Modeling Nitrogen Cycling

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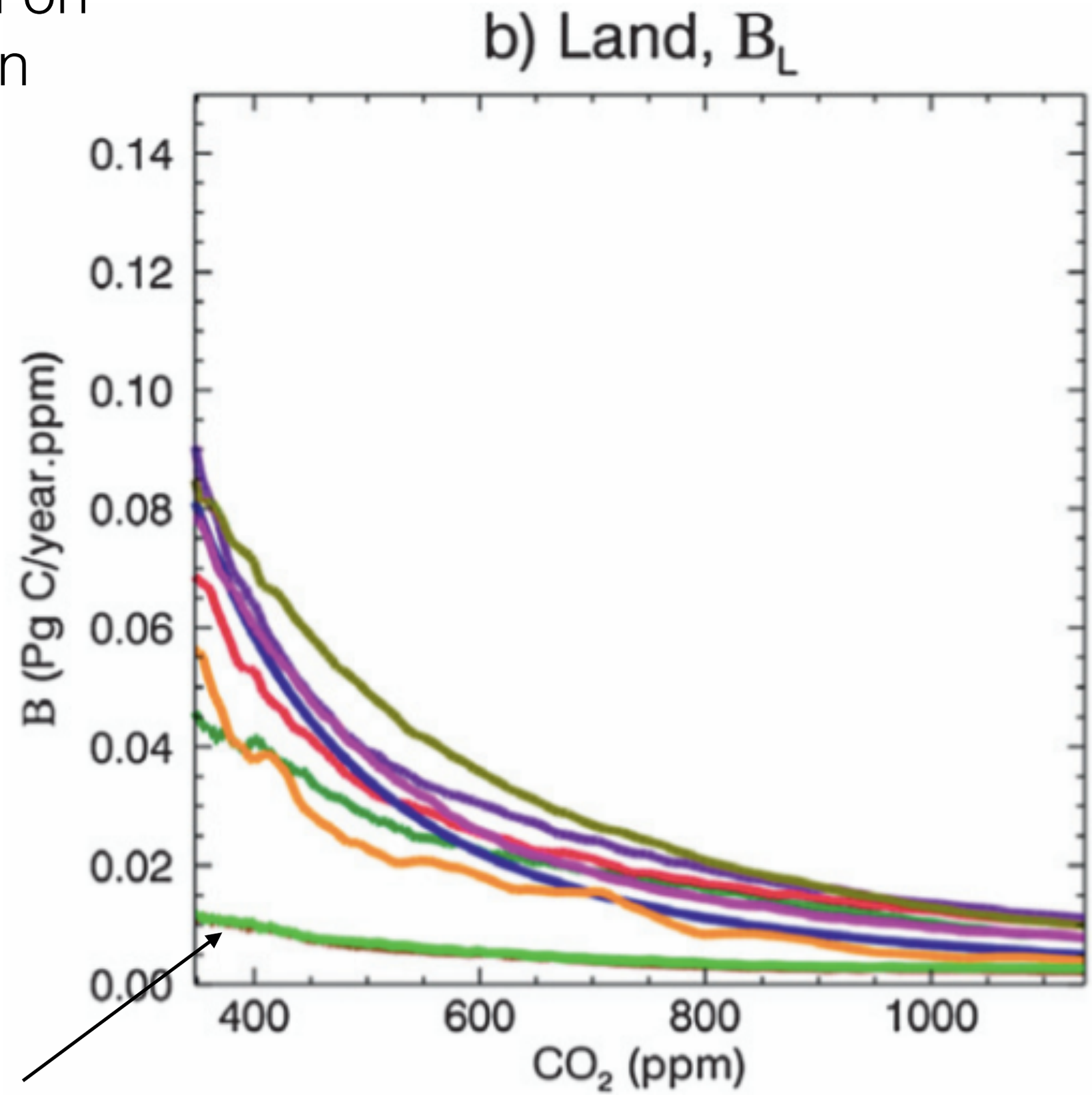
http://photos.hgtv.com/photo/fertilized-and-unfertilized-plants

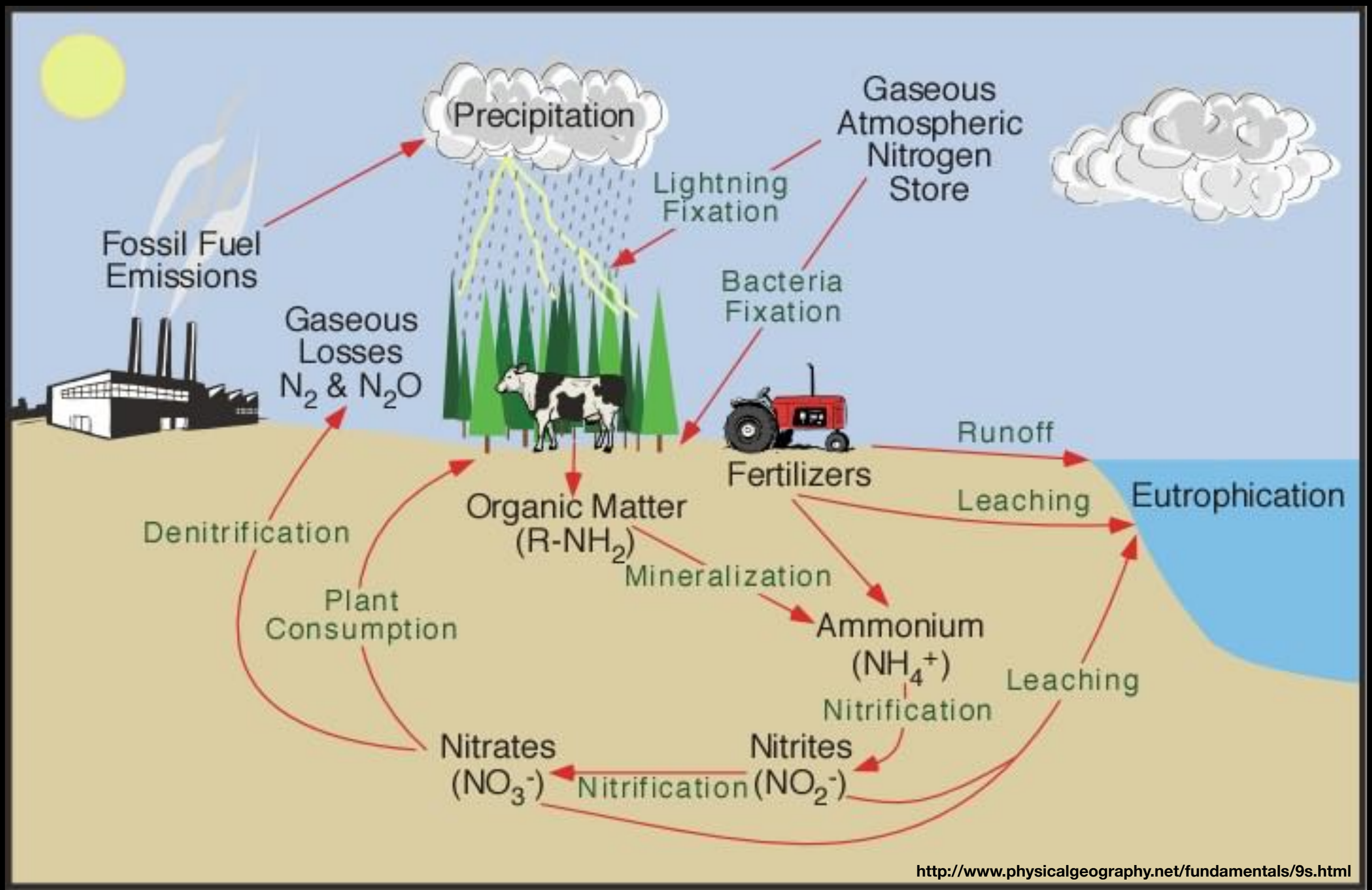
Impact of Nitrogen on simulated carbon fertilization



NCAR-CLM4(CN)

Arora et al. 2013 *J. Climate*

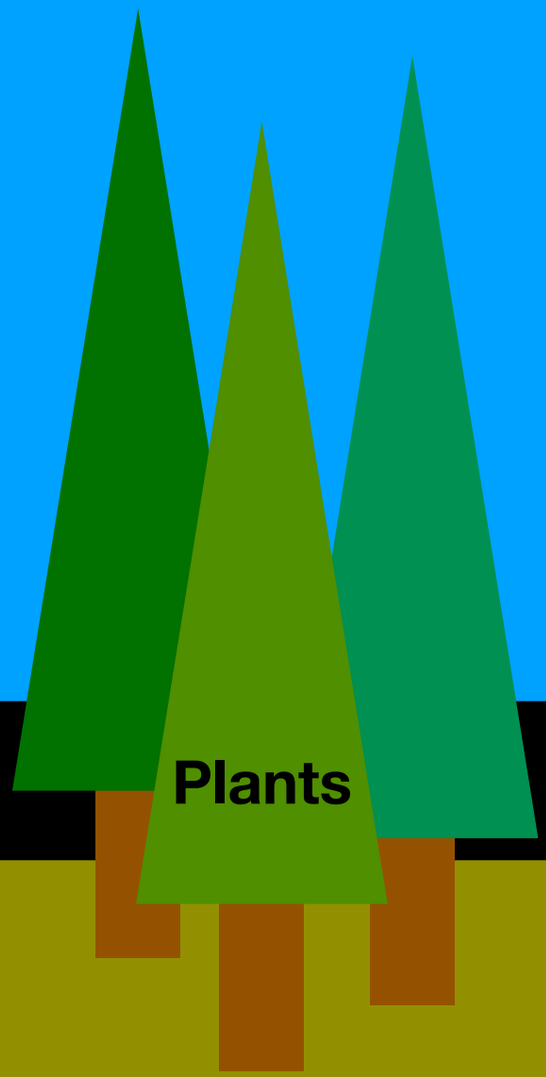
The Nitrogen Cycle



http://www.physicalgeography.net/fundamentals/9s.html

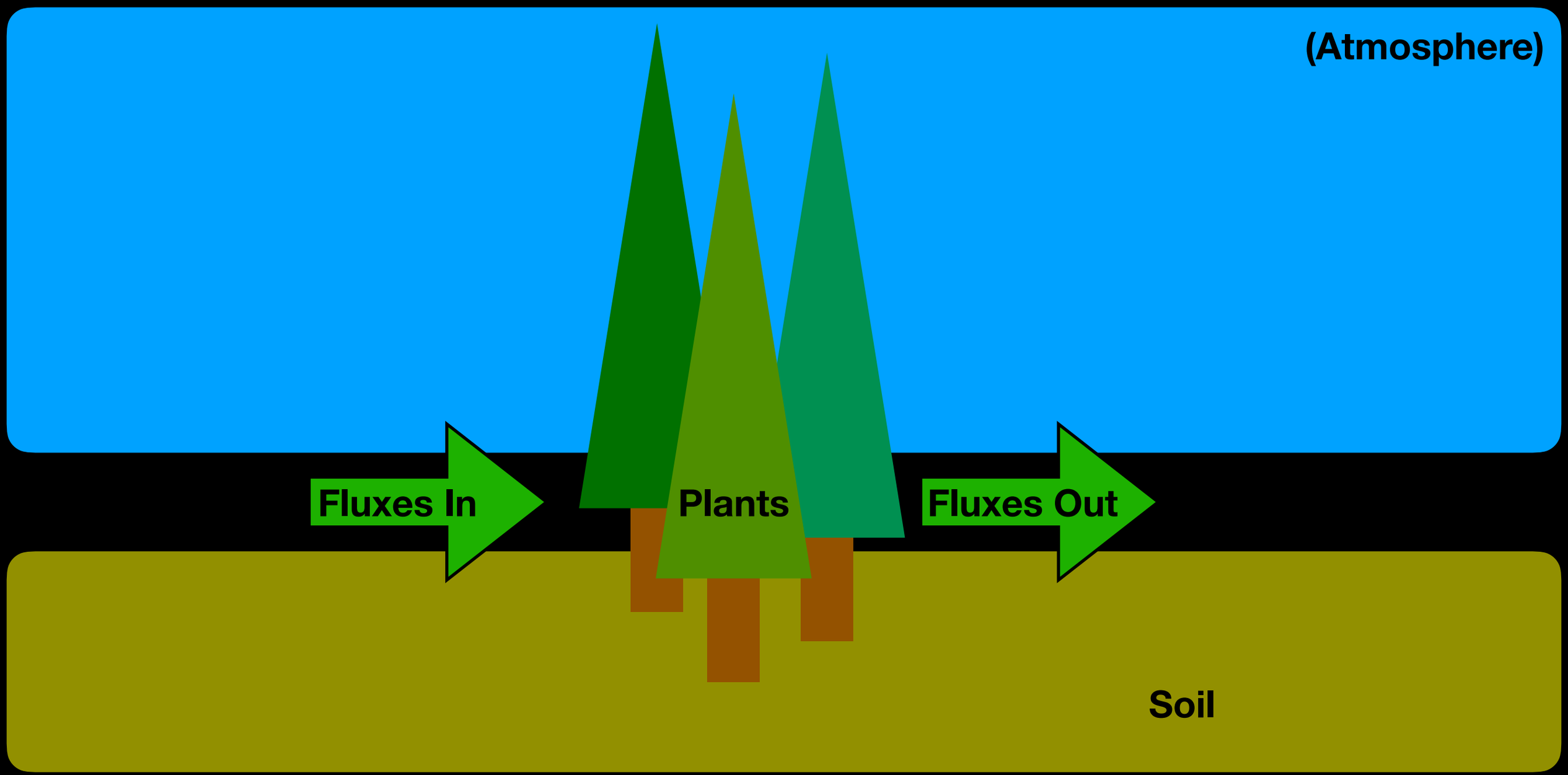
Terrestrial Nitrogen Pools

(Atmosphere)

