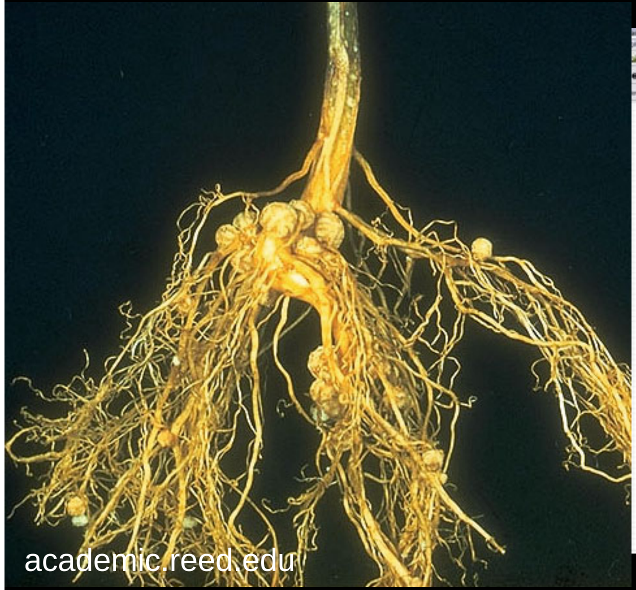
# MODELLING PLANT NITROGEN

## fixation, uptake & allocation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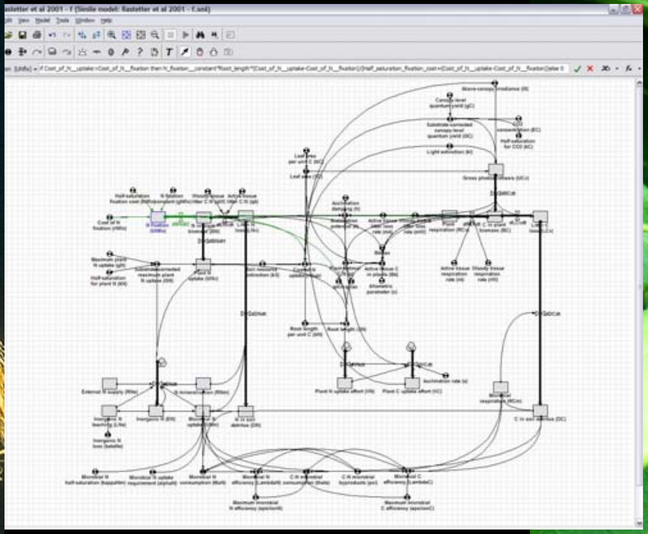


