A New Conceptual Model of Nitrogen Saturation

Based on Experimental Nitrogen Addition to an Oak Forest

Gary M. Lovett[1] and Christine L. Goodale[2]

[1]Cary Institute of Ecosystem Studies, Millbrook, NY USA, [2] Cornell University, Ithaca, NY USA

Current Conceptual Model of N Saturation

The dominant conceptual model of N saturation is based on a diagram by Aber et al. (1989, 1998) (Fig. 1) showing the temporal trend of expected responses to increasing N addition in an initially N-limited forest.

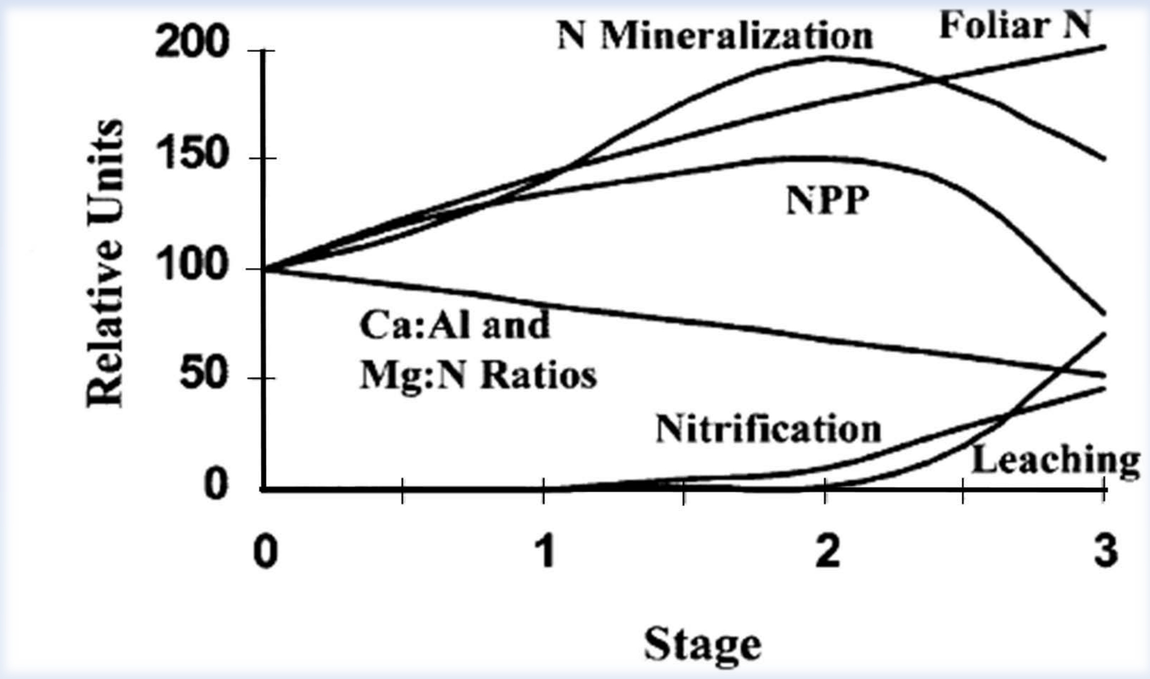
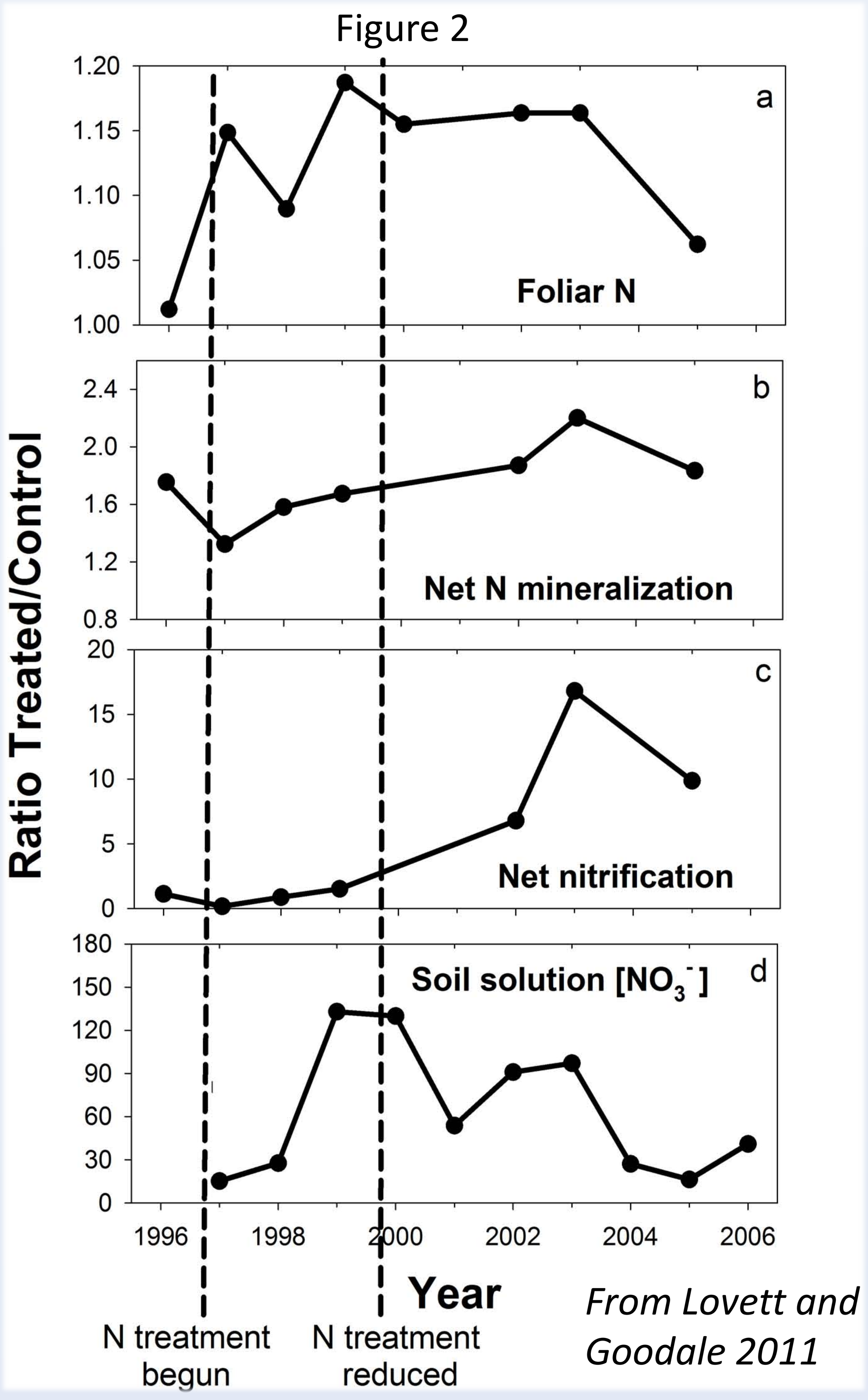


