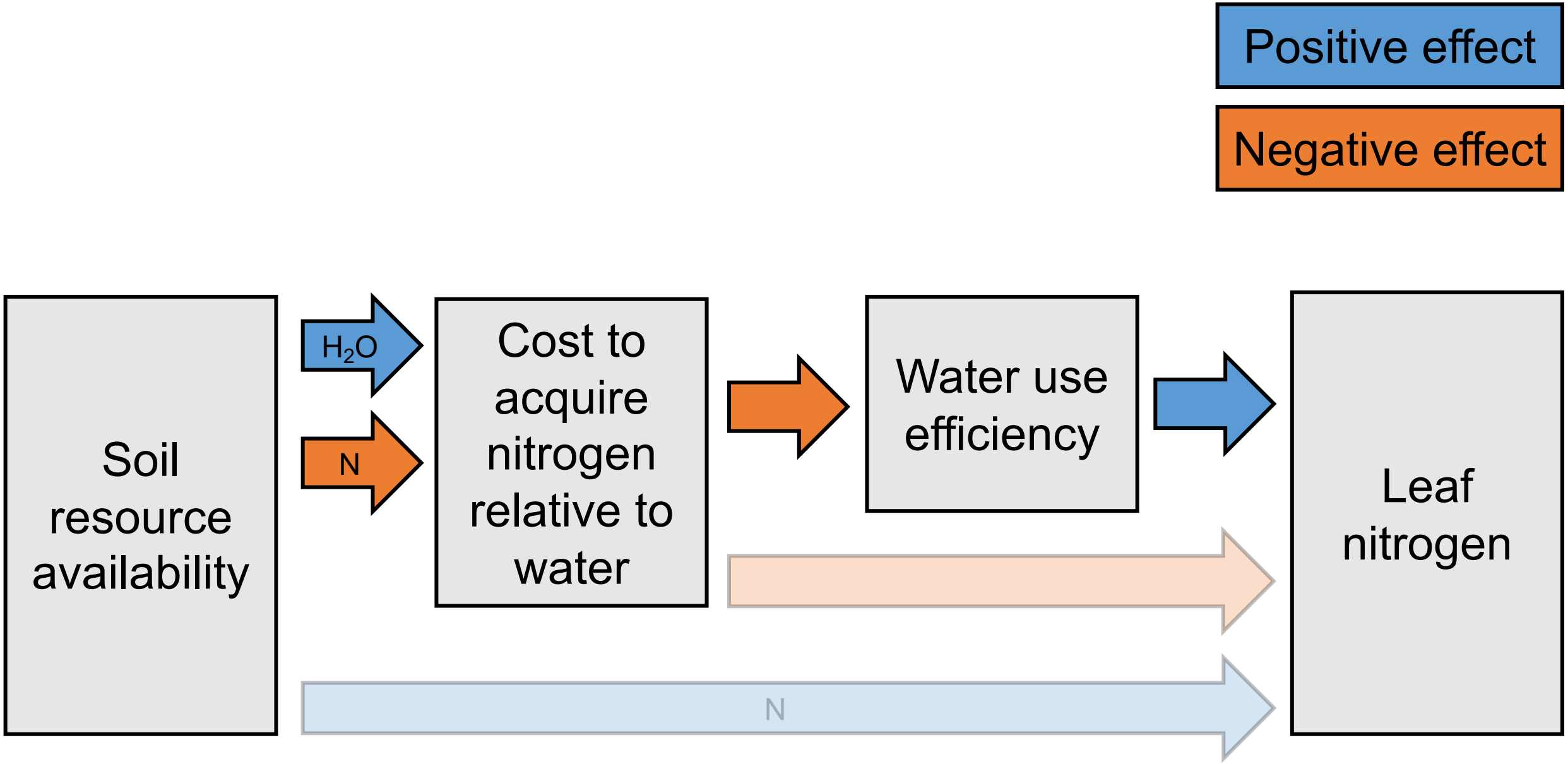
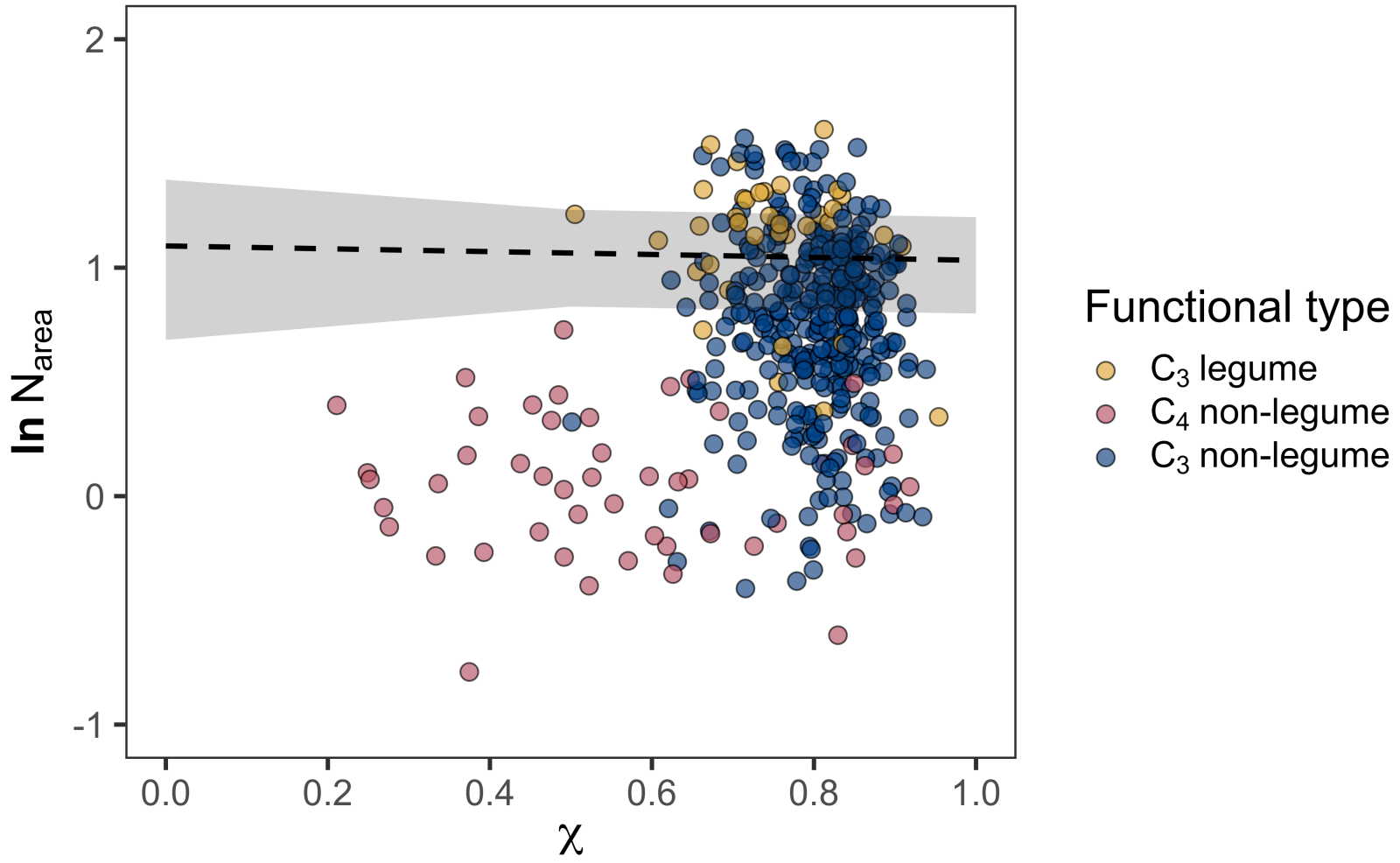