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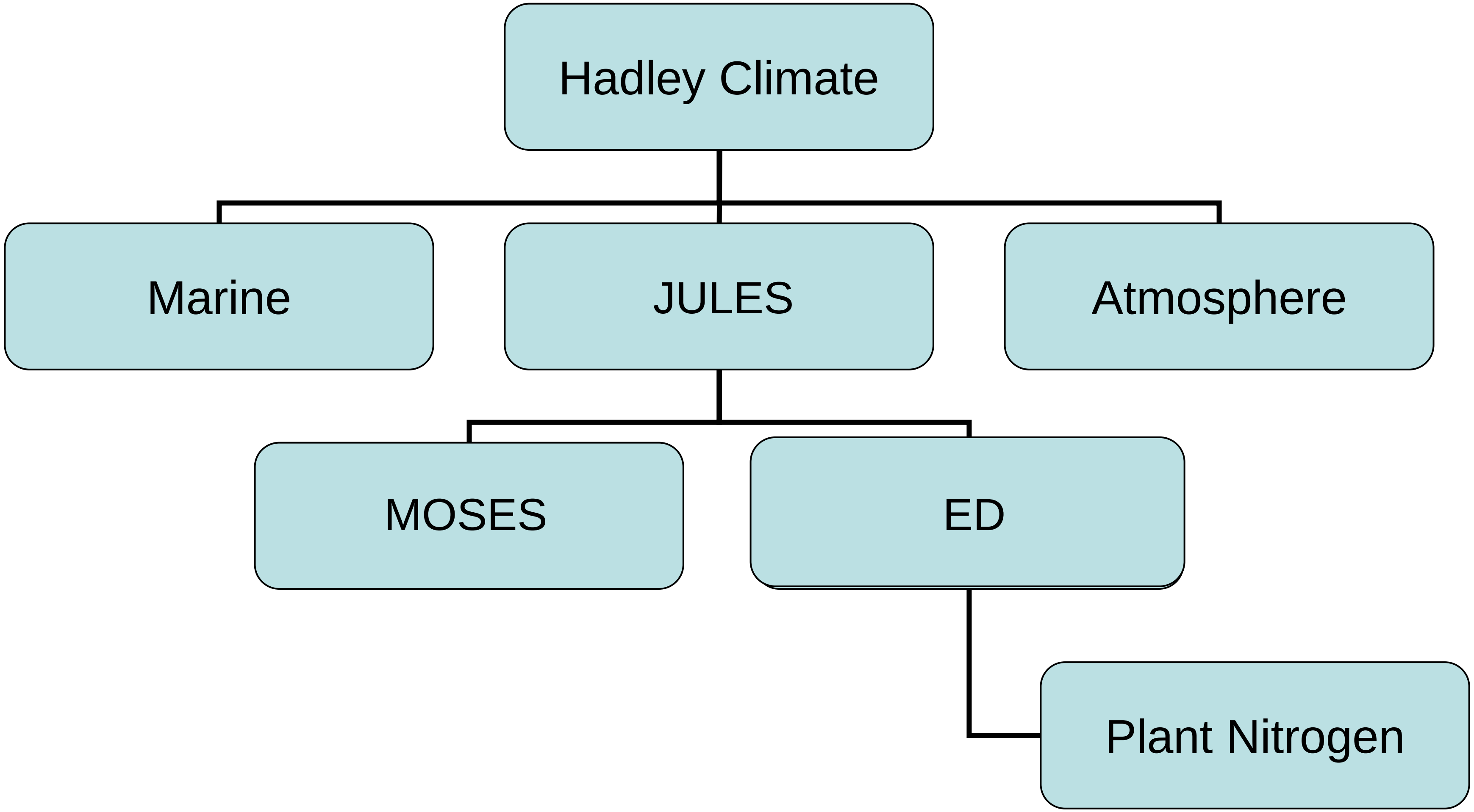
# CONTEXT



