Nitrogen cycle in land surface model

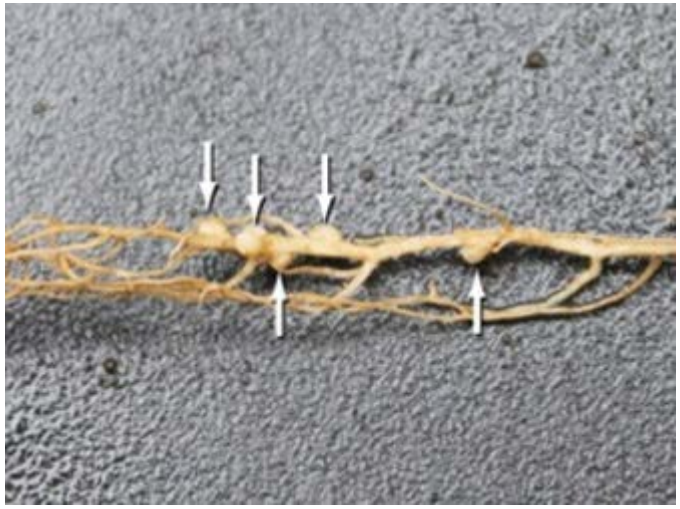
Shushi Peng

PKU

2015 PKU-LSCE Summer School, Shenzhen
Sep 21-25, 2015

Reactive Nitrogen Sources/processes

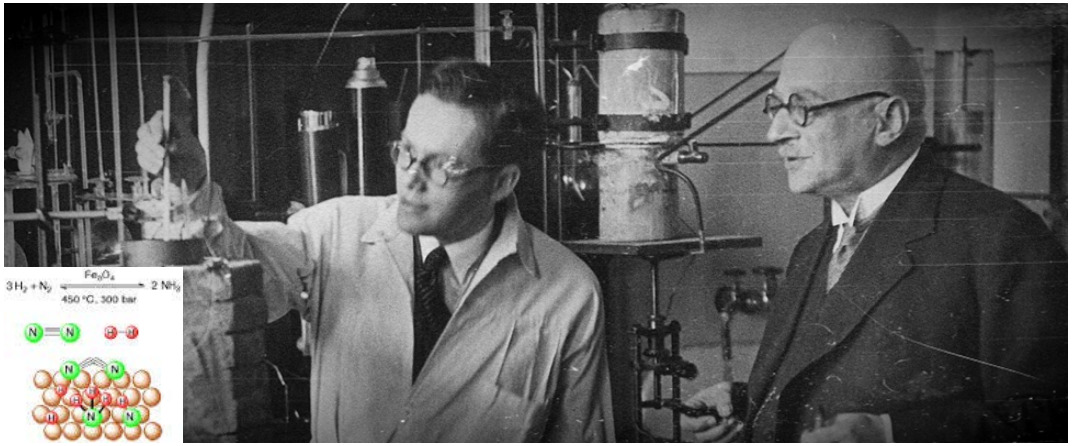
Biological Nitrogen Fixation (BNF)



