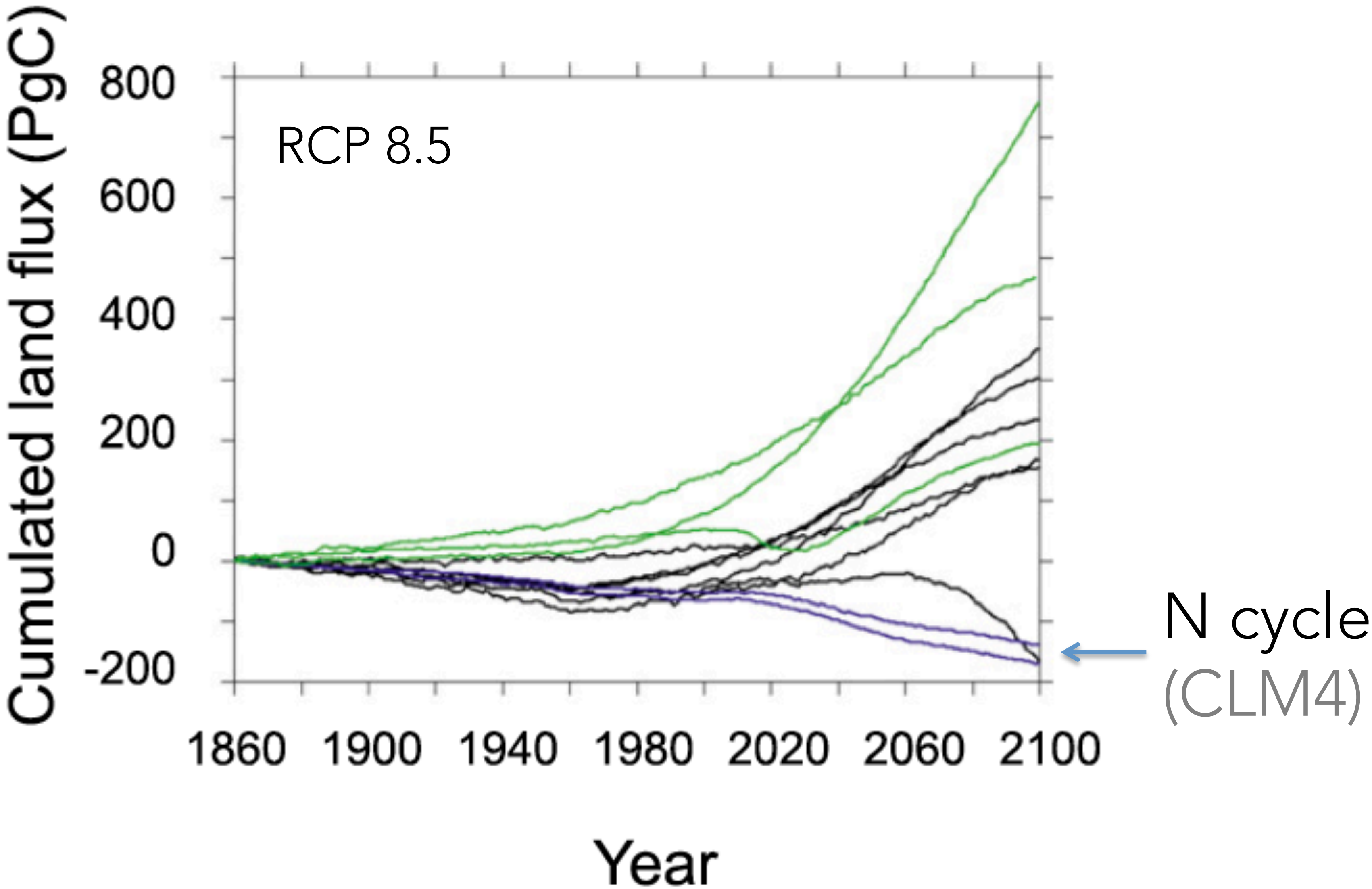
# Evaluating the short and long-term fate of N deposition in CLM5

Susan J. Cheng[1], Peter Hess[1], William R. Wieder[2], R. Quinn Thomas[3], Christy L. Goodale[1]

[1]Cornell University, [2]NCAR, [3]Virginia Tech

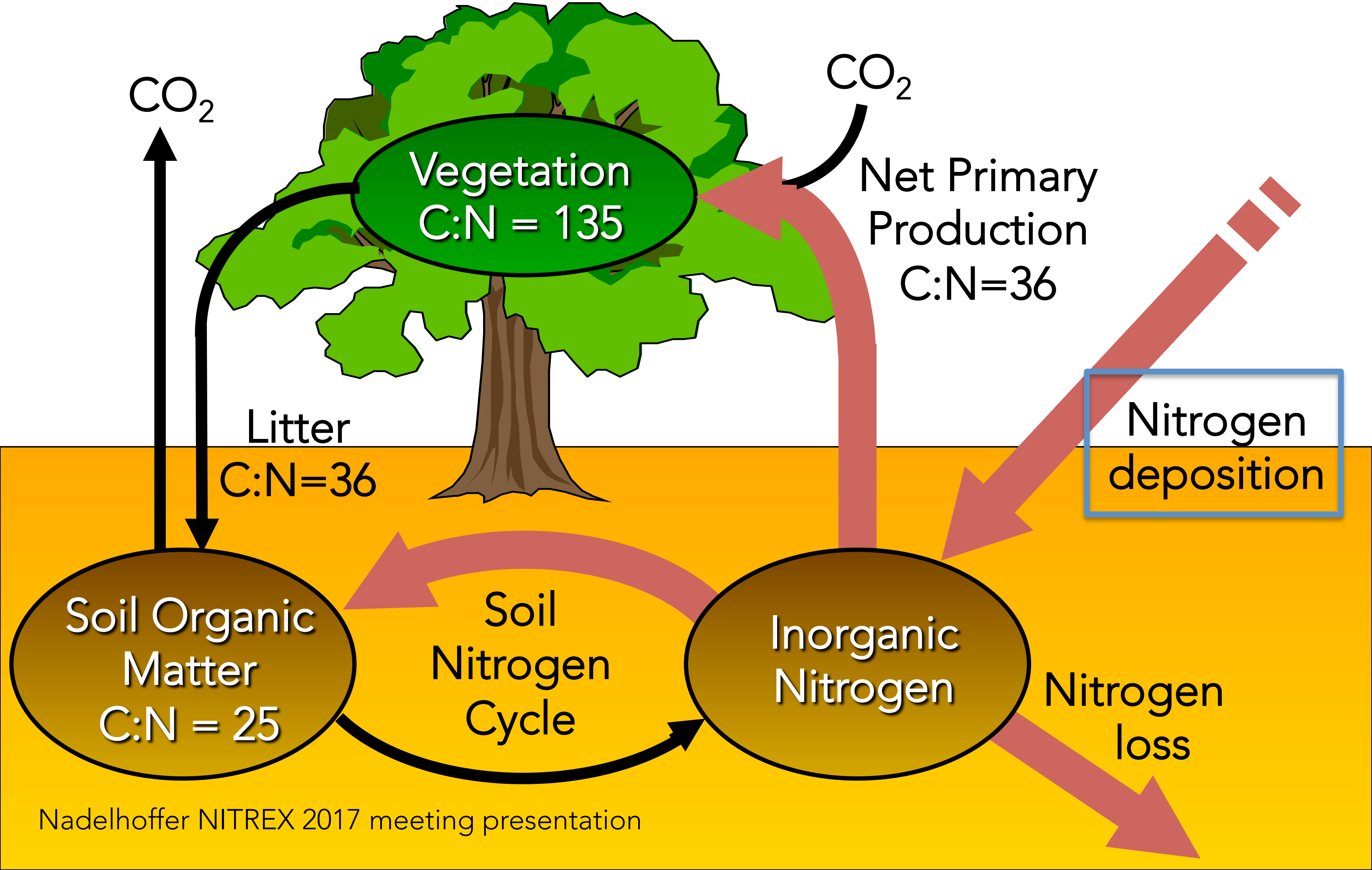
NCAR Land Model Working Group Meeting
07 February 2018

# Earth system models with a N cycle predict the land surface to be a future source of $CO_2$




Friedlingstein et al., 2014

# Fate of N defines where and how much carbon is stored




Nadelhoffer NITREX 2017 meeting presentation

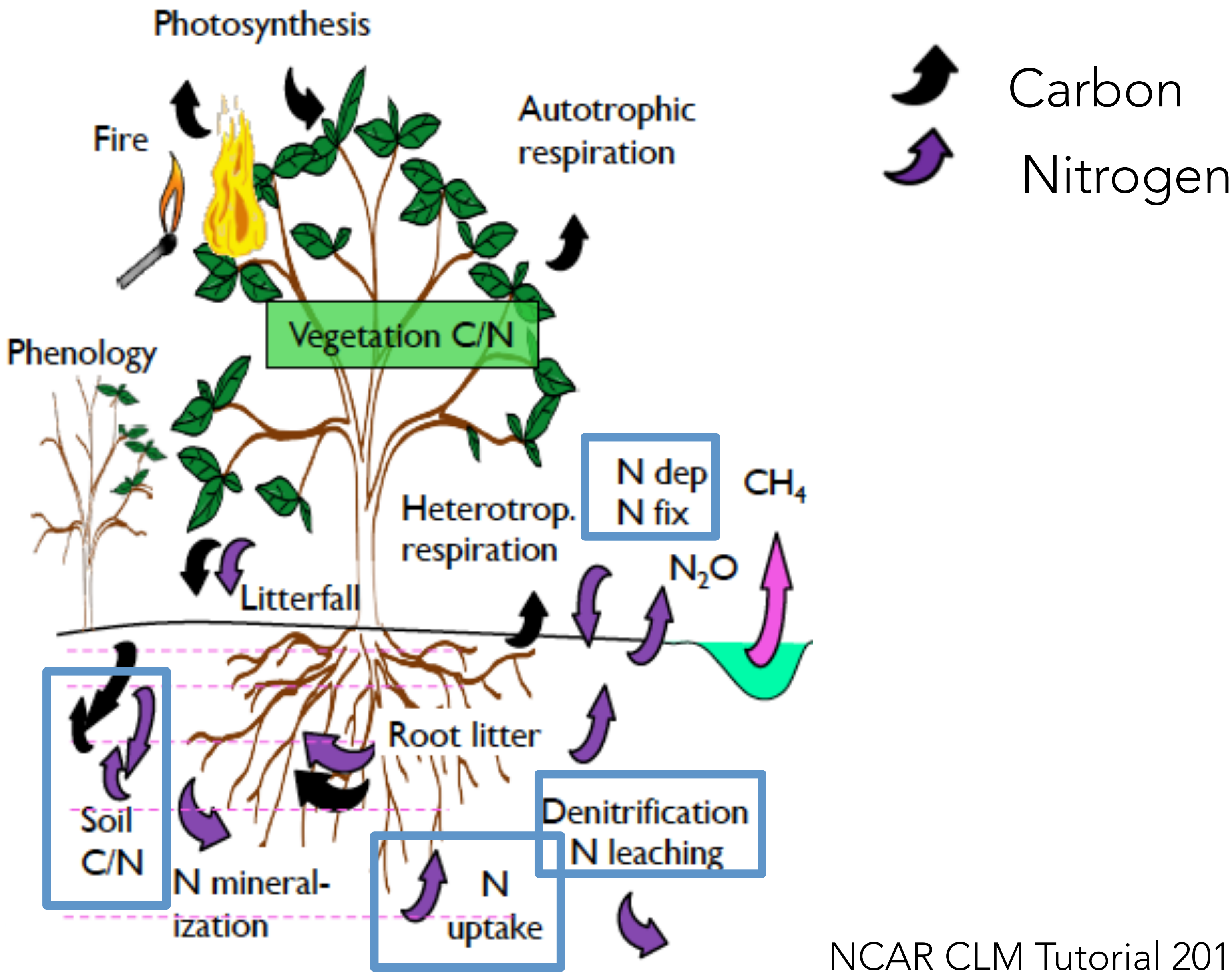
# Research Question

How well are we modeling the fate of N deposition in ecosystems over time?