Hadley Climate

Marine

JULES

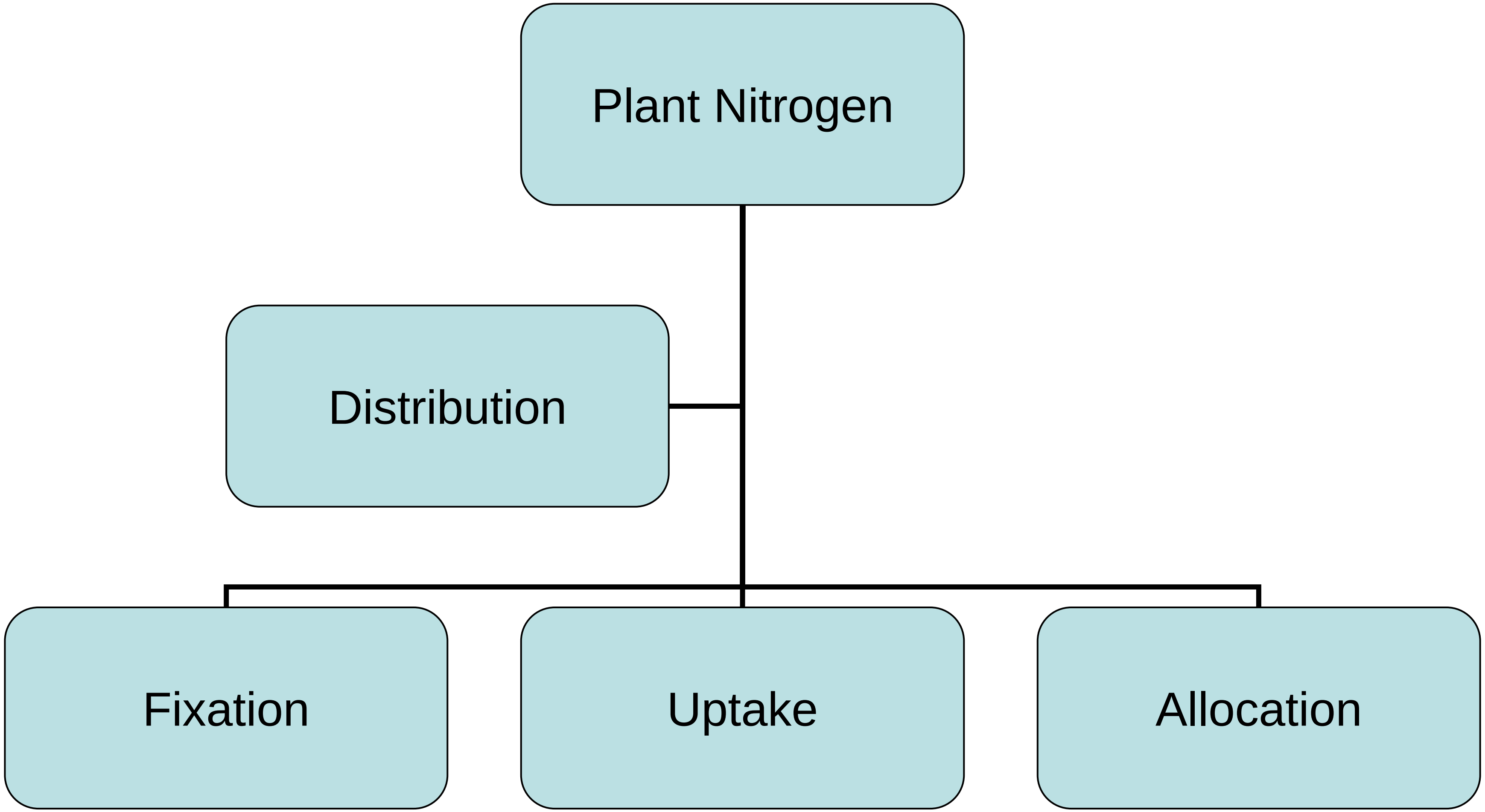
Atmosphere

MOSES

ED

Plant Nitrogen

# CONTEXT



Plant Nitrogen

Distribution

Fixation

Uptake

Allocation

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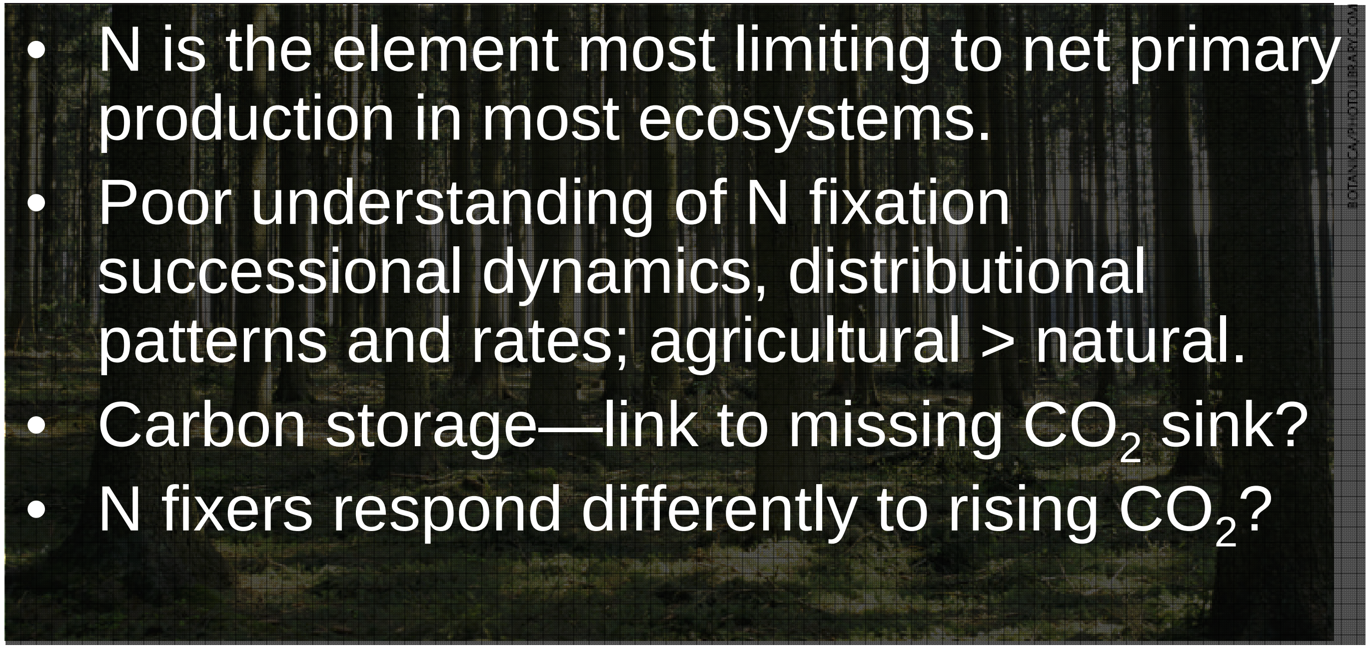
NEWS & VIEWS



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- N is the element most limiting to net primary production in most ecosystems.
- Poor understanding of N fixation successional dynamics, distributional patterns and rates; agricultural > natural.
- Carbon storage—link to missing $CO_2$ sink?
- N fixers respond differently to rising $CO_2$?