Lightning

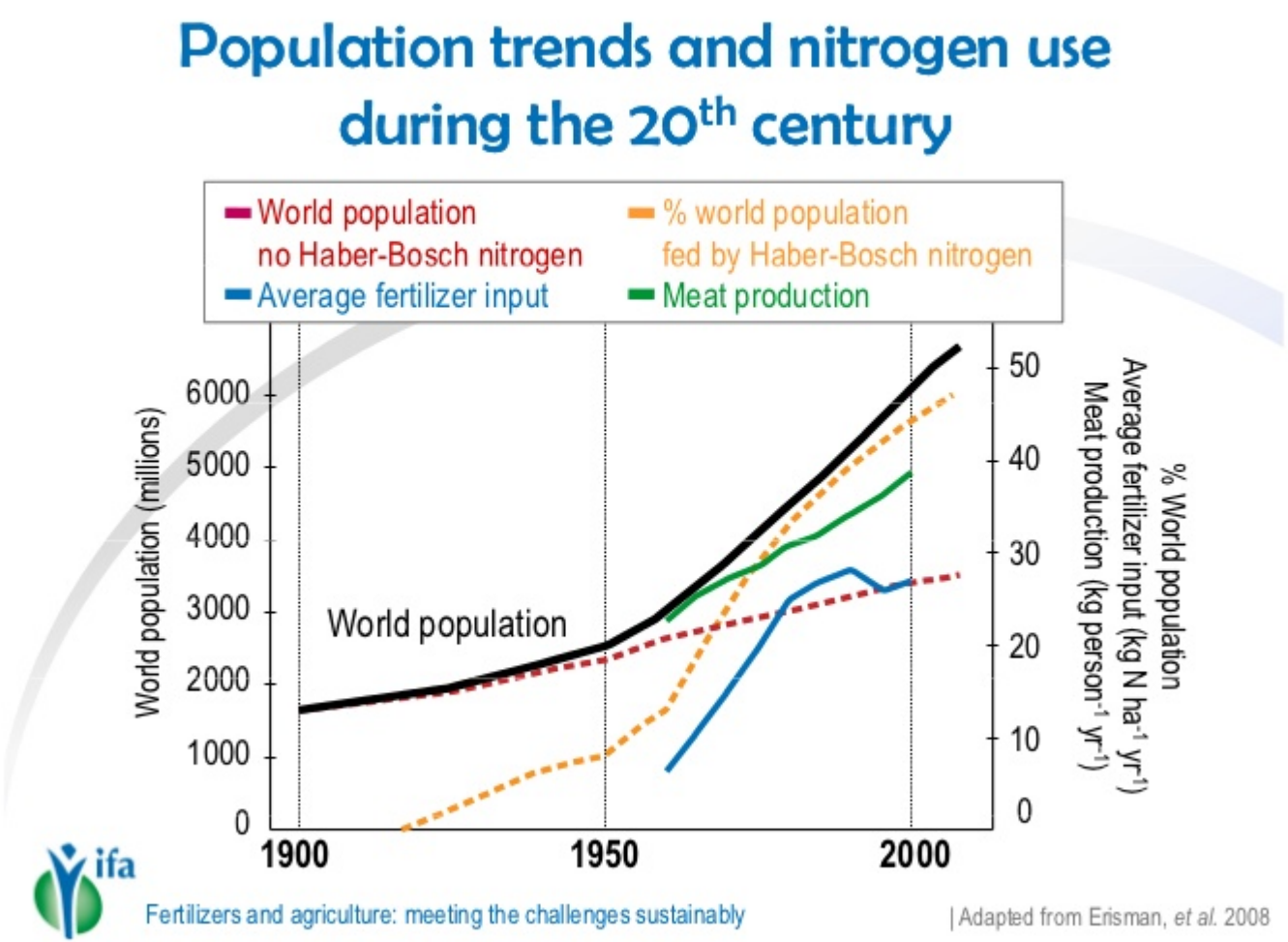
Reactive Nitrogen Sources/processes

Haber-Bosch fertilizer

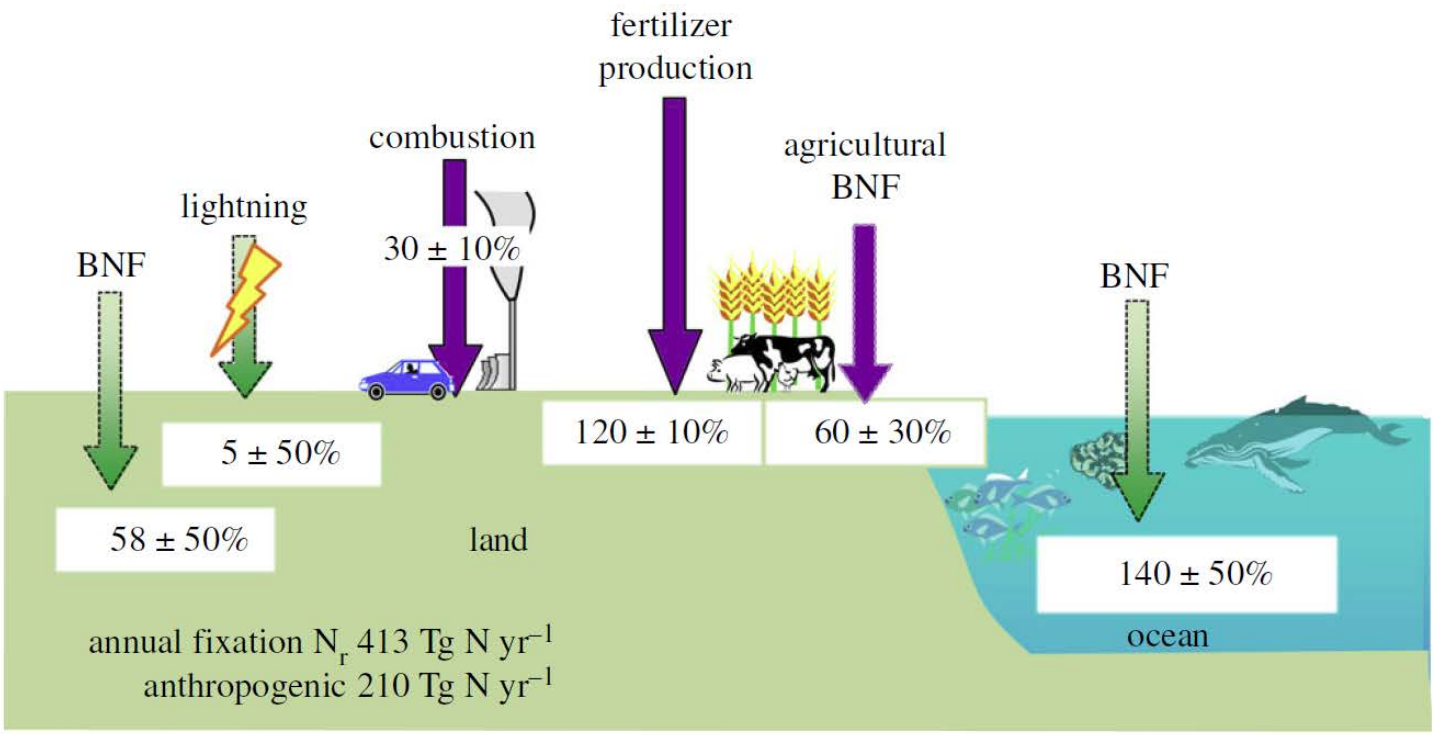


Combustion

Population Growth vs. Reactive Nitrogen Input

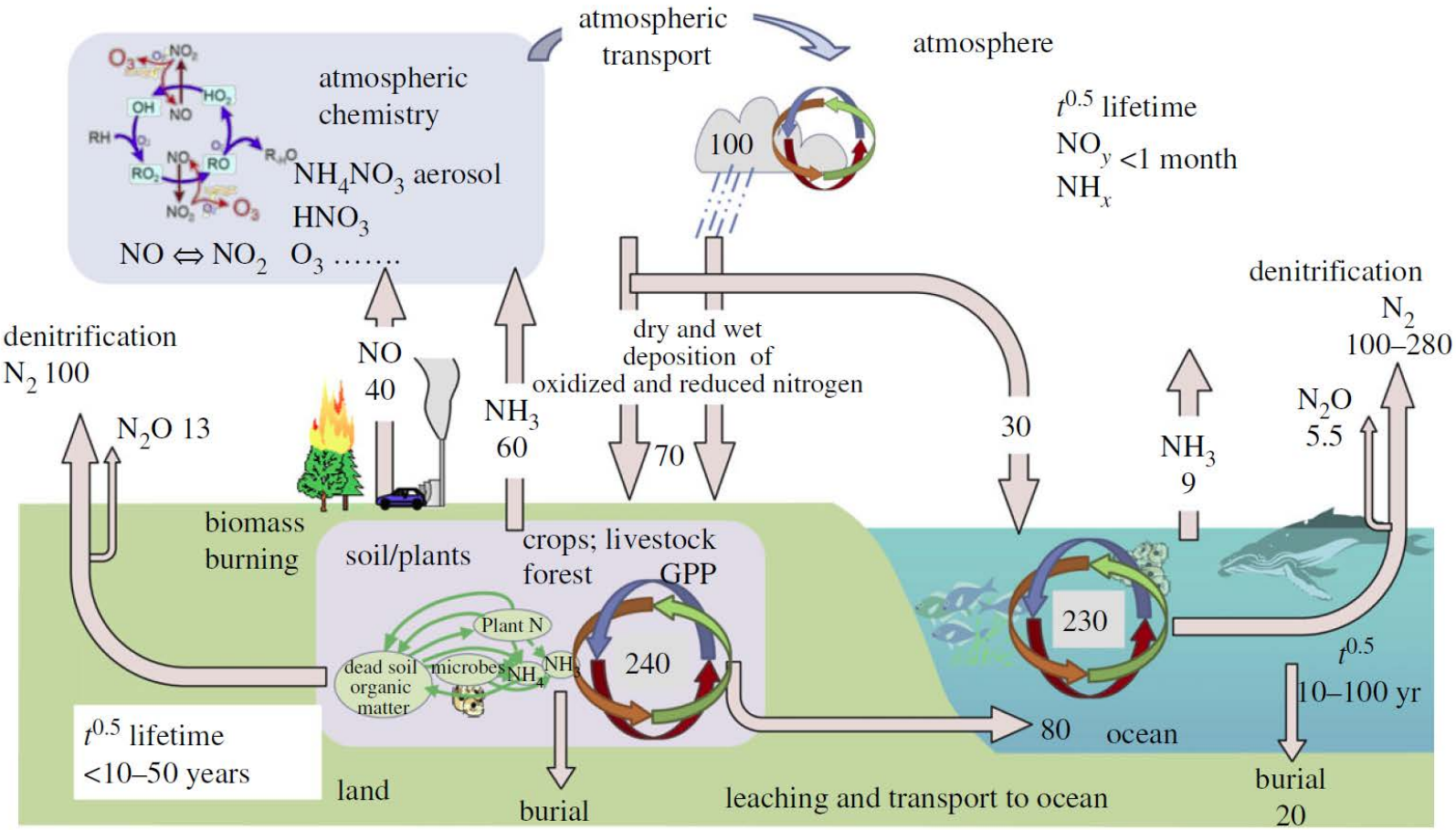


Input Reactive Nitrogen

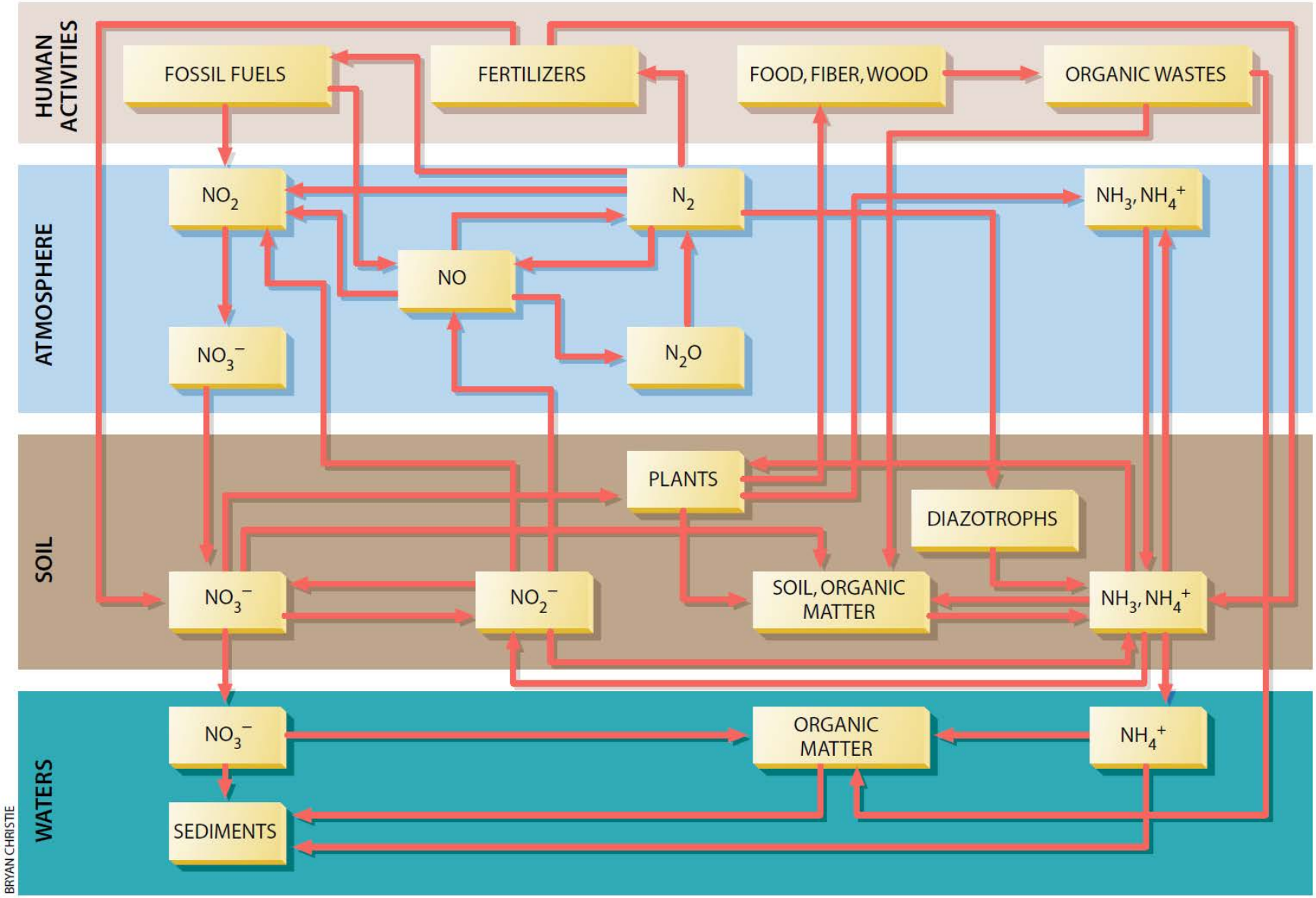


Fowler et al., 2013

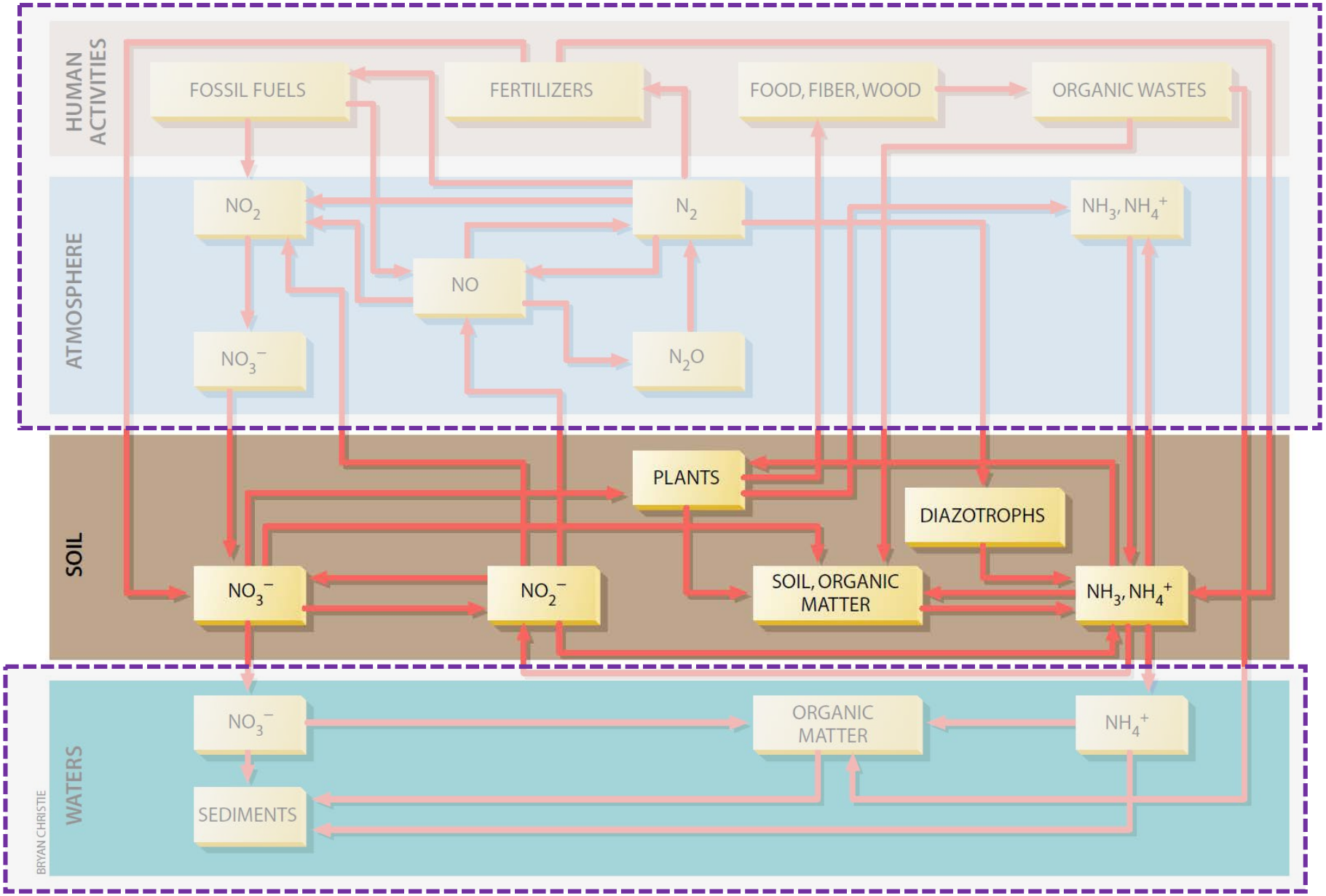
Processing and Fluxes of Reactive Nitrogen