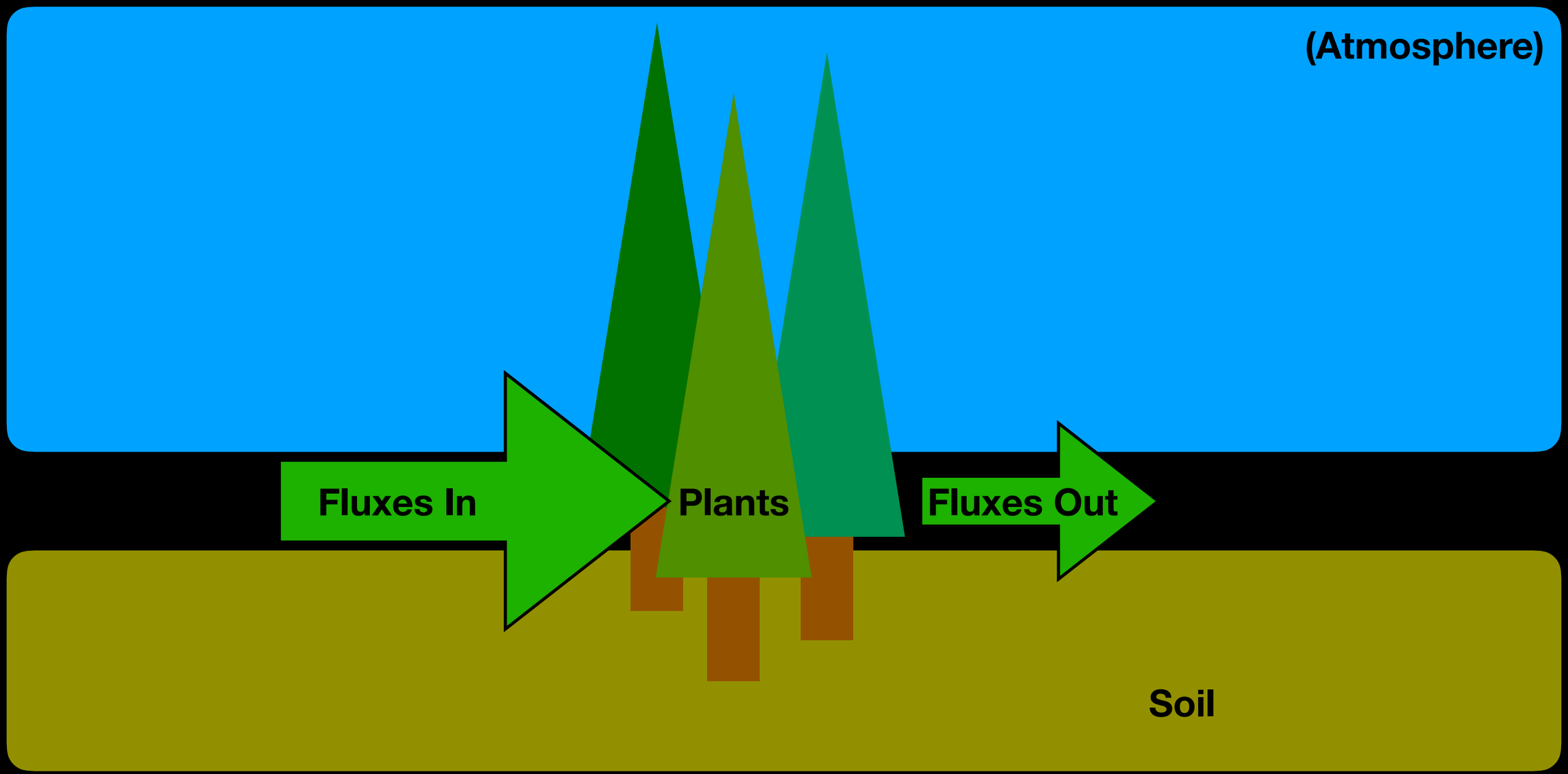


Soil

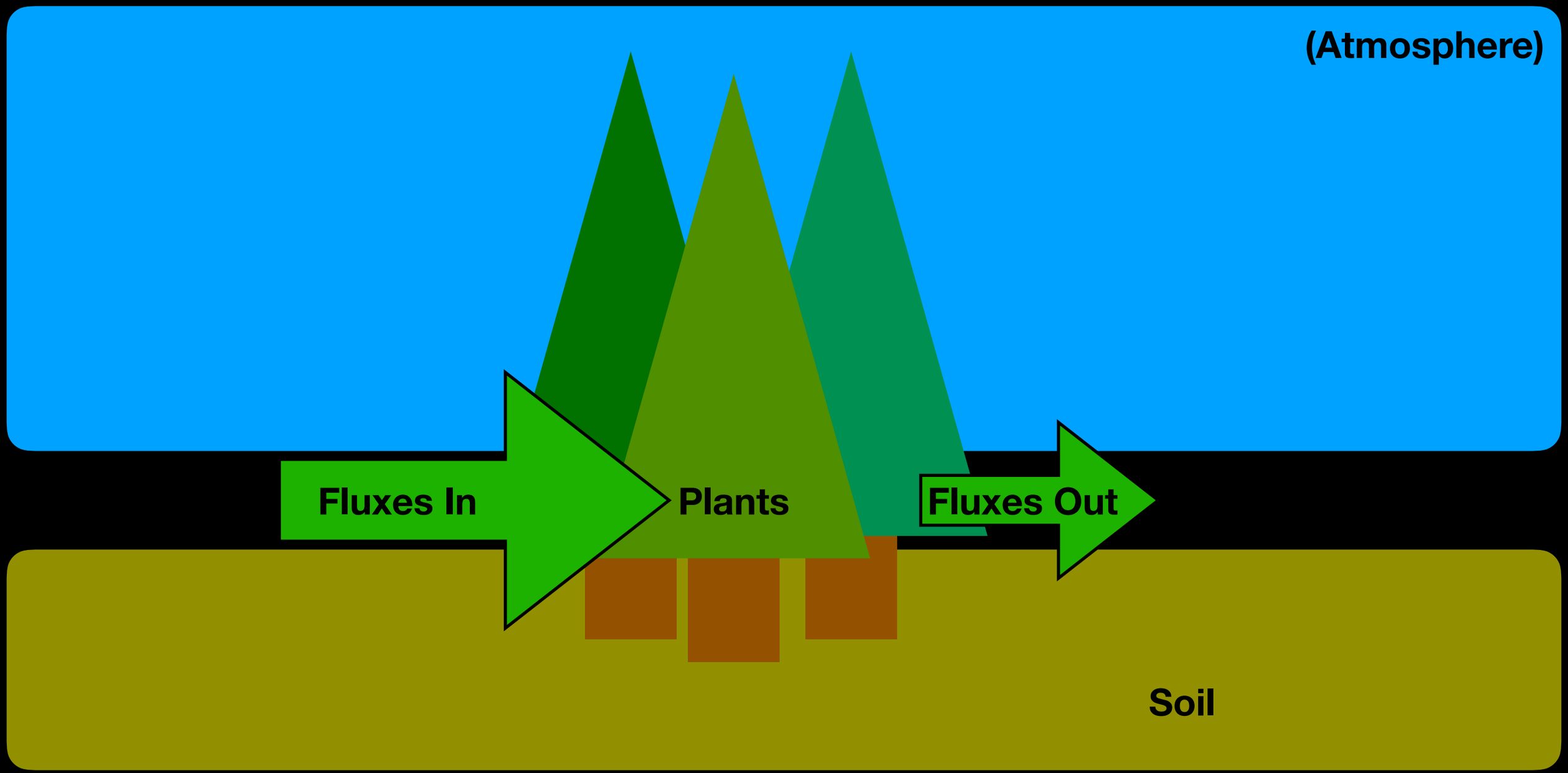
Terrestrial Nitrogen Pools



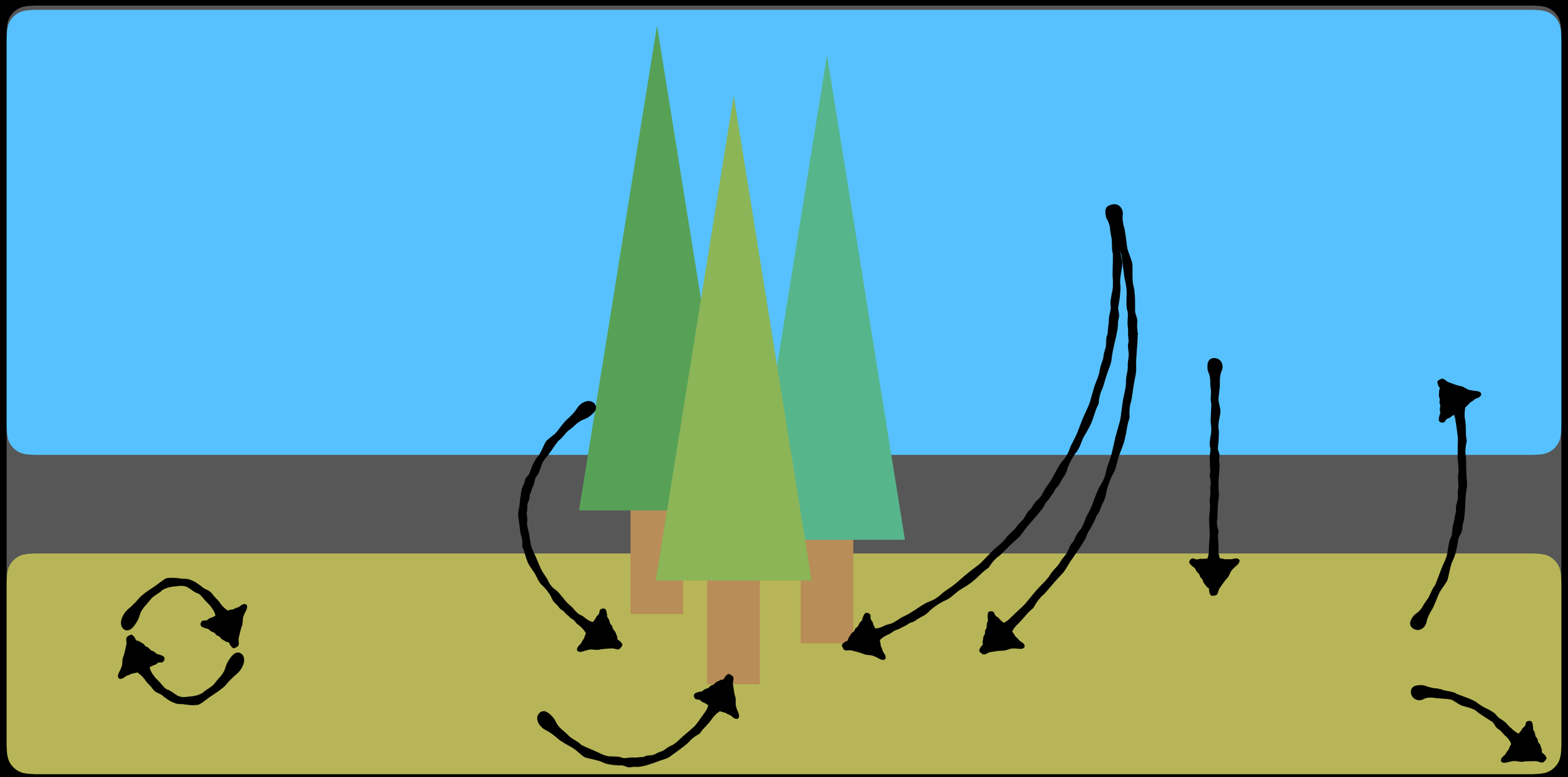
Terrestrial Nitrogen Pools



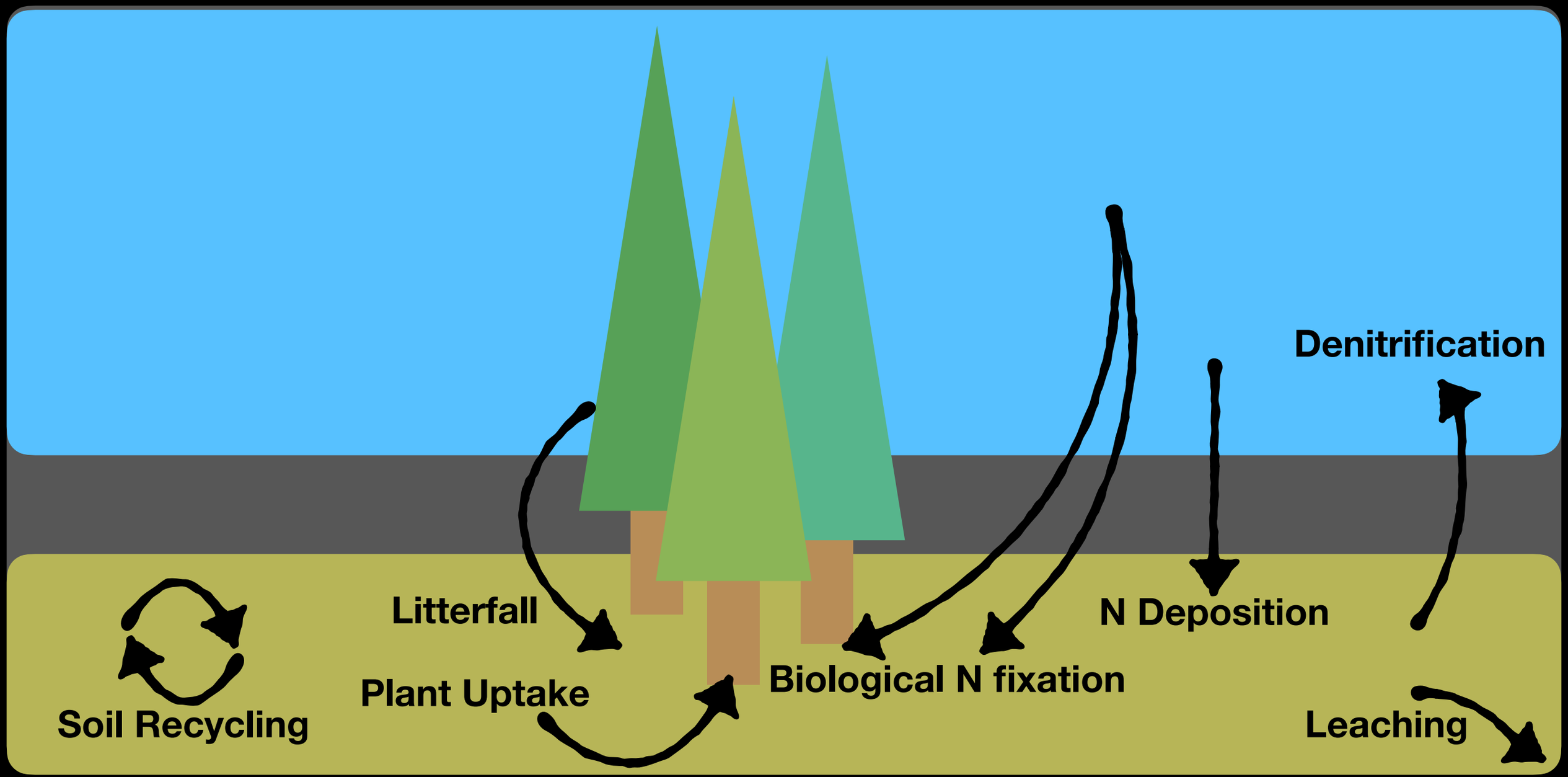
Terrestrial Nitrogen Pools



Terrestrial Nitrogen Fluxes



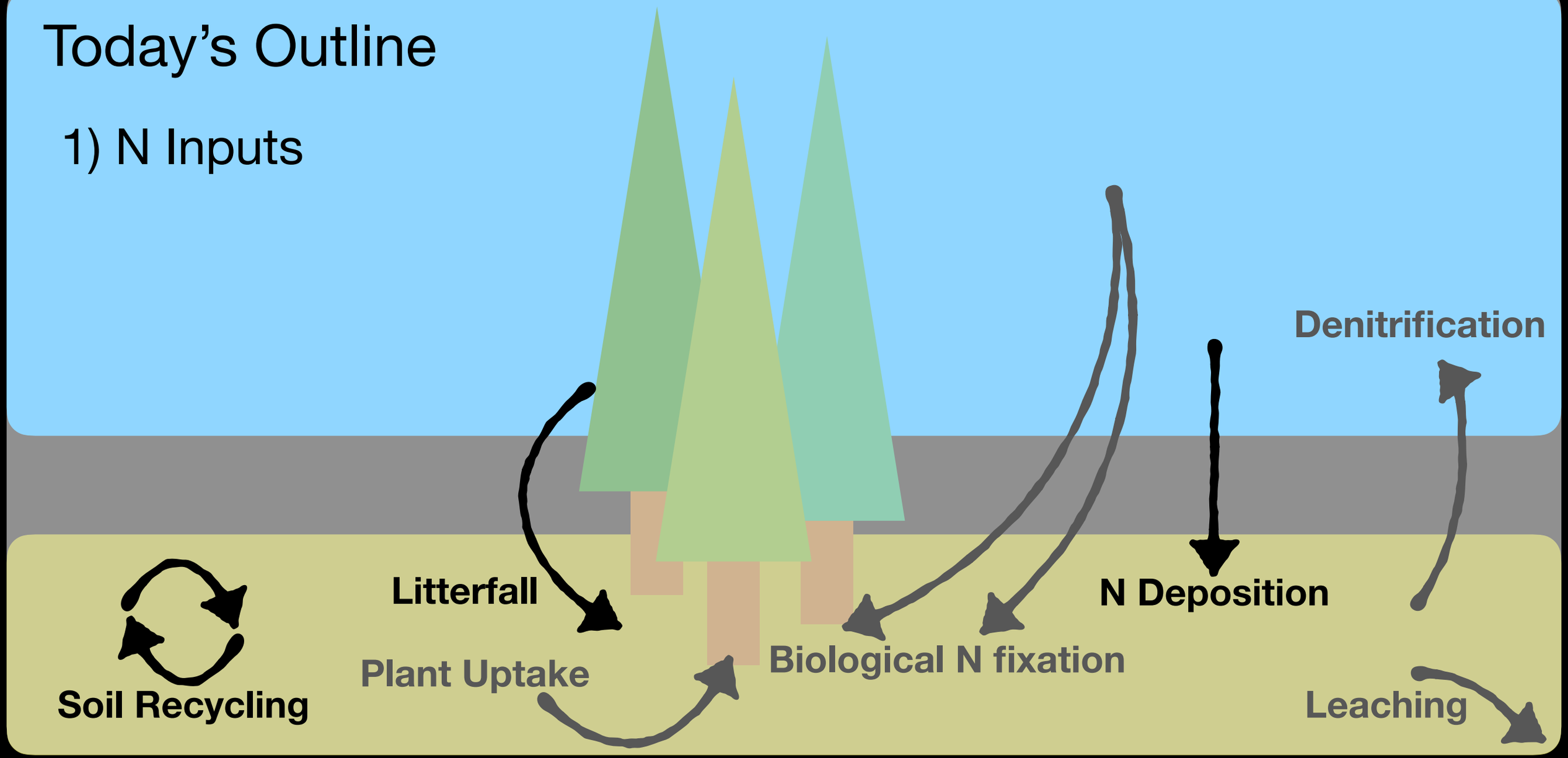
Terrestrial Nitrogen Fluxes



Terrestrial Nitrogen Fluxes

Today's Outline

1) N Inputs

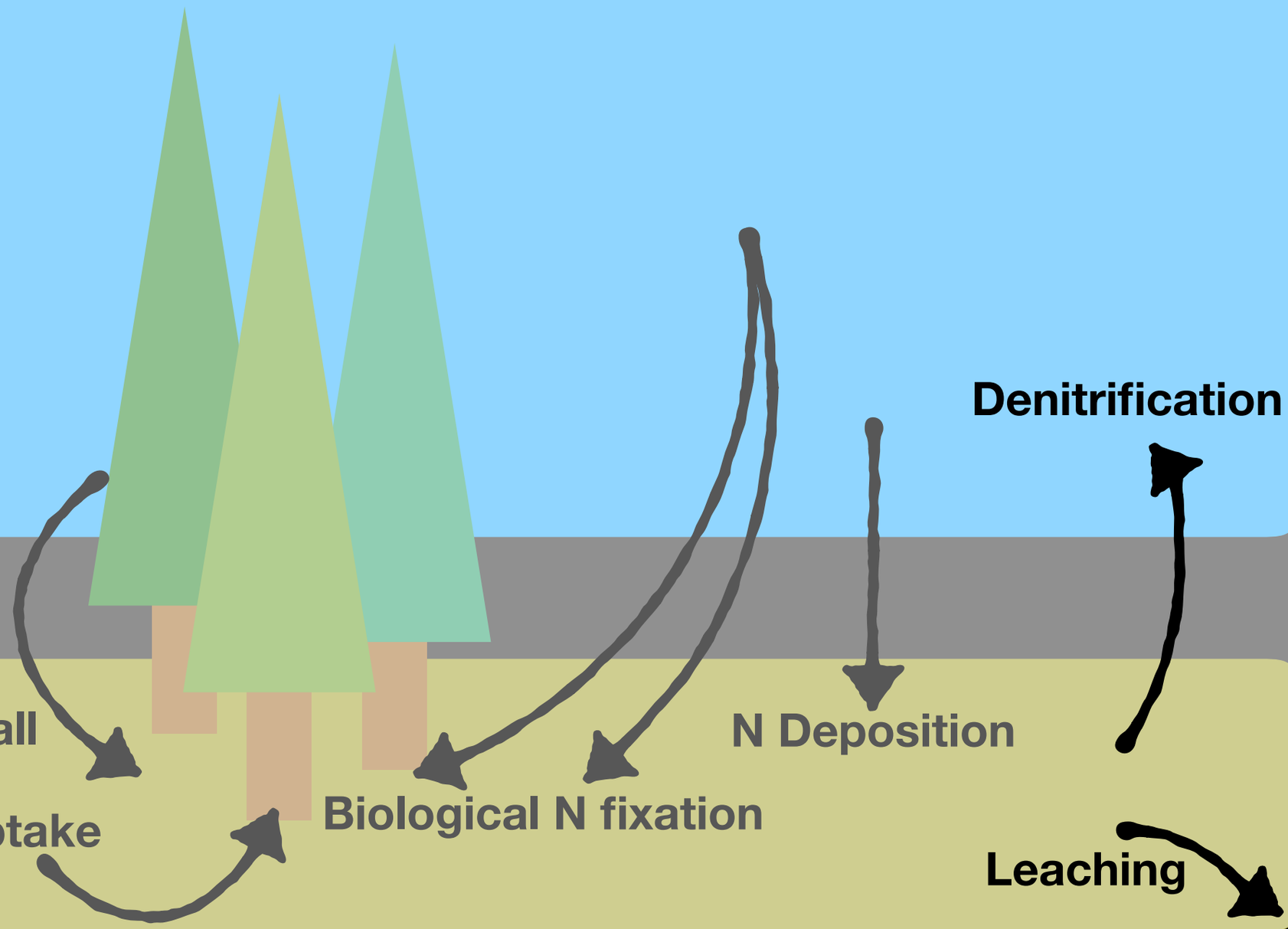


Terrestrial Nitrogen Fluxes

Today's Outline

1) N Inputs

2) N Losses