*Hypotheses*:

- Added N should mostly end up in soil pools.
- The recovery of added N in plant pools will be overestimated.
- Fate of added N in plant pools should decline over time as leaves are incorporated into soil.

# Potential fates of nitrogen in CLM5




NCAR CLM Tutorial 2016

# $^{15}N$ can trace how N moves in an ecosystem

Atmospheric N:
$^{14}N$: 99.6337 atom%
$^{15}N$: 0.3663 atom%

Apply trace amount of $^{15}N$

Measure $^{15}N$ in pools after known time

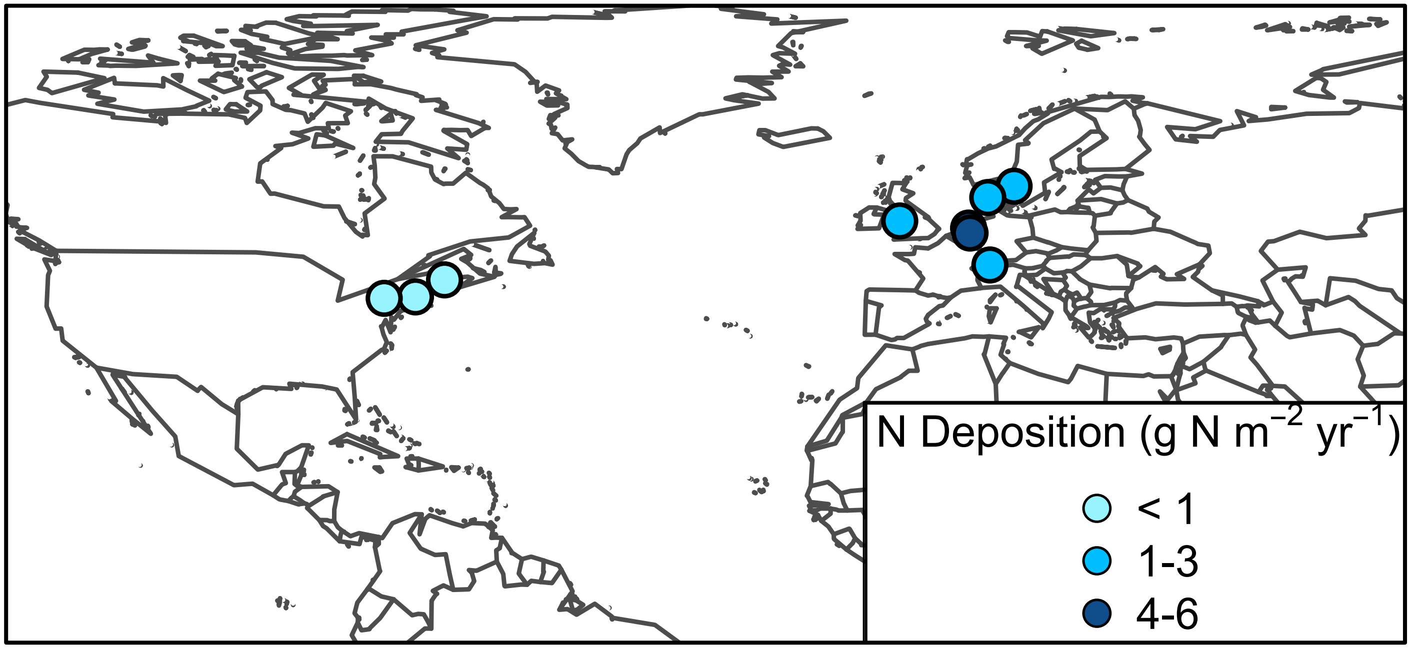




Photos from Goodale and Nadelhoffer

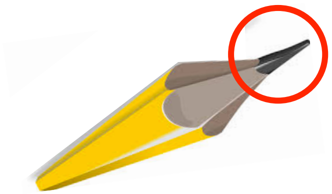
# $^{15}N$ tracer studies applied 10-25 years ago

Nitrogen Saturation Experiments (NITREX)

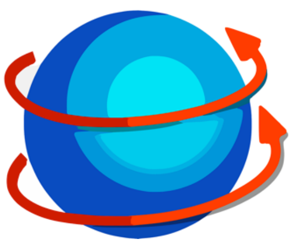



- N deposition gradient: 0.6 – 5.3 g m$^{-2}$ yr$^{-1}$
- Ambient and fertilized plots
- Two plant functional types (conifer, deciduous)

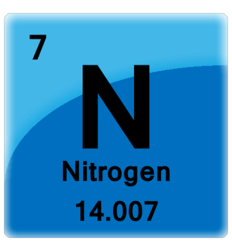
# CLM5 simulations



- Point simulations
  - Version: tag clm4_5_16_r253
  - GSWP3 meteorology
  - Clearcut to match age of forest stand
  - No fire, no land use change