Fowler et al., 2013


HUMAN ACTIVITIES
FOSSIL FUELS
FERTILIZERS
FOOD, FIBER, WOOD
ORGANIC WASTES
ATMOSPHERE
NO_2
N_2
NH_3, NH_4^+
NO
NO_3^-
N_2O
SOIL
PLANTS
DIAZOTROPHS
NO_3^-
NO_2^-
SOIL, ORGANIC MATTER
NH_3, NH_4^+
WATERS
NO_3^-
ORGANIC MATTER
NH_4^+
SEDIMENTS
BRYAN CHRISTIE

Smil, 1997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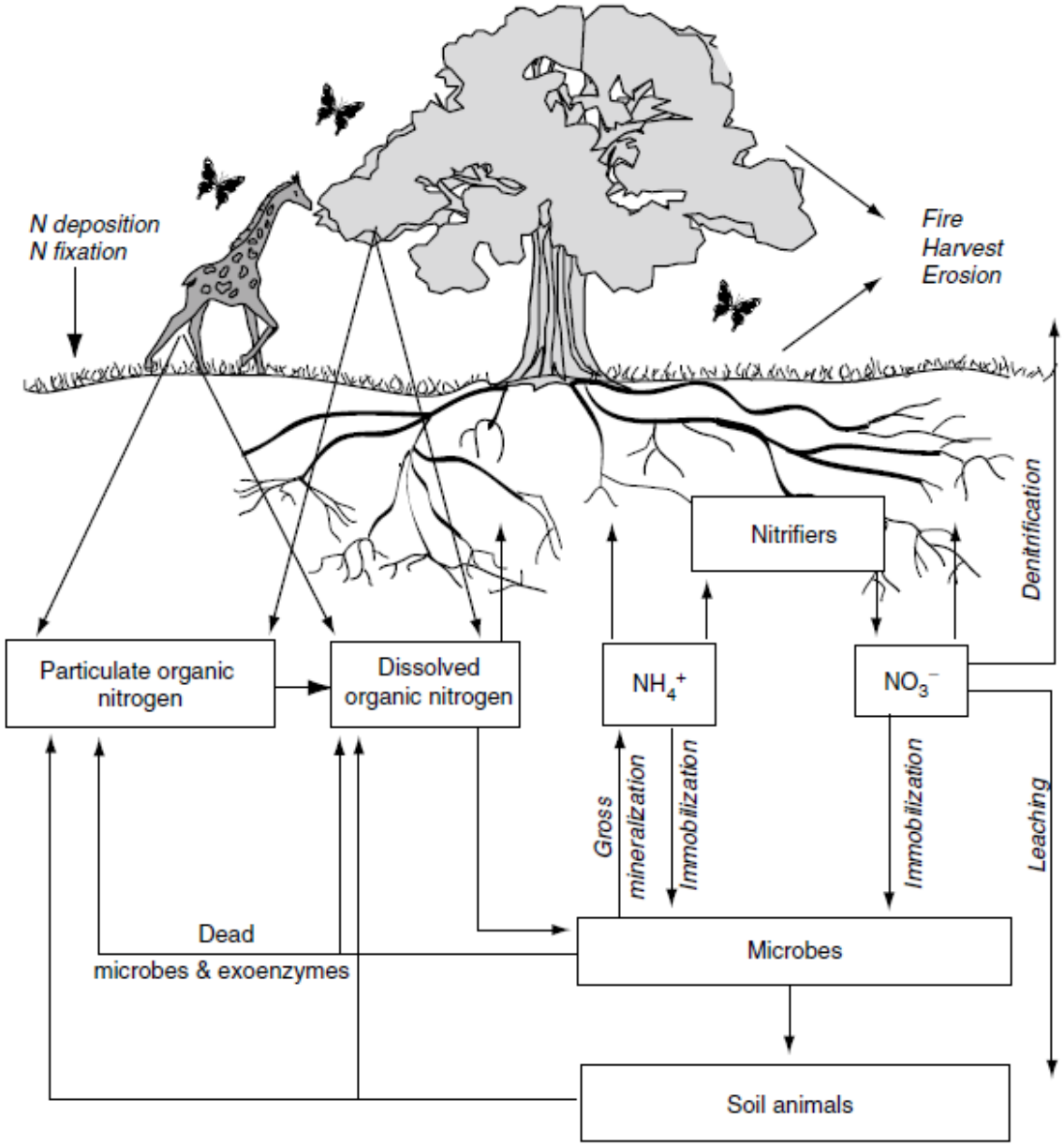
BRYAN CHRISTIE