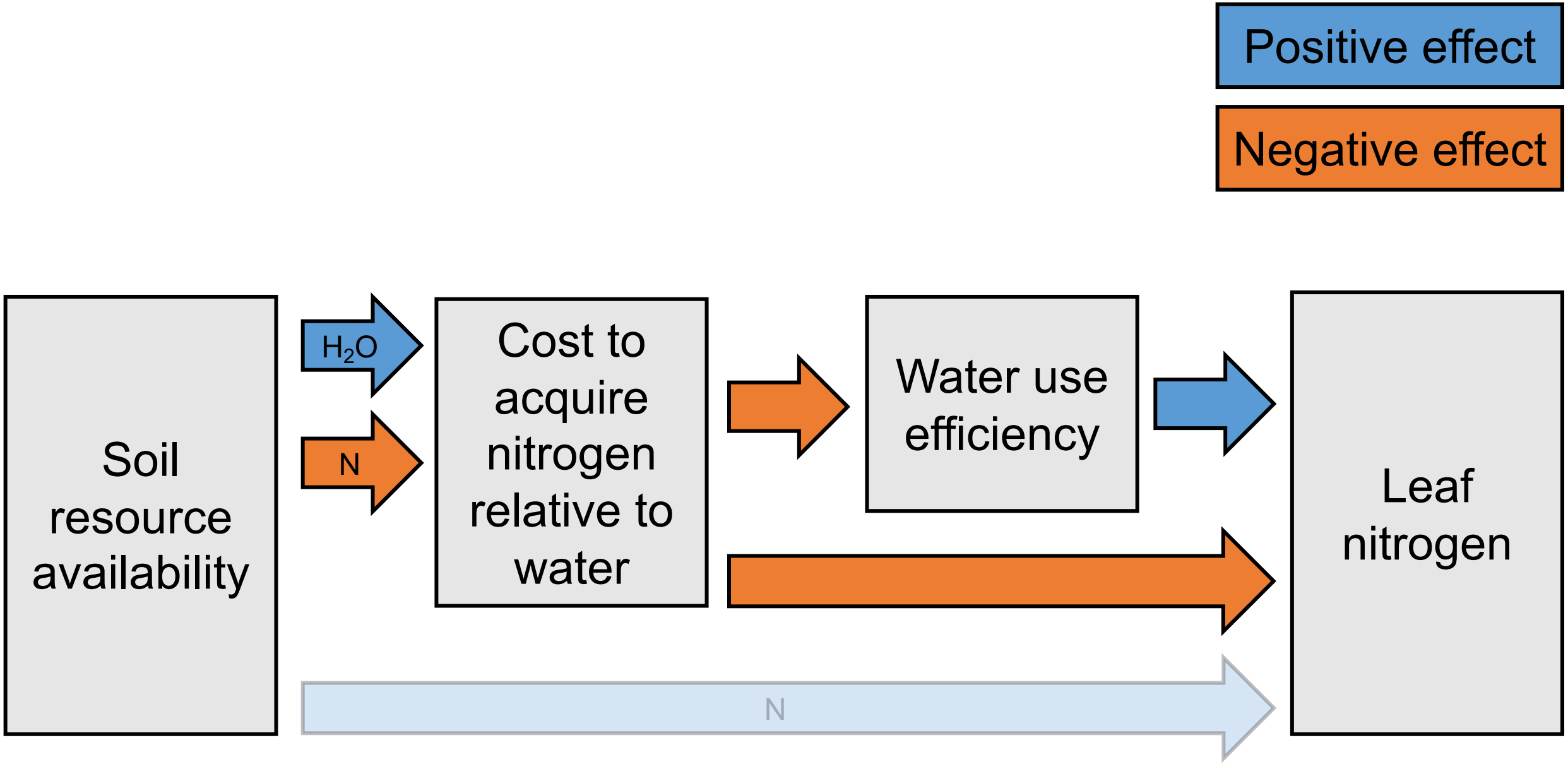
Cost to acquire nitrogen relative to water
Water use efficiency
Leaf nitrogen
N

