Building a biosphere-relevant Earth system modeling framework: Modeling impacts of atmospheric nitrogen deposition on the terrestrial biosphere

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Introduction

❖ Human activities are responsible for doubling the amount of reactive nitrogen (N) in the terrestrial biosphere, which has had numerous negative impacts on natural ecosystems, such as acidification, a decrease in biodiversity, and eutrophication (Gruber and Galloway, 2008).

❖ Additions of N in the terrestrial biosphere, such as through atmospheric deposition, may cause a carbon sequestration effect by enhancing plant growth. Unlike carbon dioxide fertilization, forests fertilized by increased N may reach a saturation level and no longer remain carbon sinks (Gruber and Galloway, 2008; Aber et al., 1989).

❖ Furthermore, effects between different species of N, ammonium and nitrates, are important because deposition values are an order of magnitude different and their sources are also different (Holland et al., 1997).

Objective

The objective of this preliminary study is to examine the relative contributions of long-term chronic increases in the atmospheric deposition of nitrates and ammonium to potential carbon sequestration. This is a first step in building a framework towards an Earth systems model, BioEarth.

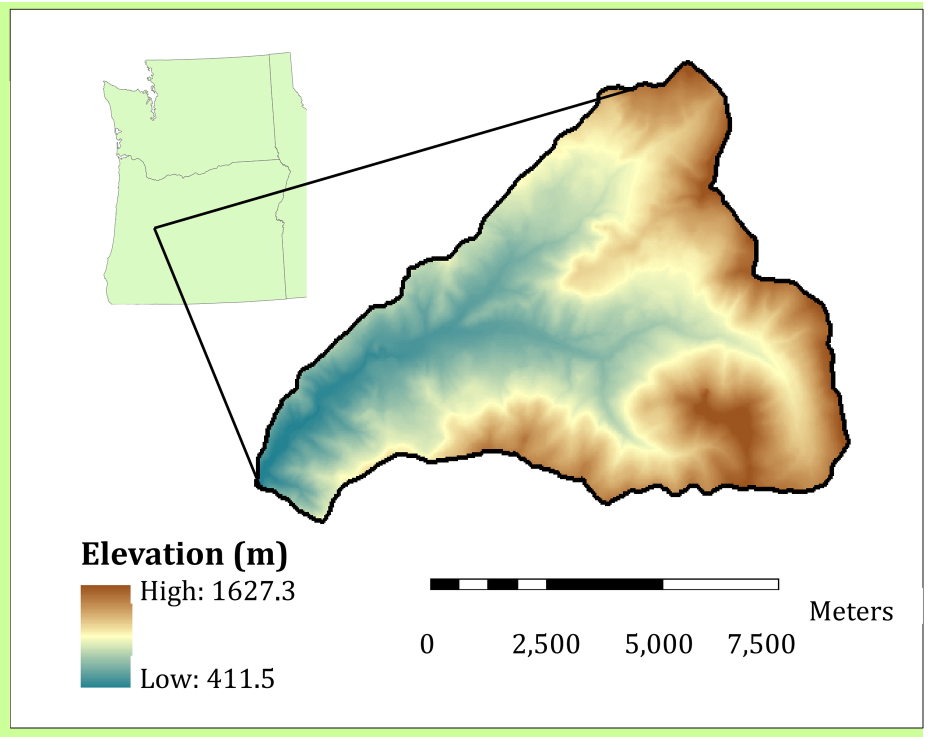
Study Area

❖ H. J. Andrews Long-Term Ecological Research (LTER) site

❖Lookout Creek Watershed (pictured left) within the McKenzie Basin in central Oregon

❖Located within Columbia River Basin

❖Abundant information on streamflow and stream chemistry concentrations since 1970s