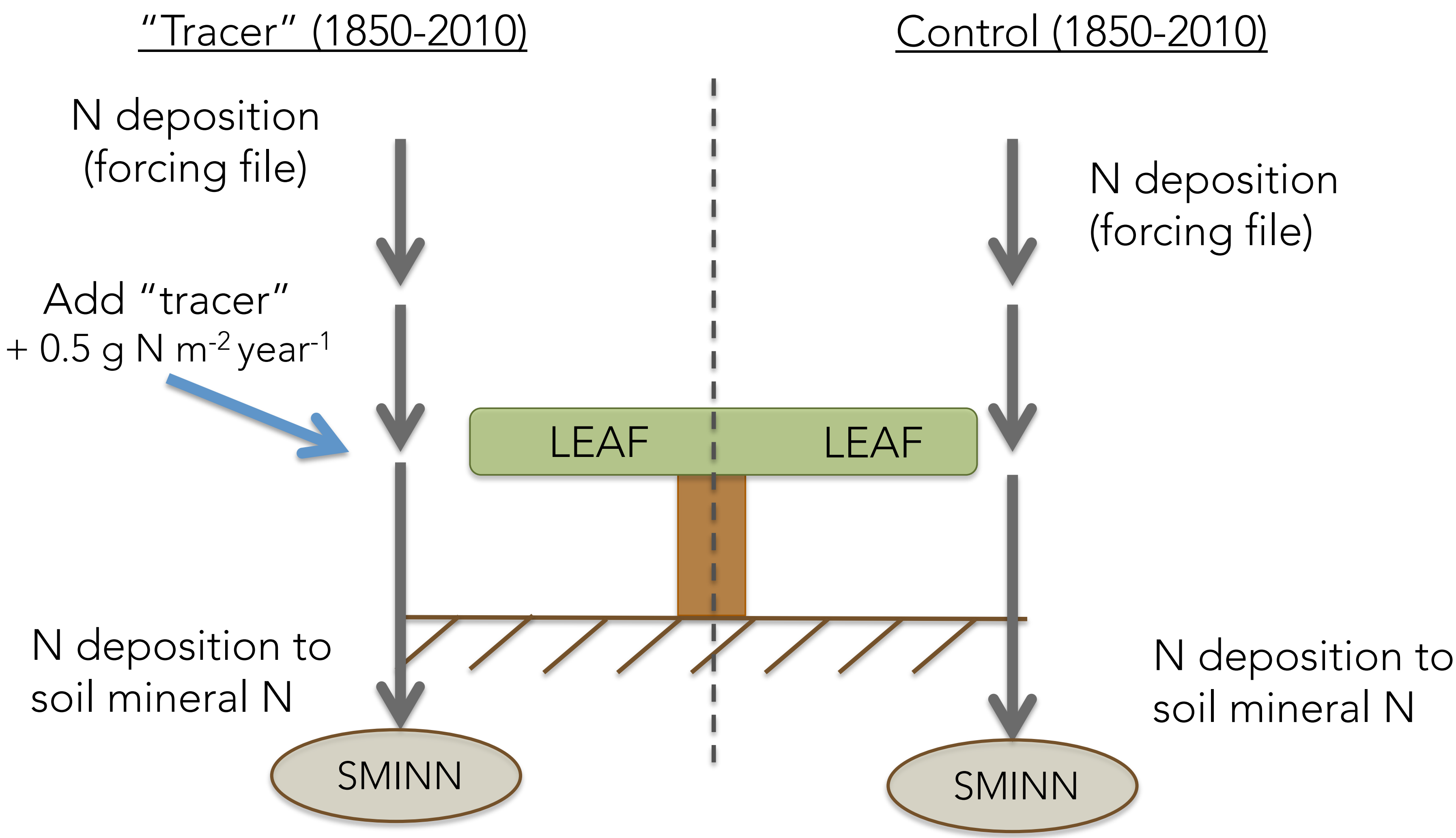


- 1850 spinup
  - One land unit
  - 1 plant functional type

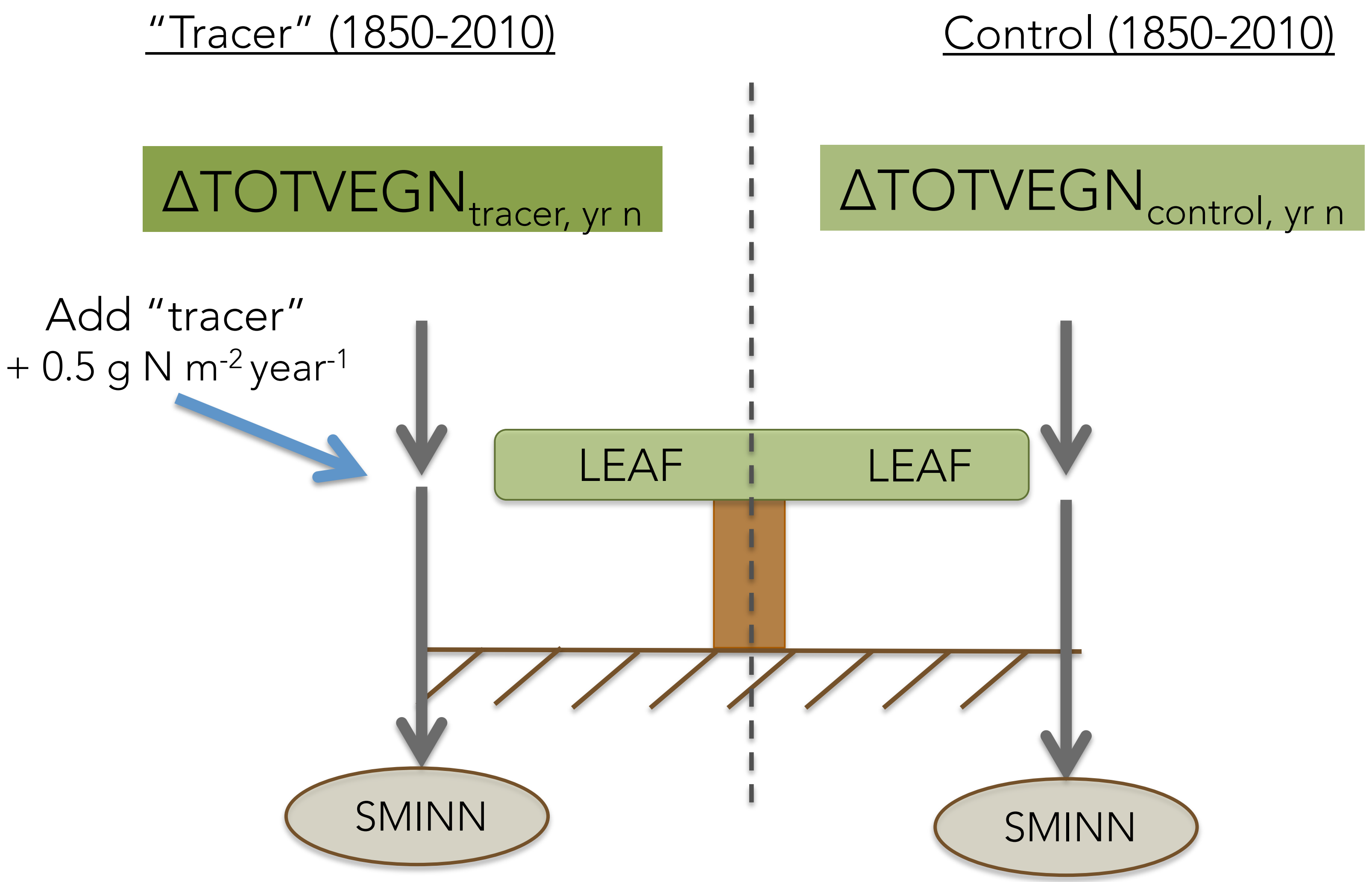



- Model default N inputs
  - Prescribed N deposition
  - Prognostic N fixation (symbiotic, free-living)

# Simulated Tracer Experiment



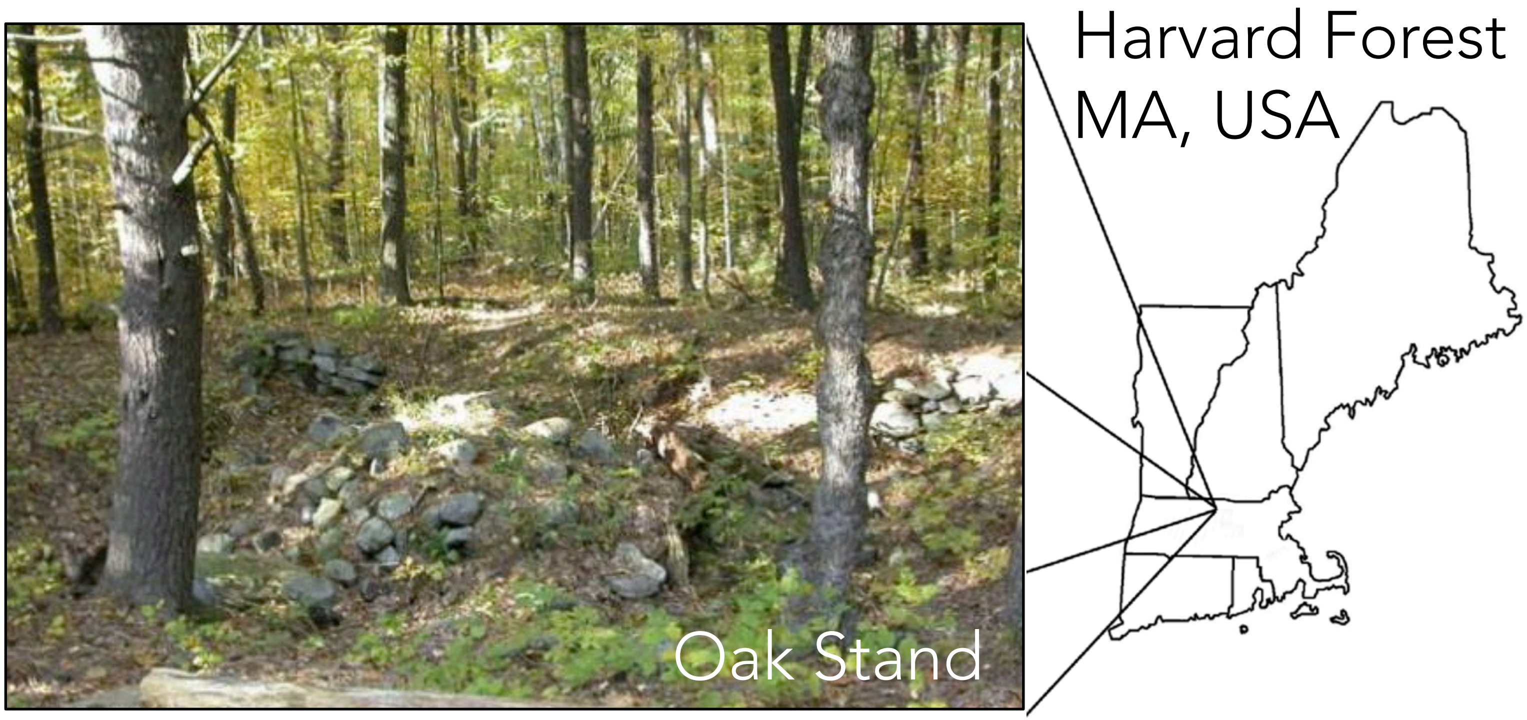
# Calculating "recovery" of added N



# Calculating "recovery" of added N

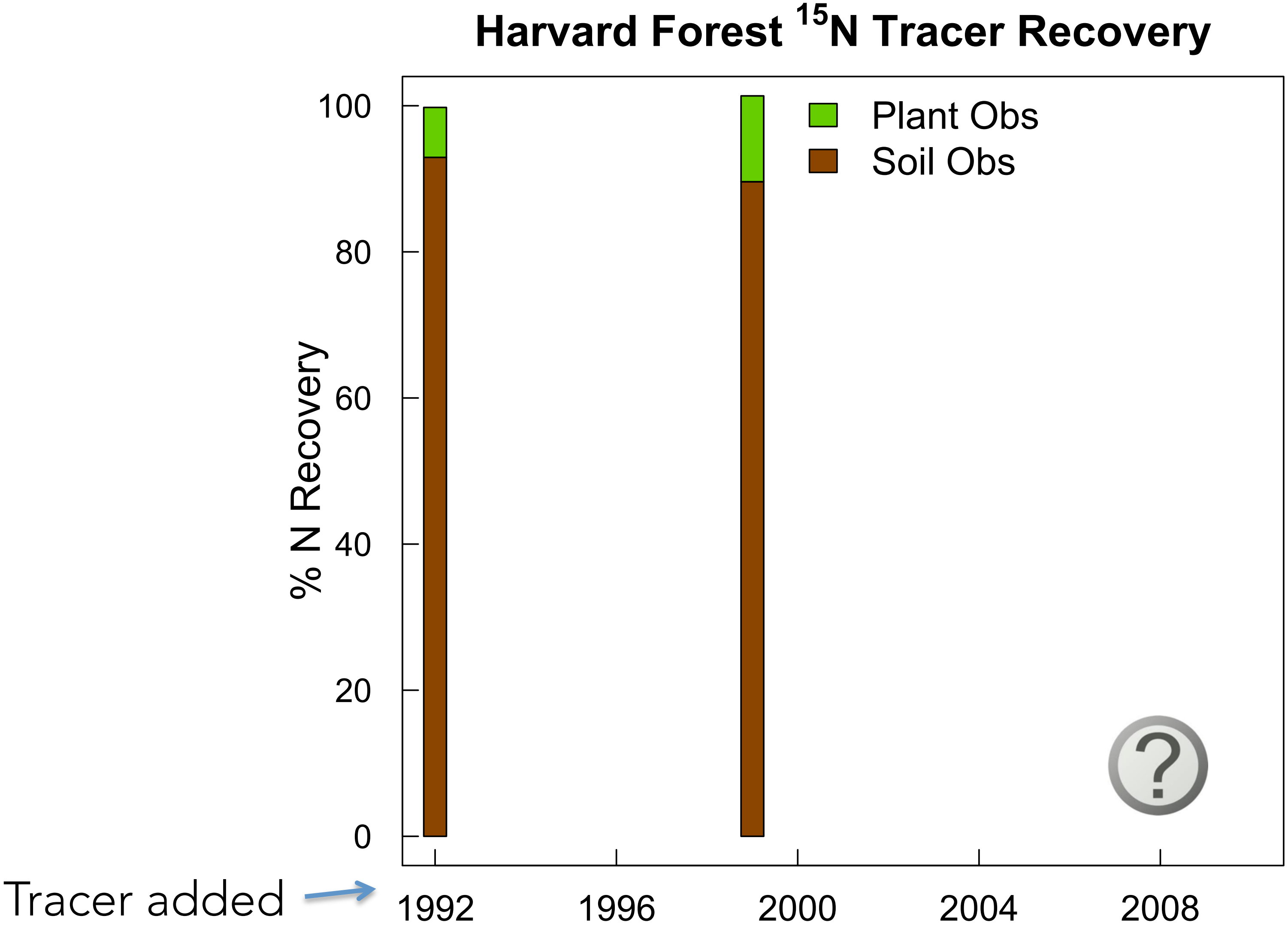
$$\%\ N\ \text{recovered} = \frac{\Delta TOTVEGN_{tracer,\ yr\ n} - \Delta TOTVEGN_{control,\ yr\ n}}{\text{Cumulative difference in N inputs}} \times 100\%$$