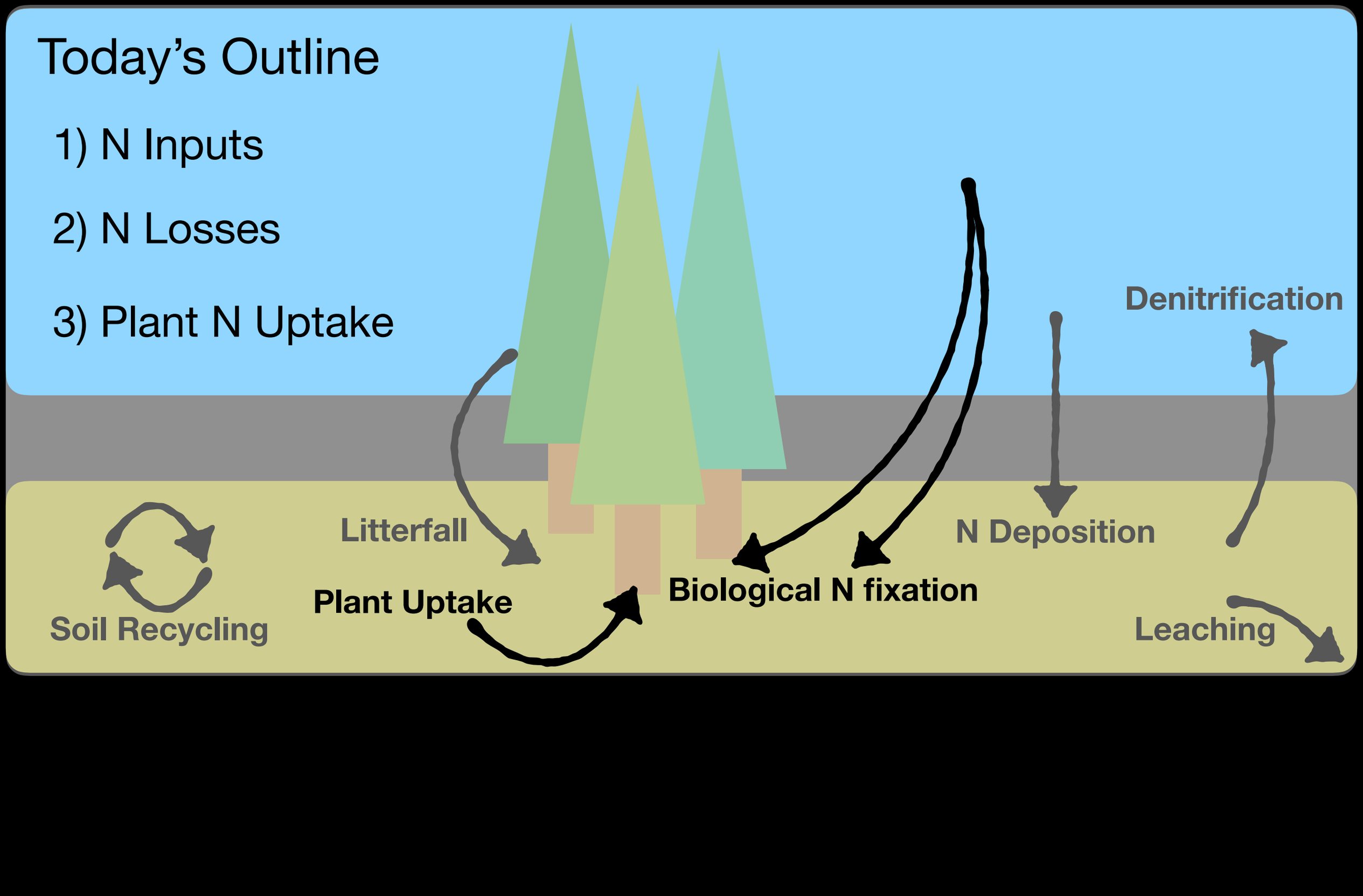
Terrestrial Nitrogen Fluxes

Today's Outline

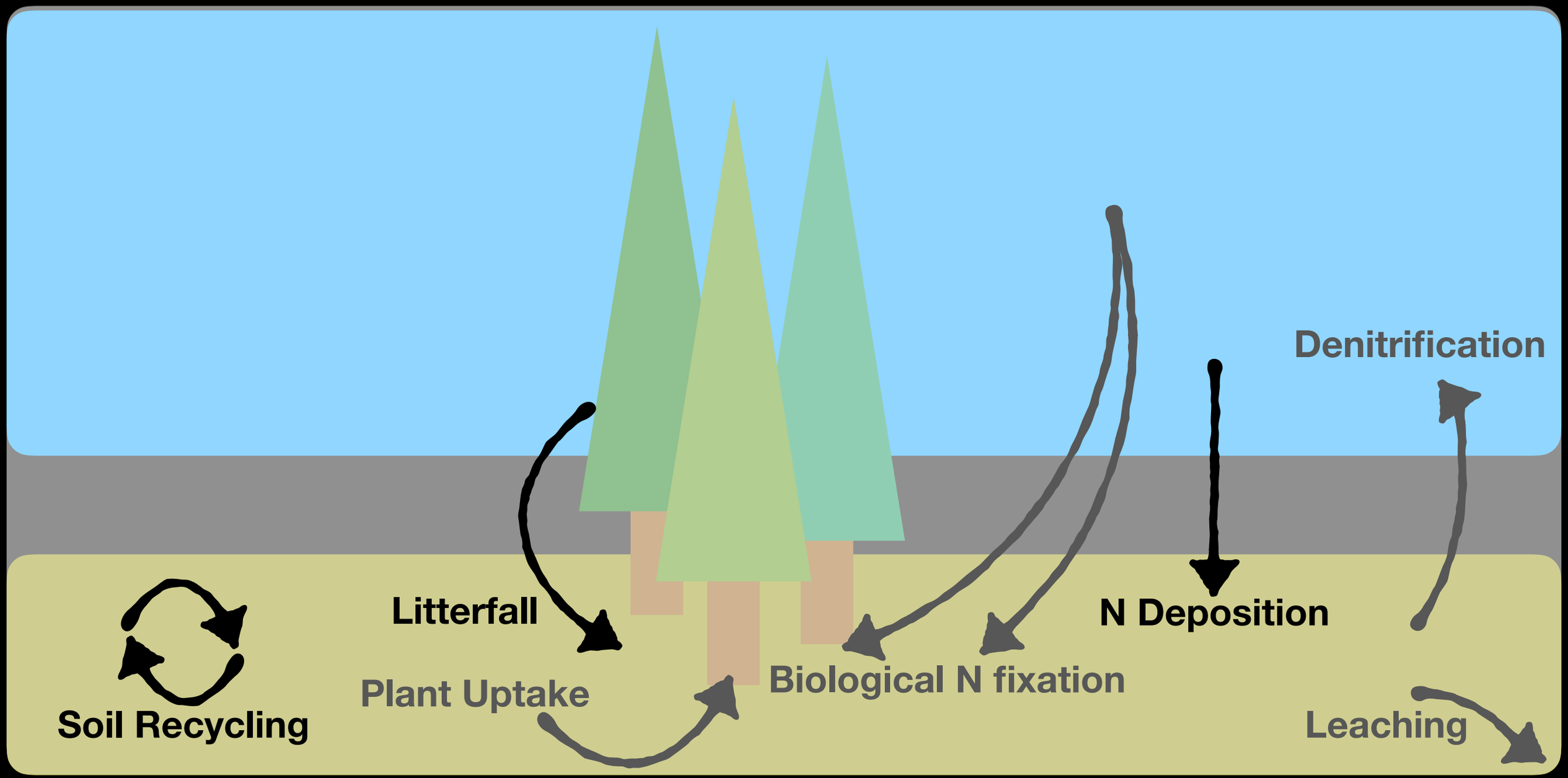
1) N Inputs

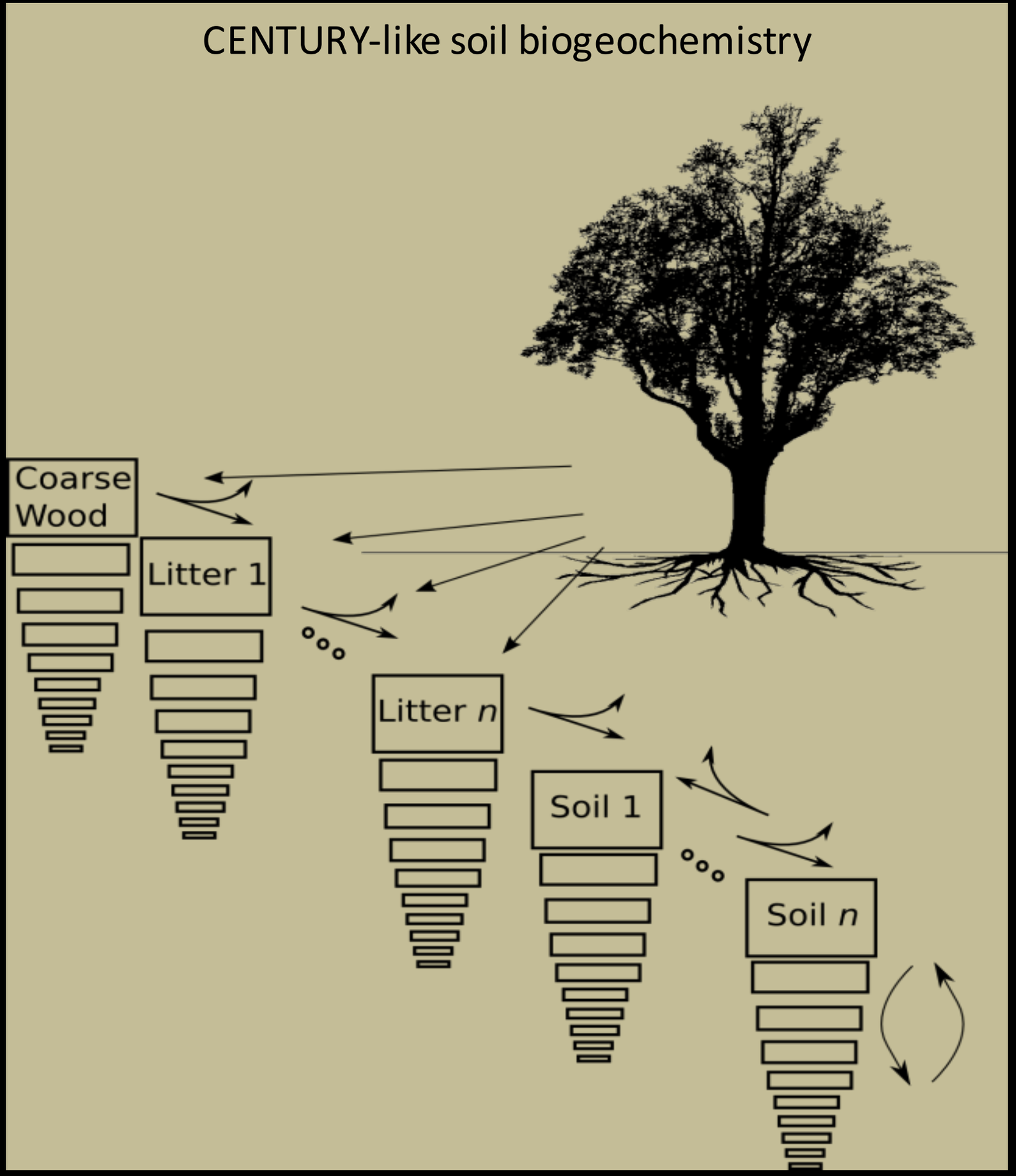
2) N Losses

3) Plant N Uptake



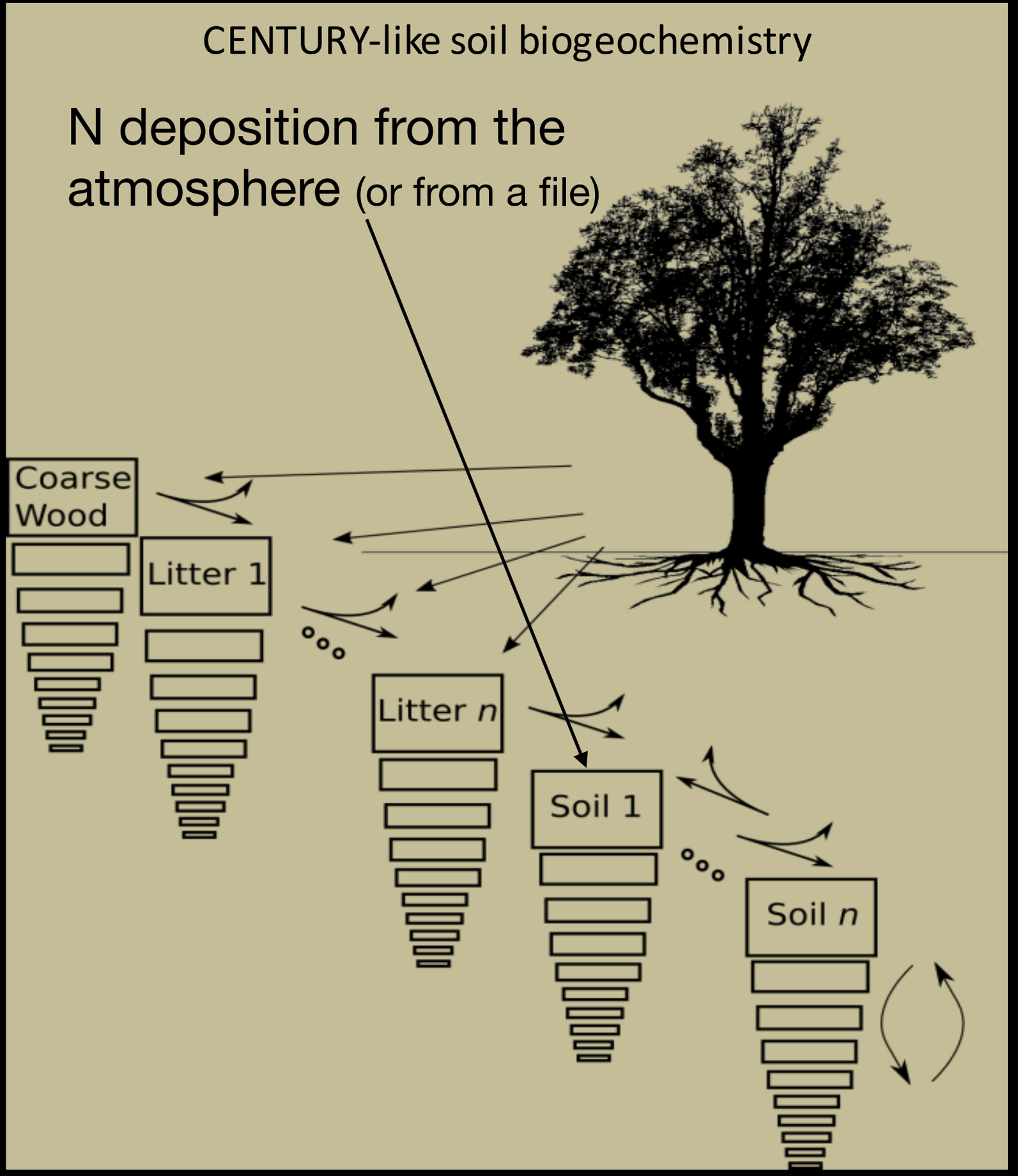
Terrestrial Nitrogen Fluxes





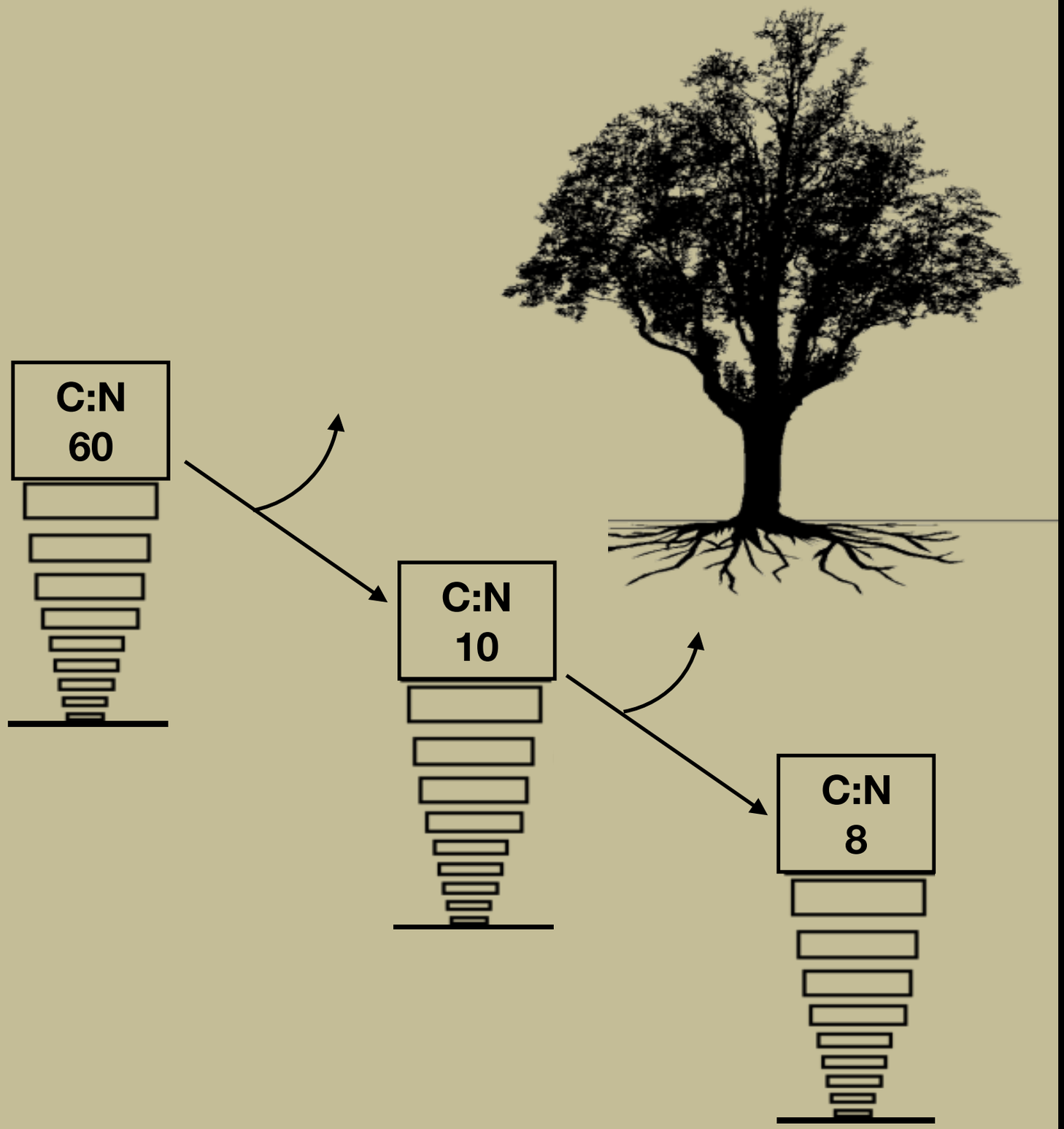
Koven et al. *Biogeosciences* 2013

CENTURY-like soil biogeochemistry



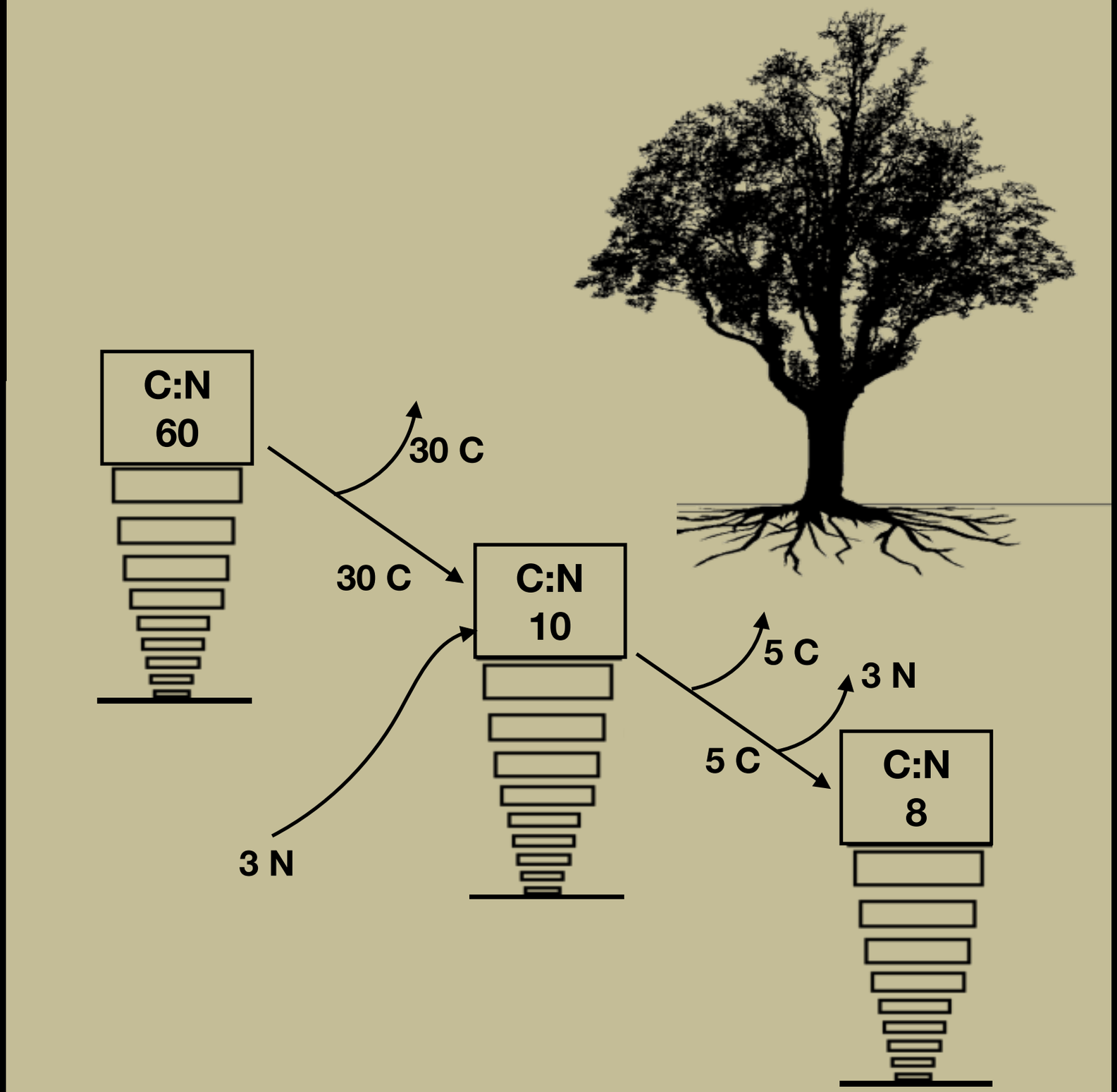
Koven et al. *Biogeosciences* 2013

CENTURY-like soil biogeochemistry



Koven et al. *Biogeosciences* 2013