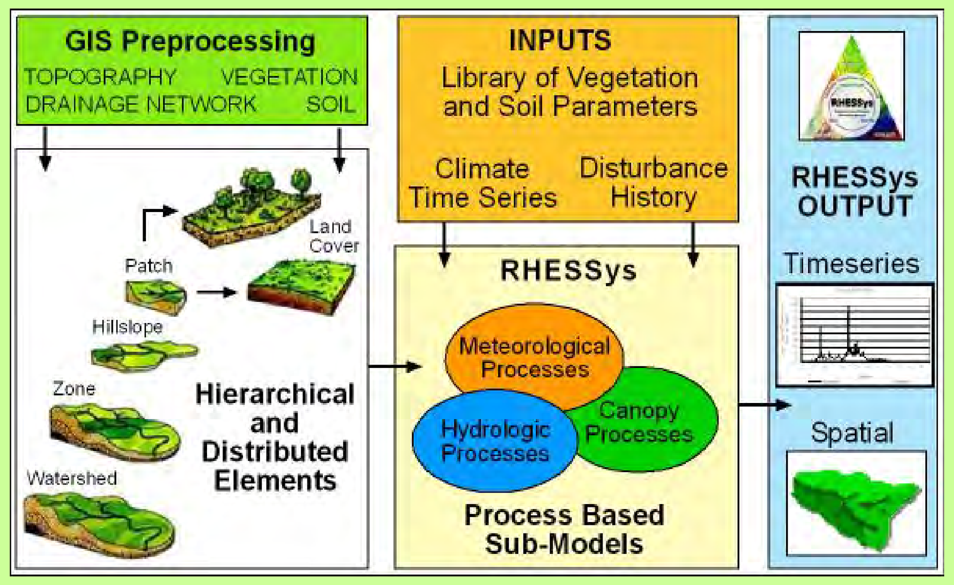


Model Description

❖ RHESSys is the Regional Hydro-ecologic Simulation System (Tague and Band, 2004).

❖ It is a physical model that incorporates hydrology with relevant biogeochemical cycling within ecosystems.

❖ Algorithms for carbon (C) and nitrogen (N) cycling within the soil and vegetation are adapted from the CENTURY and BIOME-BGC models.



Model Calibration

❖Watershed 2 of HJ Andrews was used for this study because of the readily available data and low computational time.

❖Two 'spin-up' periods were conducted to produce the worldfile used in this study.

❖ A spin-up of 800-1000 years was used to stabilize the soil.

❖ A second spin-up of about 450 years allowed vegetation to grow to a mature forest. This age roughly represents the age of pristine trees.

❖The model was calibrated by comparing observed and simulated streamflow and adjusting two parameters, the saturated hydraulic conductivity (K) and decay of K with depth (m).

❖ Nash-Sutcliffe coefficient = 0.7

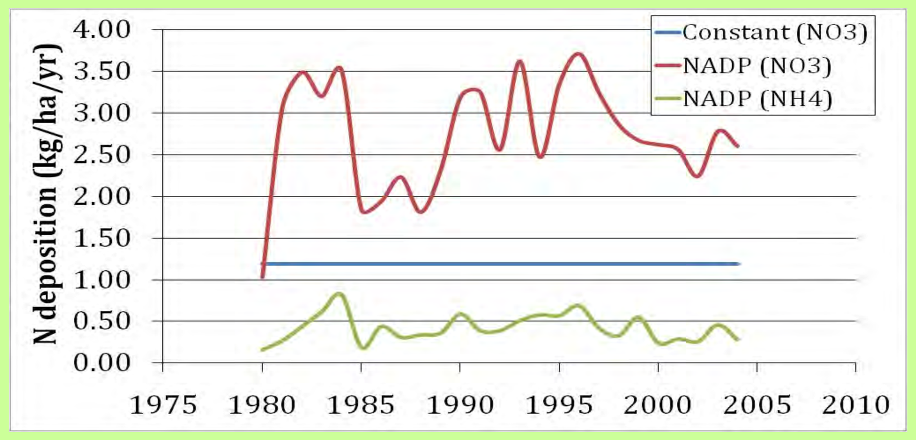
❖ Simulations represent a hypothetical Douglas Fir forest stand.

Model Inputs

❖Observed wet nitrogen deposition measurements from the National Atmospheric Deposition Program (NADP) were used as external inputs into RHESSys.