Figure 1
From Aber et al. 1989

In this model, the forest responds to increasing N availability first by increasing foliar N, which leads to higher NPP. Higher N return in litter leads to an increase in N mineralization rate, leading eventually to higher nitrification and NO_3^- leaching.

Results of N Fertilization Study

We added N (as NH_4NO_3) to 6 plots in a mixed-oak forest at the Cary Institute in Millbrook, NY, and also measured 6 paired control plots. The N additions started in 1996 at a rate of 100 kg N/ha/y, and in 2000 the rate was decreased to 50 kg N/ha/y and has continued at that rate. **Our results show patterns that are not consistent with the trends proposed by Aber et al. (1998), such as:**



Foliar N increased by about 15-20% then leveled off, then declined.

N mineralization did not change significantly.

Nitrification rate increased significantly after NO_3^- leaching had already begun

NO_3^- leaching responded very strongly early in the experiment, with concentrations reaching over 100x controls by year 3.

Rethinking the Conceptual Model

The Aber et al. conceptual model is not consistent with some of our results, nor with other results described in recent literature. For example, N additions can change plant species composition, and inhibit decomposition. **We need a new conceptual model that is broader and more consistent with recent findings**.

We start with the mass balance of N in an ecosystem:

$$I - dN_v/dt - dN_s/dt = L + G$$

I: Input rate; dN_v/dt: Vegetation sink; dN_s/dt: Soil+ detritus sink; L: Leaching rate; G: Gaseous loss rate

We distinguish between

Capacity N saturation: sink strengths in vegetation and soil are 0, and inputs = outputs