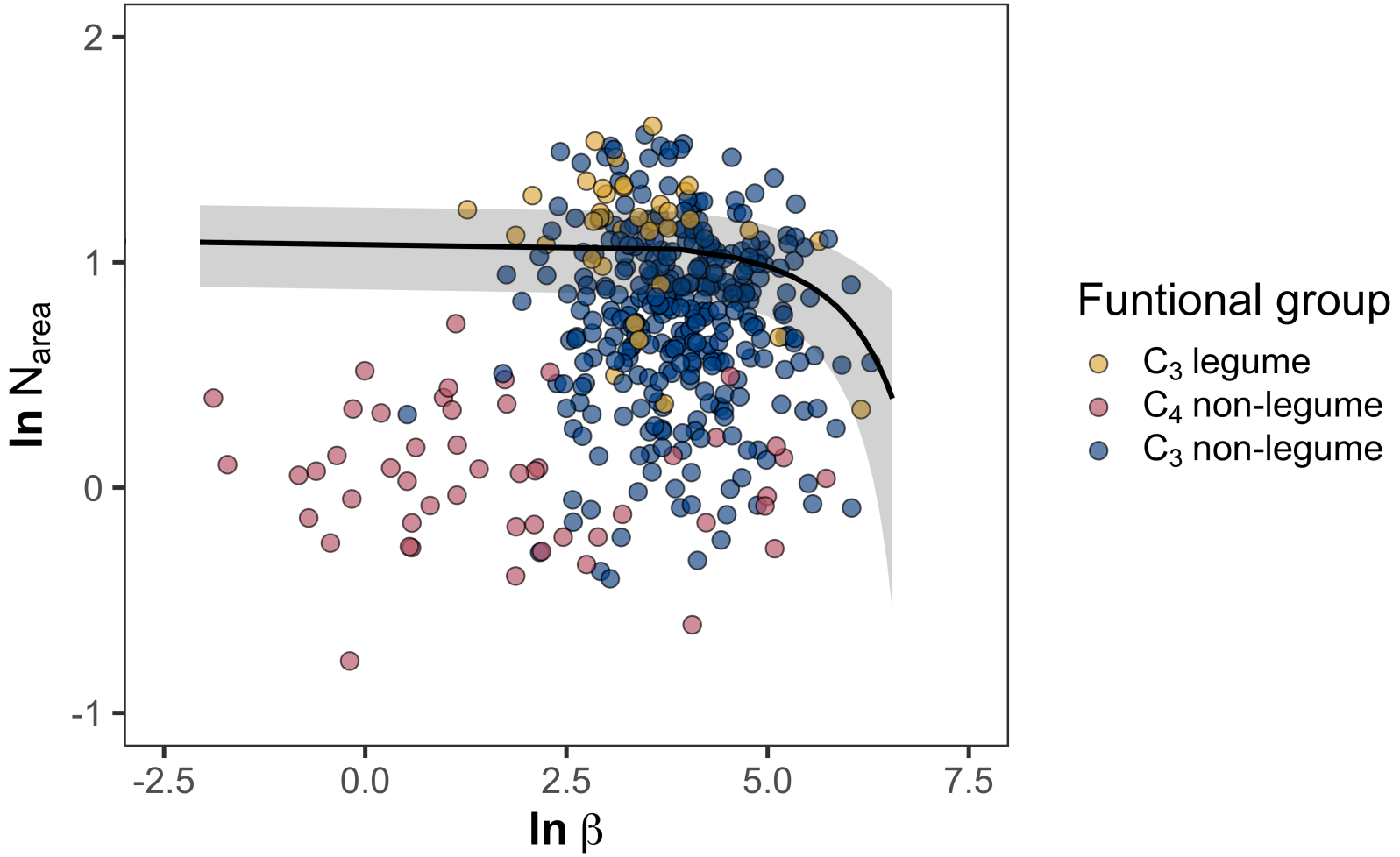

Positive effect
Negative effect
Soil resource availability
H_2O
N
Cost to acquire nitrogen relative to water
Water use efficiency
Leaf nitrogen
N

