

Written in stone?

C,N,P interactions in land surface ecosystems

Benjamin Z. Houlton

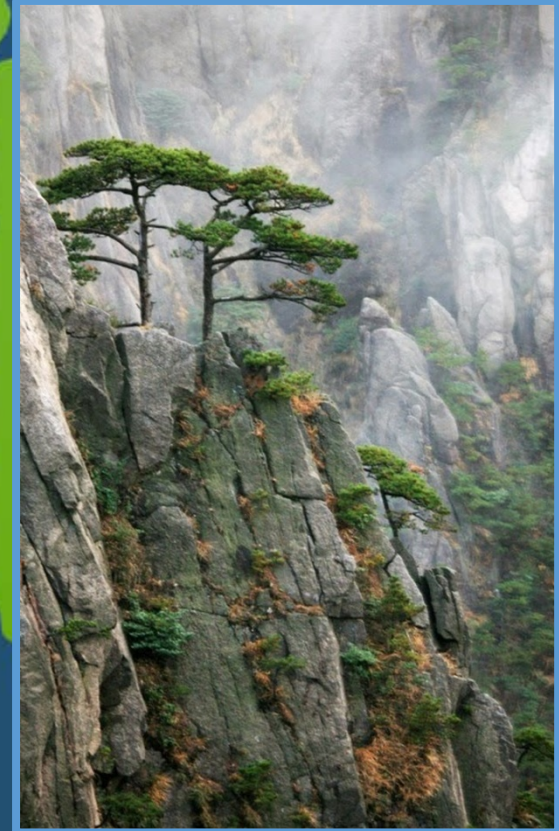
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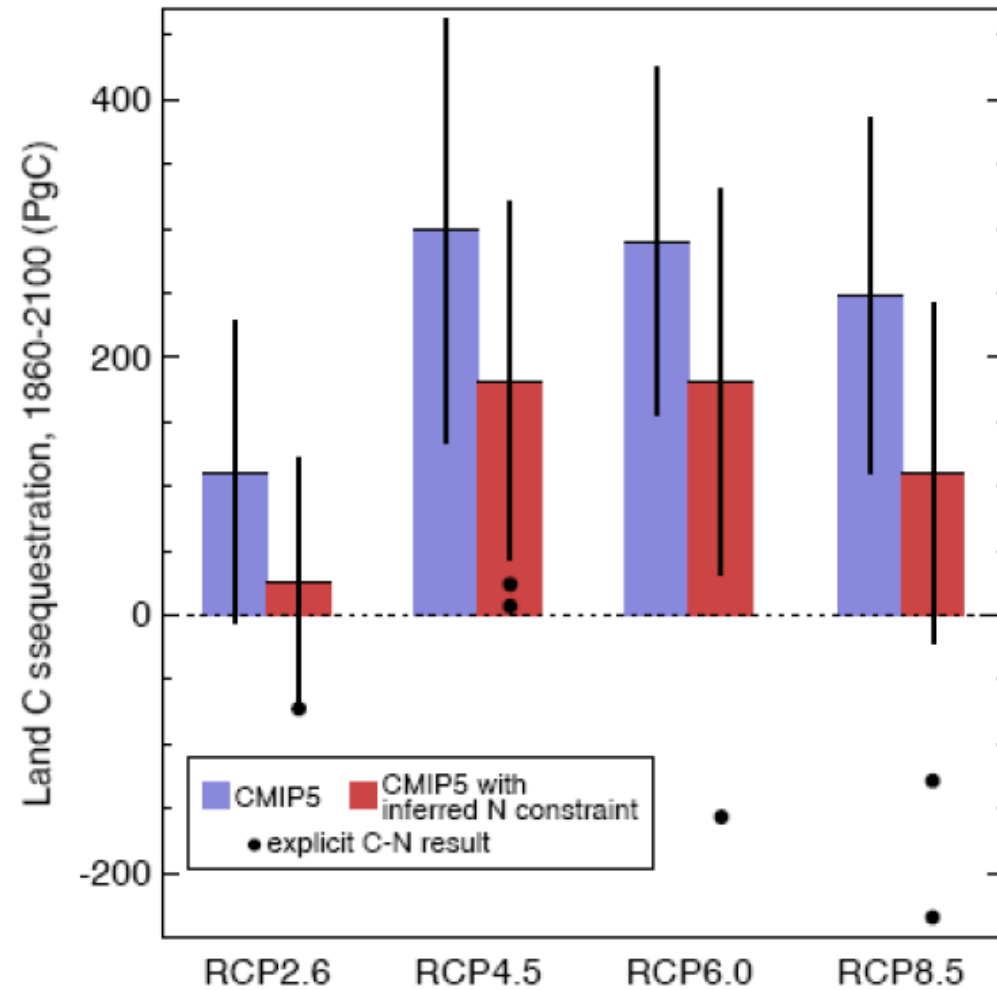
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Why nutrients?