Smil, 1997

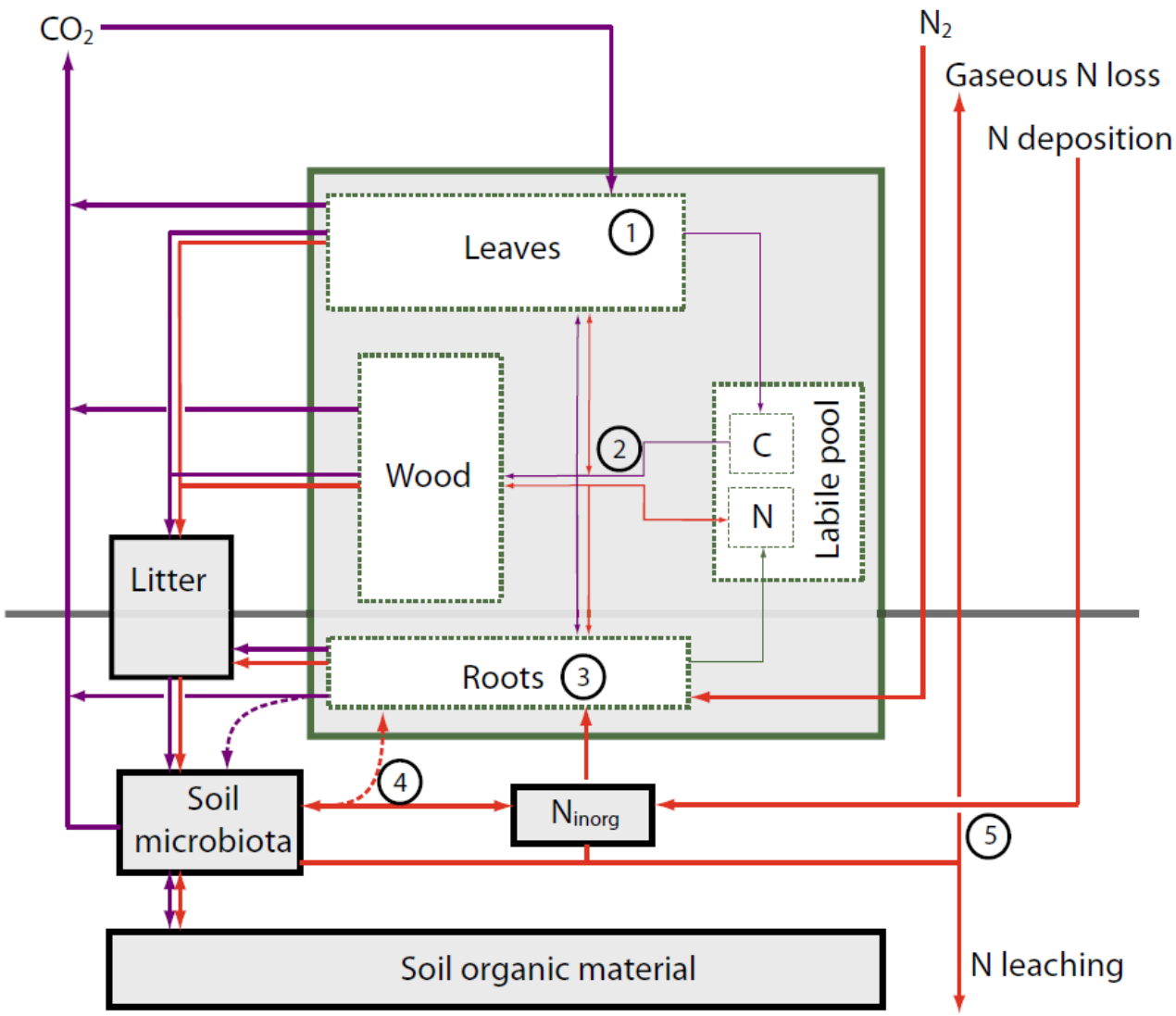
N cycle in land surface model

Cartoon of N cycle in terrestrial ecosystem



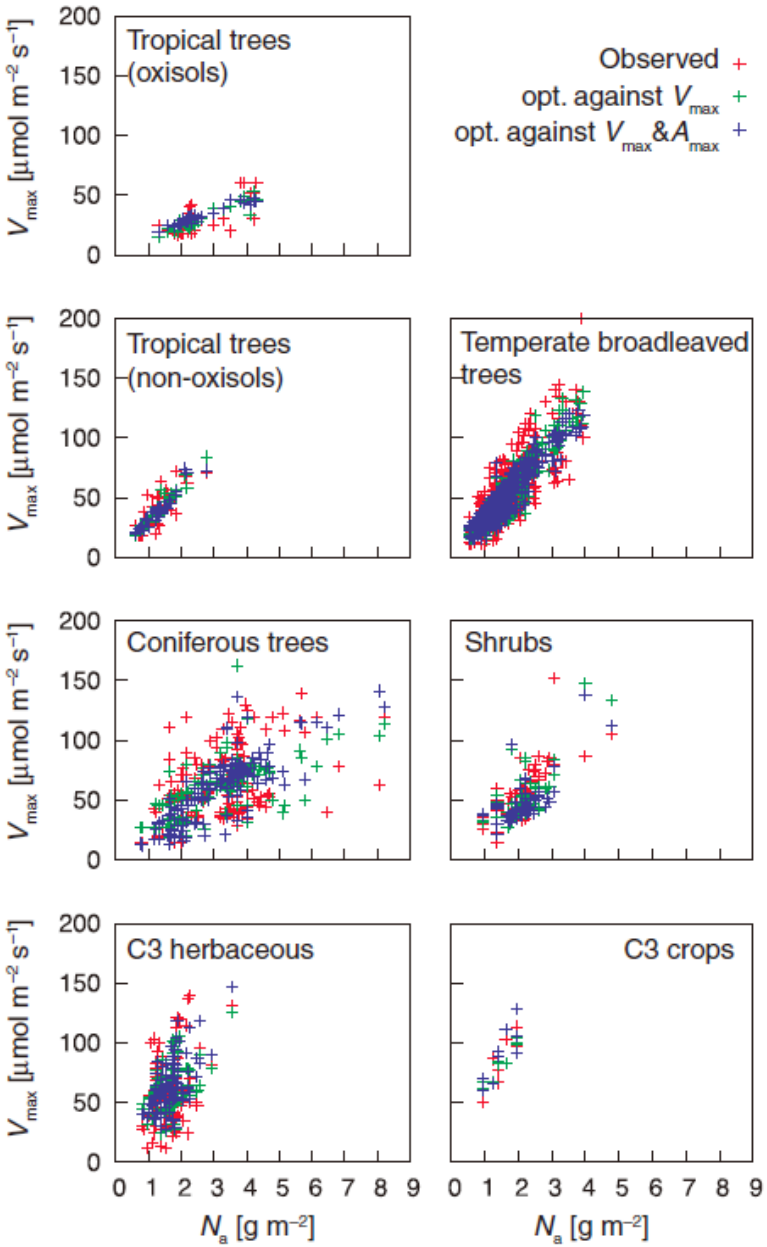
Chapin et al., 2011

Scheme of N cycle model



Zaehle et al., 2014

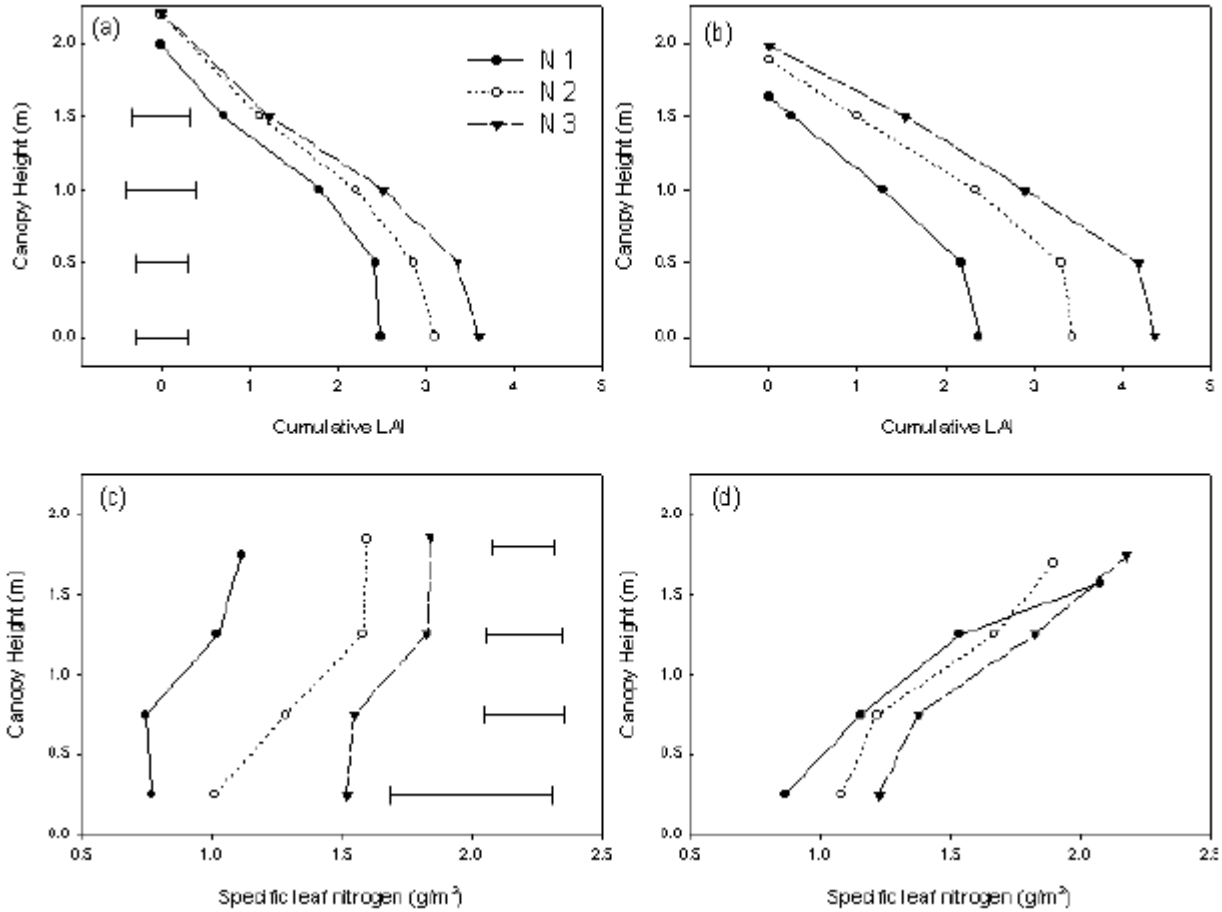
Photosynthesis



Kattge et al., 2009, GCB

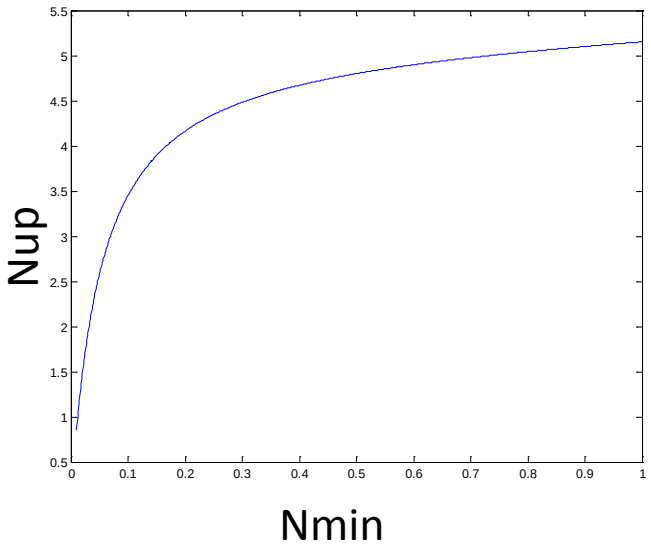
Photosynthesis

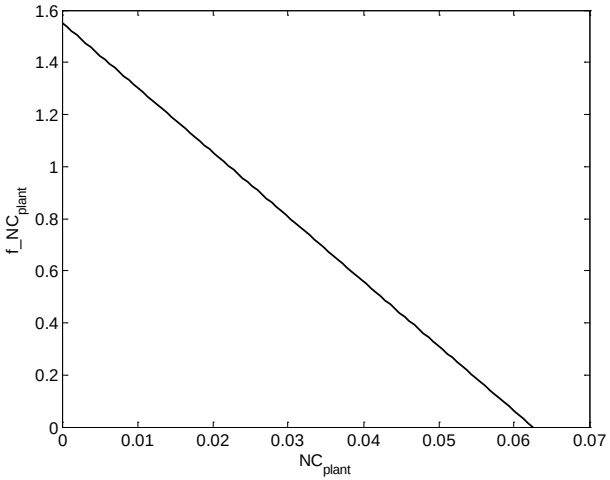
Leaf N profile



Plant N uptake

$$N_{up} = v_{max} \times N_{min} \times \left(k_{Nmin} + \frac{1}{N_{min} \times K_{Nmin}} \right) \times f(T) \times f(NC_{plant}) \times C_{root}$$





Zaehle et al., 2010

Nitrogen Allocation and Turnover