# Long-term $^{15}N$ tracer field experiments



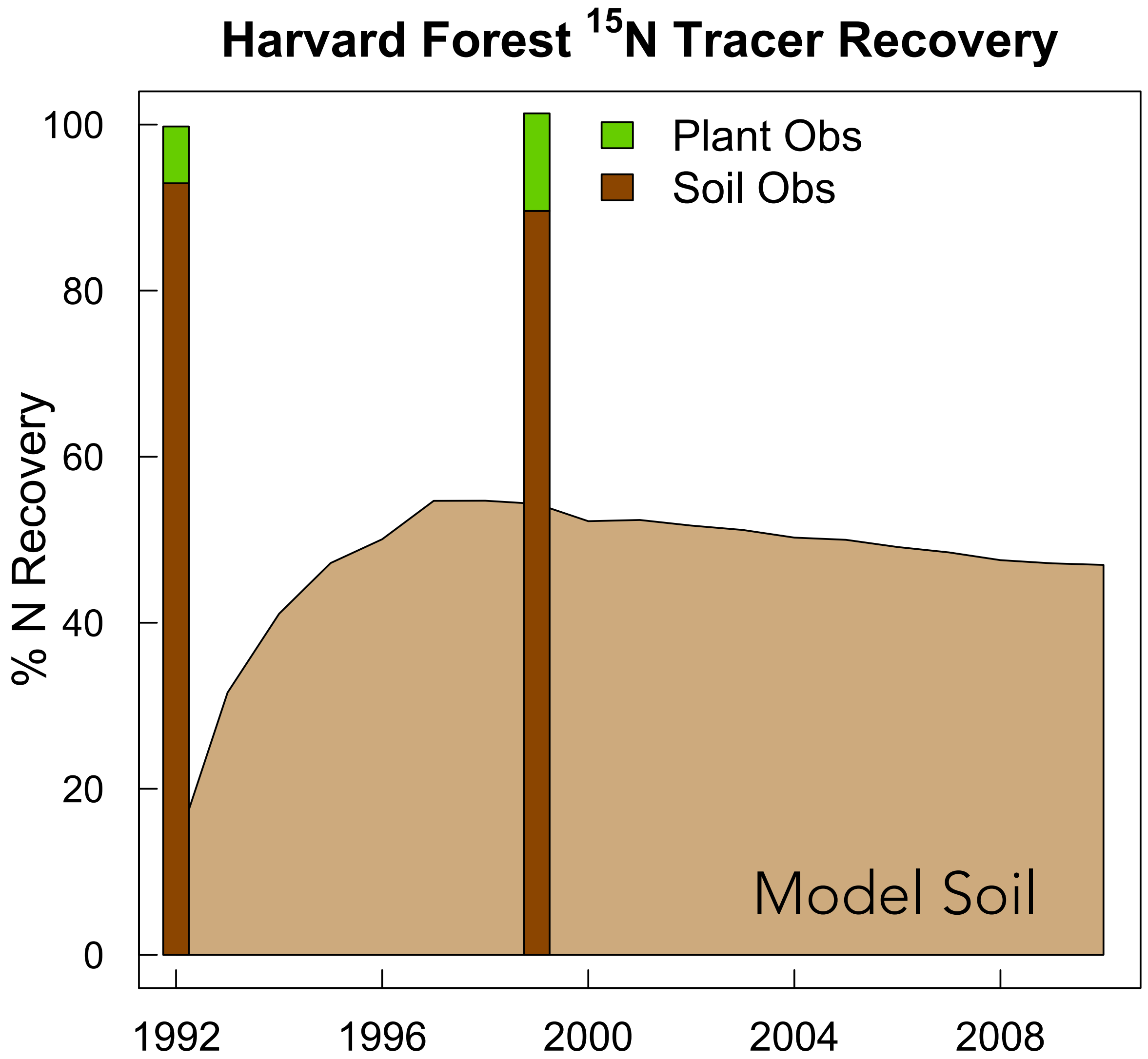

- $^{15}N$ tracer applied in 1991 and 1992
- Field sampling and % recovery after 1, 6, and 16 years

# Field data show most $^{15}N$ is recovered in soils during the short and long-term



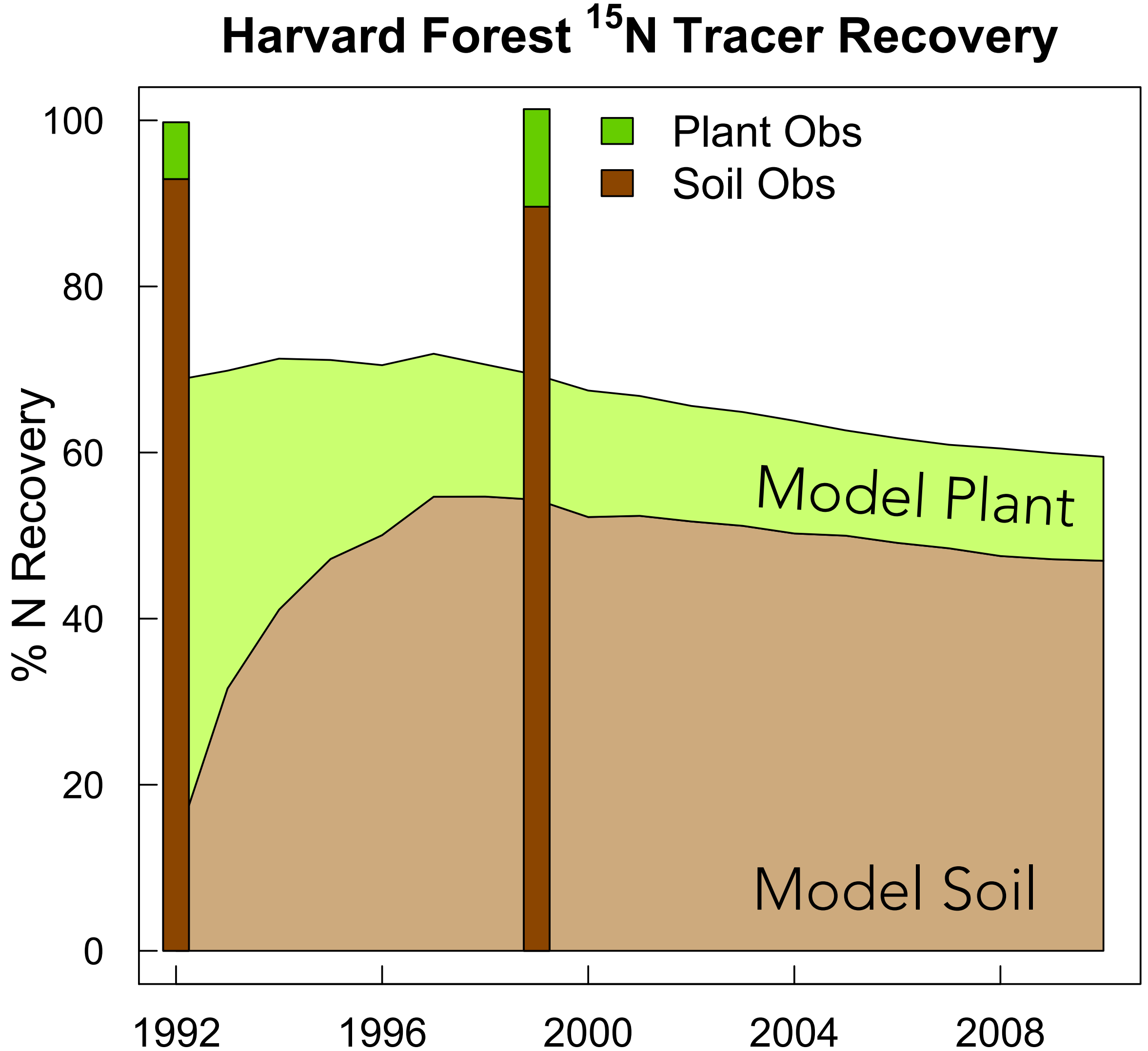

obs from: Nadelhoffer et al., 1999 *Ecol. App*, Nadelhoffer et al., 2004 *For. Ecol & Appl*

# CLM5 underestimates soil recovery of added N



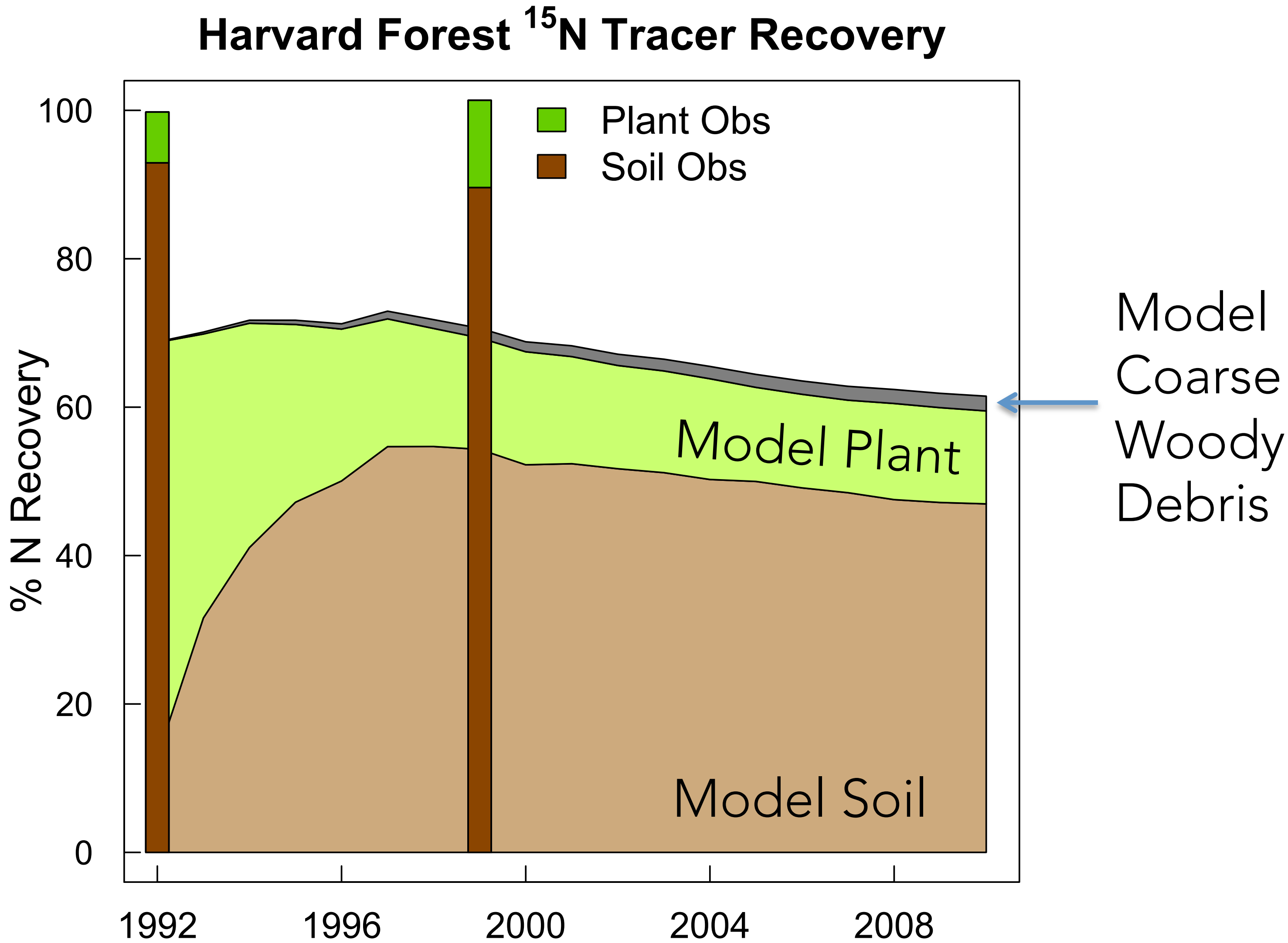

obs from: Nadelhoffer et al., 1999 *Ecol. App*, Nadelhoffer et al., 2004 *For. Ecol & Appl*