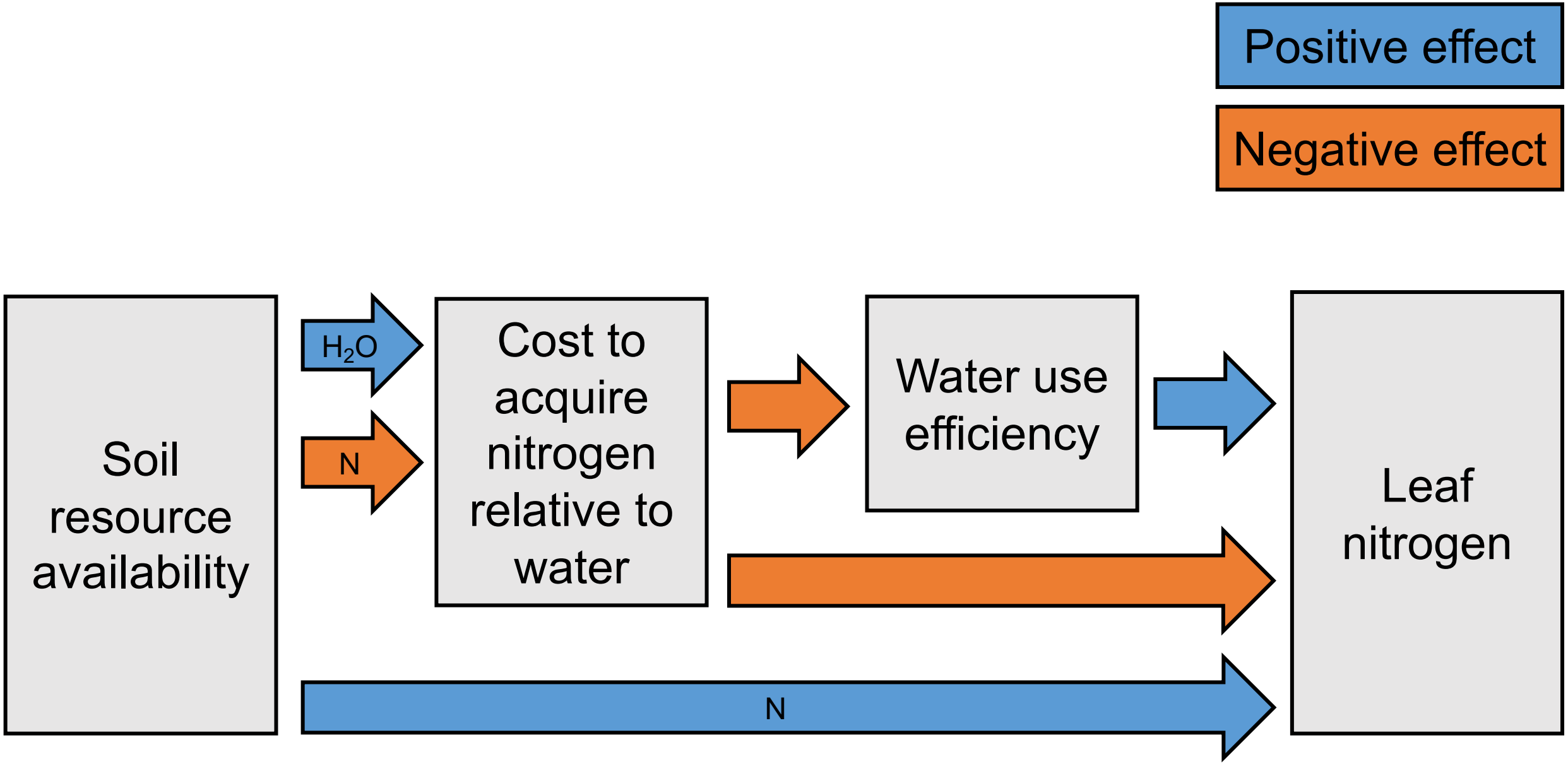
Water use efficiency **does not change** leaf nitrogen