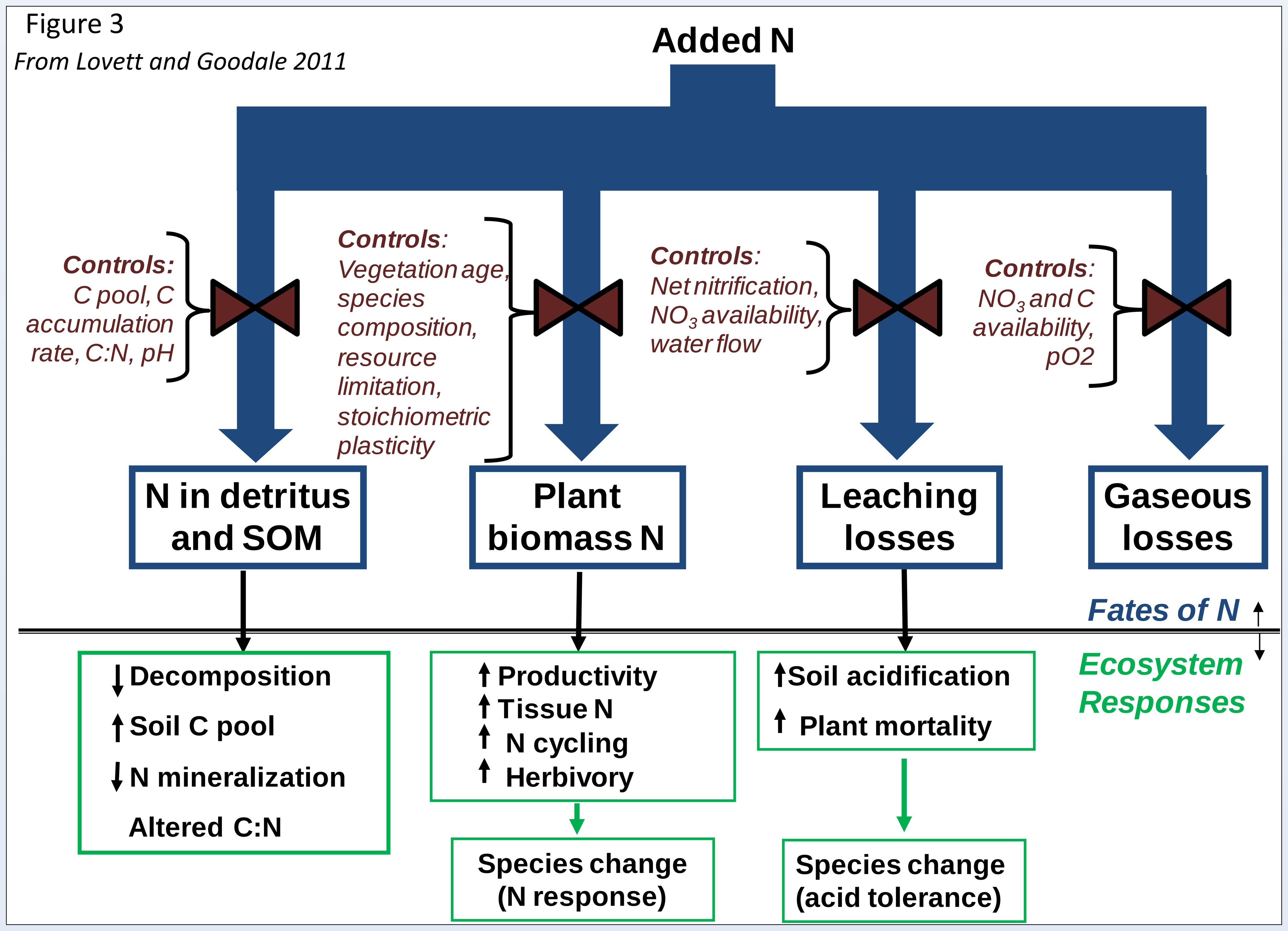
Kinetic N saturation: sink strengths are >0 but their sum is less than the input rate.

Most forests that show NO_3^- leaching are experiencing some level of kinetic saturation, but not capacity saturation.

Our conceptual model of the process (Fig. 3) starts with this mass balance. In our model:

- The N added to the system flows to 4 possible fates, constrained by the mass balance.
- The N can flow to all fates simultaneously.
- The distribution of N among these sinks and losses is determined by sink strengths and their controlling factors in each ecosystem.
- The fate of the N determines which of the many possible responses will be manifested, and in what sequence.

Figure 3
From Lovett and Goodale 2011



In this model, the temporal pattern of responses is determined by the relative strength of the sinks and loss terms and their change over time. **The sequence of responses in the Aber et al. diagram represents just one possible case**, expected only for systems in which both the vegetation and soil sink strengths are high.

References:

Aber, J.et al. 1998. Nitrogen saturation in temperate forest ecosystems: Hypotheses revisited. Bioscience **48:921-934.**

Lovett, G. M. and C. L. Goodale. 2011. A new conceptual model of nitrogen saturation based on experimental nitrogen addition to an oak forest. Ecosystems **14:615-631.**

Wallace, Z. P., G. M. Lovett, J. E. Hart, and B. Machona. 2007. Effects of nitrogen saturation on tree growth and death in a mixed-oak forest. For.Ecol.Manag.**243:210-218.**

We thank NYSERDA and NSF for support of this work.