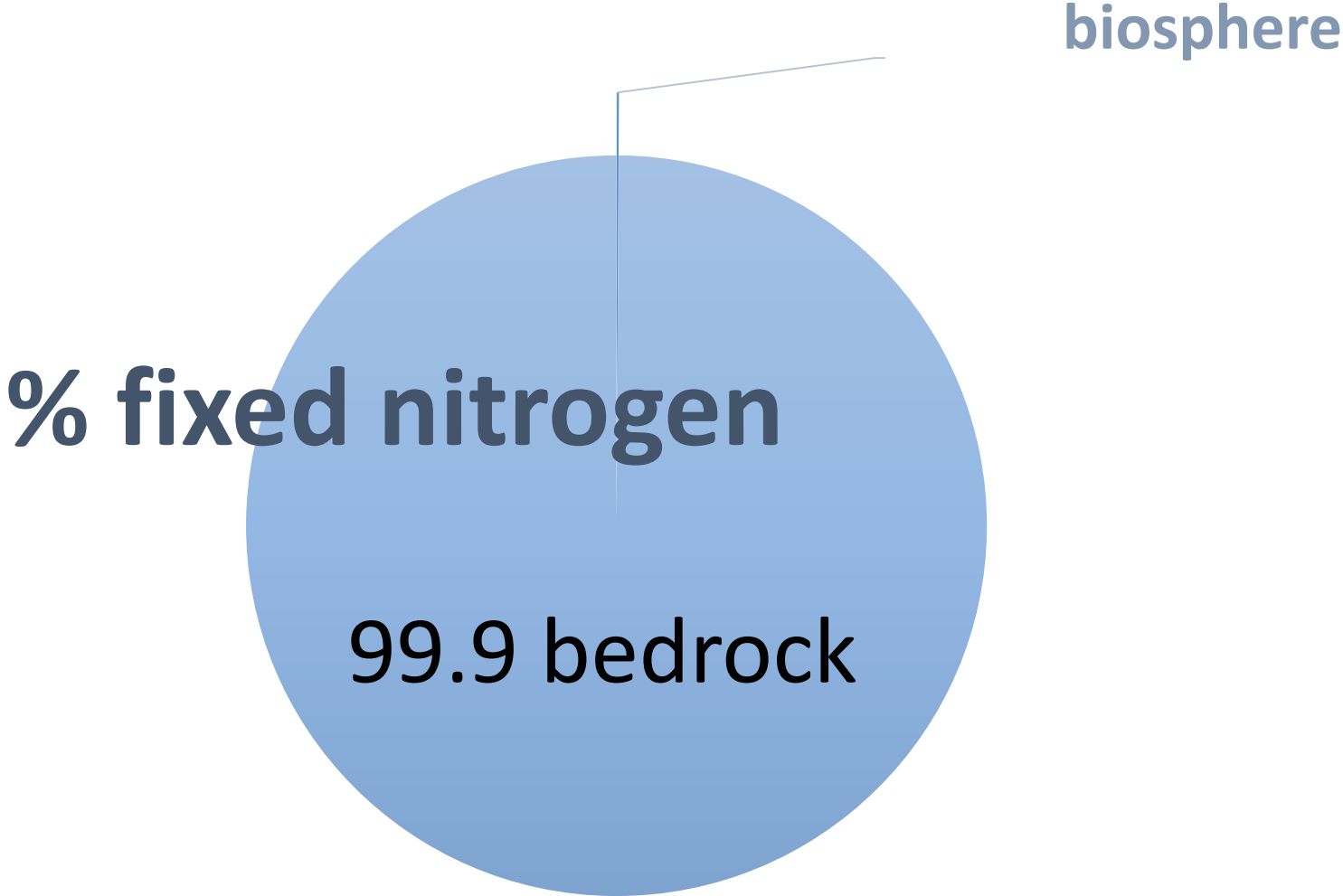
Great progress in coupled nutrient cycles – but many issues remain:

Three concepts (among others) to advance Next Gen ESMs:

1. **Setting the canvas** – linking tectonics, weathering, climate and nutrients to C
2. **Ultimate vs. proximate controls** – “nutrient limitation in disguise” via rock derived elements (include trace metals)
3. **Stoichiometric flexibility and couplings** – mineralization ratios, N and P interactions

Take Home Message: Not all nutrients affect C directly – but can and do affect one another (and C indirectly in some cases)

Concept 1. Setting the canvas



Nitrogen from the deep

Ecosystems acquire nitrogen from the atmosphere, but this source can't account for the large nitrogen capital of some systems. The finding that bedrock can also act as a nitrogen source may help solve the riddle. [SEE LETTER P.78](#)

EDWARD A. G. SCHUUR

“....the high input of nitrogen from bedrock beneath that forest — which is equivalent to atmospheric nitrogen inputs — probably represents an upper estimate for the extent of this phenomenon.”

Model Form: Mass conservation equations parameterized with field data in non-parametric statistical functions (quantile regression and generalized additive models)

Denudation:

$$D_X = Q_D \bullet \rho \bullet [X]_{rock}$$

$$Q_D(\tau | relief) = \beta_0(\tau) + \beta_{relief}(\tau) \exp(relief)$$

**Chemical
Weathering:**

$$W_x = D_x \bullet CDF_X$$

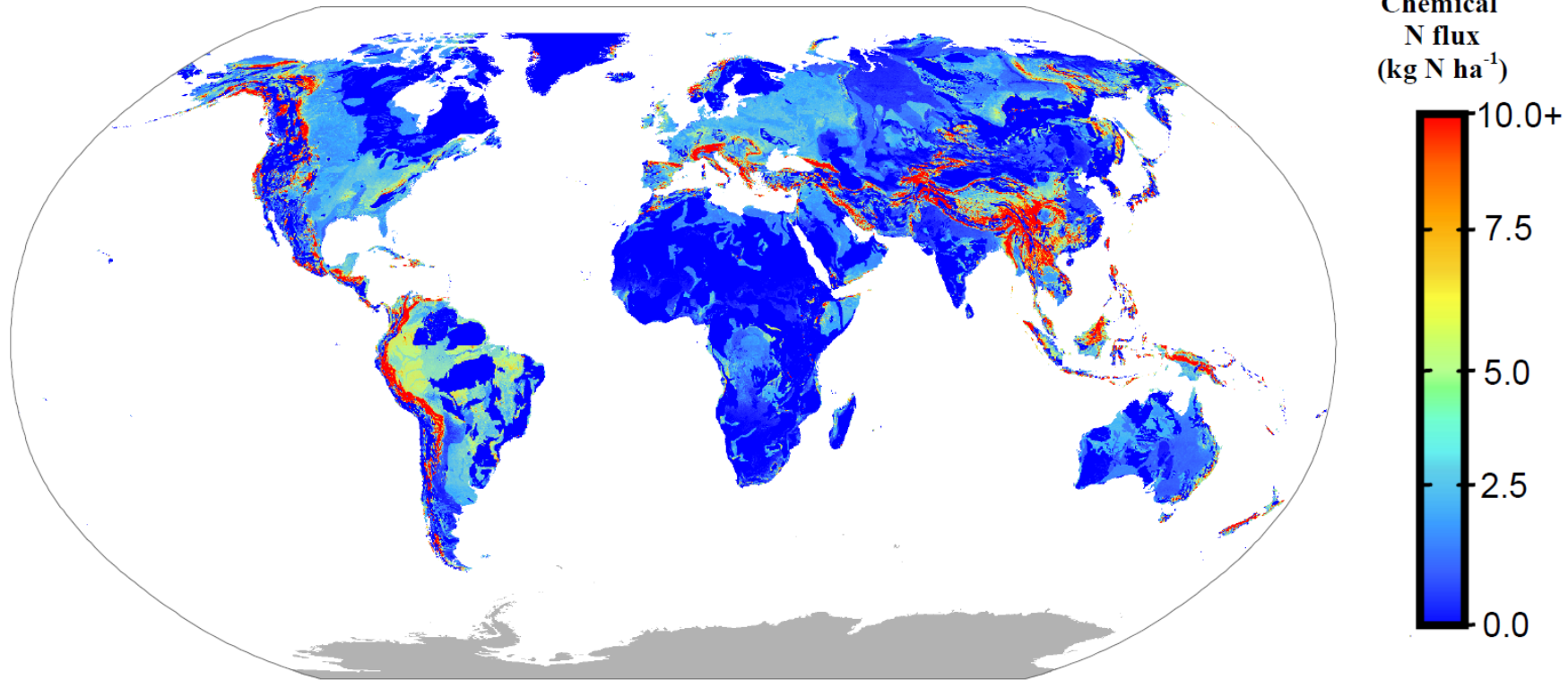
$$CDF_X = 1 - \frac{X_{soil}}{X_{rock}}$$