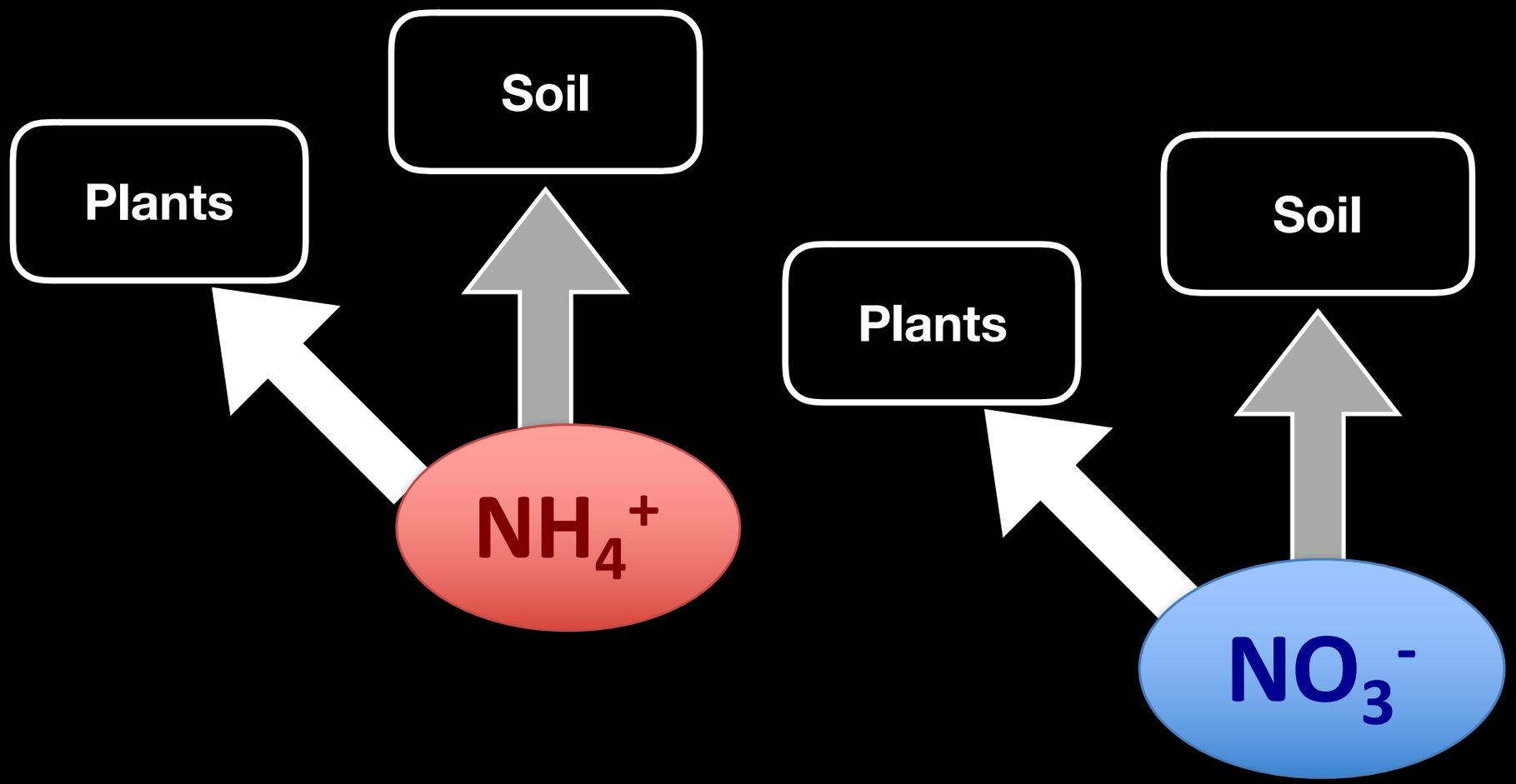
CENTURY-like soil biogeochemistry



50% of C is lost to respiration

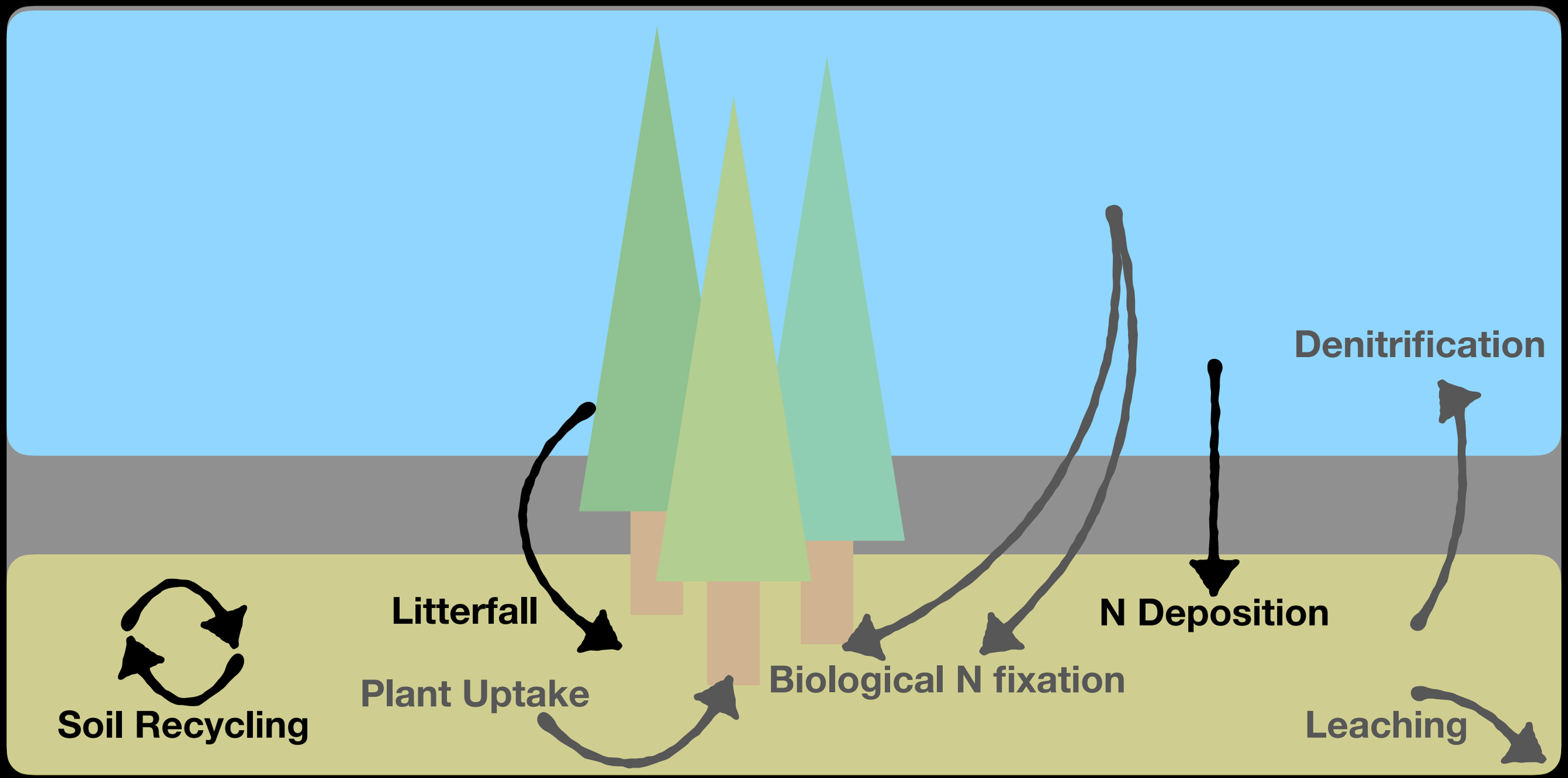
Koven et al. *Biogeosciences* 2013

N uptake & competition

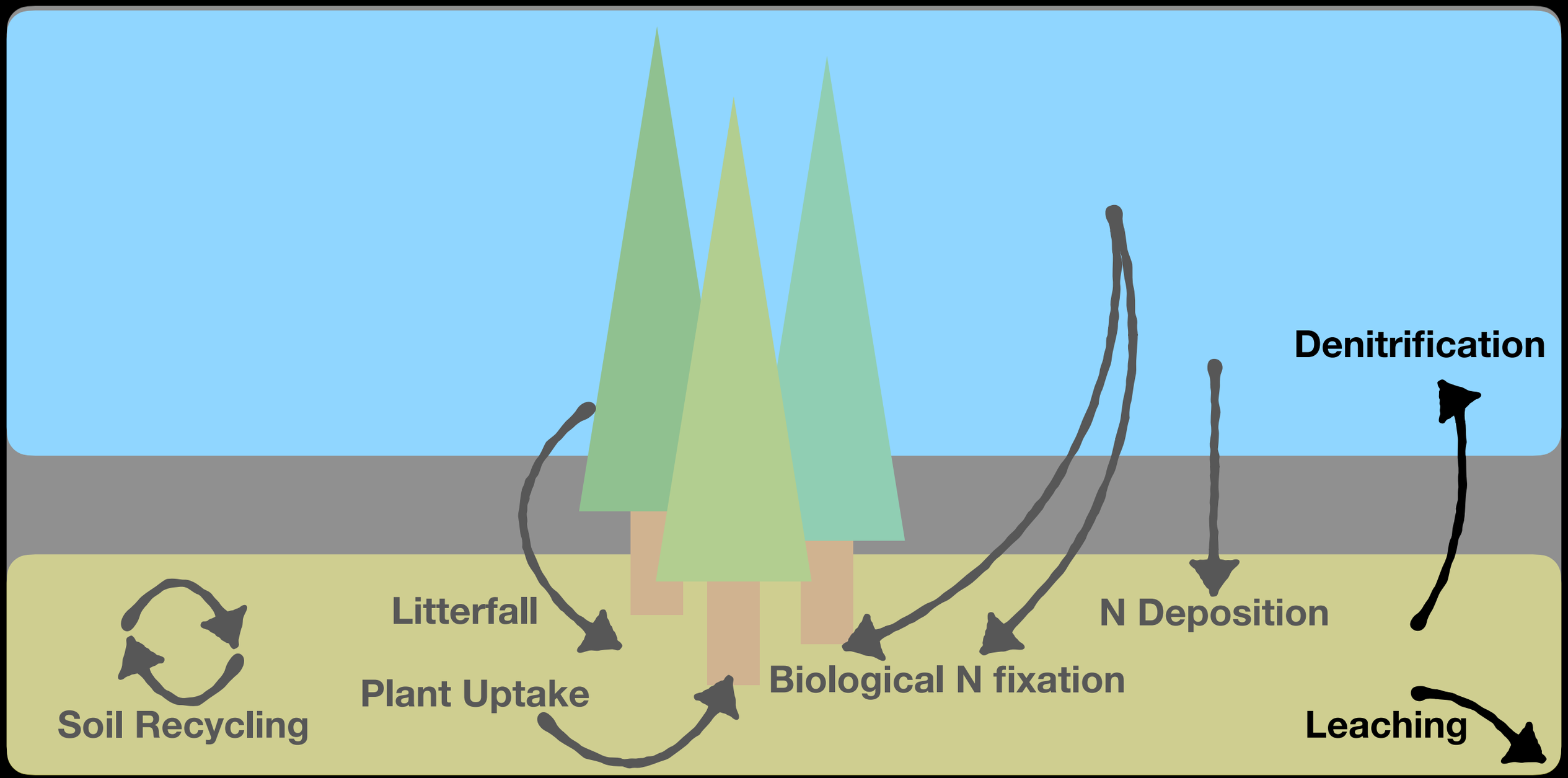


Slide courtesy of W. Wieder

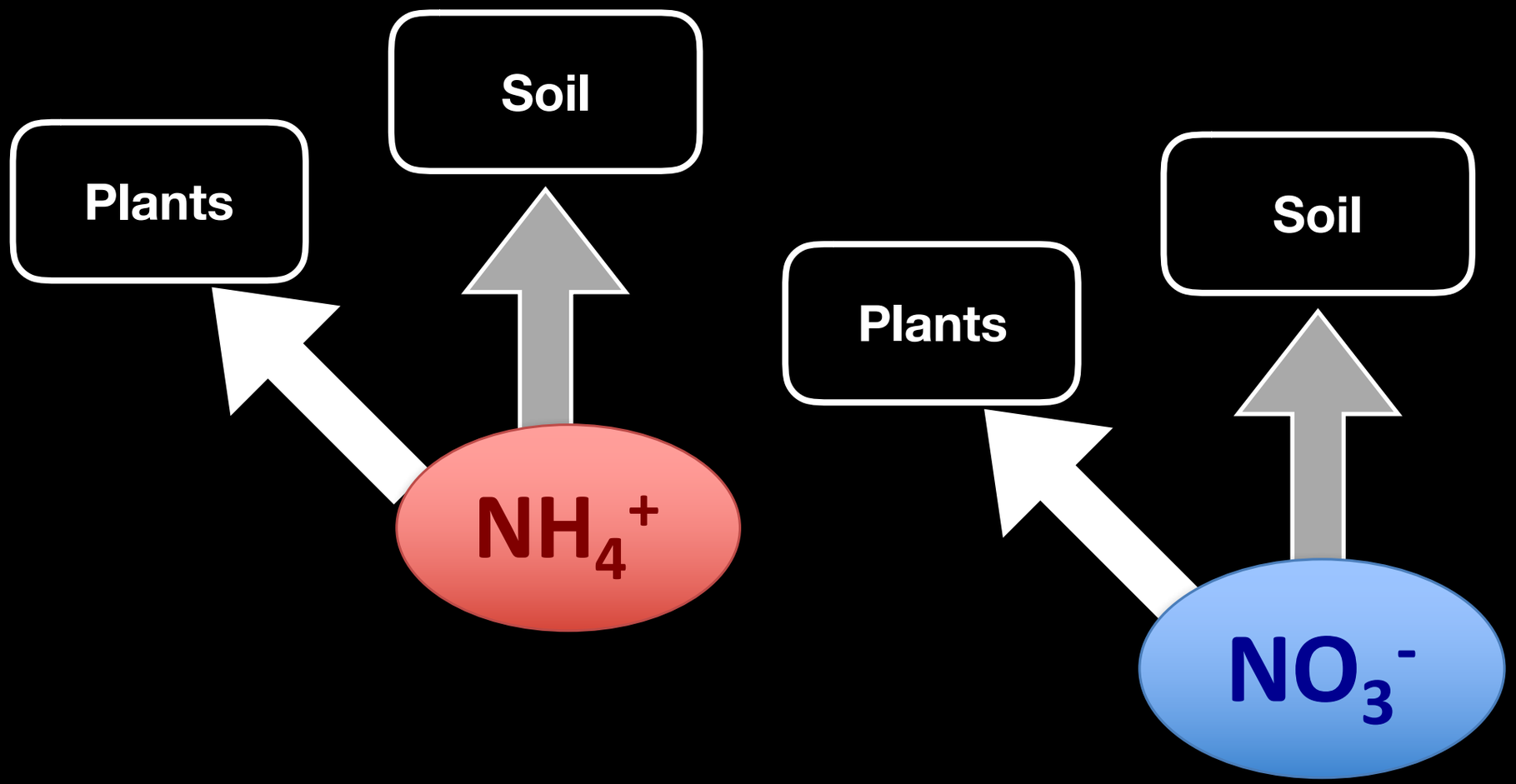
Terrestrial Nitrogen Fluxes



Terrestrial Nitrogen Fluxes



N uptake & competition



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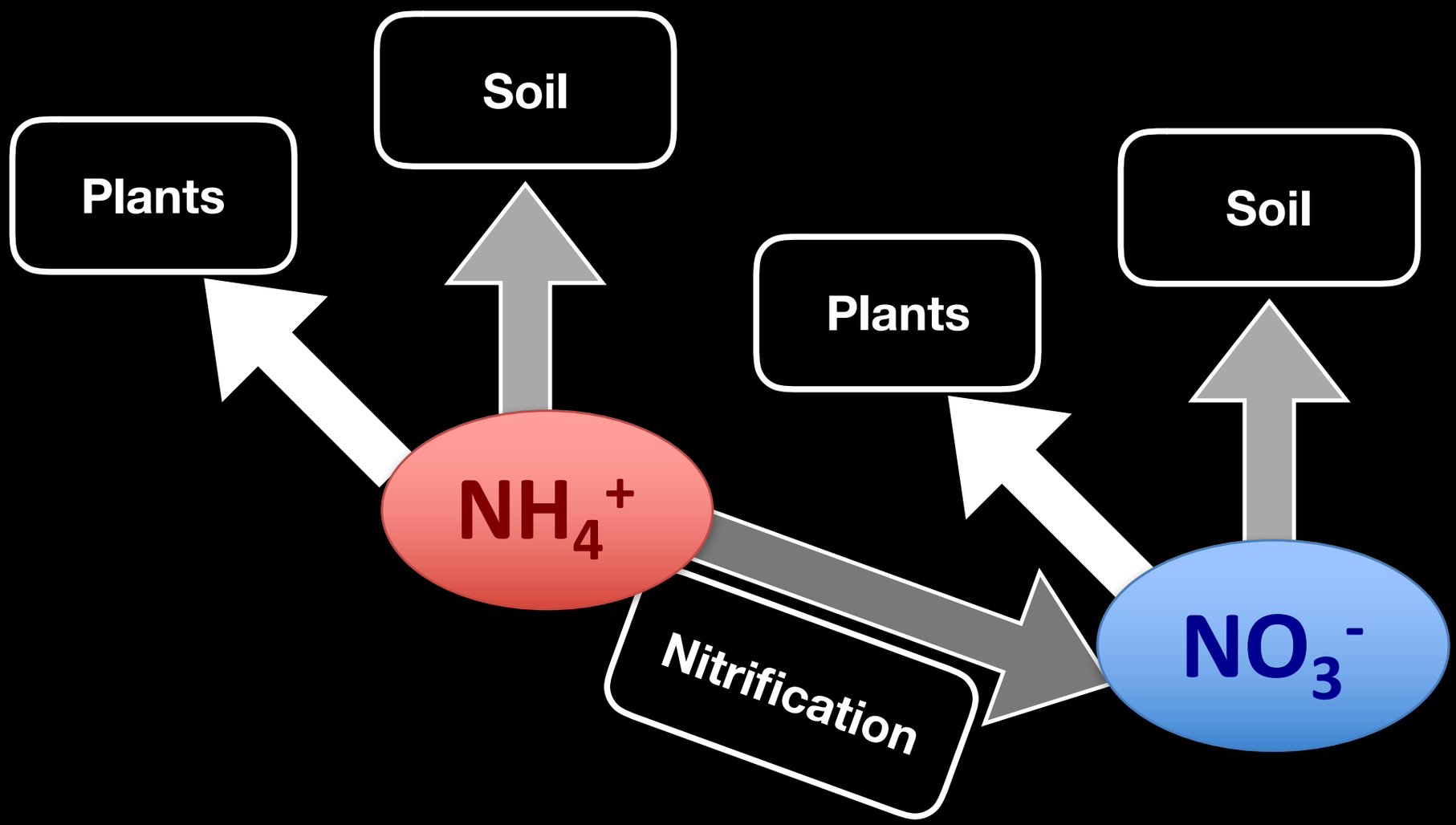
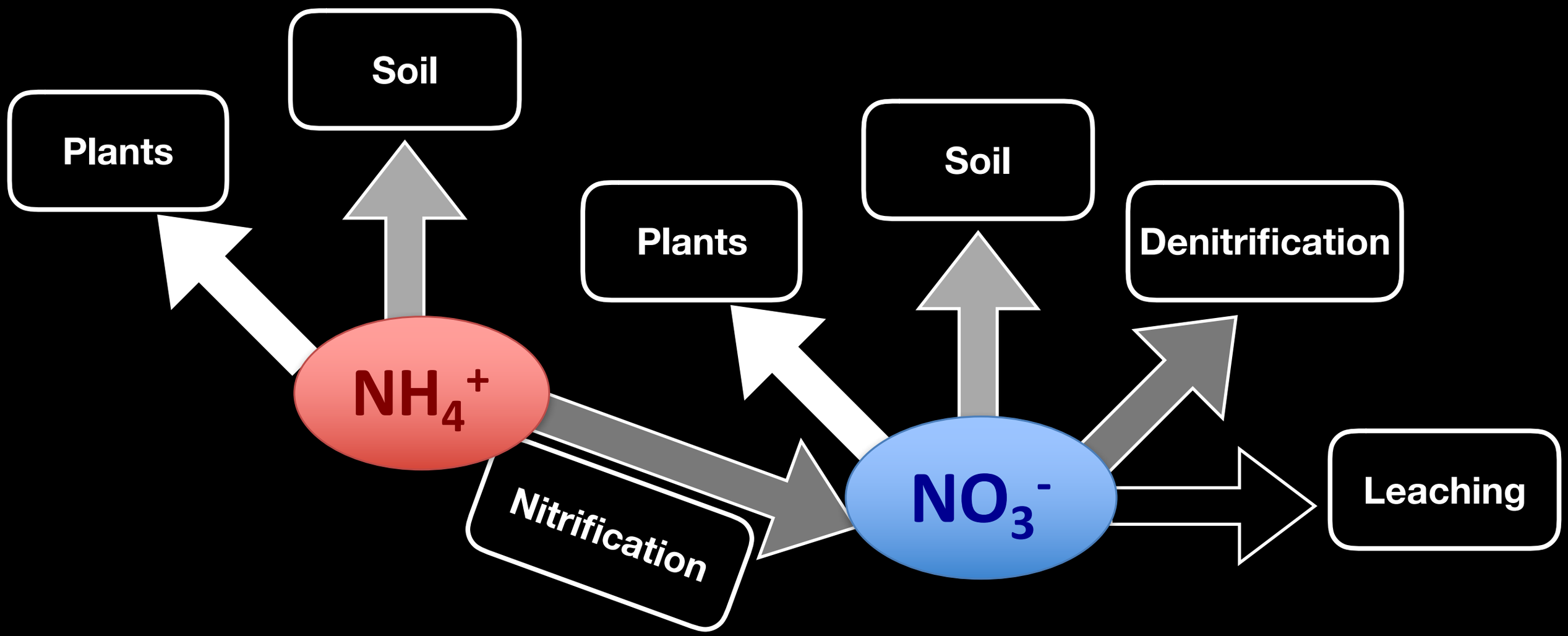