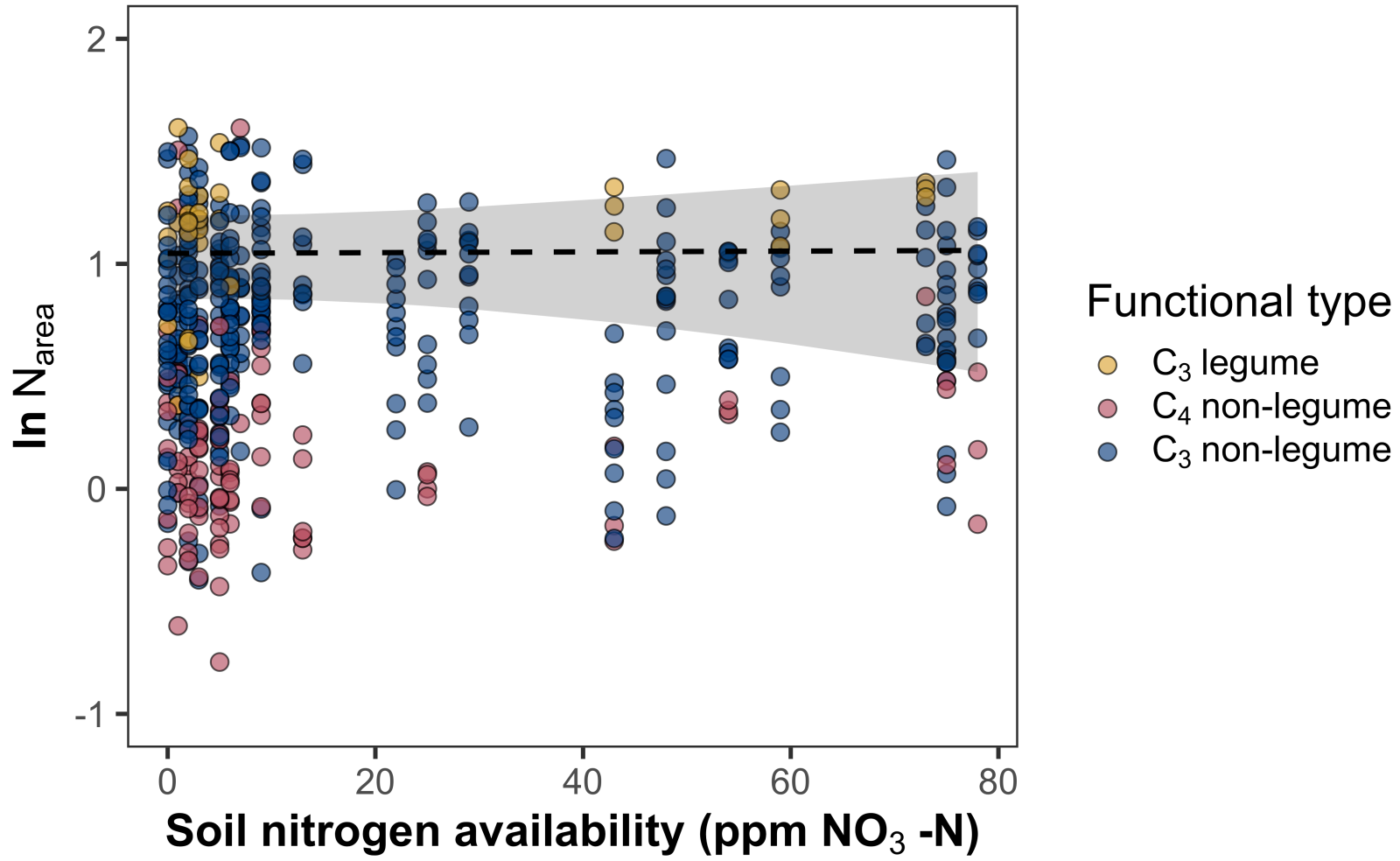

Positive effect
Negative effect
Soil resource availability
H_2O
N
Cost to acquire nitrogen relative to water
Water use efficiency
Leaf nitrogen
N

The cost to acquire nitrogen relative to water has a negative nonlinear effect on leaf nitrogen