$$g(E(CDF_{Na})) = \beta_0 + f_1(AET_{MODIS}) + f_2(H_2O_{excess}) + f_3(Relief)$$

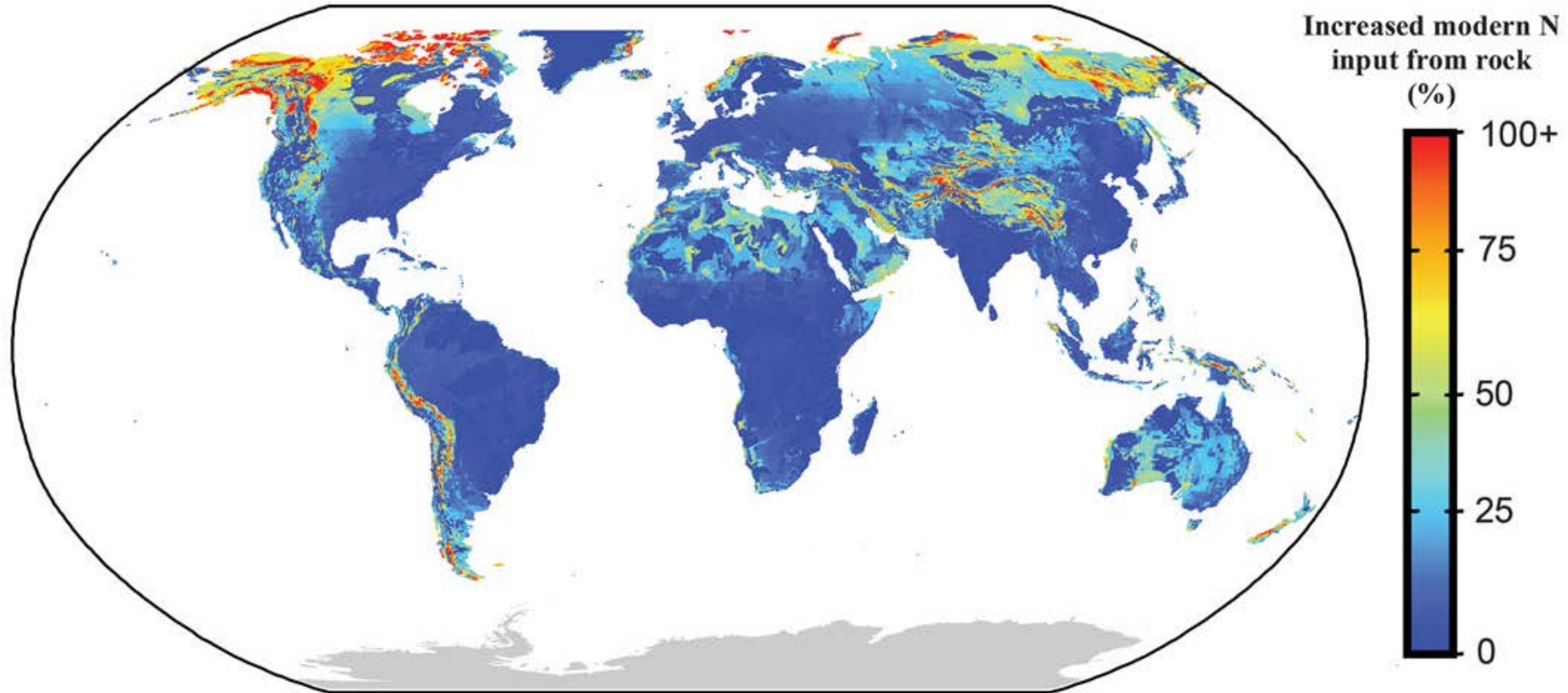
N Denudation: 20 – 31 Tg yr⁻¹

N Weathering: 11 – 18 Tg yr⁻¹

(~60% of the N denudation flux is chemically weathered)