❖The model can accept ADN as nitrates (NO_3^-) and/or ammonium (NH_4^+) species.

❖Ranges of chronic additions to the NADP time-series from 1 kg/ha/yr to 64 kg/ha/yr are created (not shown).



Preliminary Evaluation

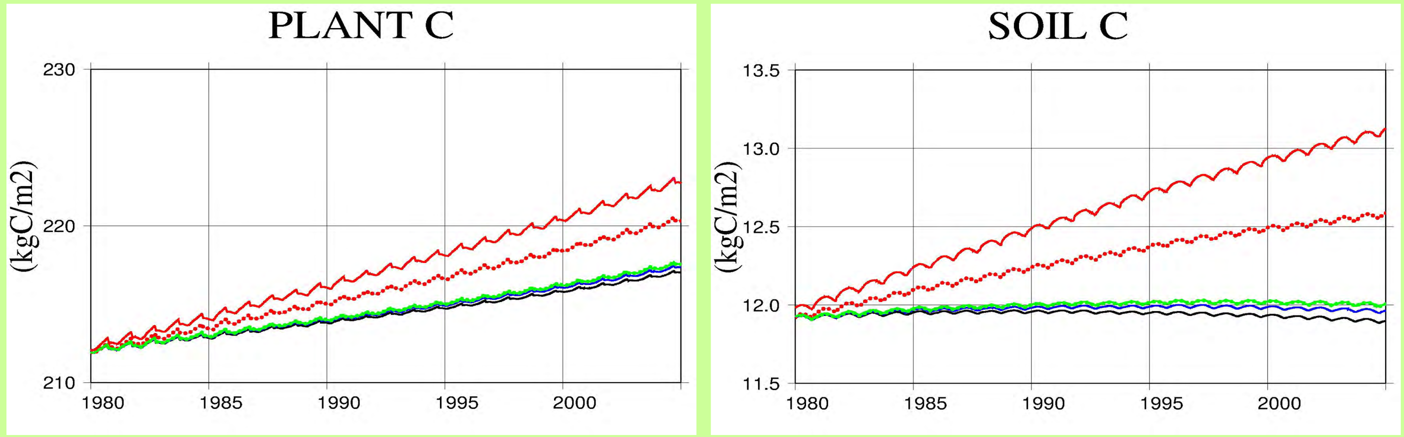
❖Hydrologic calibration (1960 – 1979).

❖ A preliminary evaluation on sub-watershed 2 (W2) was performed using streamflow N. Average fluxes were noticed for both observed and simulated.

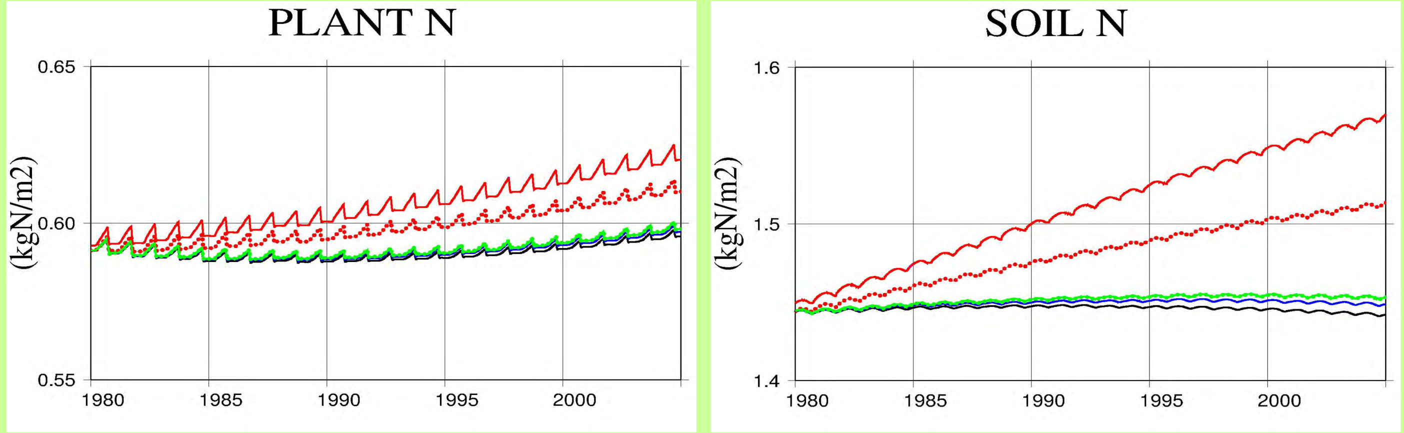
❖Simulated streamflow nitrates were higher than observed. This overestimation may indicate some future work on these processes and simply that in-stream processes of nitrates are not included in the model.