$$\frac{\partial N_{labile}}{\partial t} = \sum_{i=NH_4,NO_3} N_{up,i} + \sum_{t=leaf,root} \tau_t \times f_{trans,t} \times N_t - G_N \pm S_N$$

$$G_N = (f_l + \lambda_r \times (f_r + f_f + f_{sg}) + \lambda_{sap} \times f_s) \times (1 + D_{leaf}) \times nc_{leaf} \times (1 - r_g) \times G_C$$

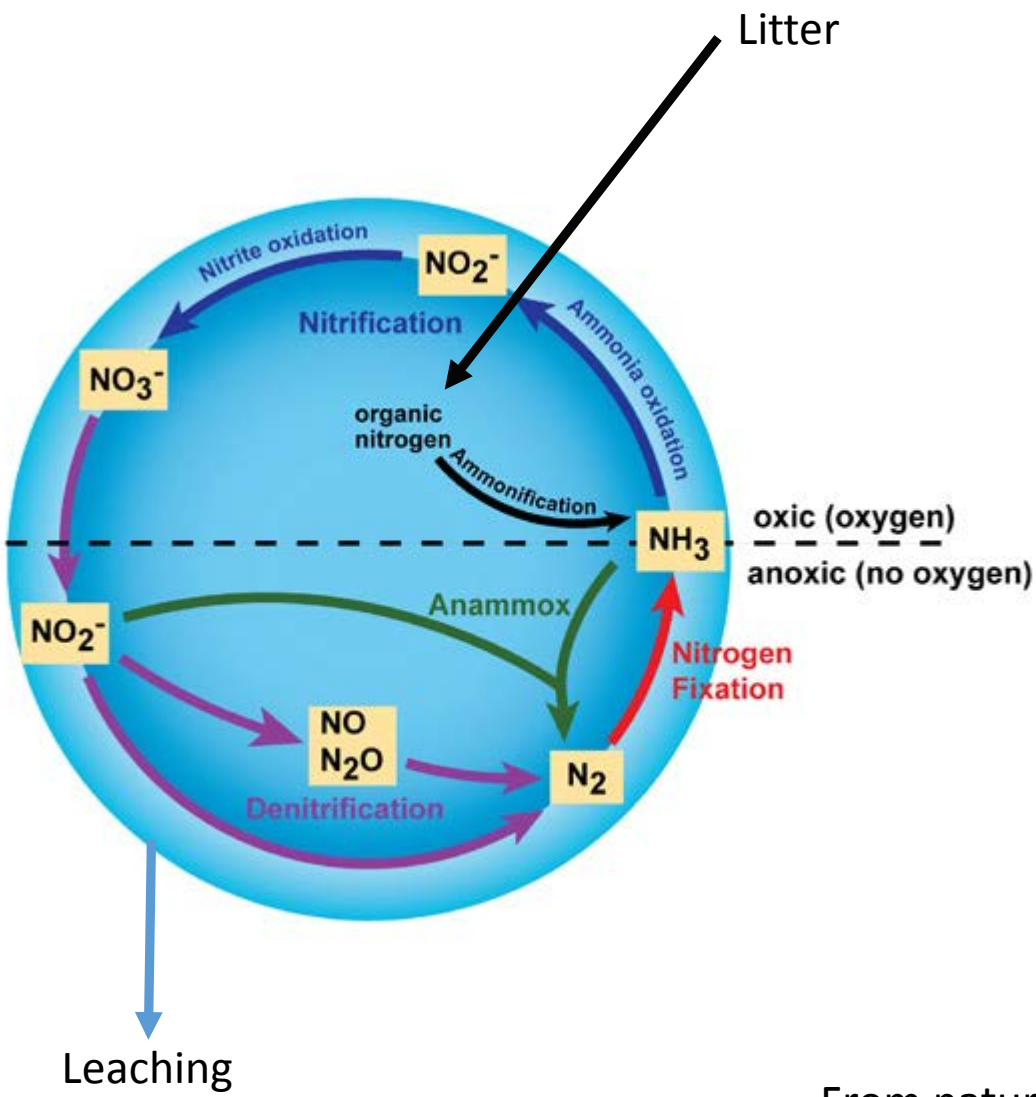
$$n_{scal} = k_{Nalloc} \times \frac{NC_{plant}}{nc_{leaf,ave}}$$

$$D_{leaf} = \begin{cases} N_{labile} < G_N & : D_{max} \times \left(1 - exp\left[-\left(\frac{2 \times nc_{leaf}}{nc_{leaf,min} + nc_{leaf,min}}\right)^8\right]\right) \\ N_{labile} \geq G_N & : D_{max} \times exp\left[-\left(\frac{2 \times nc_{leaf}}{nc_{leaf,min} + nc_{leaf,min}}\right)^8\right] \end{cases}$$