Rock N inputs increase natural N inputs 8 to 26 %



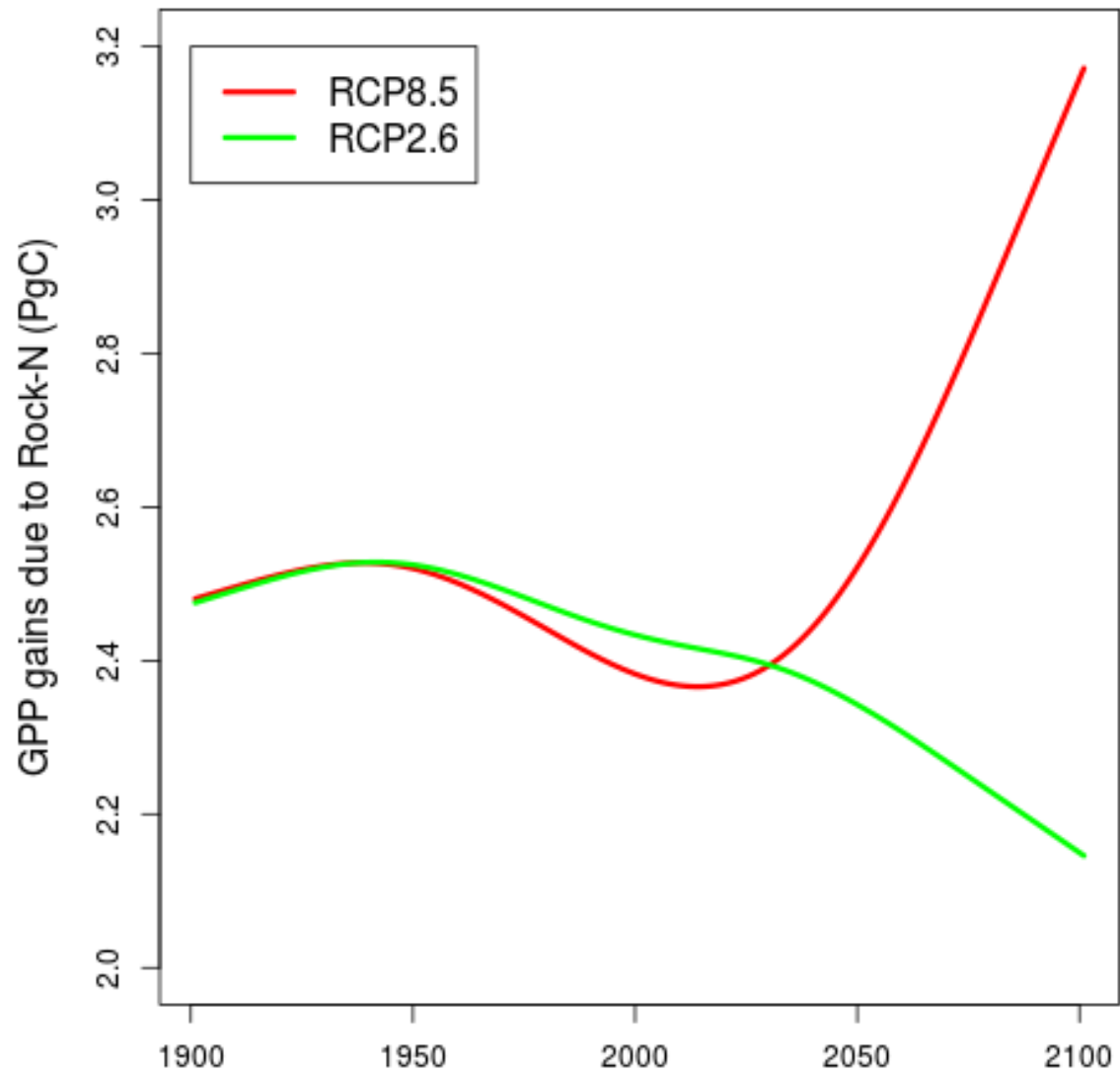
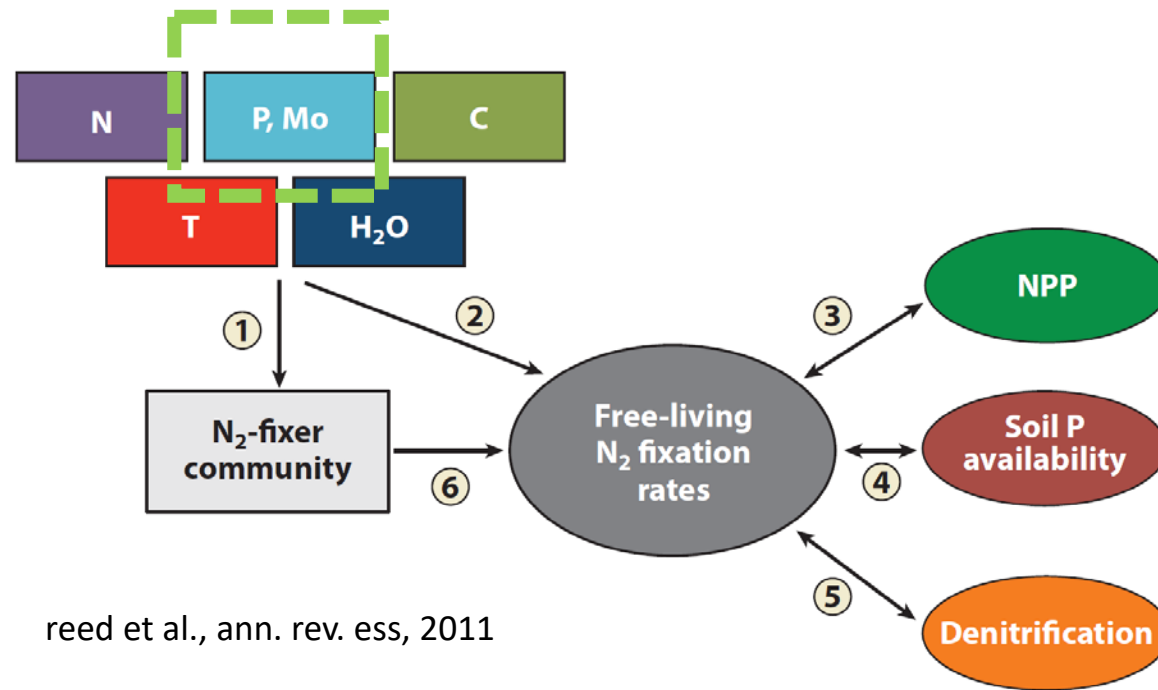


Fig: Δ GPP (global total) or increase in GPP only due to Rock-N - change due to combined impact of climate change and Rock-N weathering flux