Slide courtesy of W. Wieder

N uptake & competition

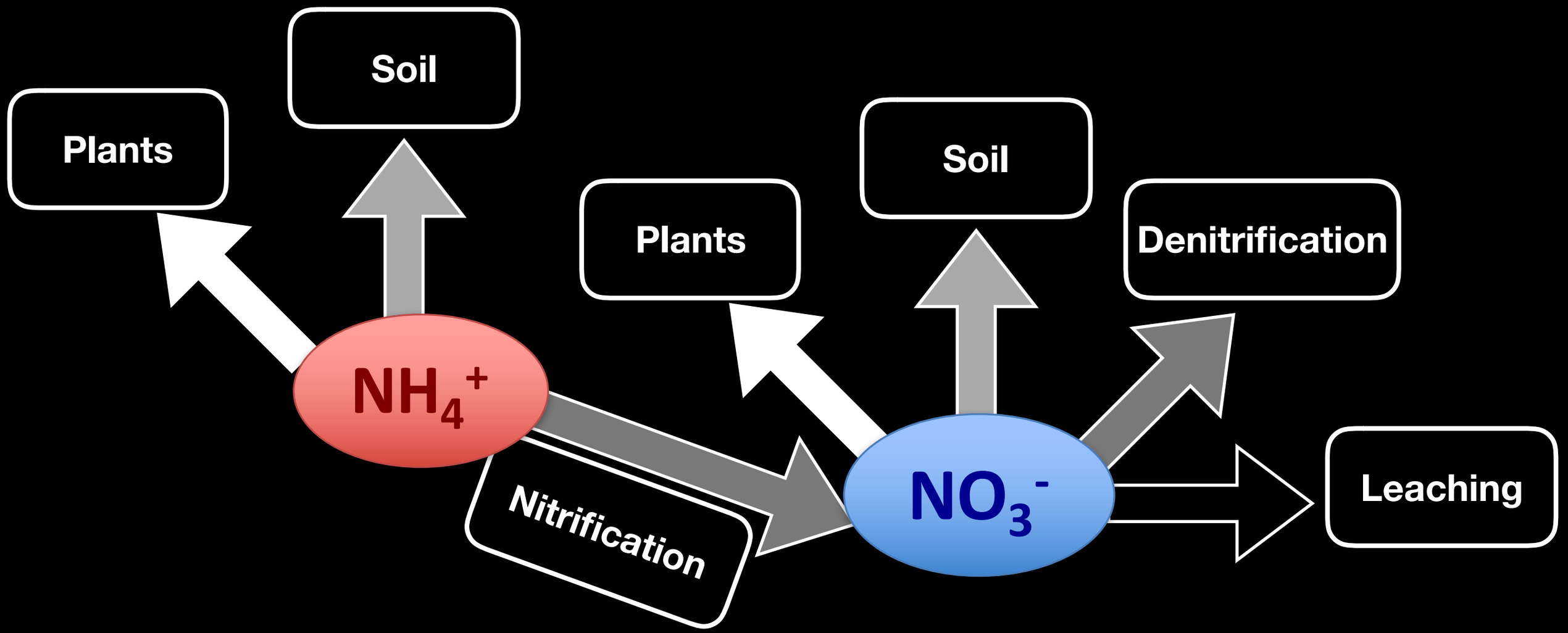


Slide courtesy of W. Wieder

N uptake & competition

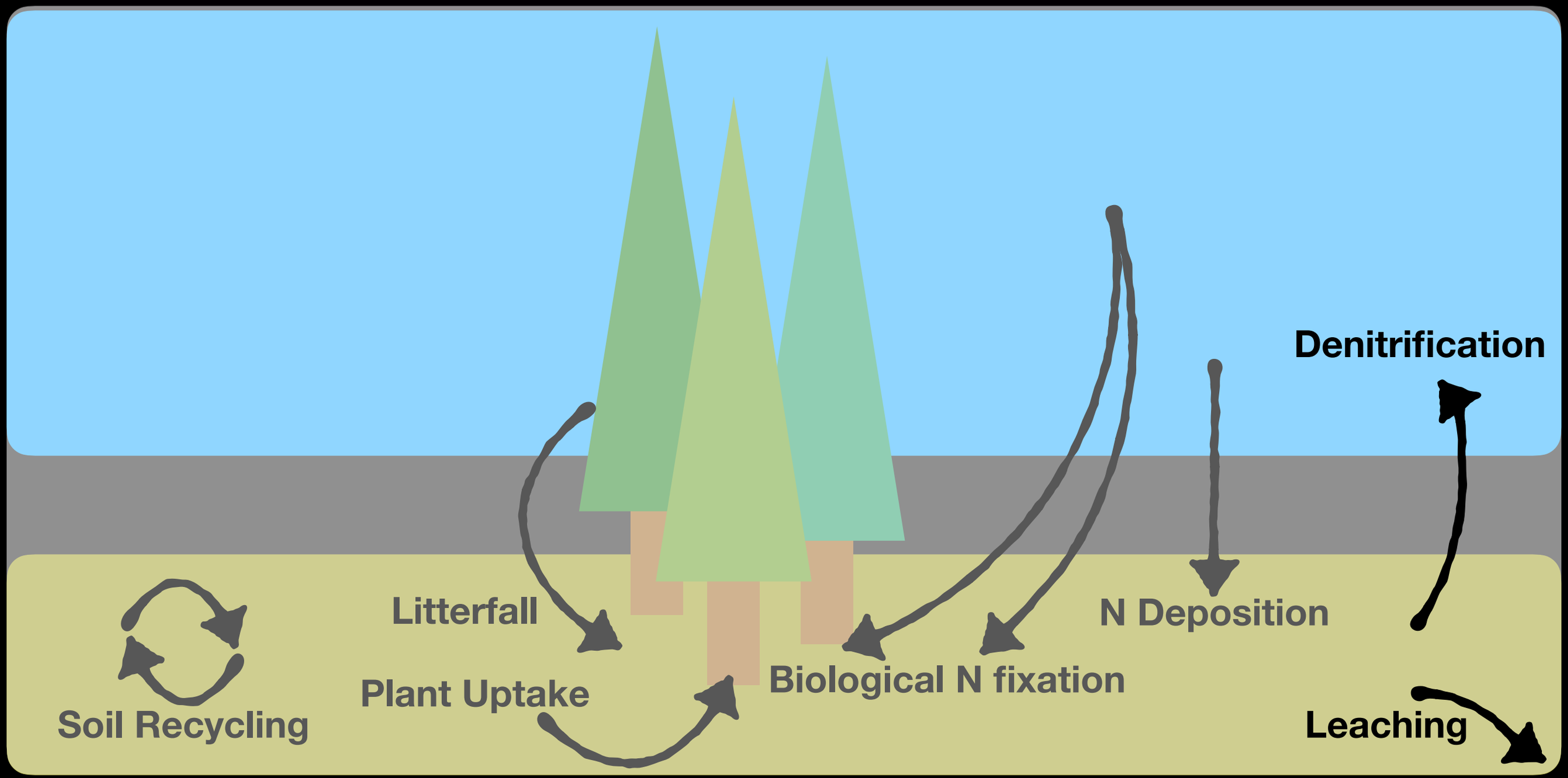
Known Issues:

- Large denitrification fluxes
  (Thomas et al. 2013 GBC; Houlton et al. 2015 NCC)
- No leaching or DON losses
  (Nevison et al. 2016 JAMES)

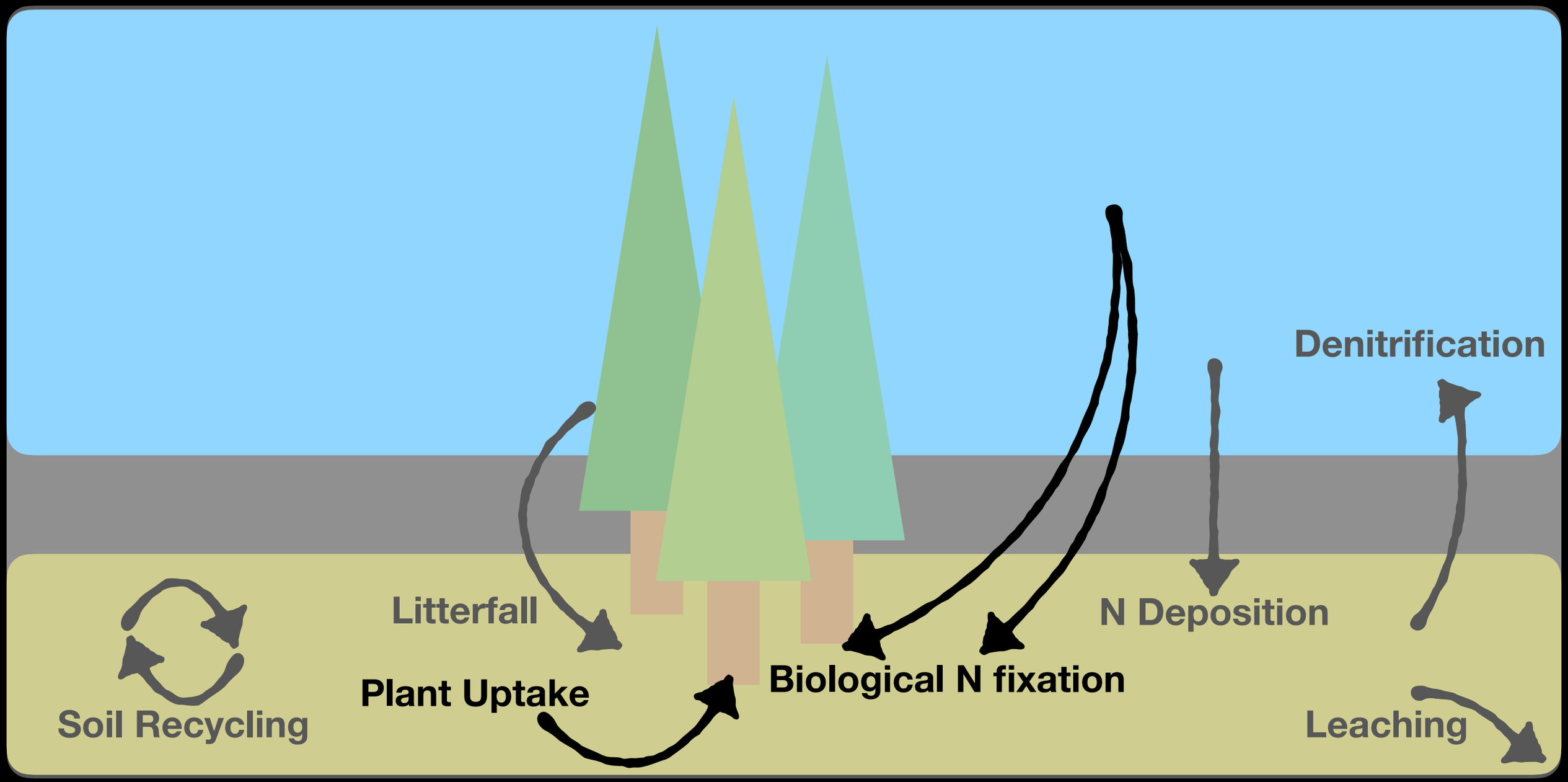


Slide courtesy of W. Wieder

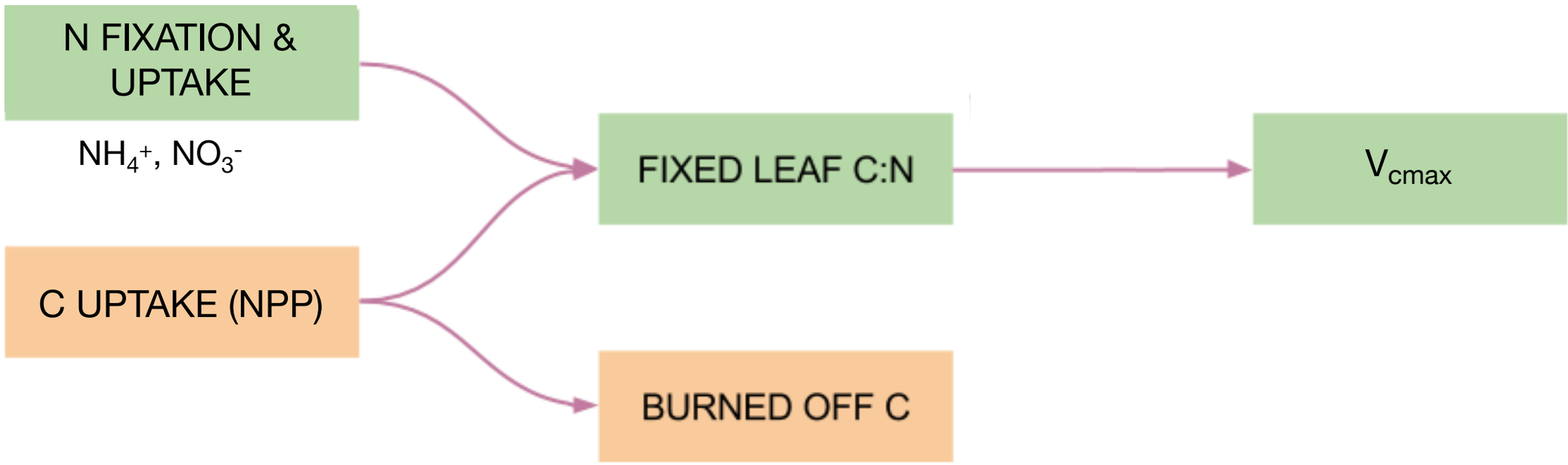
Terrestrial Nitrogen Fluxes



Terrestrial Nitrogen Fluxes



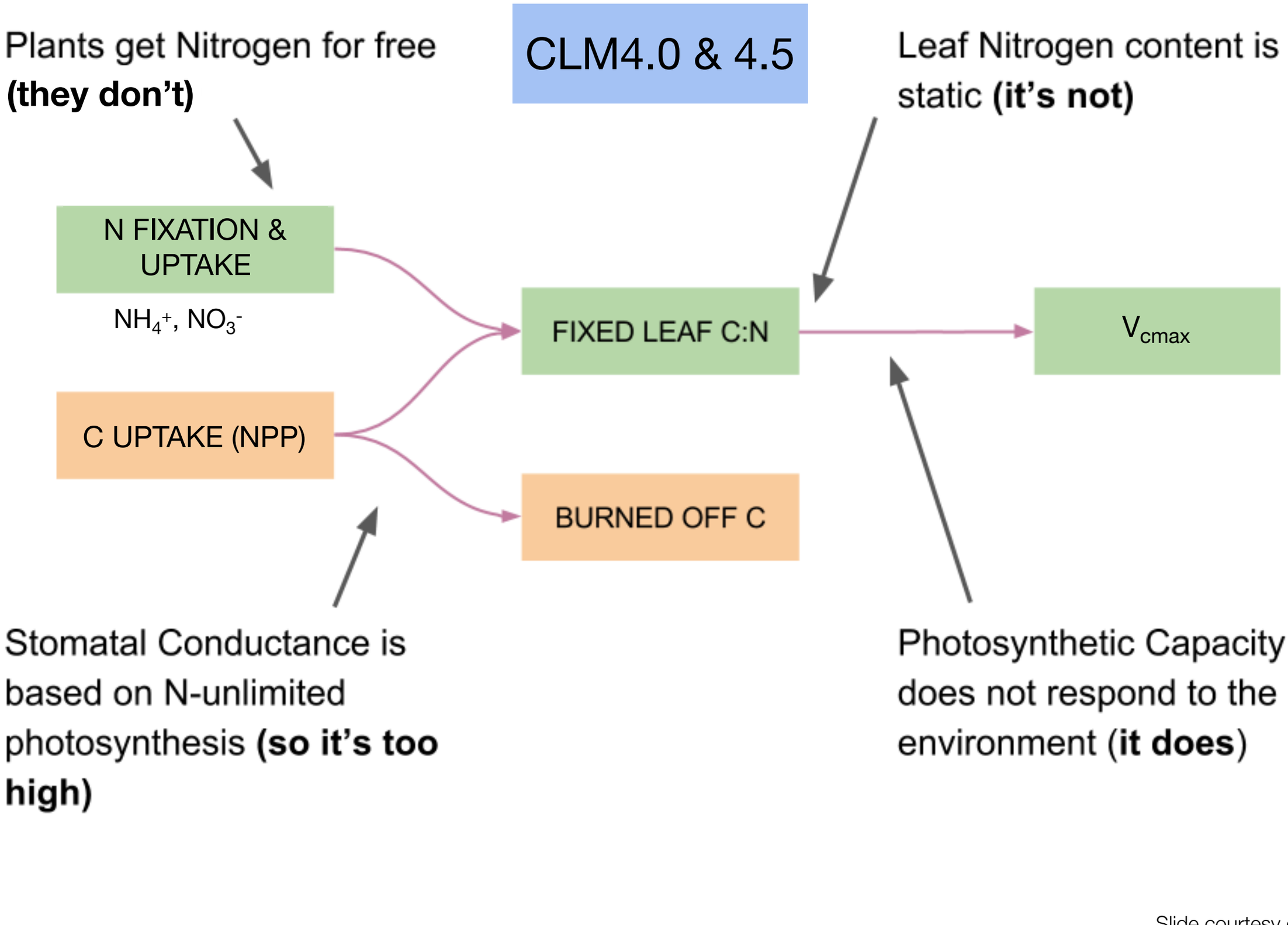
CLM4.0 & 4.5



Slide courtesy of R. Fisher

Issues raised with the CLM N cycle

(CLM4.0 and CLM4.5 N cycle is similar to N representation in other terrestrial models)



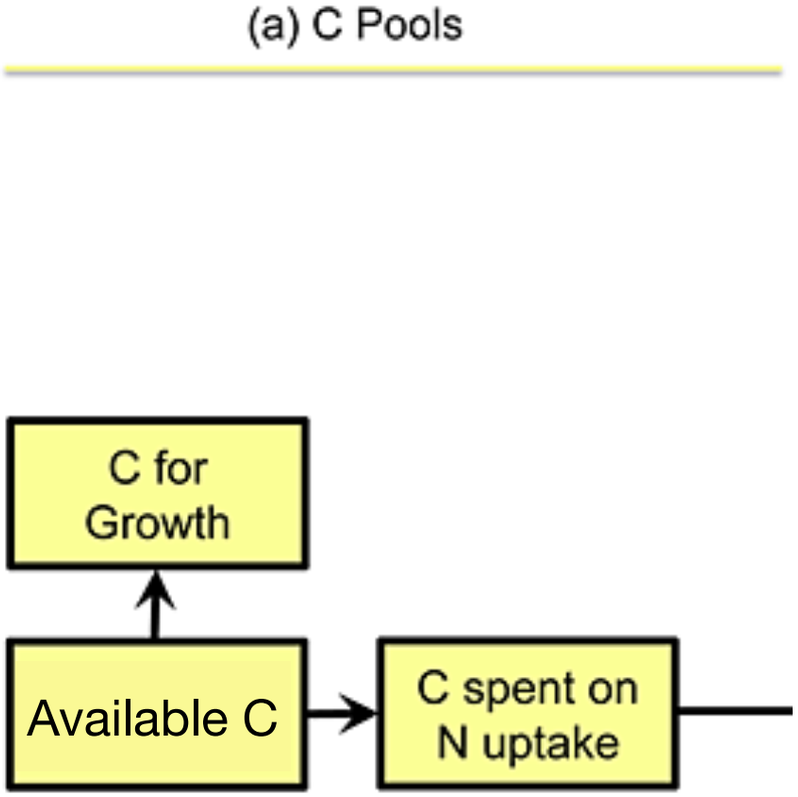
Slide courtesy of R. Fisher

Problem 1: Plants get Nitrogen for free

The FUN* Model

A marketplace for Nitrogen Uptake

*__F__ixation and __U__ptake of __N__itrogen



Hypothesis:
Plants will take up N from the cheapest sources

Based on work by:
J. Fisher et al. 2010 *GBC*
Brzostek et al. 2014 *JGR-Biogeosciences*