$$n_{lim} = min\left(1.0, \frac{g_{max} \times N_{labile}}{G_N}\right)$$

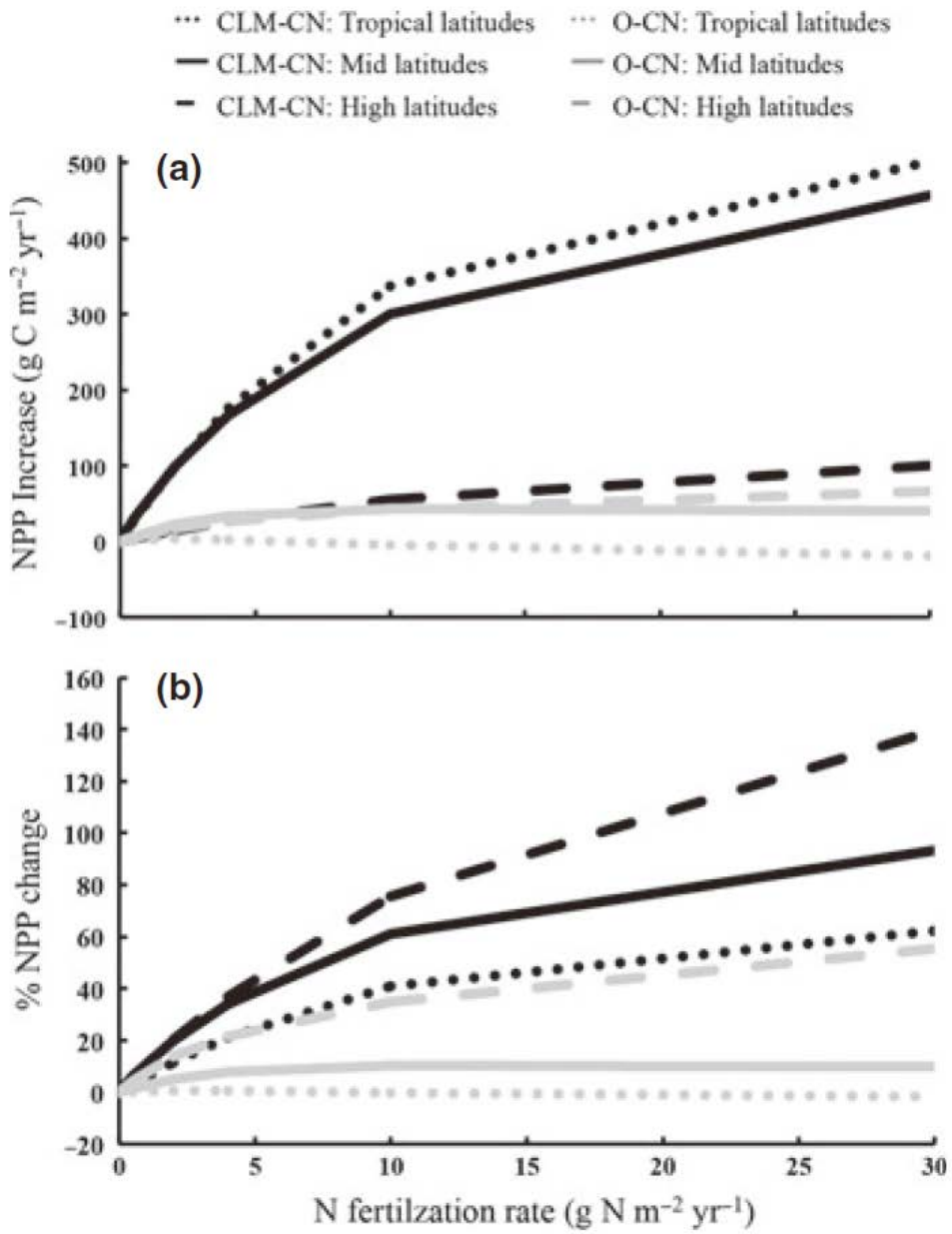
Zaehle et al., 2010

Nitrogen in Soil



From nature.com

NPP response to N fertilzation

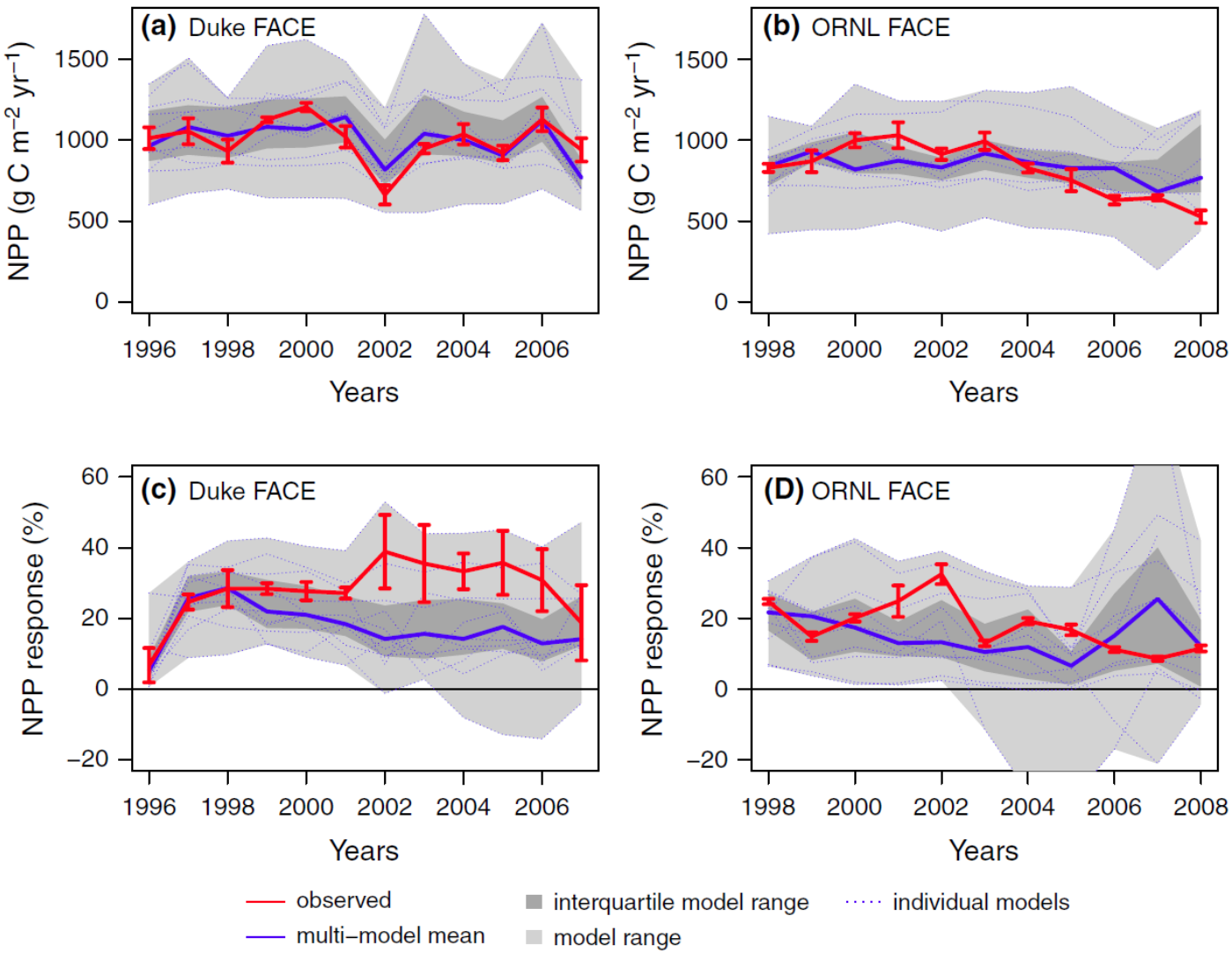


Thomas et al., 2013

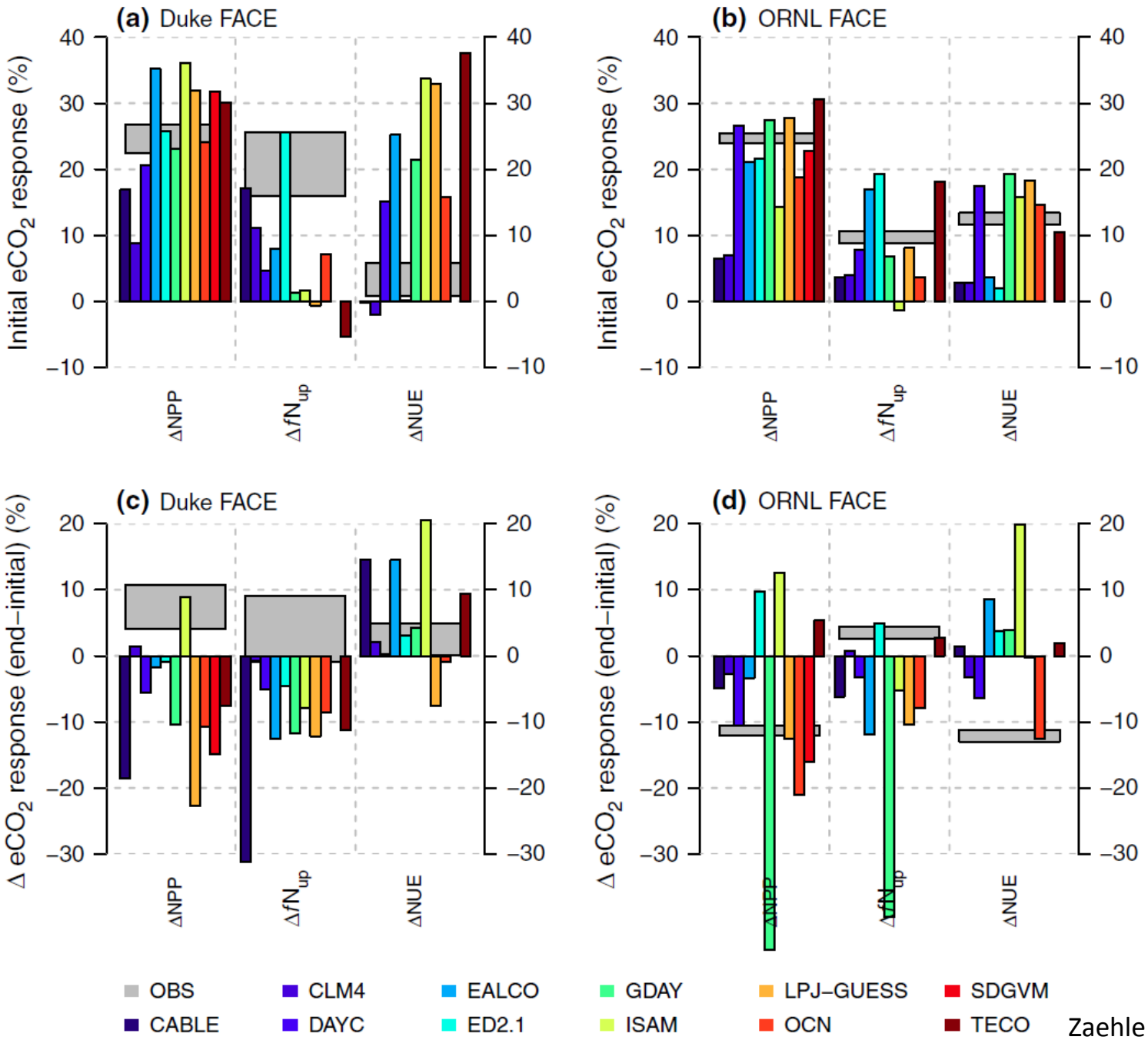
C-N Model inter-comparison on FACE

Ambient

eCO_2



Zaehle et al., 2014



Zaehle et al., 2014

The Nitrogen Paradox in Tropical Forest Ecosystems

Lars O. Hedin,[1] E.N. Jack Brookshire,[1]
Duncan N.L. Menge,[1,2] and Alexander R. Barron[1]