Concept 2. Ultimate vs. Proximate Controls

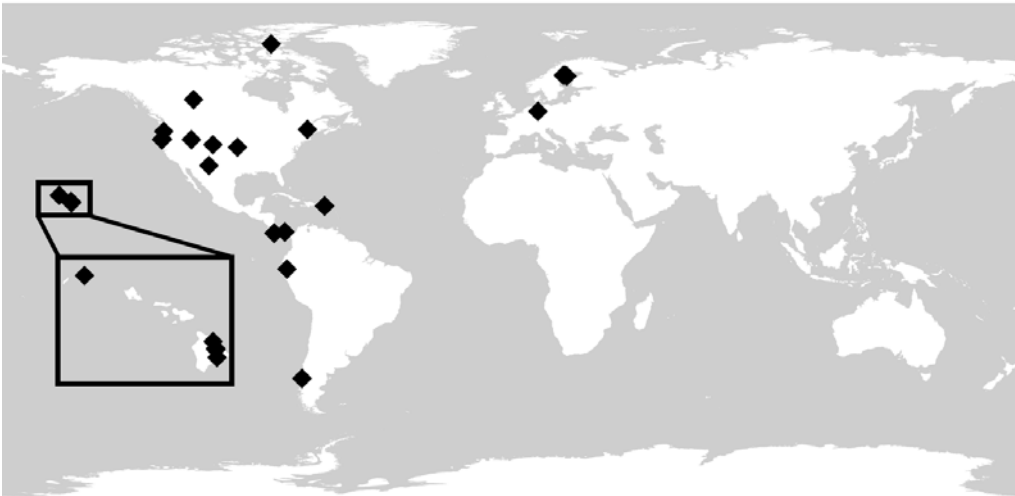


hypothesis: trace metal and P controls over N fixation
(limitation in disguise, after vitousek and howarth, 1991)

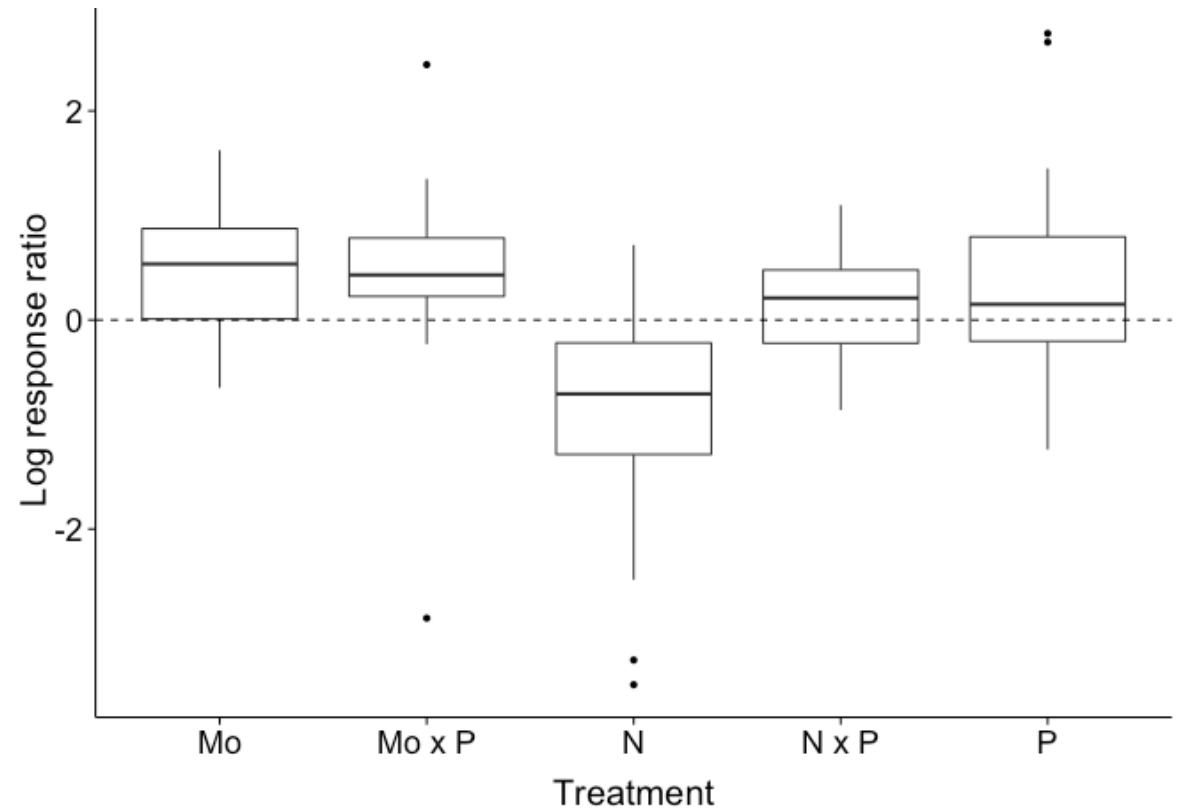
Nutrient limitation of terrestrial free-living nitrogen fixation

Katherine A. Dynarski  and Benjamin Z. Houlton

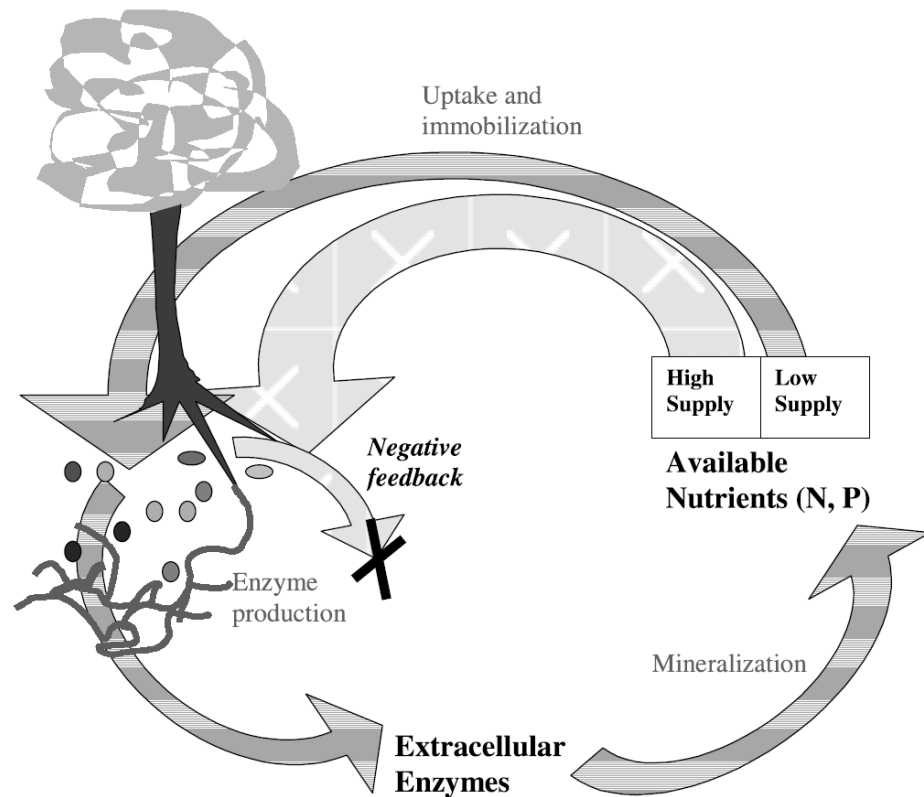
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N fixation increases with Mo
(less so with P) and
decreases with N