Slide courtesy of R. Fisher

The FUN* Model

A marketplace for Nitrogen Uptake

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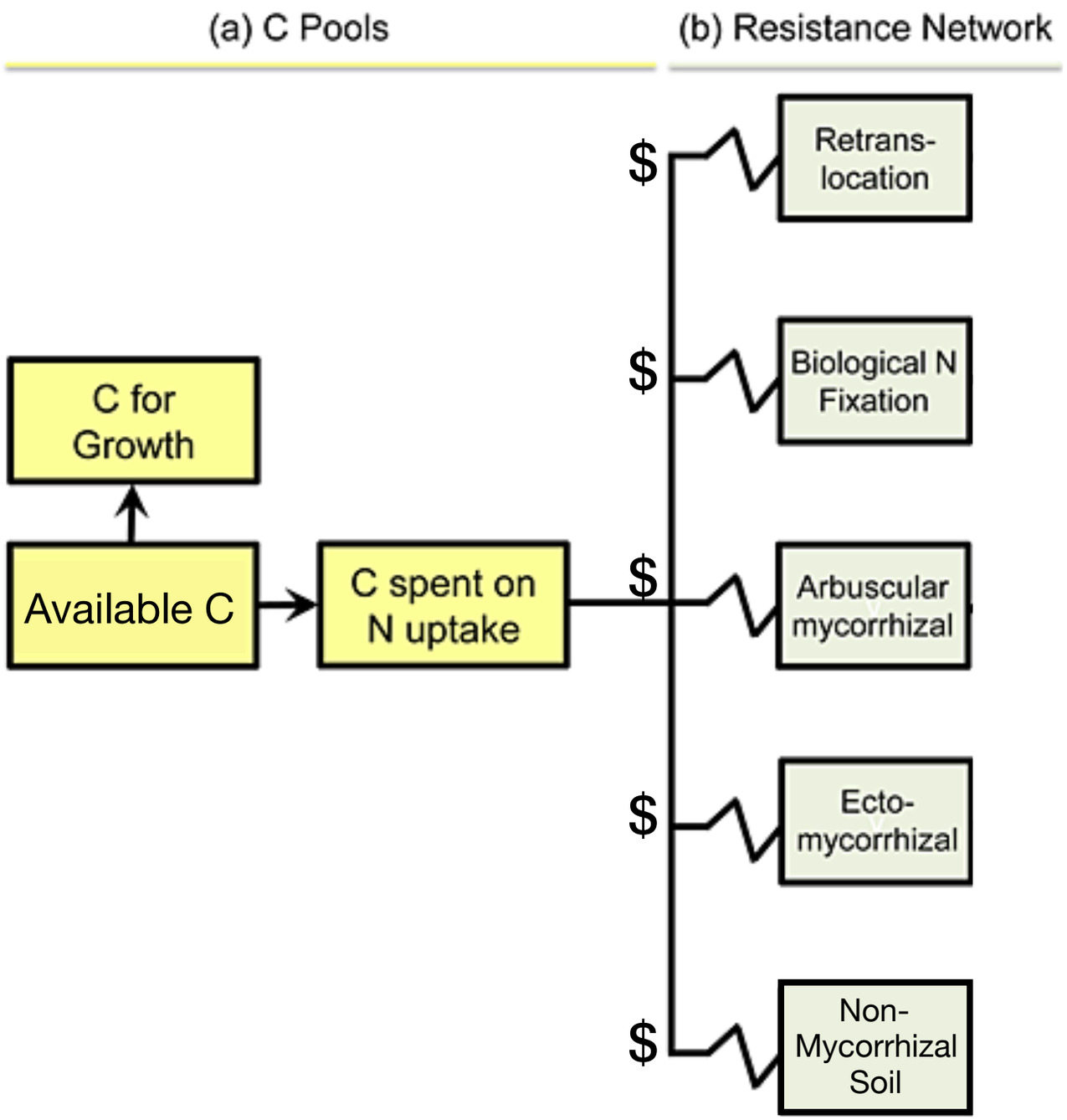

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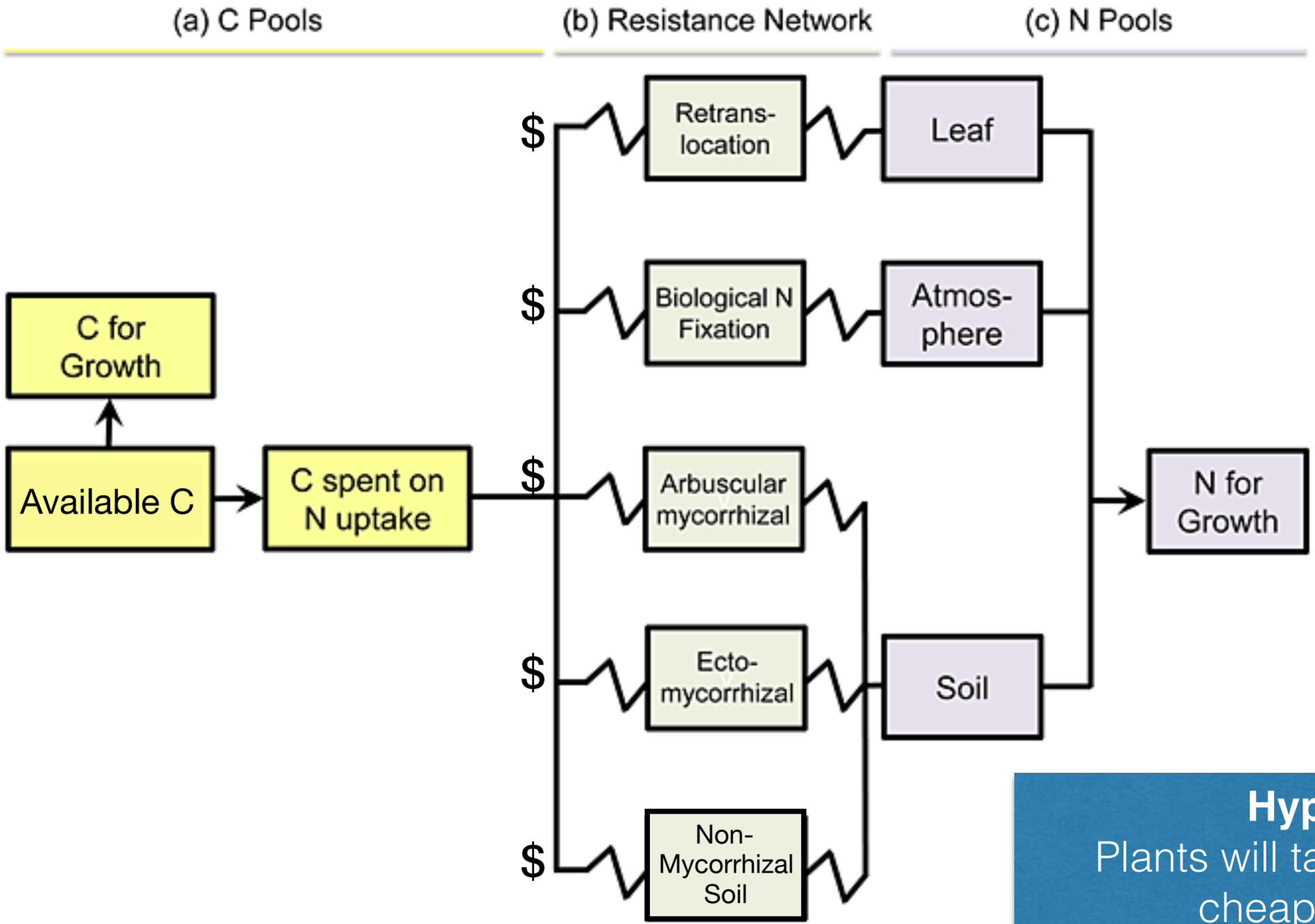

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The FUN* Model

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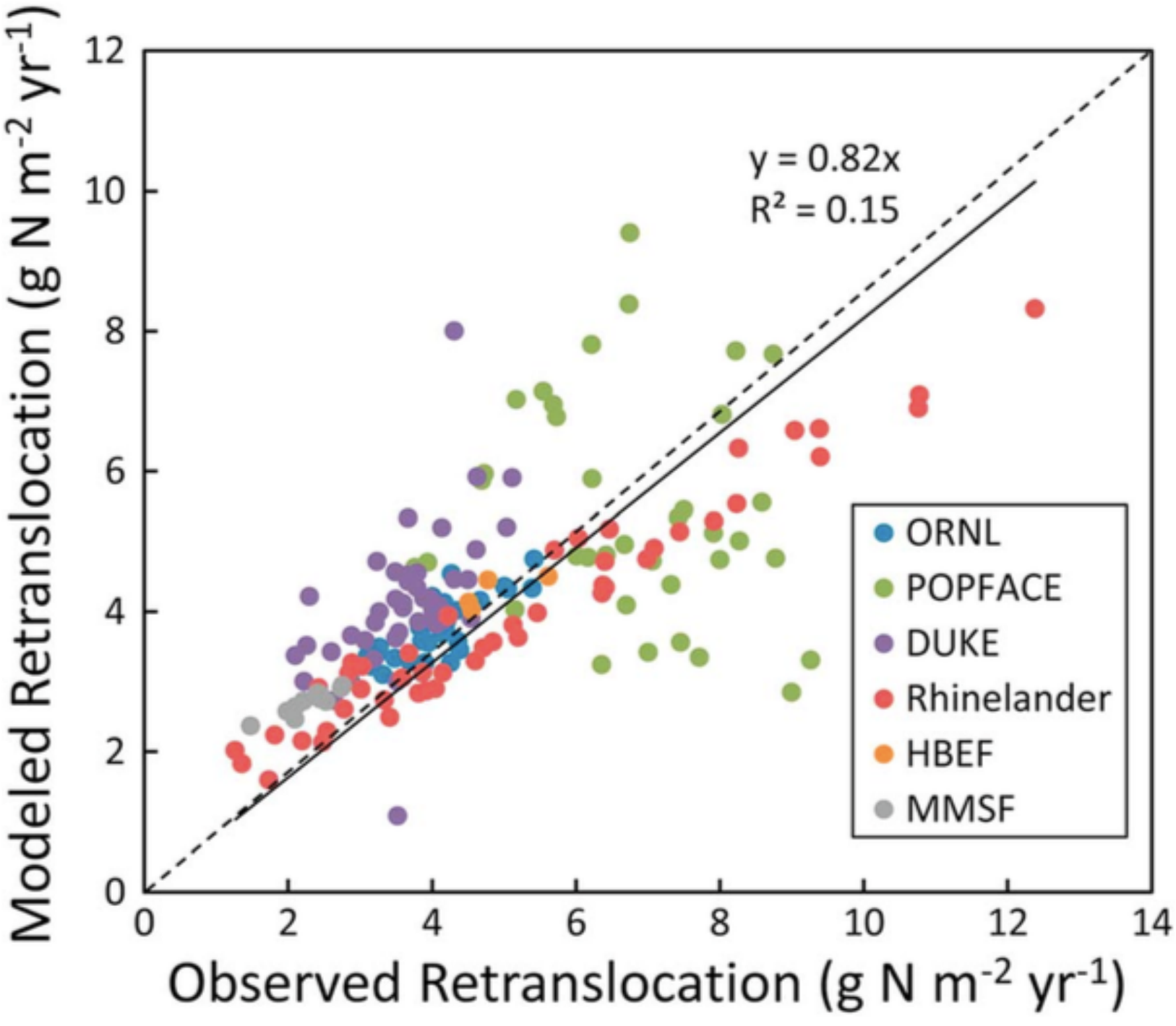


Fisher et al. 2010 *GBC*, Brzostek et al. 2014 *JGR-Biogeosciences*

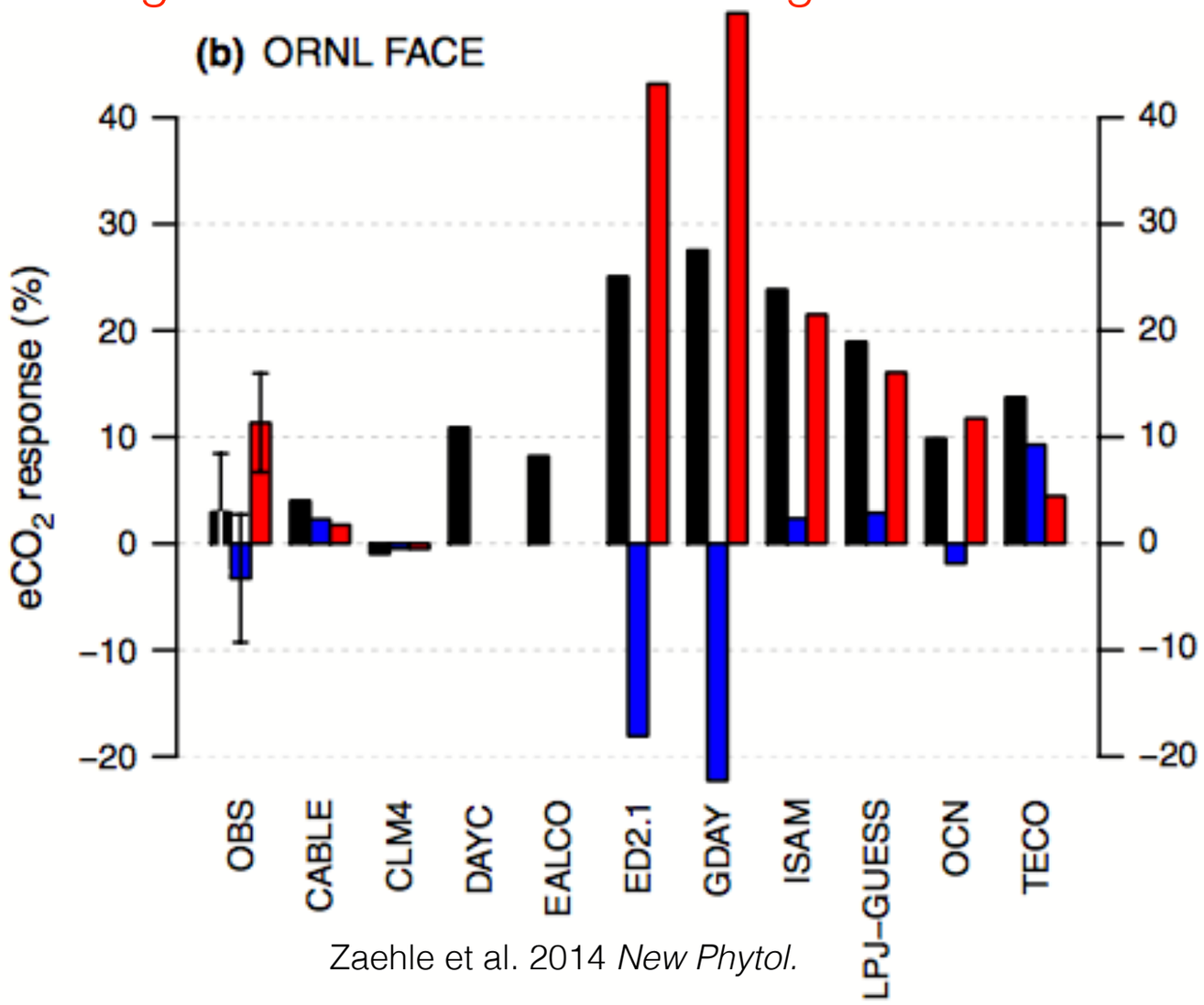
Problem 2: Leaf Nitrogen content is static

The FlexCN Model

Variable carbon:nitrogen ratios

Motivation:

Increase in biomass production due to increased nitrogen use efficiency (NUE)
Change in NUE attributed to increased allocation
Change in NUE attributed to change C:N ratio



Zaehle et al. 2014 *New Phytol.*

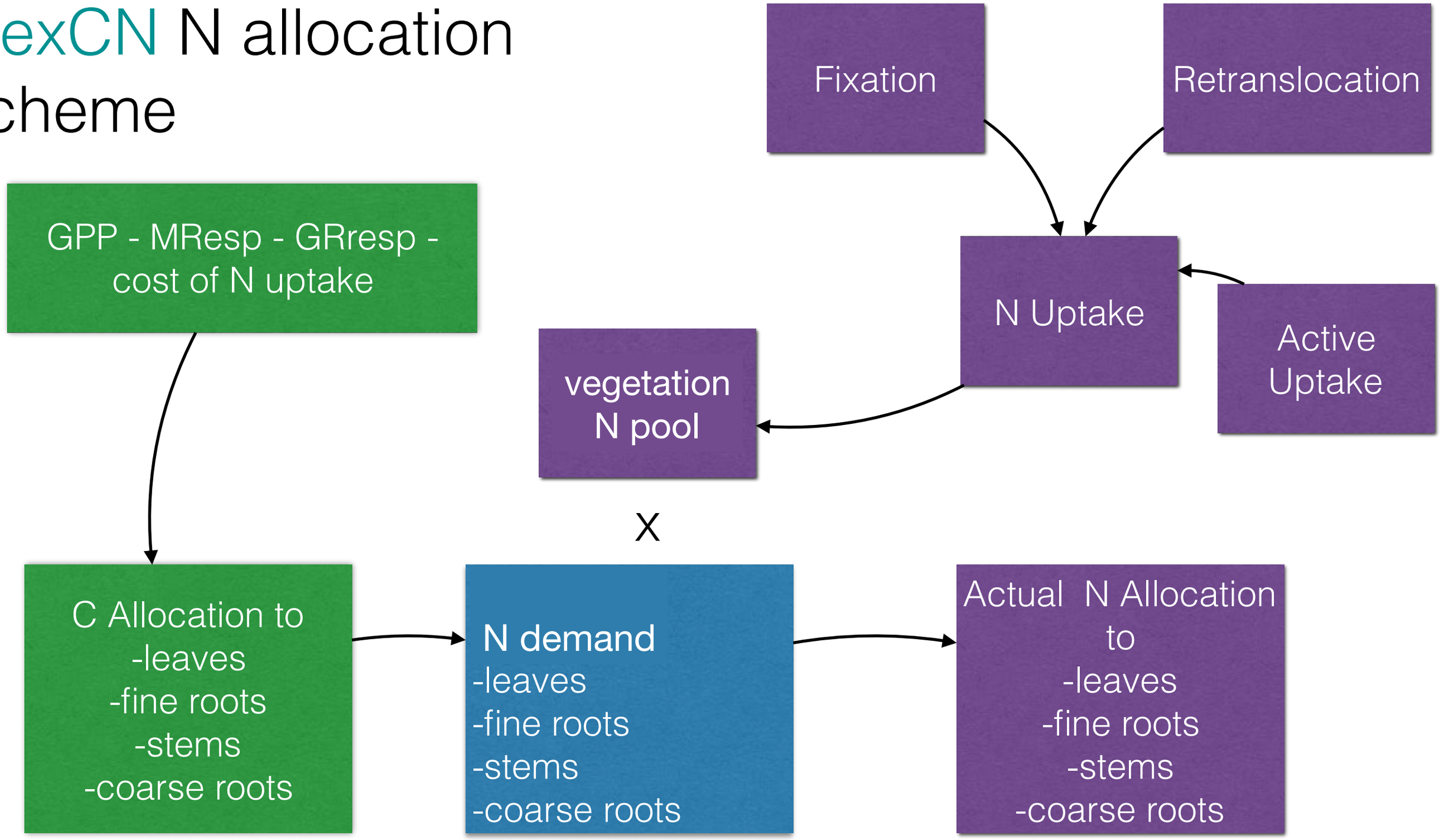
‘FlexCN’ allows for tissue-level variation in C:N ratio relative to target parameter.

Hypothesis: Plants will vary their tissue Carbon:Nitrogen ratio as N availability varies in space and time

FlexCN based on work by Ghimire et al. (2016) *JAMES*

Slide courtesy of R. Fisher

FlexCN N allocation scheme



If N uptake is too low, C:N ratios will increase

Slide courtesy of R. Fisher

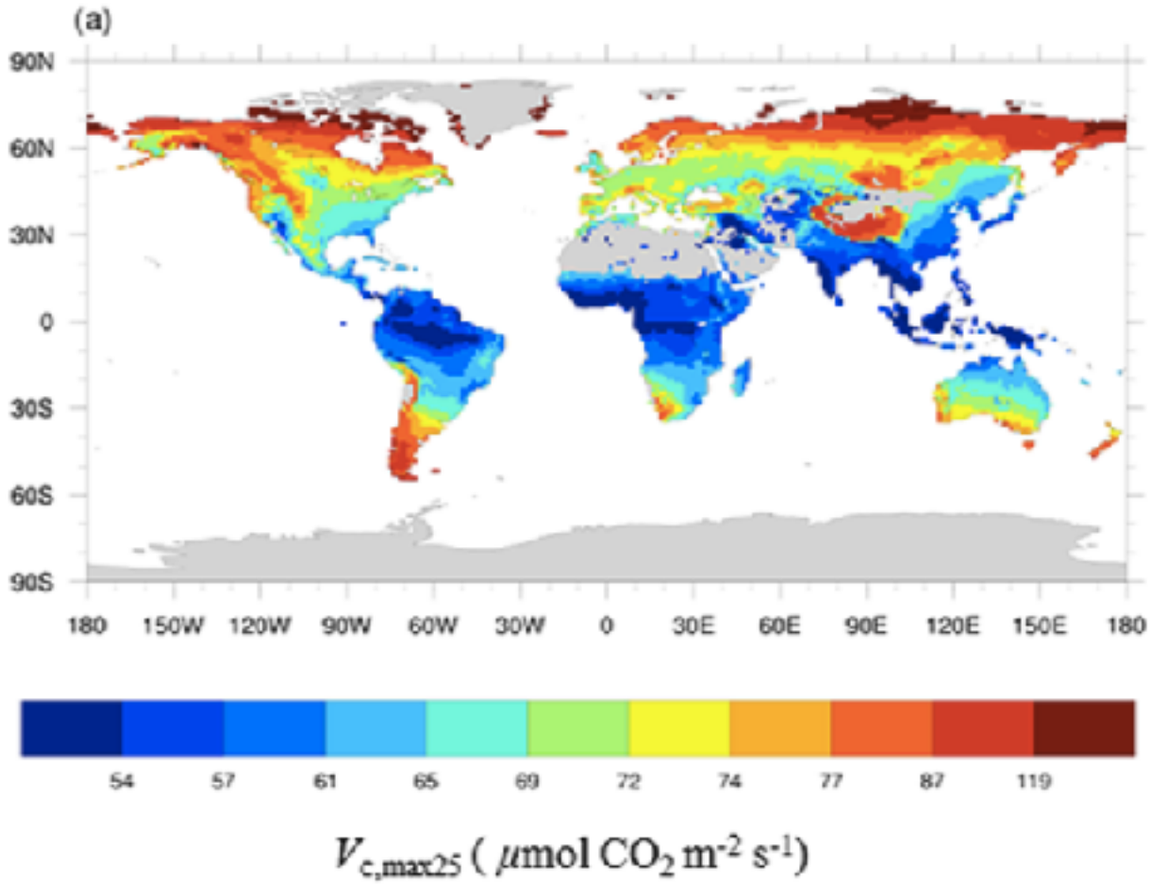
Problem 3: Photosynthetic capacity does not respond to the environment

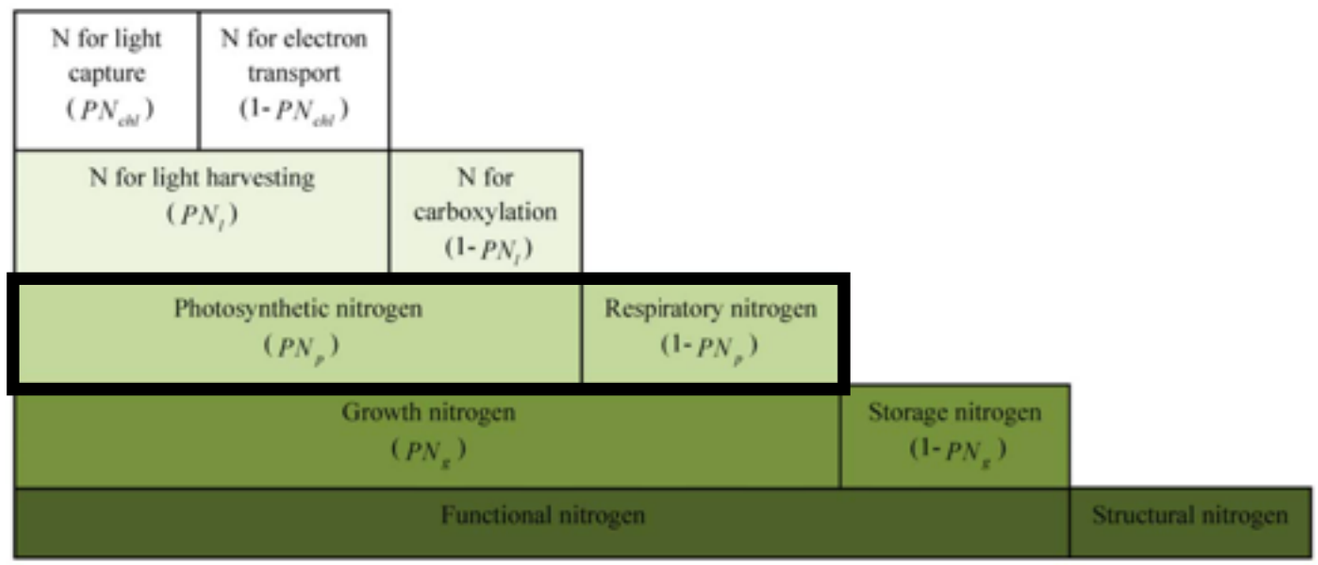
The LUNA* Model

How best to use the Nitrogen you have?