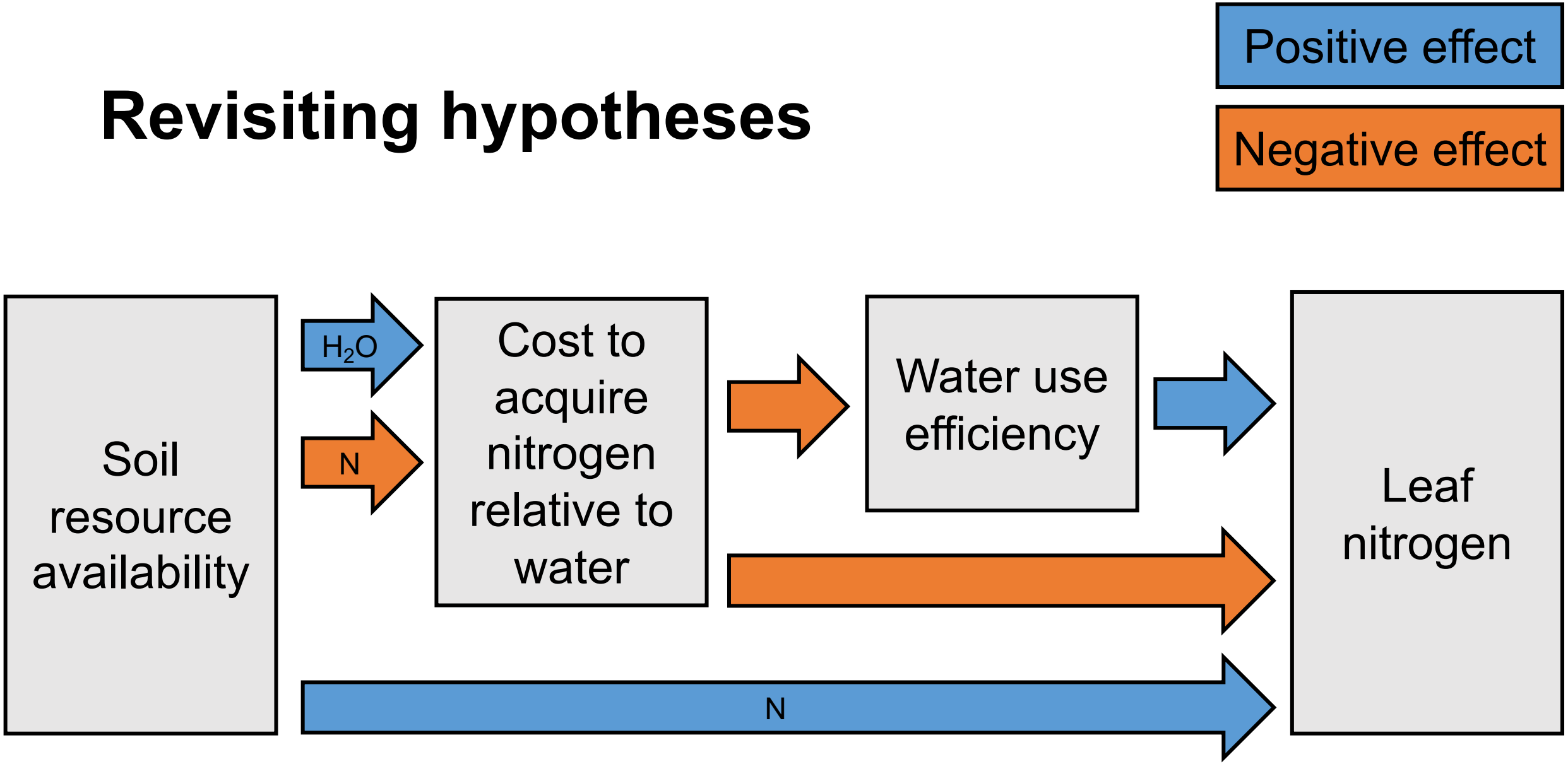



Positive effect
Negative effect
Soil resource availability
H_2O
N
Cost to acquire nitrogen relative to water
Water use efficiency
Leaf nitrogen
N

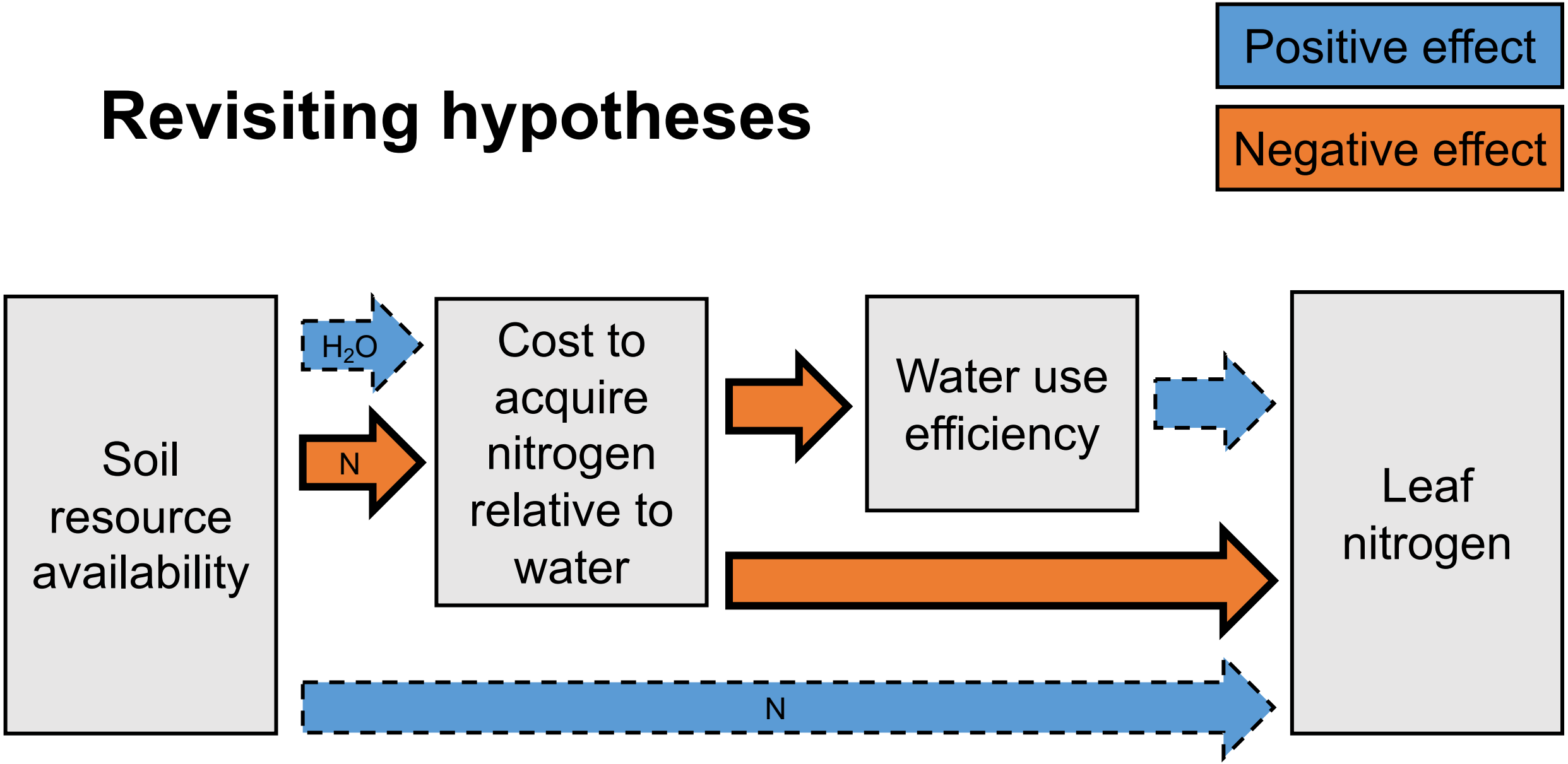
Soil nitrogen availability **does not change** leaf nitrogen