Concept 3. Stoichiometric flexibility and (un)couplings



hypothesis: preferential P mineralization (vs. N)
(after mcgill and cole, 1981)

Logic:

- N is typically bonded to C; mineralizes with C

- P is found in di-esters (DNA, RNA); can be decoupled from N and C

Terrestrial N/P mineralization ratios

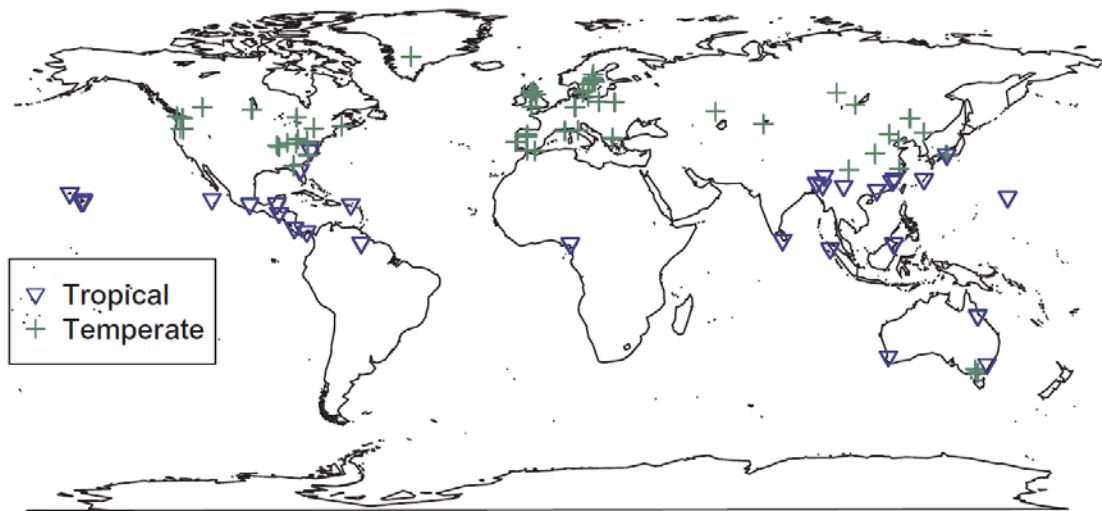
Global Ecology and Biogeography, (Global Ecol. Biogeogr.) () 25, 335–346

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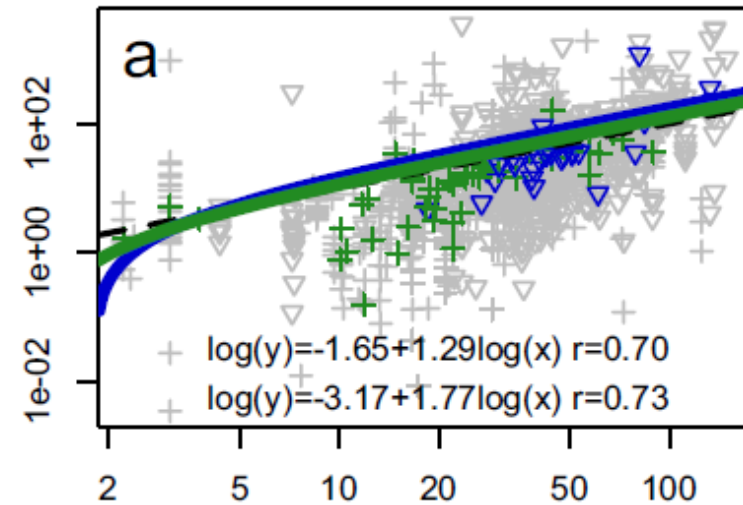


Mineralization ratios of nitrogen and phosphorus from decomposing litter in temperate versus tropical forests

Alison R. Marklein^{1,2}, Joy B. Winbourne^{1,3}, Sara K. Enders¹,
David J. X. Gonzalez^{1,4}, Tiff L. van Huysen¹, Jorge E. Izquierdo¹,
Derrick R. Light¹, Daniel Liptzin^{1,5}, Kimberley E. Miller^{1,6}, Scott L. Morford¹,
Robert A. Norton¹ and Benjamin Z. Houlton^{1*}



N:P leaf net mineralization (molar)



N:P leaf litter (molar)

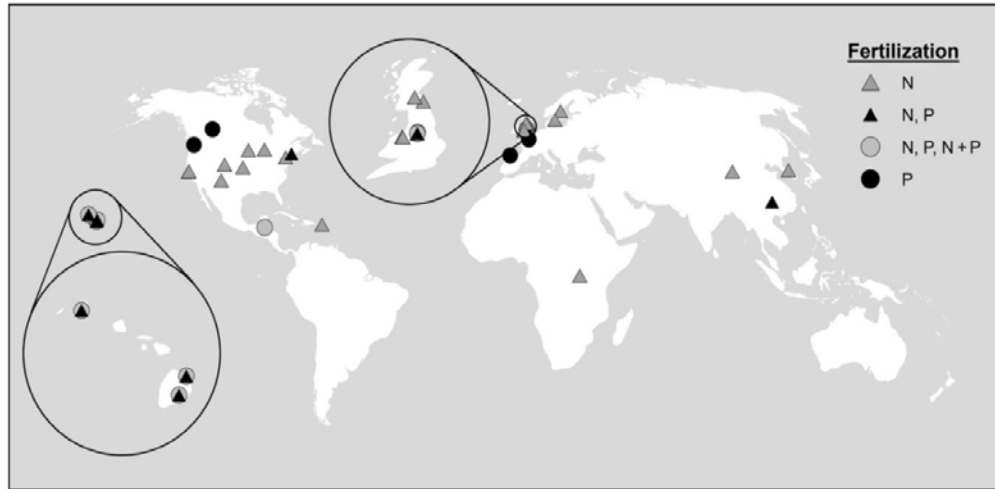
Global evidence for rapid P mineralization