# CLM5 overestimates short-term plant recovery of added N



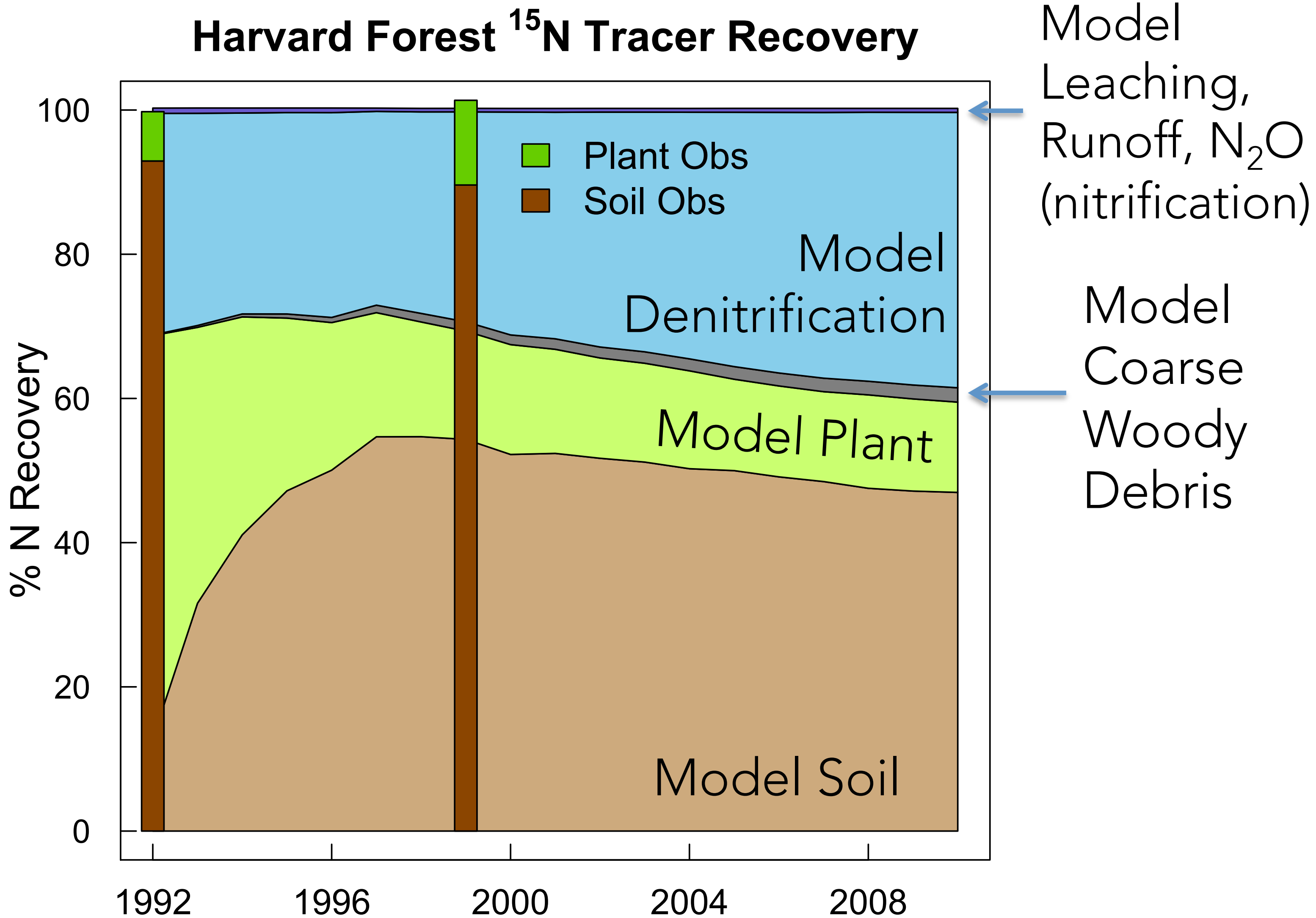

obs from: Nadelhoffer et al., 1999 *Ecol. App*, Nadelhoffer et al., 2004 *For. Ecol & Appl*

# CLM5 underestimates total recovery of added N

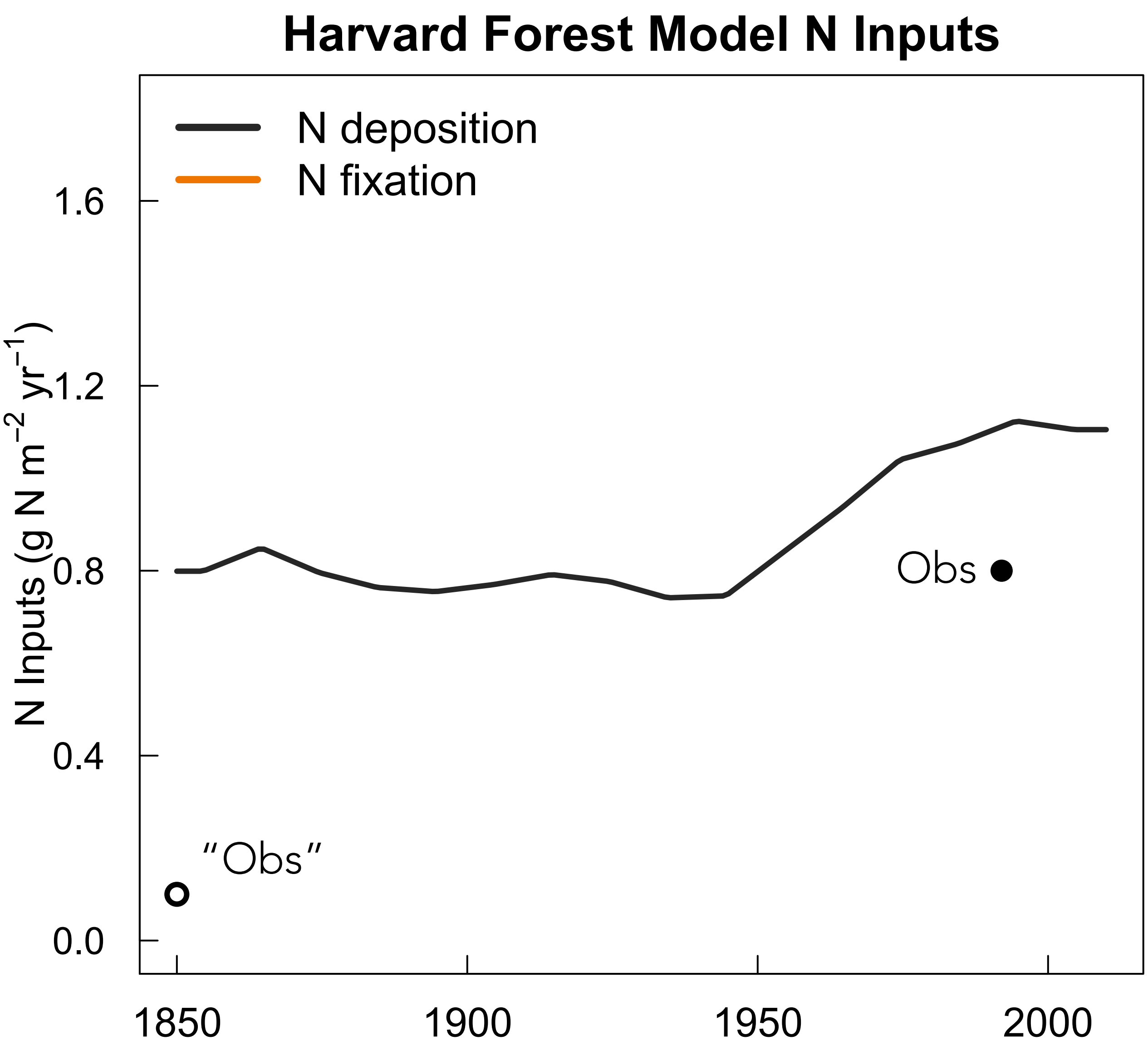



obs from: Nadelhoffer et al., 1999 *Ecol. App*, Nadelhoffer et al., 2004 *For. Ecol & Appl*

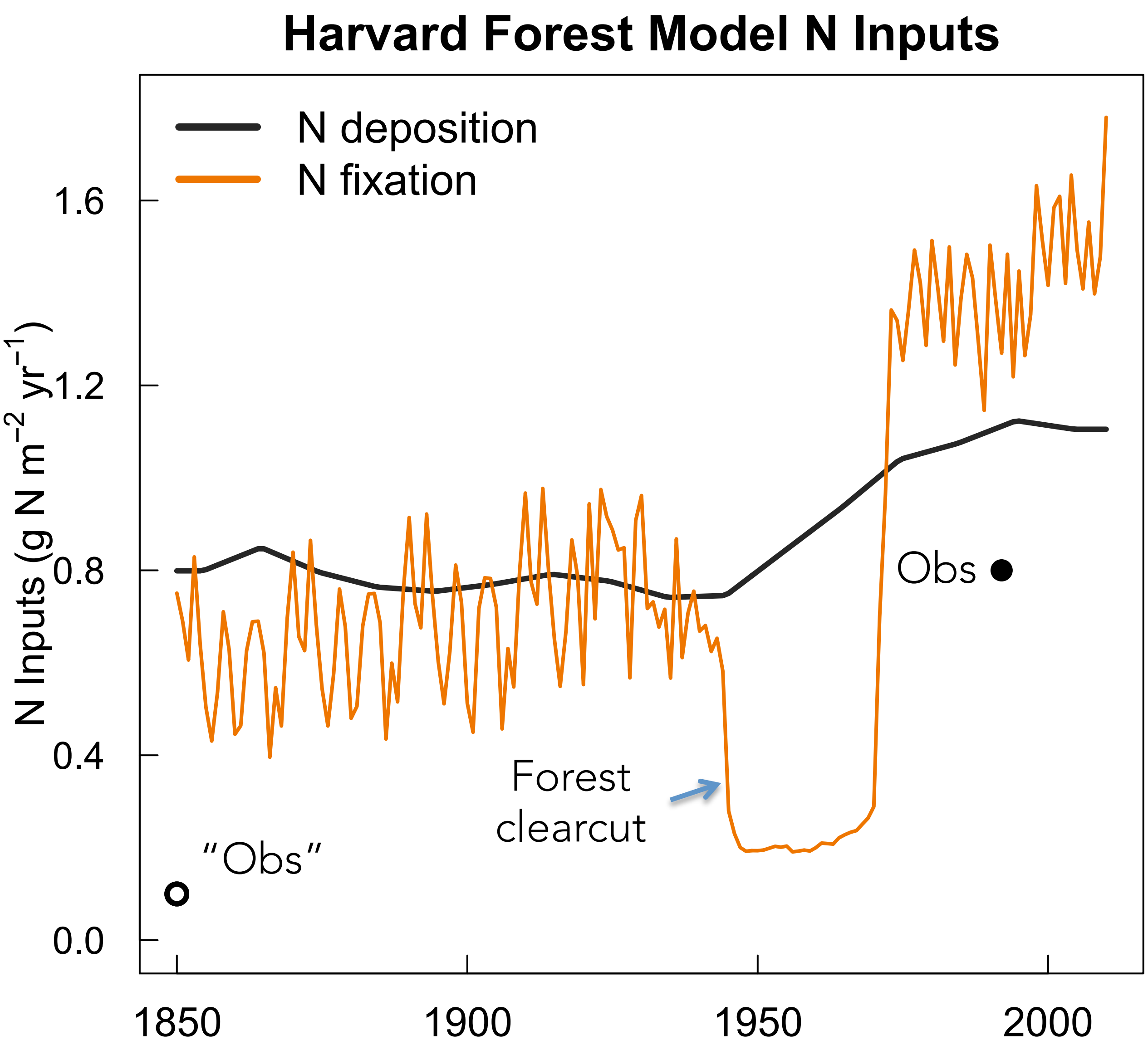
# CLM5 overestimates loss of added N to denitrification