ENVIRONMENTAL SCIENCE

# Nitrogen impacts on forest carbon

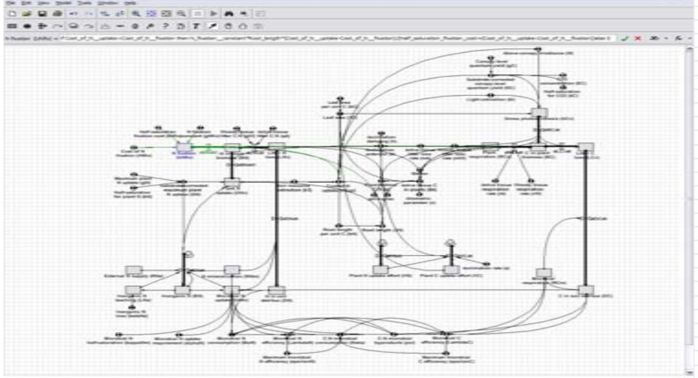
Peter Högberg

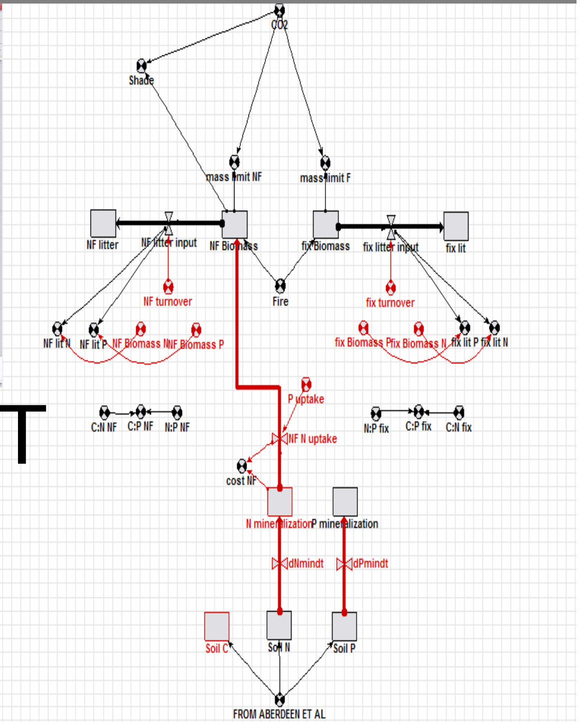
**Does the extra nitrogen input from anthropogenic sources mean that more carbon from the atmosphere is being locked up in boreal and temperate forests? 'Yes' is the answer to emerge from the latest analysis.**

Since the Industrial Revolution kicked into gear, at around the beginning of the nineteenth century, the atmospheric concentration of carbon dioxide has increased from 280 to 380 parts per million[1]. Starting a century later, there has been an even more dramatic increase in the industrial fixation of atmospheric nitrogen into agricultural fertilizers, and in the production of nitrogen oxides from combustion biomass and the concentration of the photosynthesizing enzyme RUBISCO (Fig. 1a, overleaf). These changes lead to greater capture of energy in sunlight and greater photosynthesis per unit area of forest. They also cause a shift in the allocation of plant carbon from roots and their symbiotic mycorrhizal fungi towards above-ground structures such as woody tree trunks (Fig. 1b). As carbon in wood deposition indicate that extra nitrogen does not stimulate carbon sequestration by trees[9], and that relatively little of the nitrogen added to forests becomes immobilized in wood[4].

To address this controversy, Magnani *et al.*[5] analysed the carbon balance across a network of forest sites encompassing the levels of nitrogen deposition experienced by most of western Europe and the conterminous United States.