[1]Department of Ecology and Evolutionary Biology, Princeton University, Princeton, New Jersey 08540; email: lhedin@princeton.edu

[2]National Center for Ecological Analysis and Synthesis, Santa Barbara, California 93101

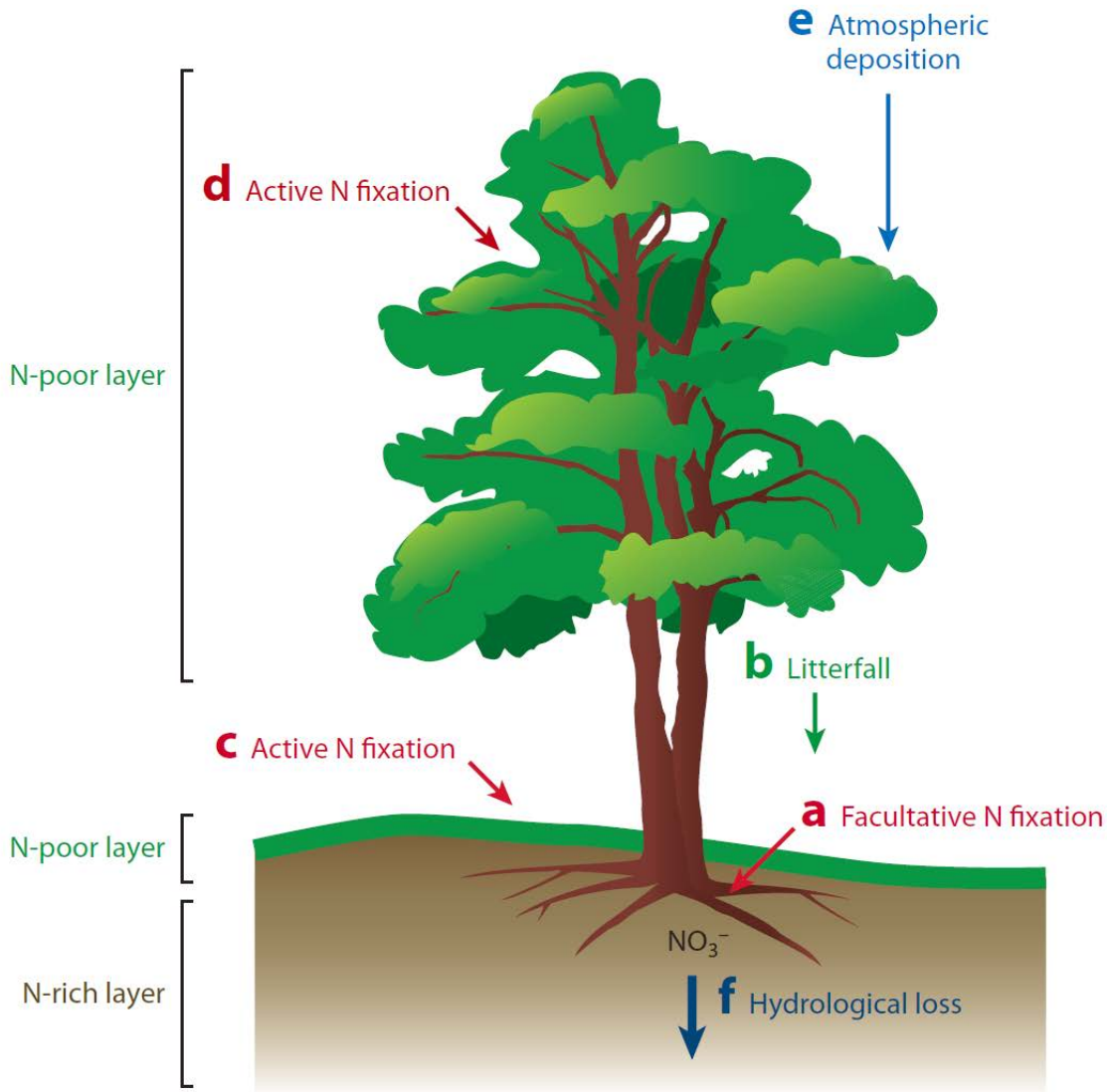
identifies a fundamental contradiction across scales of biological organization: Though BNF can sufficiently resolve the emergence of N richness at the level of ecosystems, the explanation is inconsistent with theoretical expectations of how BNF should function as an adaptive strategy at the level of individual organisms.

BNF

Obligate VS Facultative

Selfless VS Selfish

The Leaky Nitrostat Model



Hedin et al., 2009

Perspectives

- Plant uptake
- BNF
- Allocation
- NUE

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

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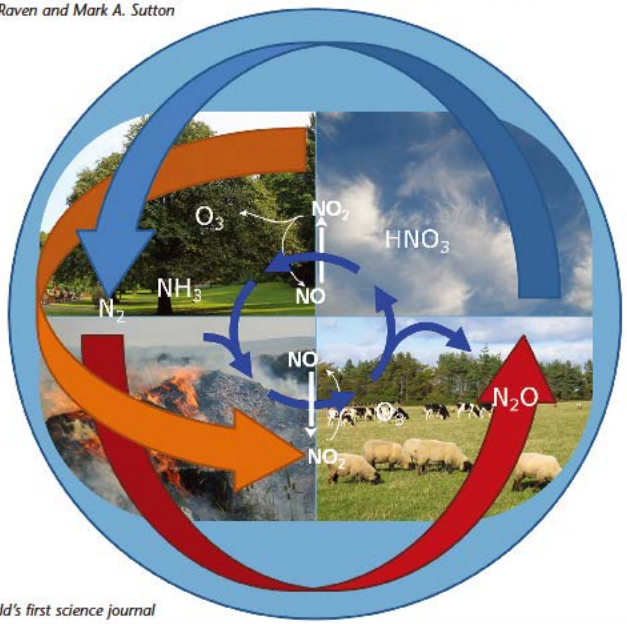