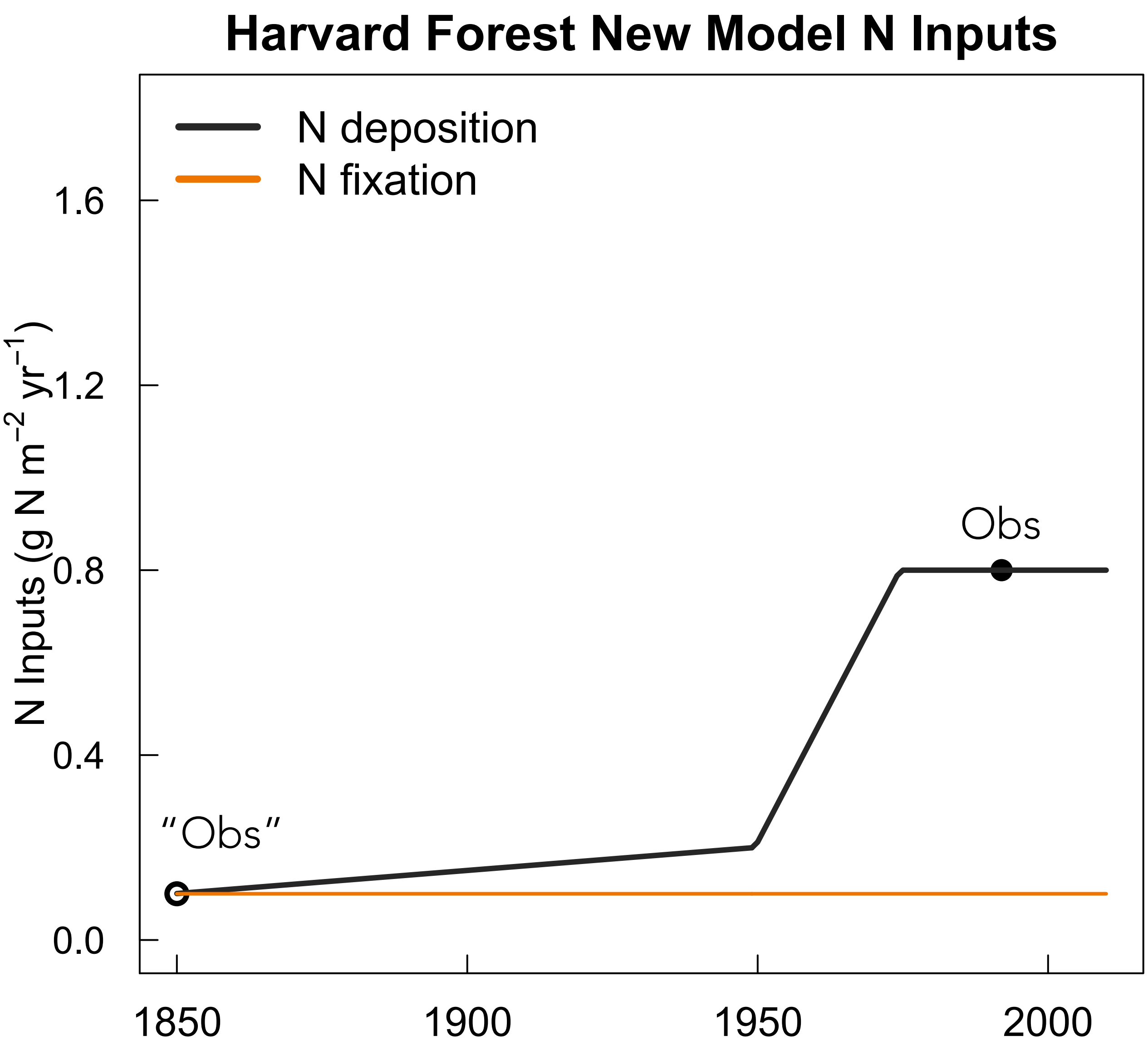
# Model N inputs into ecosystem are too high



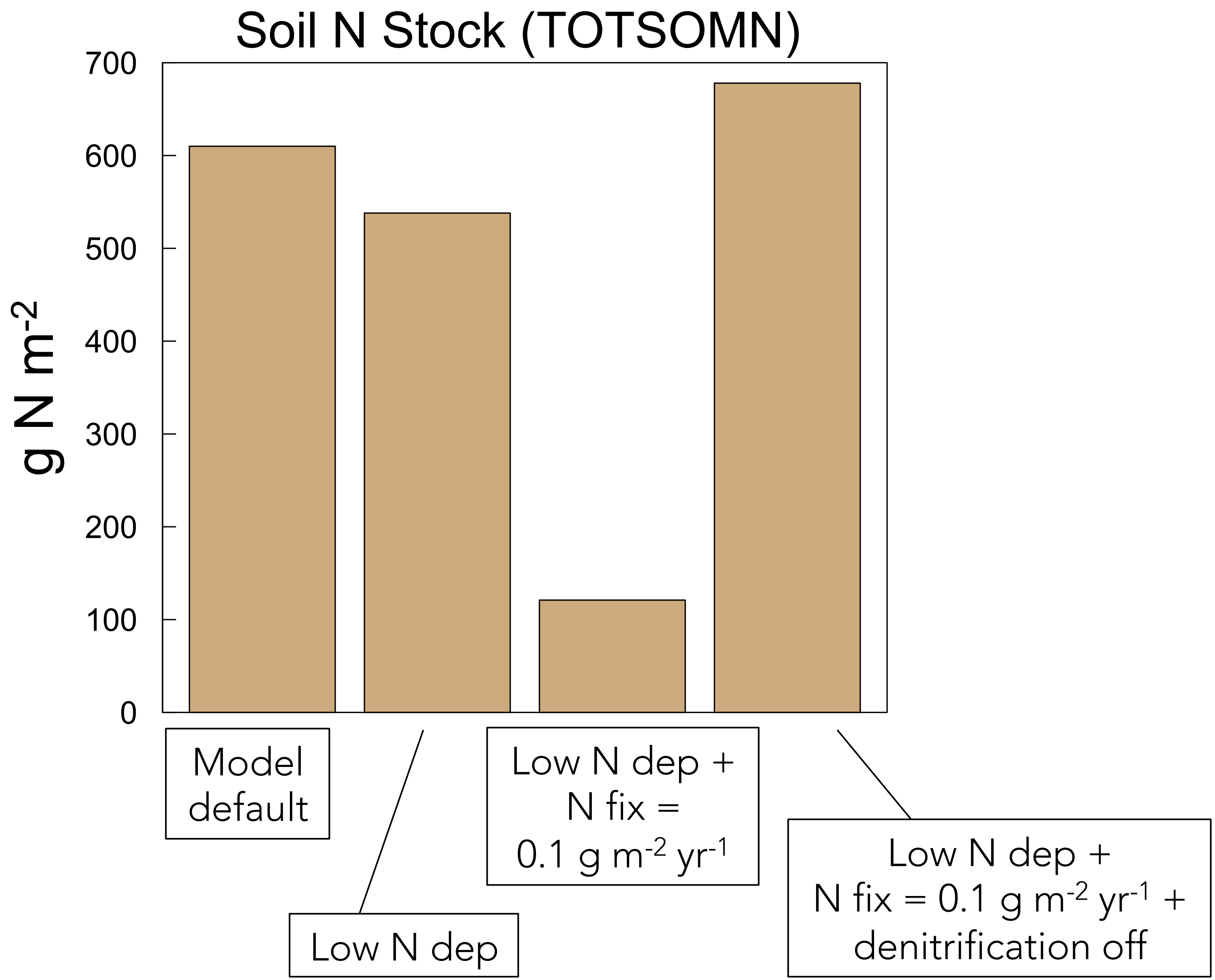
# Model N inputs into ecosystem are too high