Revisiting hypotheses



Revisiting hypotheses



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- Hannah German
- Avery Schoenherr

Travel funds

- ESA Biogeosciences Section
- ESA Physiological Ecology Section

Follow me on Twitter! @EvanPerkowski

Shoot me an e-mail! Evan.A.Perkowski@ttu.edu

Thank you!

Slides available at:

https://github.com/eaperkowski/esa2022

Extra slides

Resource unit cost ratio (β)

cost of acquiring and using N

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

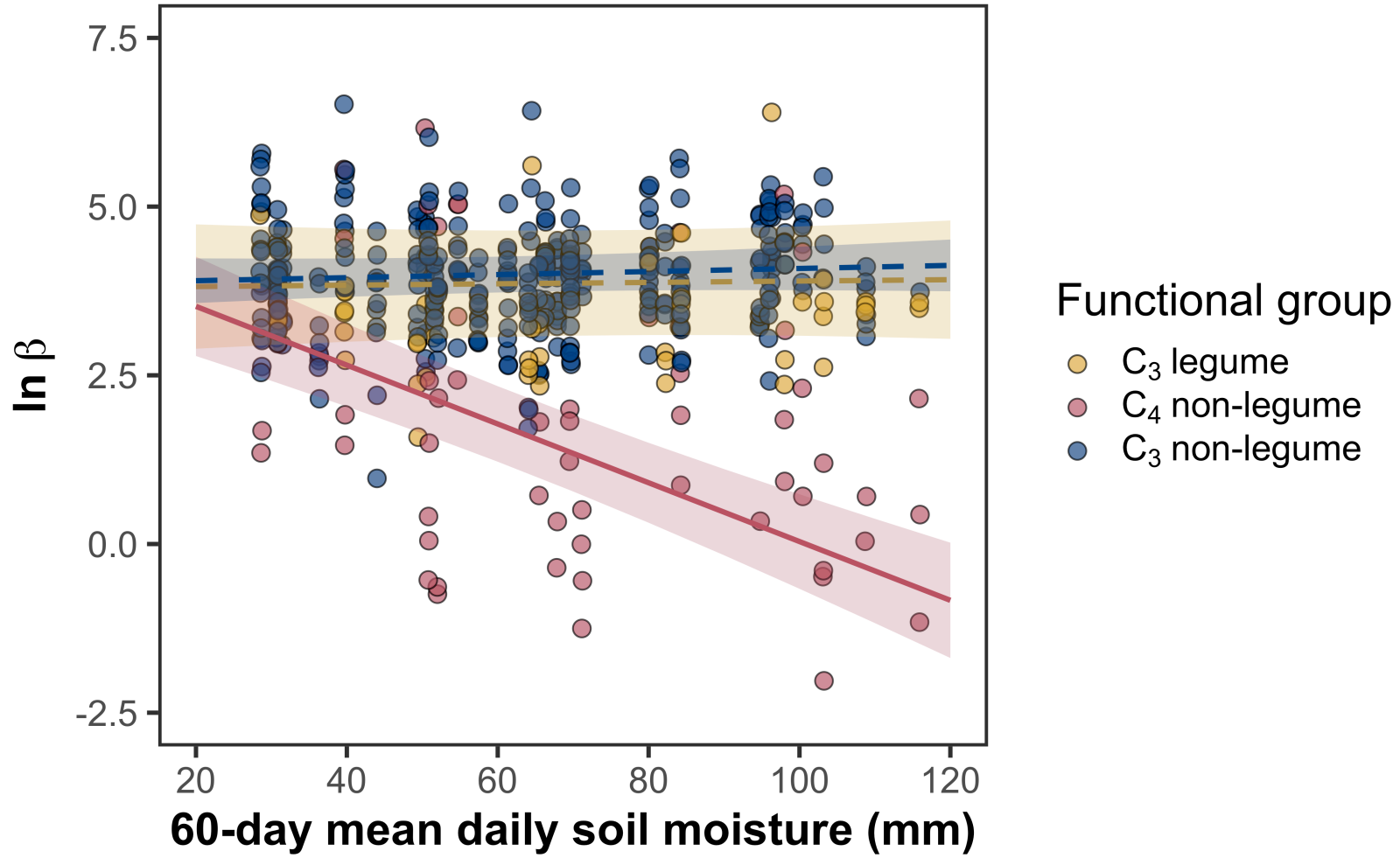