# N MODELS





- In JULES: ?
- C:N ratios
- “Century”—Linear function of ET
  - – Schimel et al. 1997
- “A Simple Model of N Fixation”
  - – Vitousek & Field, 1999; Vitousek et al. 2002
- “Multiple Element Limitation”
  - – Rastetter et al. 2001

# MODEL APPROACH

- Modelling theory from evapotranspiration:

  AET = PET*f(available $H_2O$, LAI, …)

  ANU = PNU*f(available N, uptake rate, fixation cost)

# PLANT N MODEL

- ANU = PNU*f(available N, uptake rate, fixation cost)
- ANU = PNU*$(f_{SN}f_{NT}+f_{fix}f_{NT})$
- PNU = biomass*(actual C:N/optimal C:N)
- $f_{SN}$ = f(root depth, soil depth, soil N)
- $f_{NT}$ = f(transpiration)
- $f_{fix}$ = f(ability, energetic cost, NPP, $f_{SN}$)
  - If fixer AND NPP>energetic cost, then 1-$f_{SN}$ else 0

*ANU = PNU under well-fertilized conditions*

*AET = PET under well-watered conditions*

- Plant N Allocation = ANU*f(compartmental biomass, compartmental C:N’s, litterfall, re-translocation)

# SUCCESSION

- Why don’t N fixers take over the world?

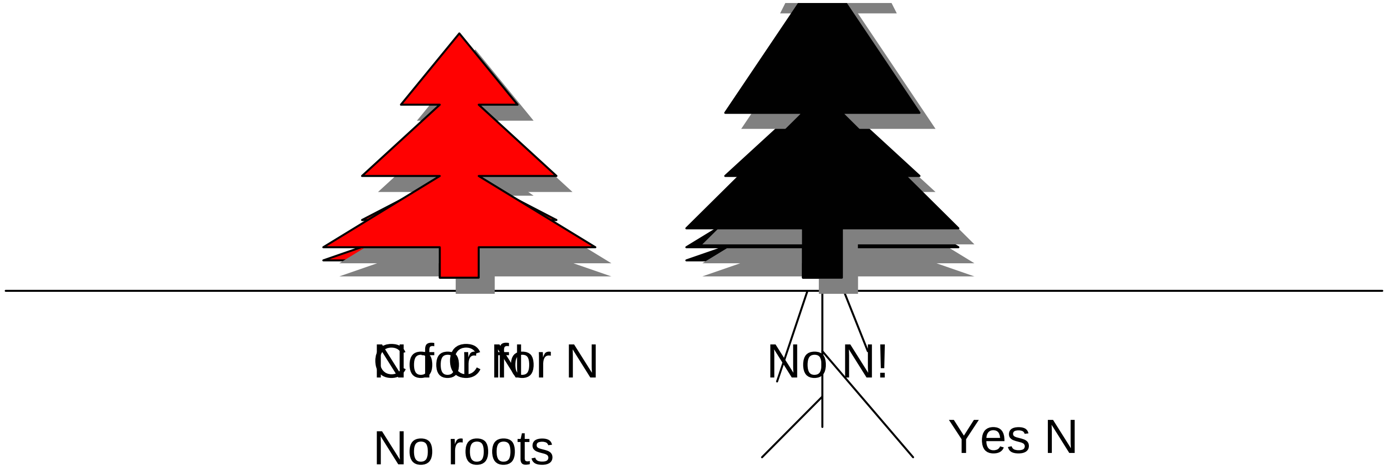
  (Vitousek & Howa al. 2002)

  - “The widespread oc P in terrestrial and marine ecosystems is *some* em that N fixers should have a substantial **comp** N is limiting, and that their activity in turn shoul
  - “Why then are N fix in all systems where N limits primary productivity

# SUCCESSION

- Succession
  - – Low available N, high light
  - – Roots not established

– N fixation is restricted to the **early phases of succession** (Schlesinger 1991, Cleveland et al. 1999, Crews 1999, Sprent 1999, Vitousek et al. 2002) despite the persistence of N limitation on production late in succession. This **paradox** has yet to be explained adequately (Rastetter et al. 2001).



# OBSERVATIONS

- The conditions that favor N fixation are:
  - a) Elevated $CO_2$ (Havelka et al. 1982, Vance & Heichel 1991)
  - b) Open canopy (Rastetter et al. 2001)
  - c) Low available N (Havelka et al. 1982)
  - d) Extended root system (Rastetter et al. 2001)
  - e) Evapotranspiration (Schimel et al. 1997)
  - f) NPP (Cleveland et al. 1999)
- N fixation is difficult to measure in the field, especially in **non-agricultural** systems (Vitousek et al. 2002).

# FIELD WORK