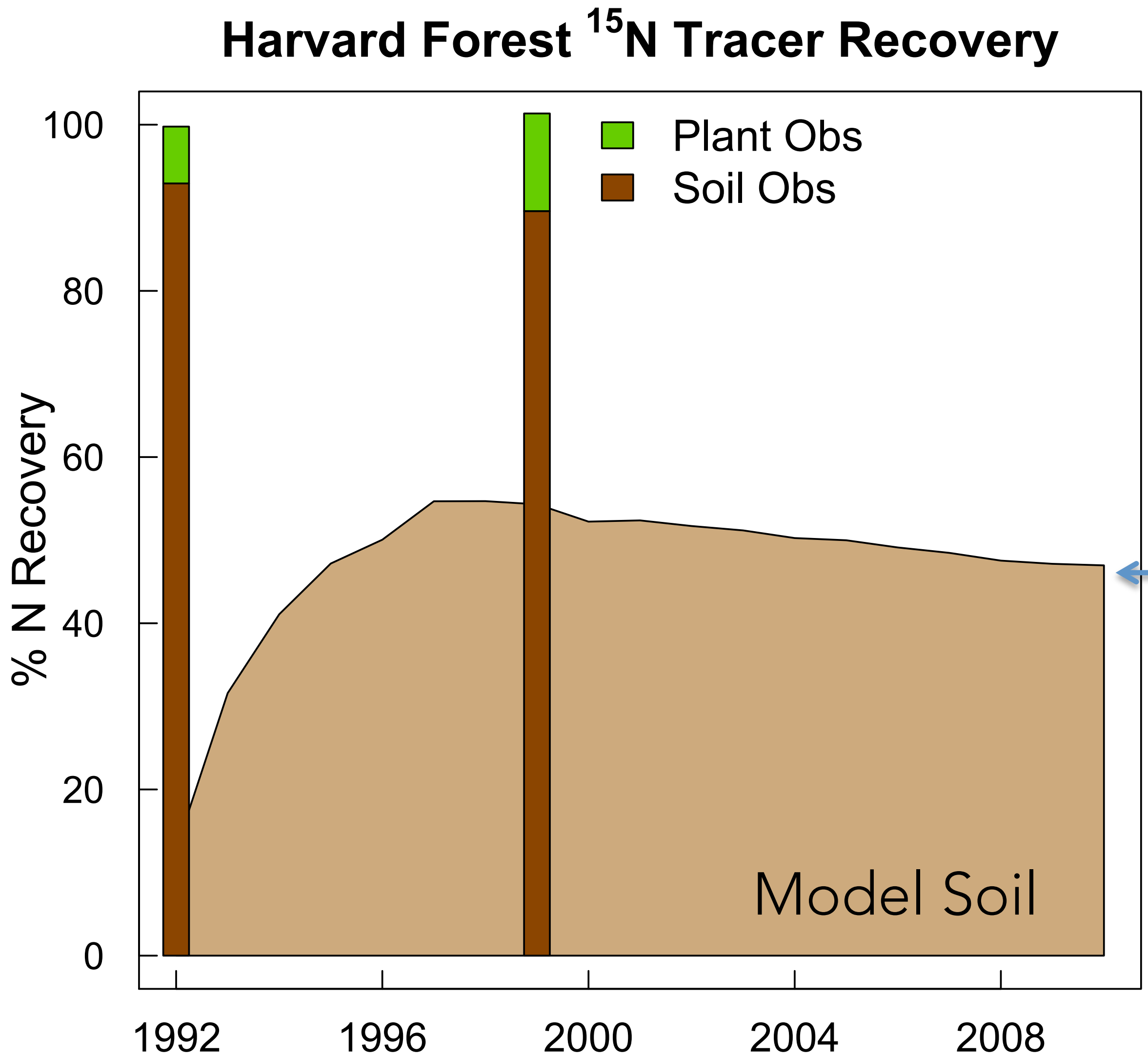
# Adjusted N fluxes for transient case (1850-2010)



# End-of-spinup soil stocks vary with N fluxes



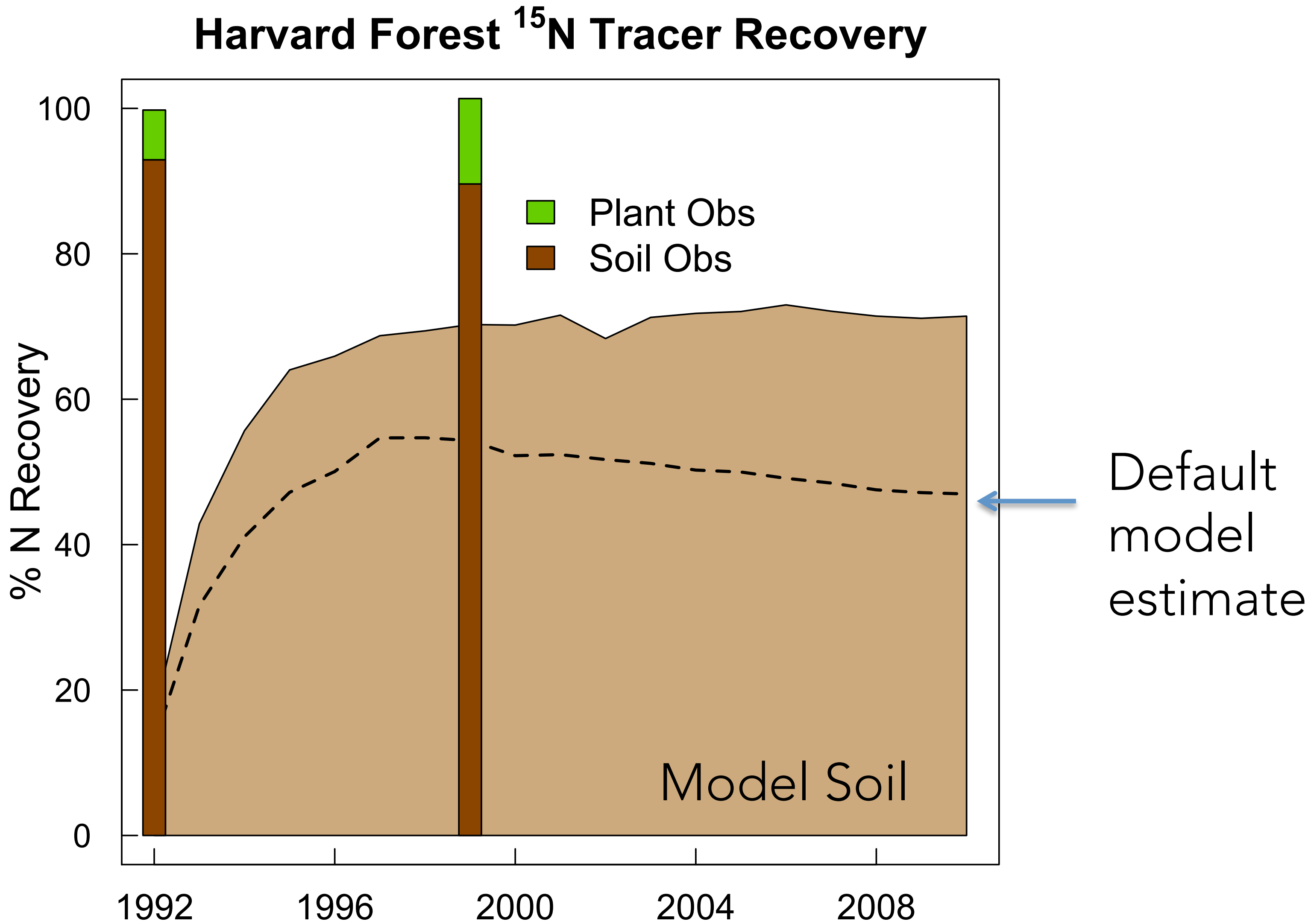
# CLM5 underestimates soil recovery of added N




Default model estimate

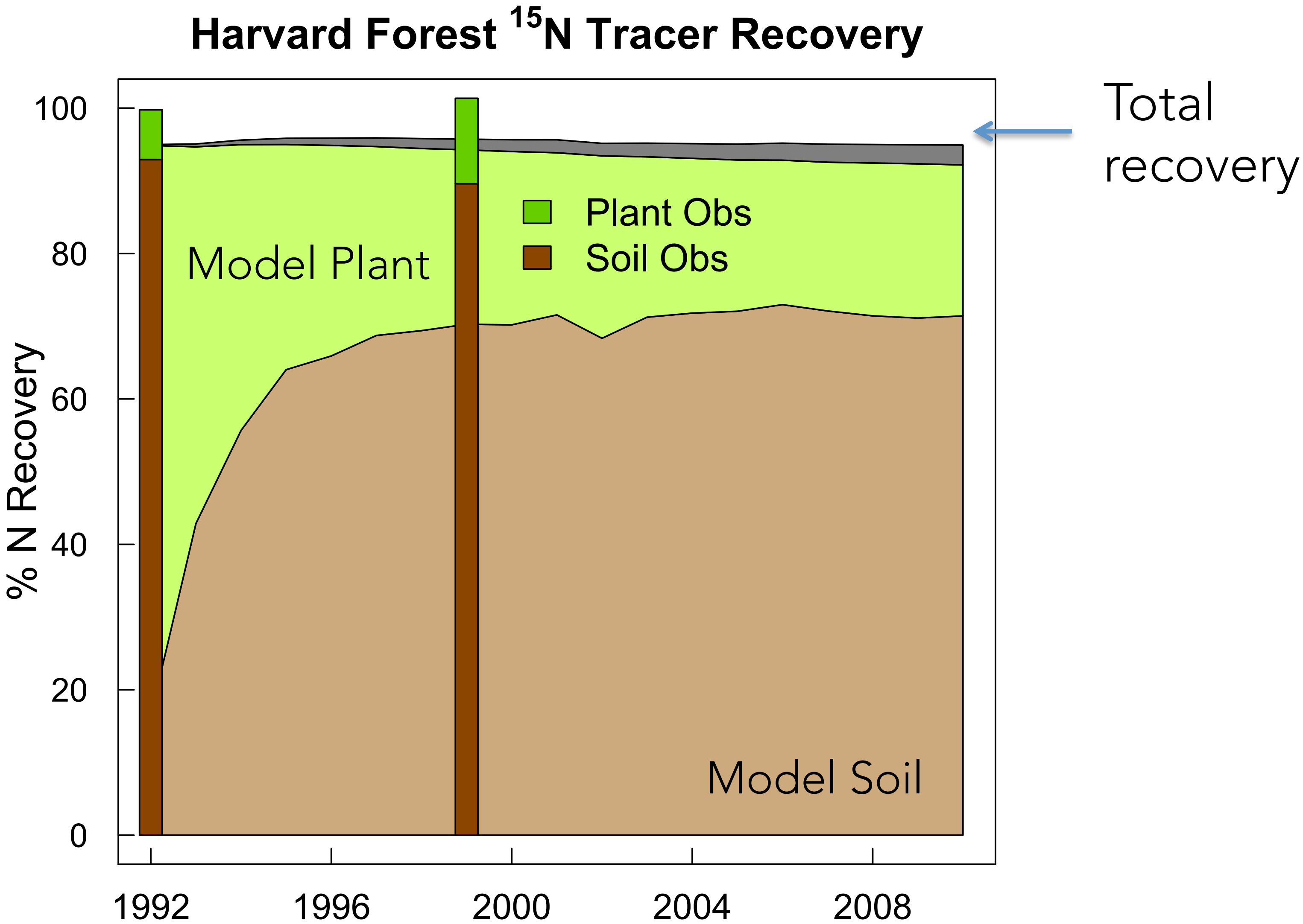
obs from: Nadelhoffer et al., 1999 *Ecol. App*, Nadelhoffer et al., 2004 *For. Ecol & Appl*