cost of acquiring and using H_2O

Resource unit cost ratio (β)

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

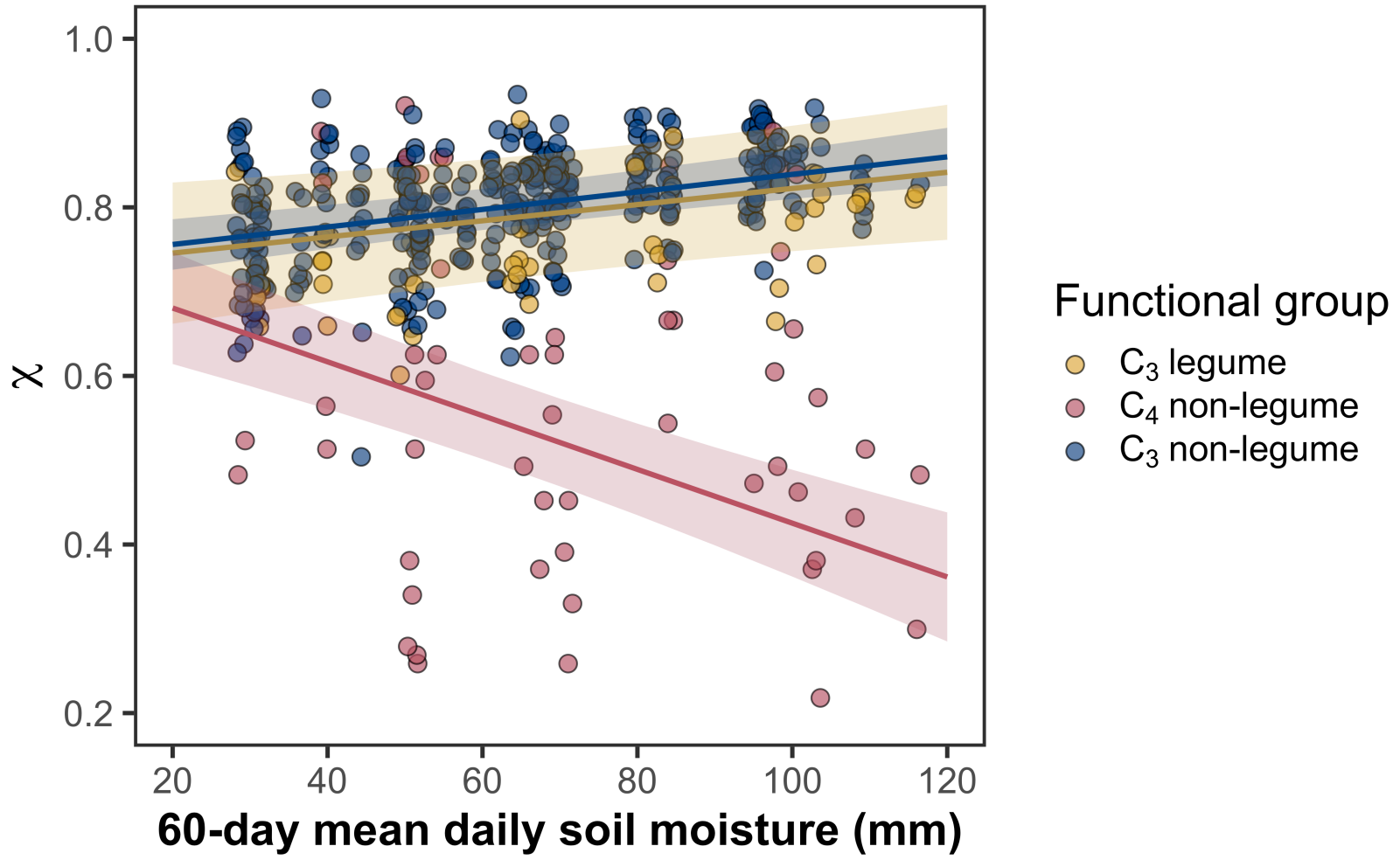
C_4 non-legumes experience a reduction in these relative costs with increasing soil moisture

Cost of acquiring nitrogen relative to water



Soil moisture **decreases** water use efficiency, a pattern observed only in C_3 species

Increasing WUE



Soil nitrogen availability **increases** water use efficiency, but only in non-legumes

Increasing WUE