	Litter		Net mineralization		No. of sites	No. of sequences
	Mean	<i>r</i>	Mean	<i>r</i>		
Leaf (temperate)	19 (15–23)	0.69	9 (7–12)	0.42	54	192
Leaf (tropical)	50 (43–59)	0.90	36 (31–42)	0.92	30	169
Wood	11 (4–30)	0.93	2 (1–5)	0.96	4	9
Root	13 (5–37)	0.74	9 (4–25)	0.81	5	16
Total (temperate)	15		6			
Total (tropical)	28		17			

Marklein et al., Global Ecology & Biogeography, 2015

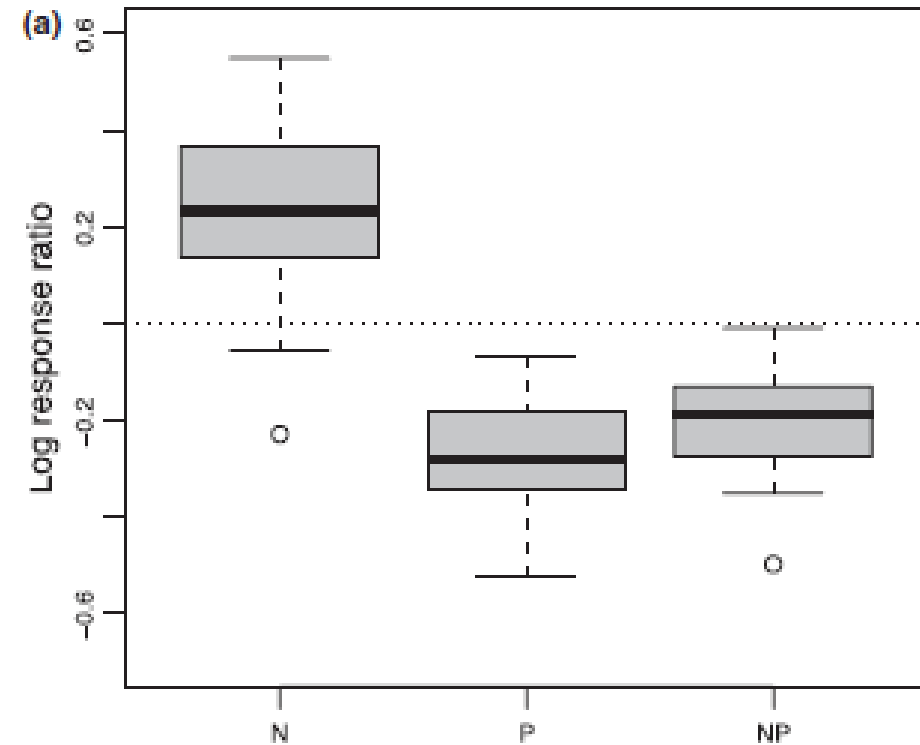
N/P mineralization <
N/P of forest litter

N inputs accelerate P mineralization rates



global meta-analysis reveals an increase in plant and microbial P degrading enzymes (phosphatases) with added N

root and soil phosphatase activity



NextGen framework for ESMs

1. Setting the canvas

uplift, climate, parent material, geobiology

Classes of Interaction:
N – limits productivity and P mineralization
P – limits productivity and N fixation
Trace metals – control N fixation