*__L__eaf __U__se of __N__itrogen for __A__ssimilation

Predicted optimal photosynthetic capacity

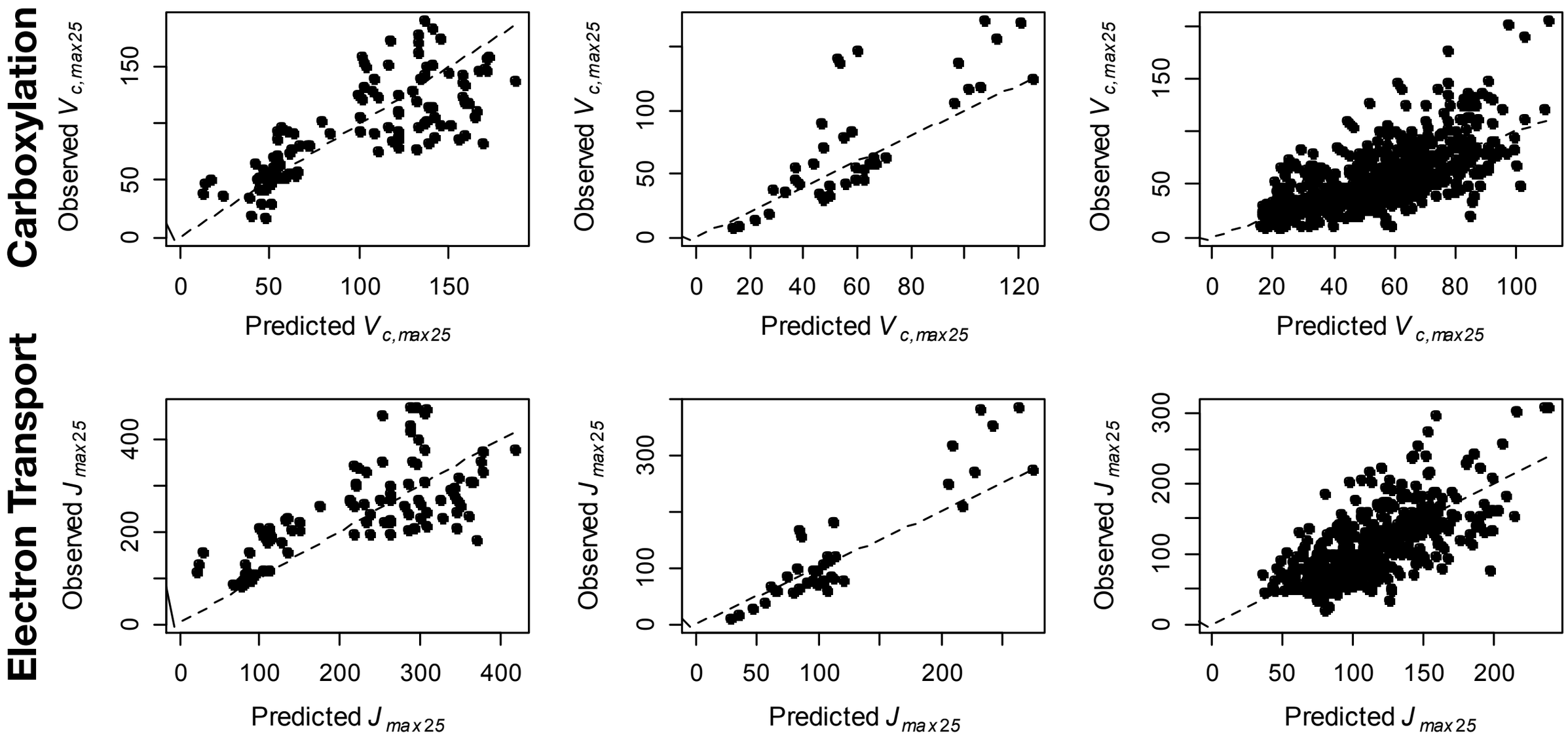




Hypothesis: Leaf Nitrogen is distributed so that light capture, carboxylation and respiration are co-limiting

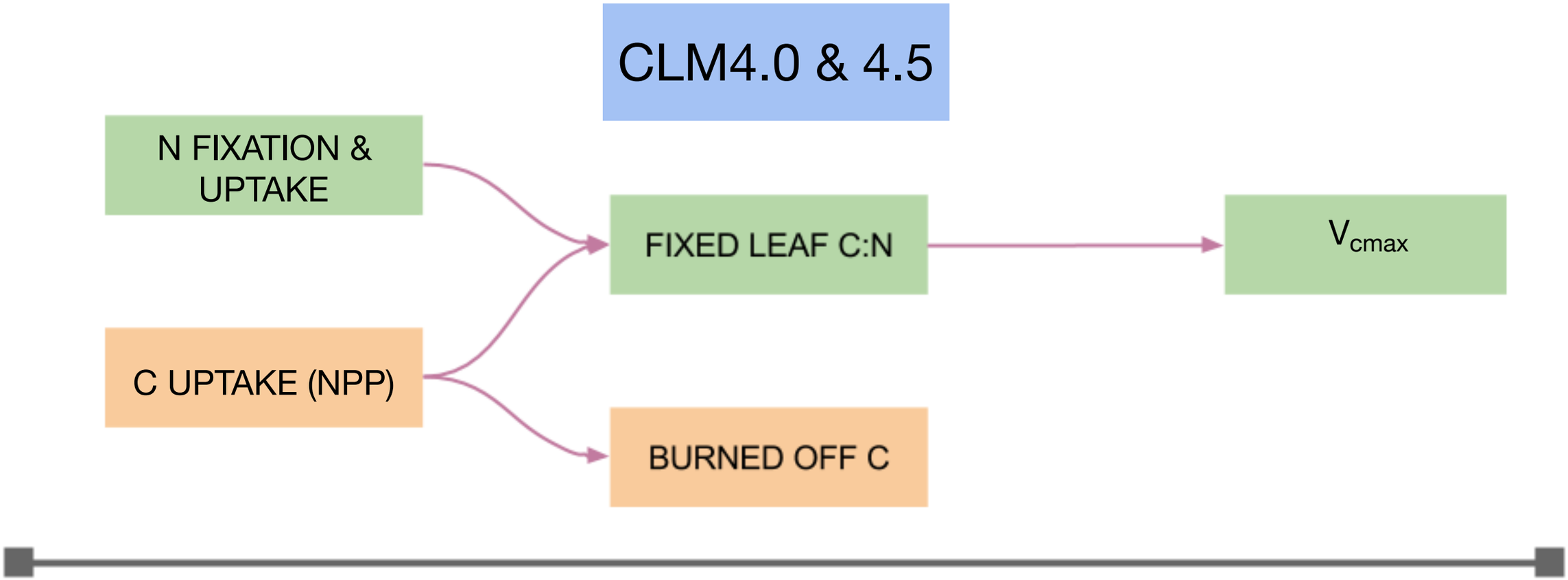
Xu et al. 2012 *PLOS,* Ali et al. 2016 *GMS*

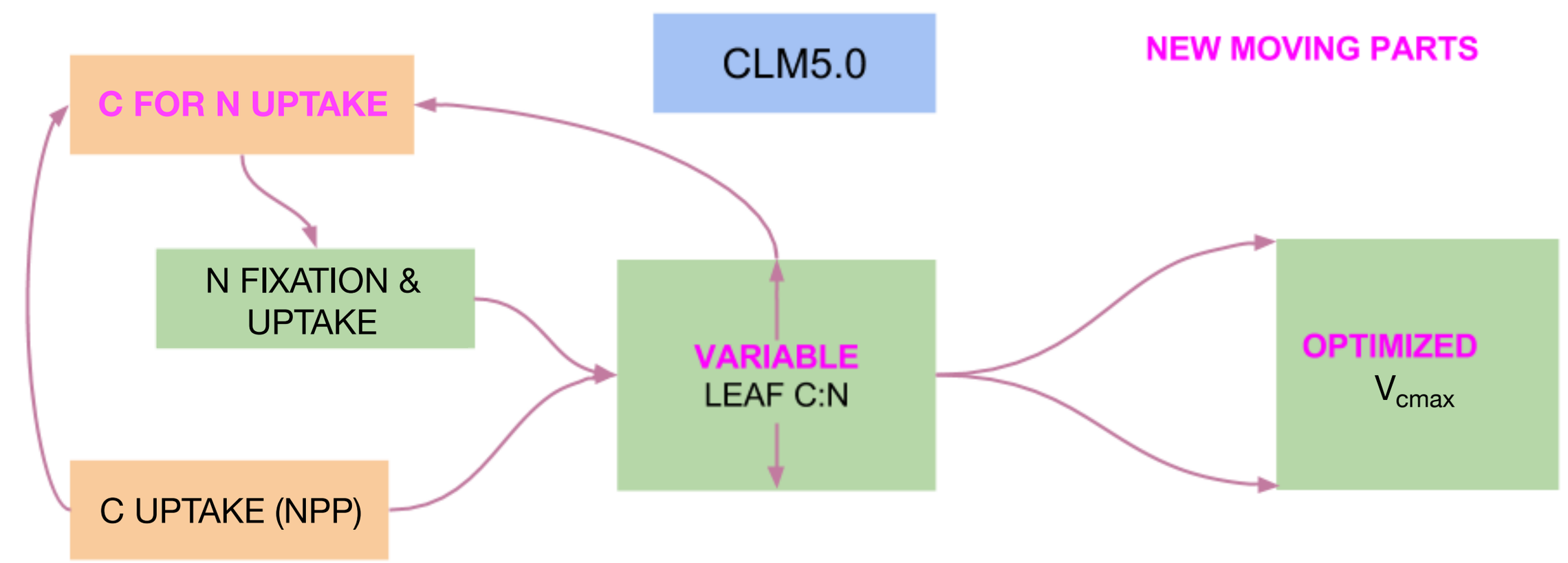
LUNA performance vs. observations



adapted from Ali et al. 2016 *GMS*

Slide courtesy of R. Fisher





Slide courtesy of R. Fisher

Plants pay for fixed & active Nitrogen uptake (in Carbon)

CLM5.0

Leaf Nitrogen content varies with the cost of N uptake

NEW MOVING PARTS

C FOR N UPTAKE

N_UPTAKE

VARIABLE
LEAF C:N

OPTIMIZED
V_{cmax}

C UPTAKE (NPP)

Stomatal Conductance is based on N-limited photosynthesis

Photosynthetic Capacity is optimized with environmental drivers

Slide courtesy of R. Fisher

N limitation in CLM5

Nitrogen is not abundant for some reason

N uptake becomes more expensive

A higher fraction of NPP is spent on uptake.

Tissue C:N ratios increase

NPP for growth decreases

N available for photosynthesis declines

Slide courtesy of R. Fisher

Recap of Plant N Representation

- Similar to soil N representation, most models simulate plant N based on availability in soil pools, C pools, and static C:N

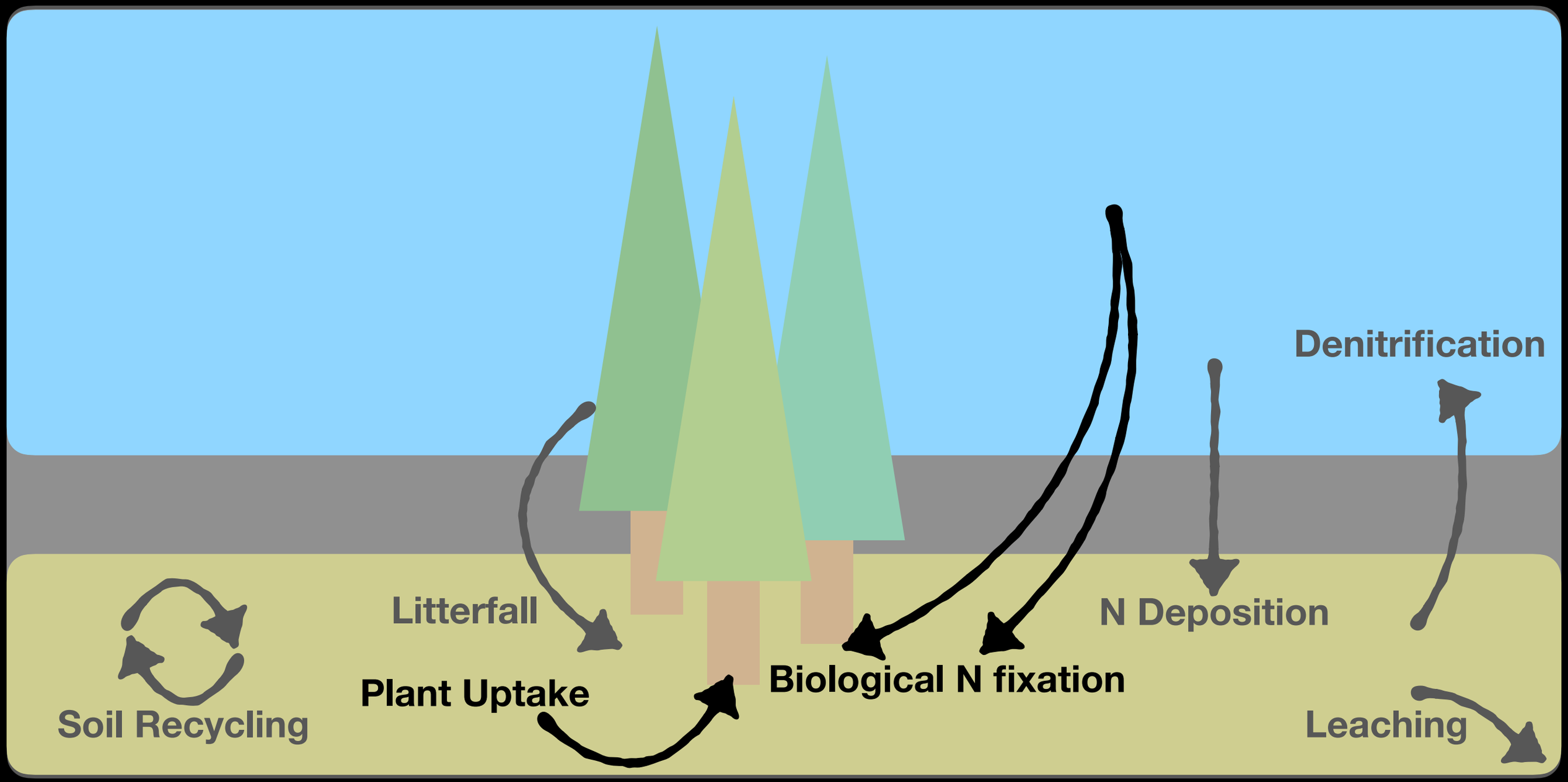
- N fixation is typically represented as a proportion of GPP

- The new CLM5 N cycle model is substantially different from other models and fixes numerous theoretical problems with the previous CLM N cycle by:
  - allowing N to change (C:N and photosynthetic capacity)
  - paying for N uptake

- The model allows comparisons with many new data streams (N fixation, C:N ratio, V_{cmax} variation)

Slide courtesy of R. Fisher

Terrestrial Nitrogen Fluxes



Slide courtesy of W. Wieder

Biogeochemistry in CLM

4.0

4.5

5.0

Slide courtesy of W. Wieder

Biogeochemistry in CLM

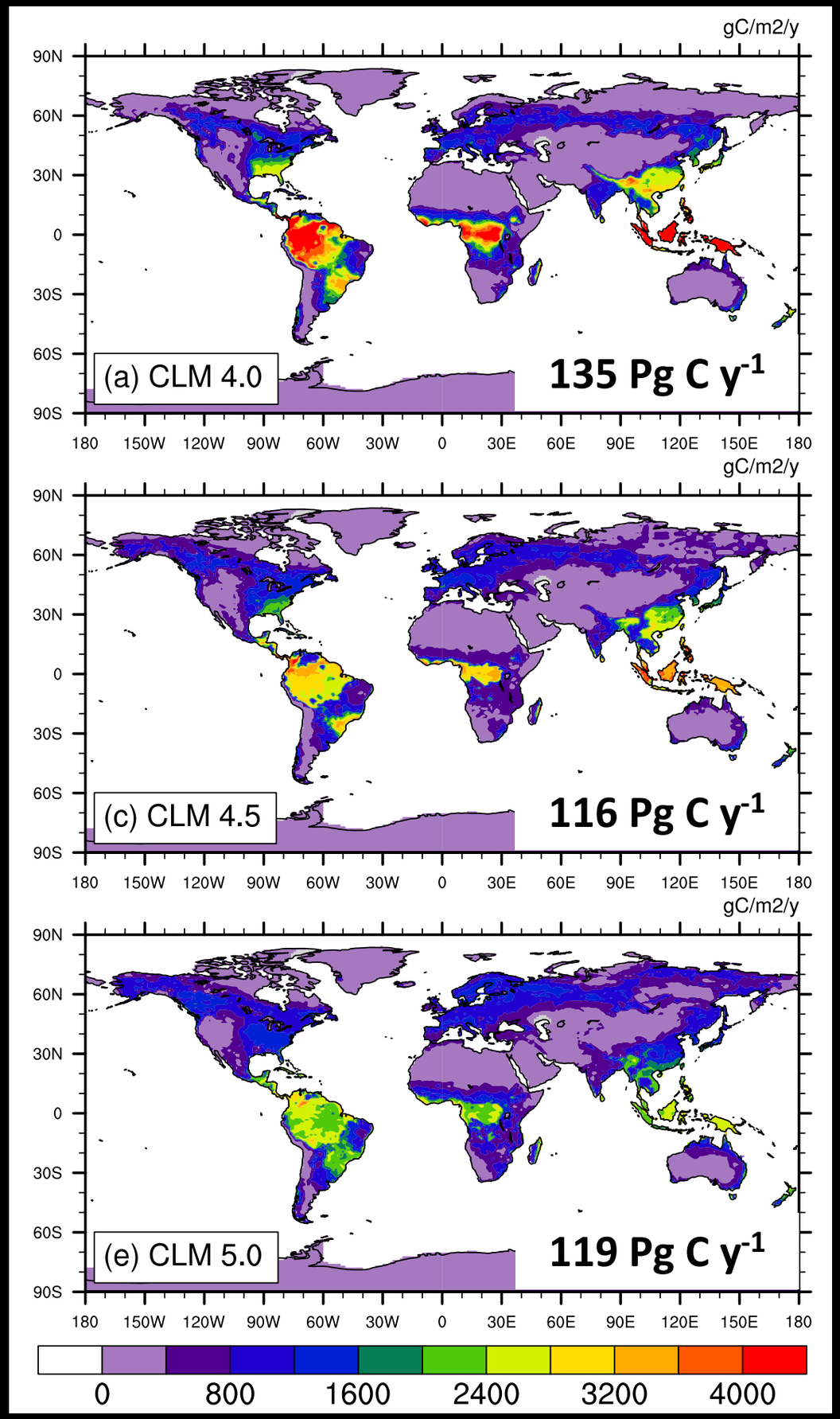
4.0 4.5 *5.0*

For each model version comparing:

- Control
- +N (1989-2010 fertilized 5 gN m^{-2} yr^{-1})

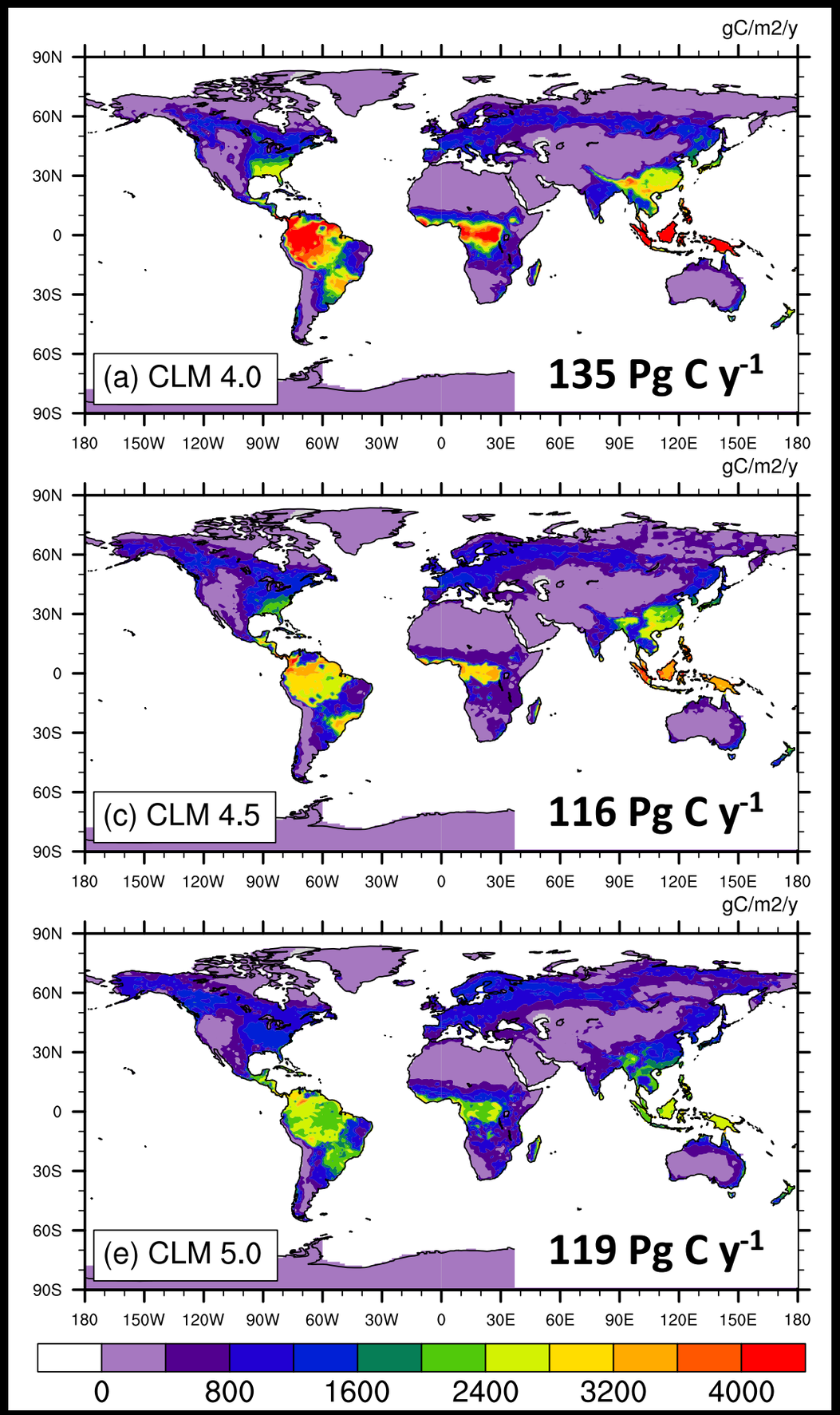
Slide courtesy of W. Wieder

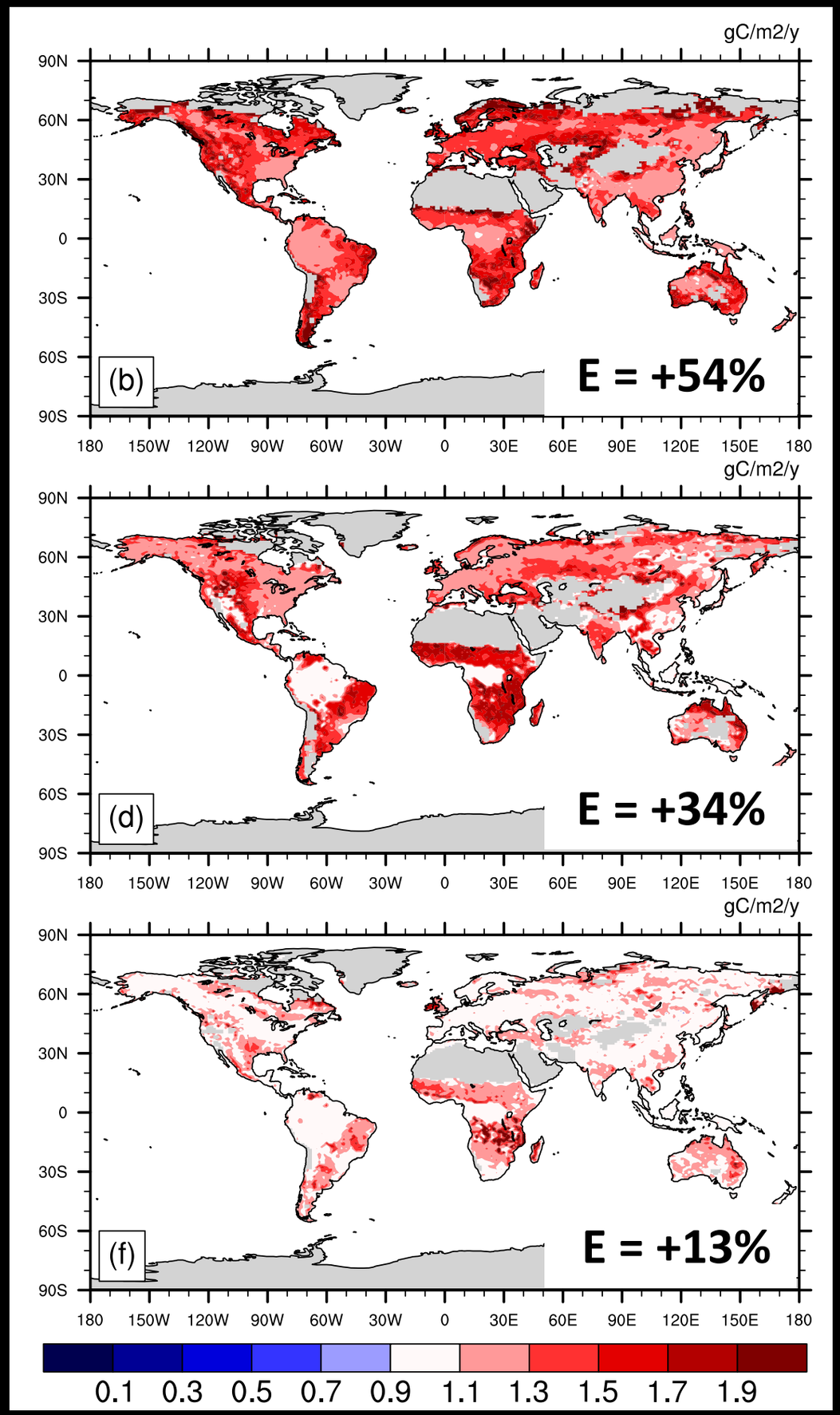
Control GPP [2010]



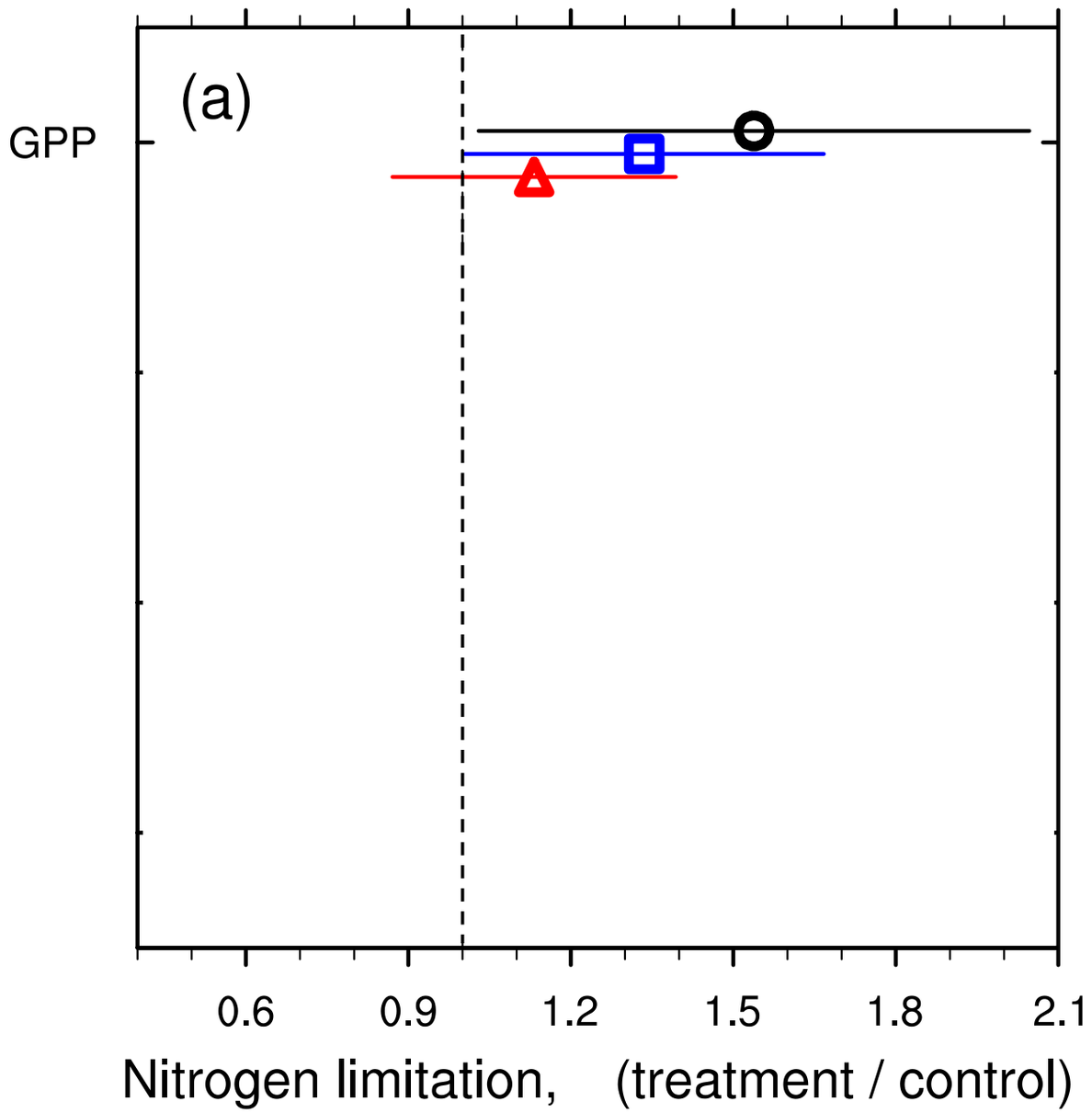
Slide courtesy of W. Wieder

Control GPP [2010] +N





N Fertilization effect



Slide courtesy of W. Wieder

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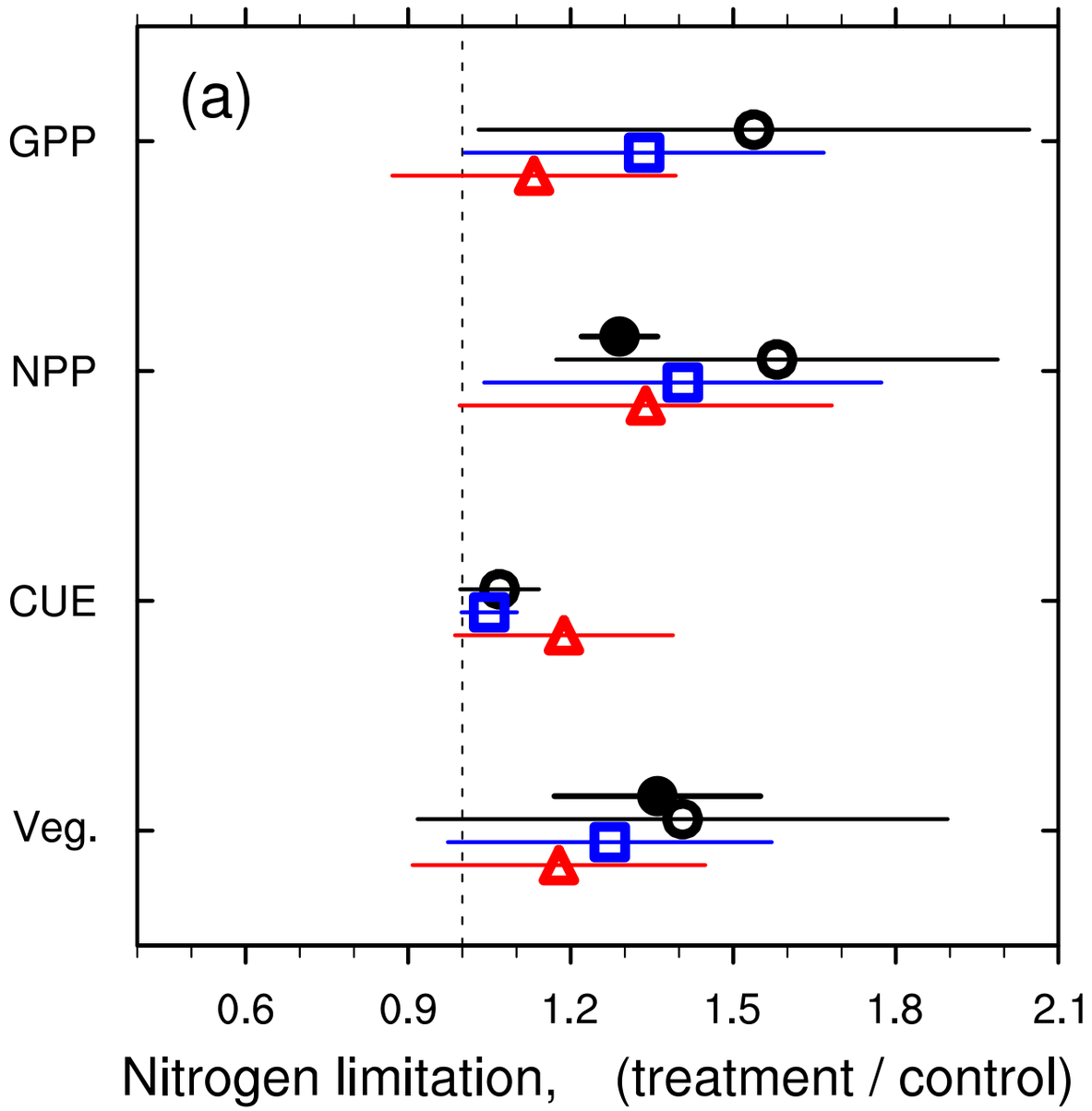
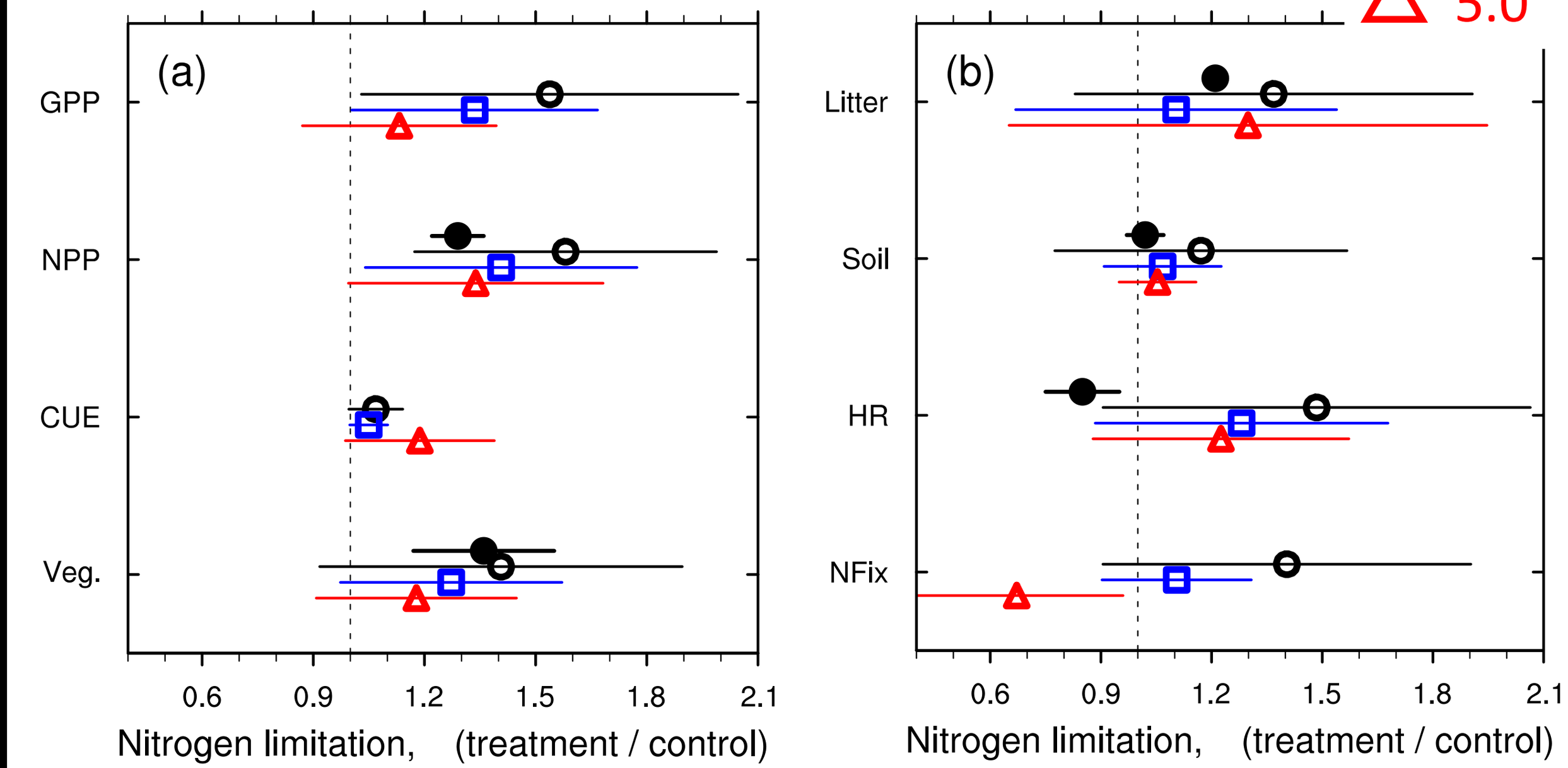


Obs.
4.0
4.5
5.0

Obs from LeBauer & Treseder 2008, Lu et al. 2011
Jannsens et al 2010, Liu & Greaver 2010

Slide courtesy of W. Wieder

N Fertilization effect



Obs from LeBauer & Treseder 2008, Lu et al. 2011
Jannsens et al 2010, Liu & Greaver 2010

Slide courtesy of W. Wieder

Conclusions

- N inputs are from deposition, fixation, and litter
- Sequential solving for soil pools and fluxes based on C demand
- N losses are empirical functions based on N pools
- Plant N uptake previously based on C demand, new updates for CLM5 mechanistically realistic
- Newer versions of CLM are less sensitive to N fertilization