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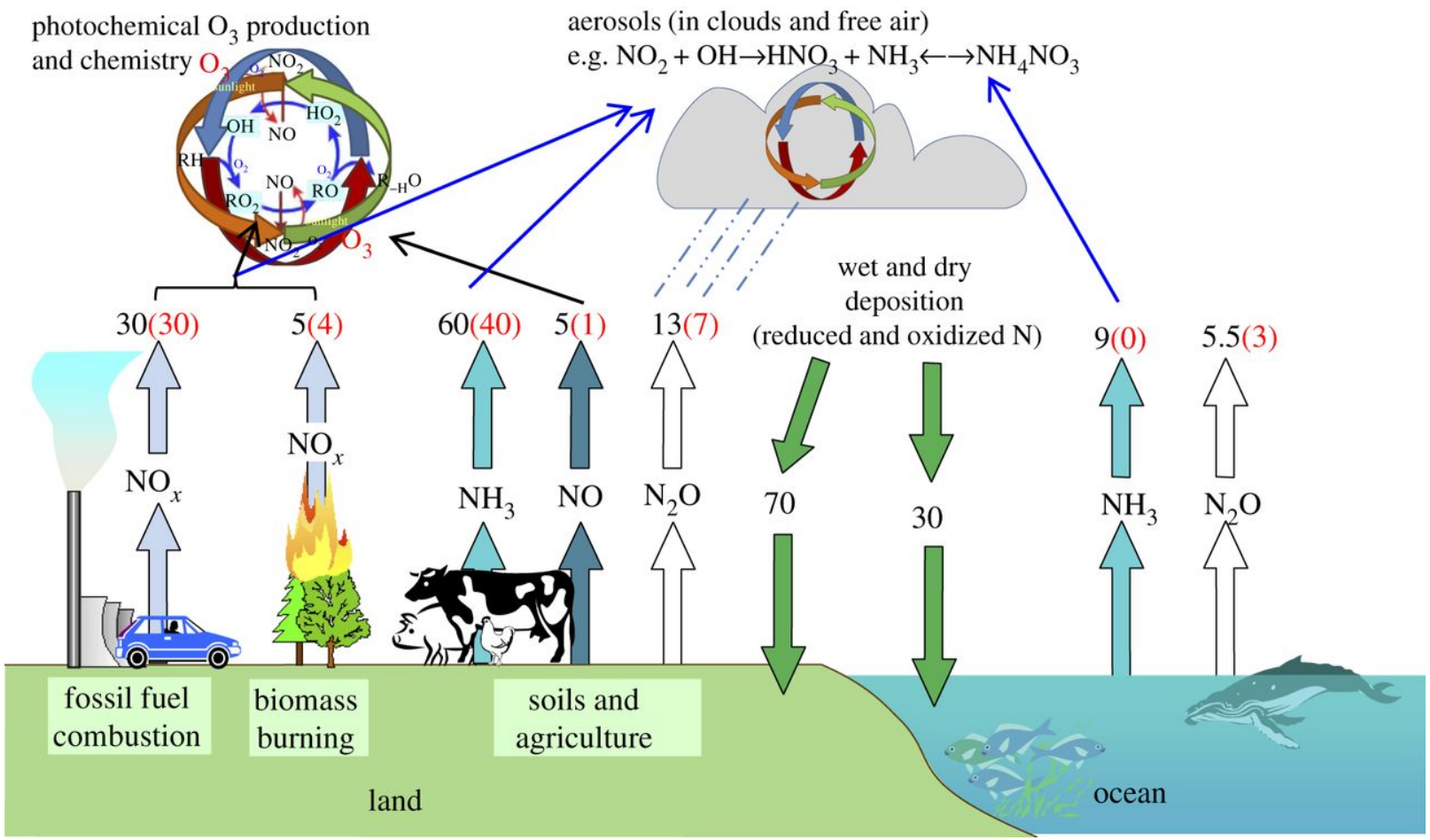
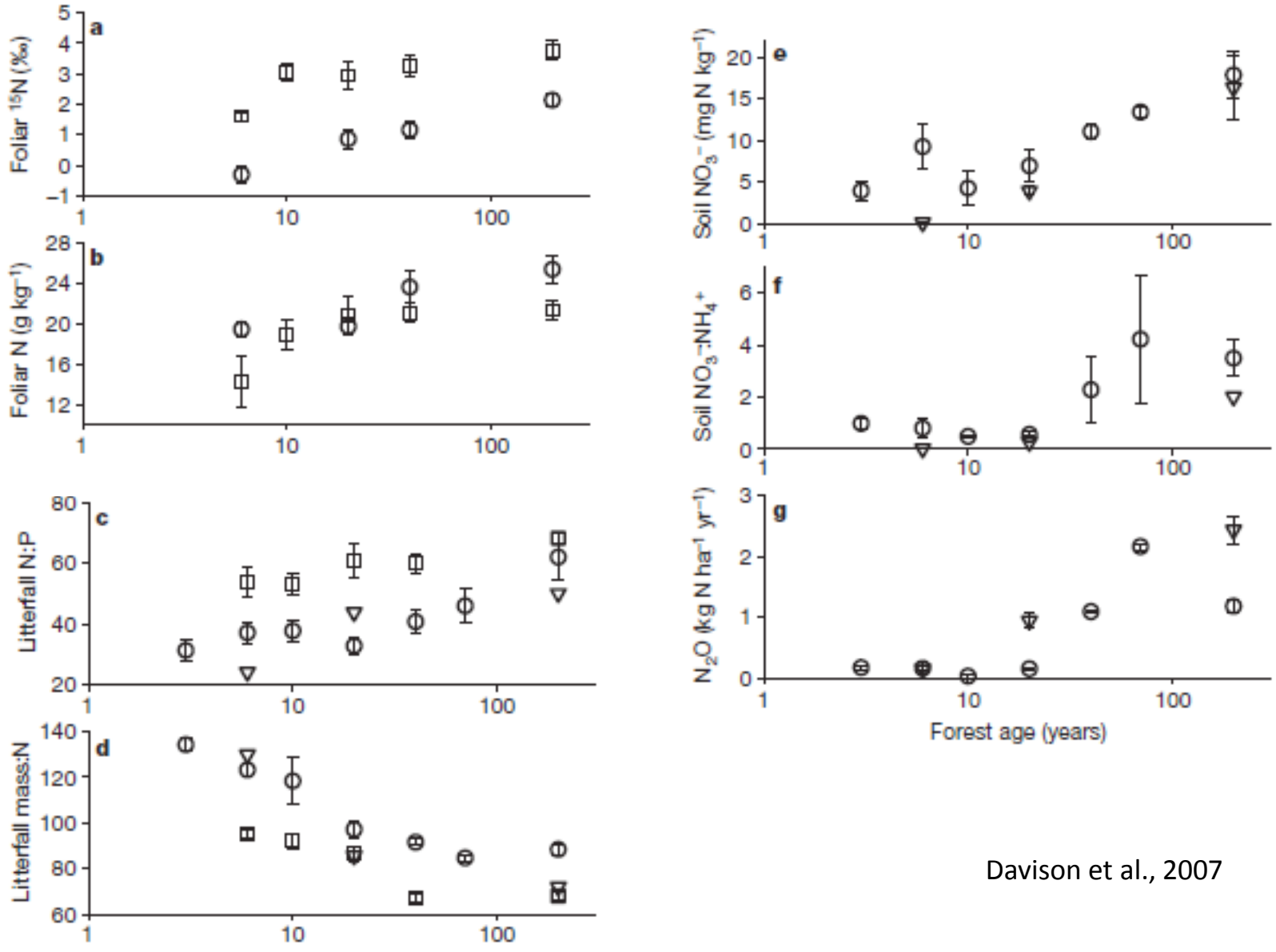
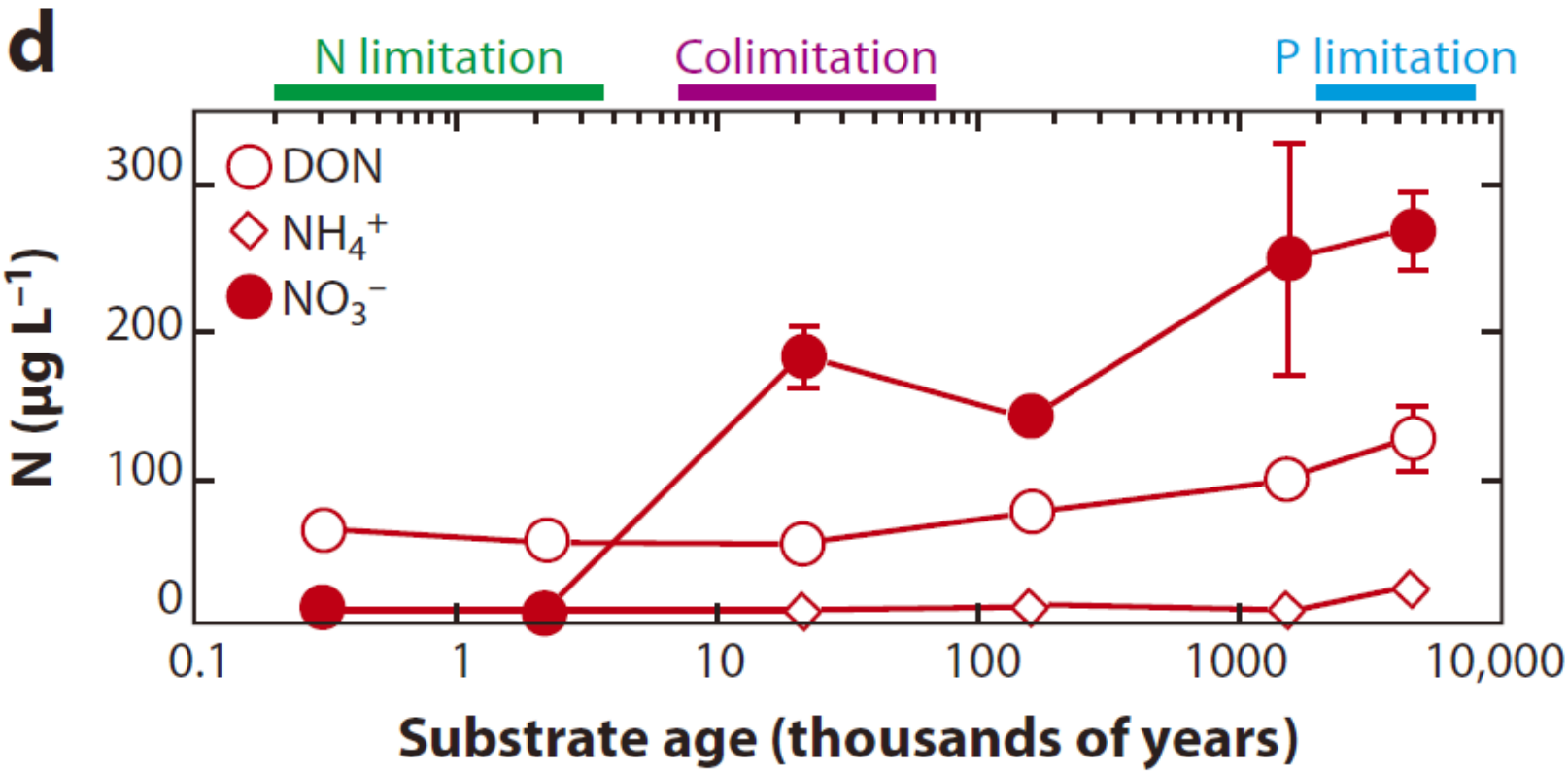

photochemical O_3 production and chemistry
aerosols (in clouds and free air)
e.g. $NO_2 + OH \rightarrow HNO_3 + NH_3 \leftrightarrow NH_4NO_3$
O_2
NO_2
sunlight
OH
NO
HO_2
RH
O_2
NO
RO
$R_{-H}O$
RO_2
sunlight
NO_2
O_3
30(30)
5(4)
60(40)
5(1)
13(7)
wet and dry deposition (reduced and oxidized N)
9(0)
5.5(3)
NO_x
NO_x
NH_3
NO
N_2O
70
30
NH_3
N_2O
fossil fuel combustion
biomass burning
soils and agriculture
land
ocean



Davison et al., 2007



Hedin et al., 2009