N

P, Fe, Mo

+

N fixation

N Deposition

N demands increase

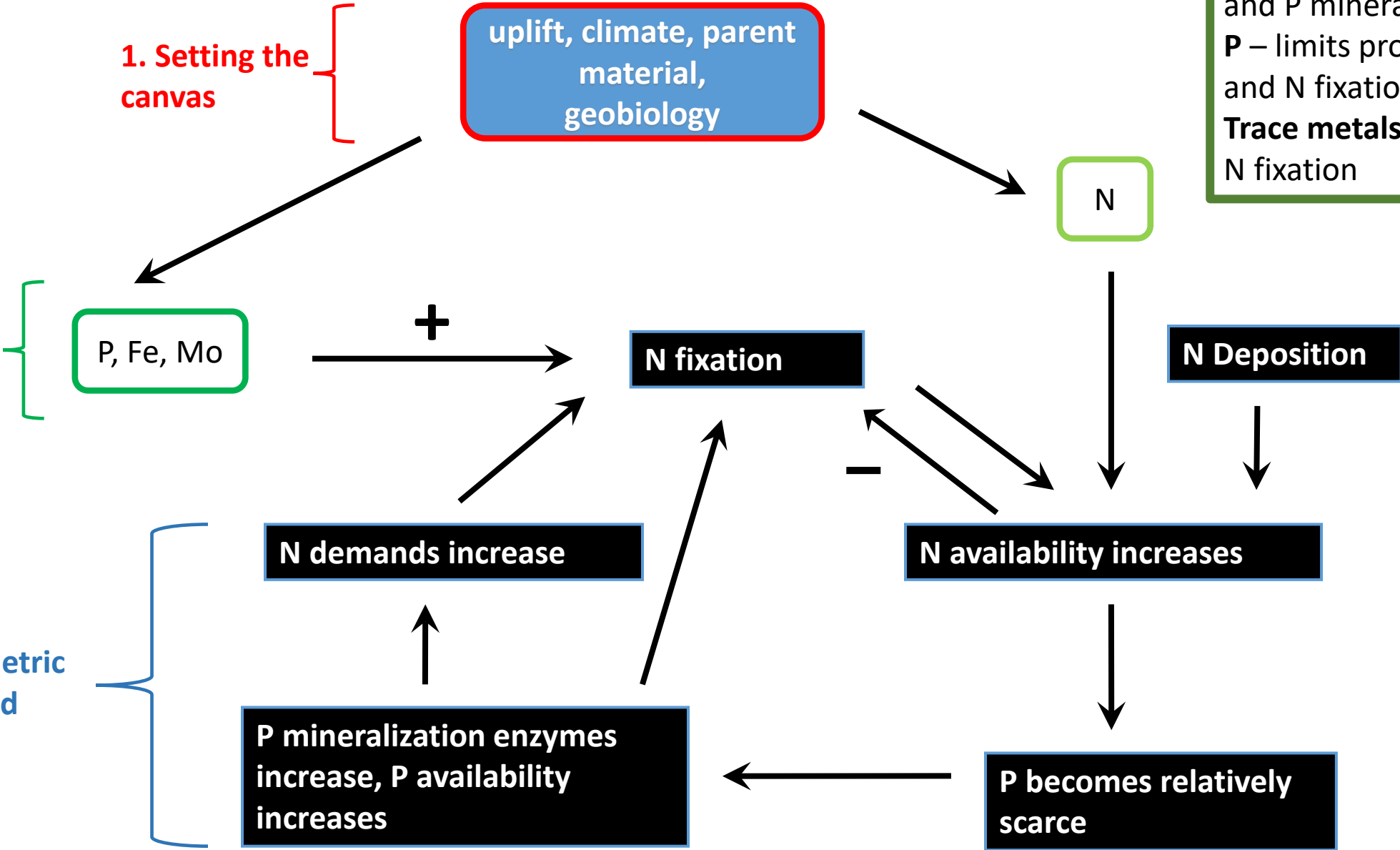
N availability increases

3. Stoichiometric flexibility and couplings

P mineralization enzymes increase, P availability increases

P becomes relatively scarce

2. Ultimate vs proximate "disguise nutrients"





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Stone forest Yunnan province

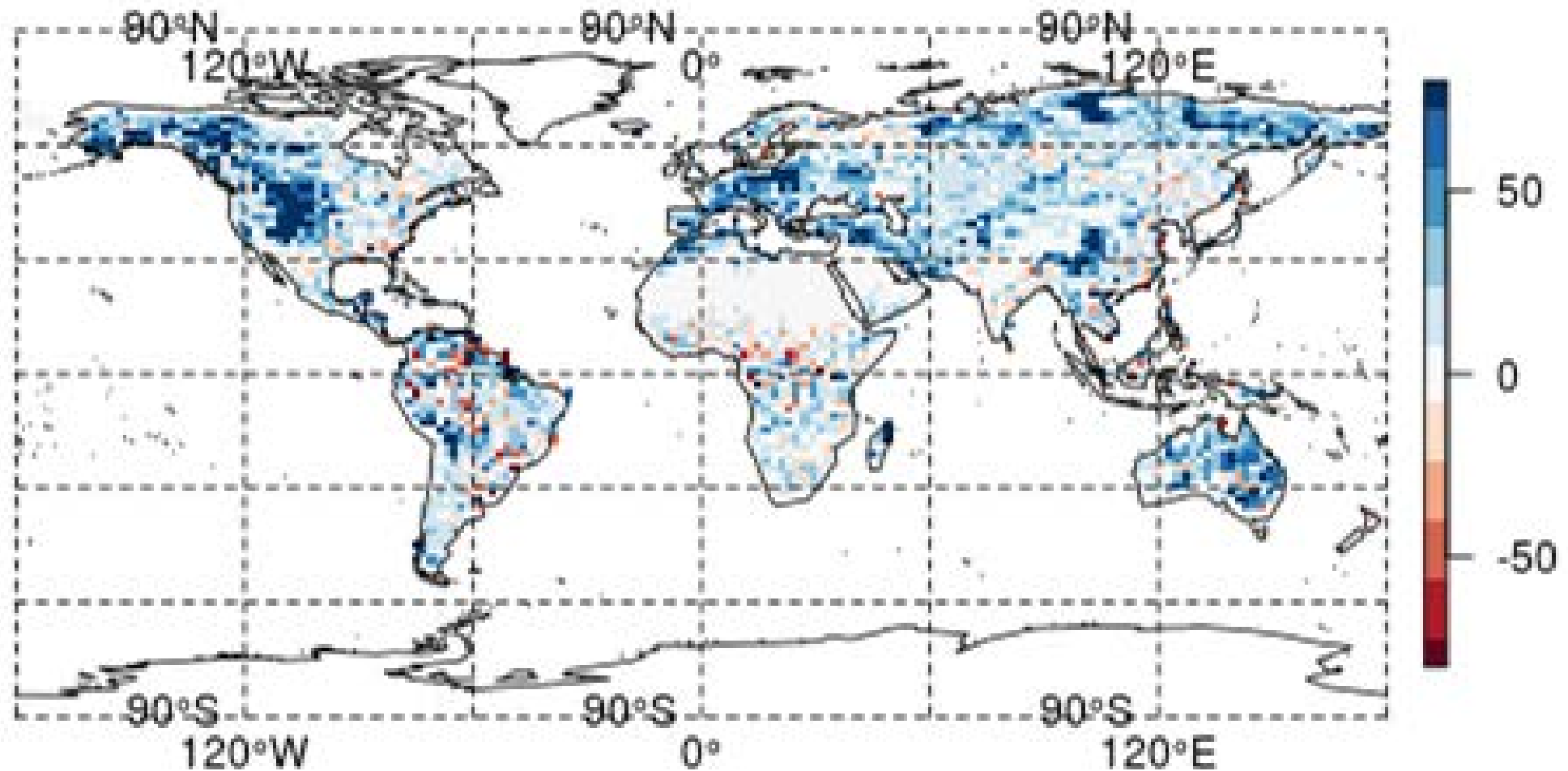


Fig: Δ GPP or increase in GPP only due to Rock-N for 2000s (2000-09 mean) - Units: gC/m²; NOTE: Red spots (GPP reduction) are model artifacts due to random nature of mortality in 'cohort' mode