# Adjusted CLM5 reduces the underestimate of soil recovery of added N

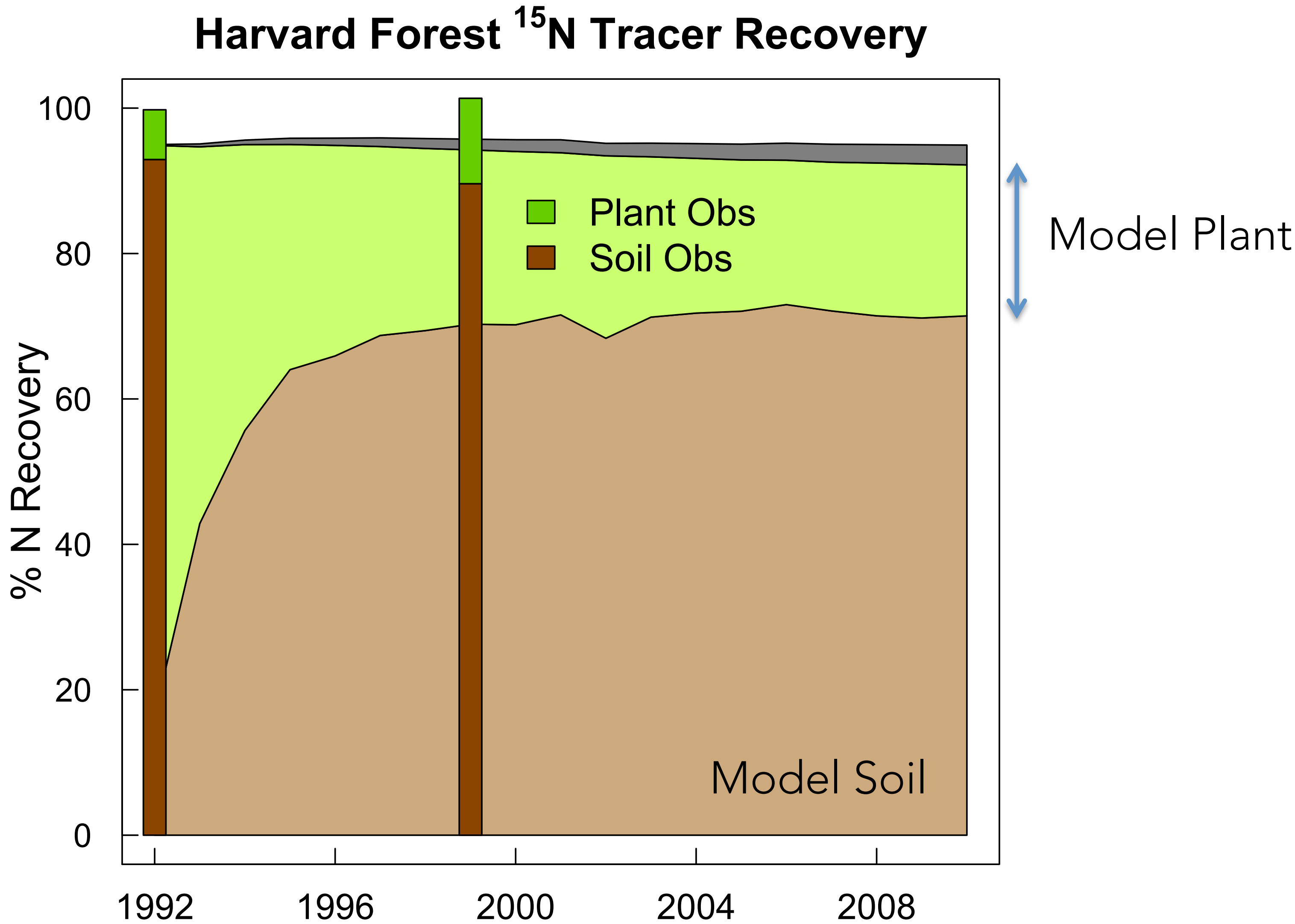



obs from: Nadelhoffer et al., 1999 *Ecol. App*, Nadelhoffer et al., 2004 *For. Ecol & Appl*

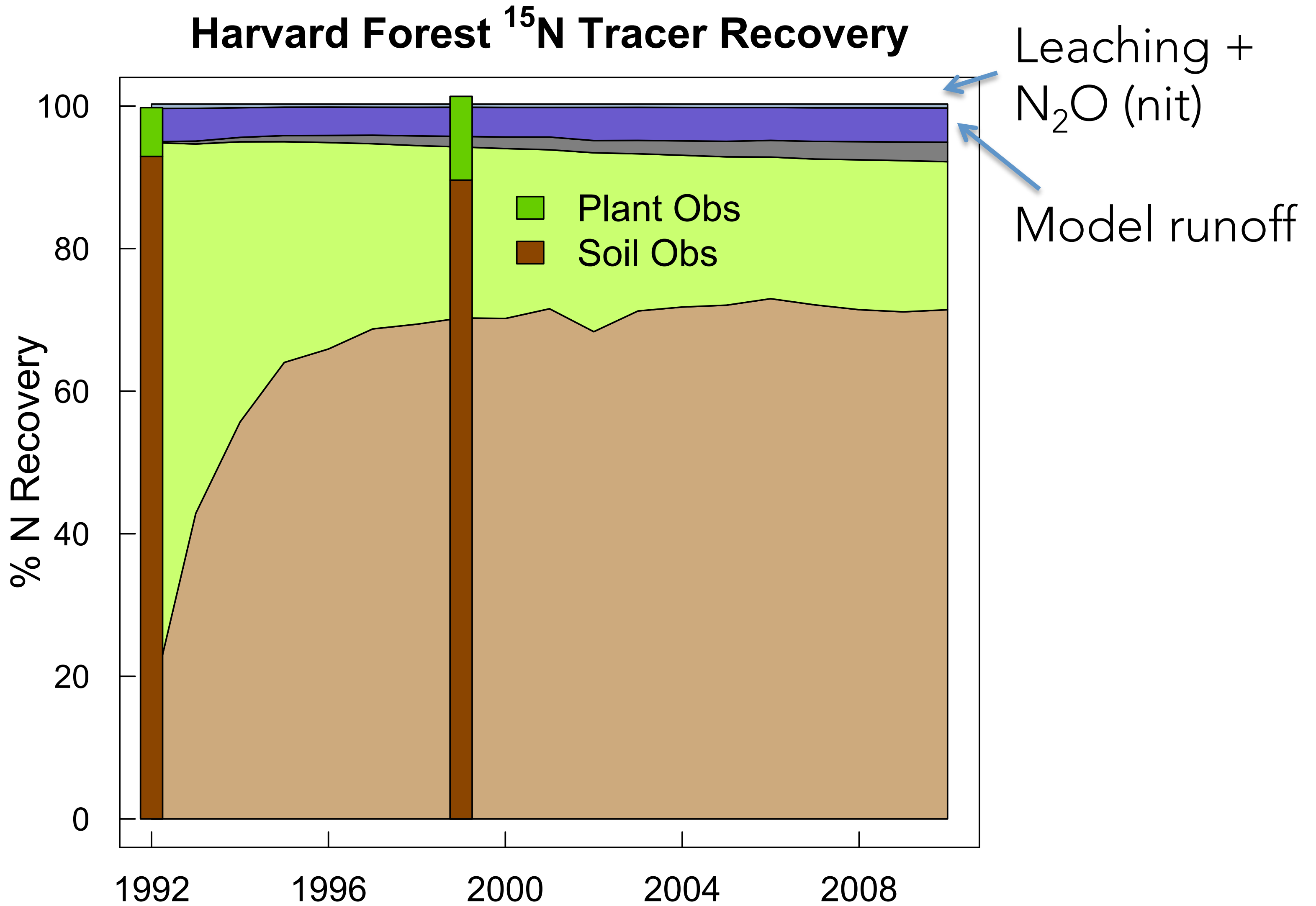
# Changing N cycling increases total retention of added N



# Adjusted CLM5 continues to overestimate plant recovery of added N



# Fate of N losses in ecosystem shift when denitrification turned off



# Summary of default CLM5

How well are we modeling the fate of N deposition in ecosystems over time?

- Added N mostly ends up in soils in the long-term, but CLM5 underestimates the amount.
- Modeled fate of N in plant pools declines over time, but is overestimated in the short-term.
- Total recovery of N is underestimated in the short- and long-term.

# Summary of adjusted CLM5

How well does an adjusted CLM5 model the fate of N deposition in ecosystems over time?

- Total recovery of added N better matches observations in the short- and long-term.

- More of the added N is recovered in soils in the long-term.

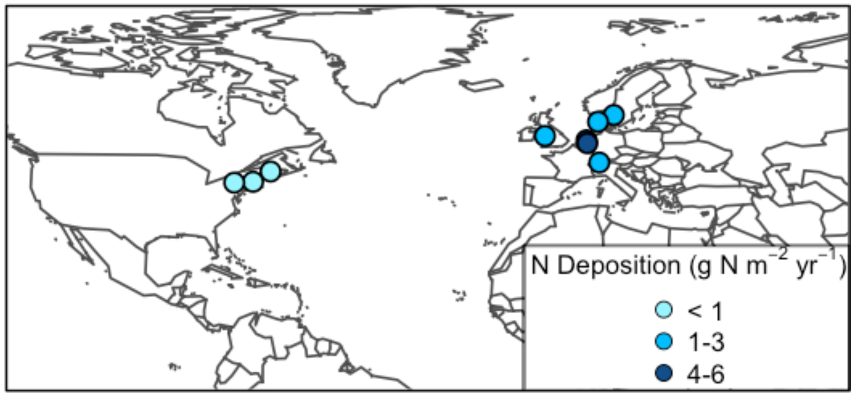
- Modeled fate of N in plant pools is overestimated in the short- and long-term.

# Conclusions

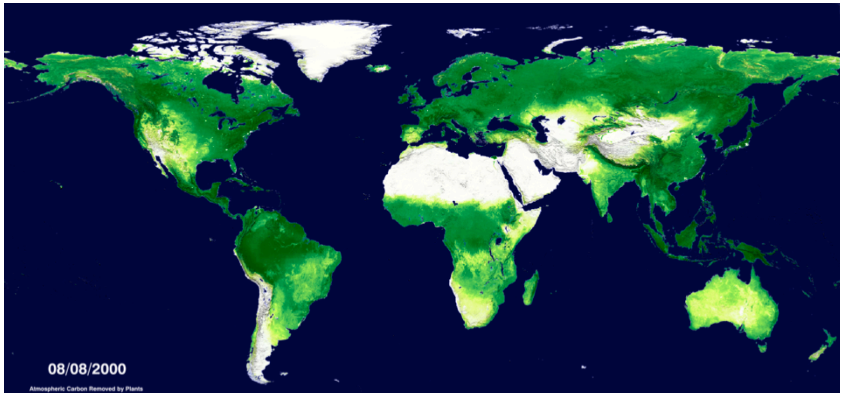
- CLM5 does not accurately predict the fate of added N.
  - Soil stocks are approx. correct, but with N inputs that are too high.
  - Correcting N inputs and outputs leads to less loss of added N.
  - Need to improve competition between plants and immobilization (N limitation).
- Adds uncertainty to predictions of the forest carbon sink as climate and soil nutrient availability change in the future.

# Future Work

- Run for all sites and fertilization levels




- Compare impact on the carbon stocks




- Examine fate of N inputs in crops

# Acknowledgements

Danica Lombardozzi (NCAR)
CISL team!
Julius Vira (Cornell)
Ben Ahlswede (Virginia Tech)
NITREX team members

NITREX 2017 Meeting

USDA NIFA

United States Department of Agriculture
National Institute of Food and Agriculture

Funding from the National Institute of Food and Agriculture (NIFA)/US Department of Agriculture (USDA) grant 2015-67003-23485


Questions?