Preliminary Results

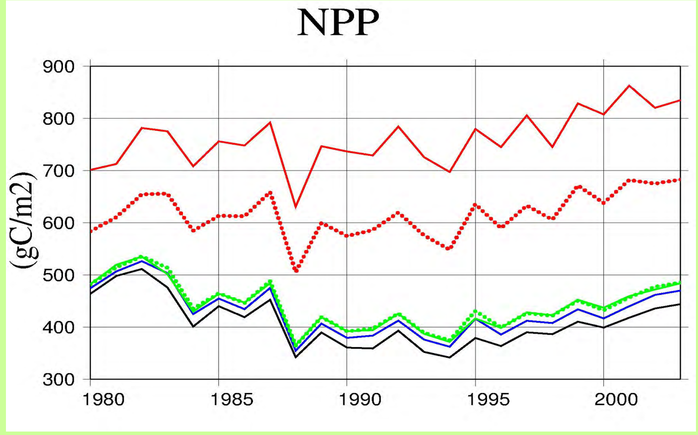
Default (Constant N) | NADP | +4 kg/ha/yr in NO3 | +64 kg/ha/yr in NO3 | +4 kg/ha/yr in NH4 | +64 kg/ha/yr in NH4



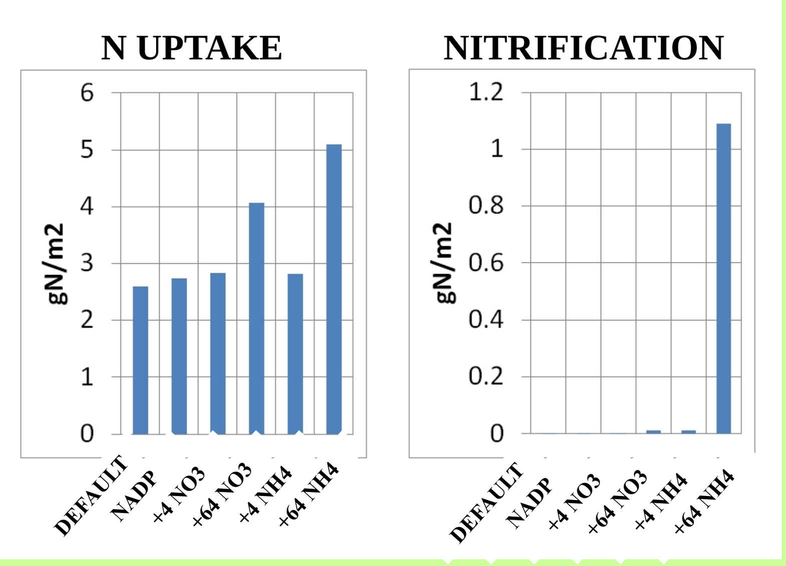
❖Positive trends in plant C and plant N are seen from RHESSys output. Increases of 64kg/ha/yr result in the most increase of C in these two storage pools. In soil C, additions of low ADN follow the default and NADP results with negative trends.



❖Similar to plant C and soil C, positive trends in plant and soil N are seen. Increases of 64kg/ha/yr result in the most increase of N in these two storage pools. In soil N, additions of low ADN follow the default and NADP results with negative trends.

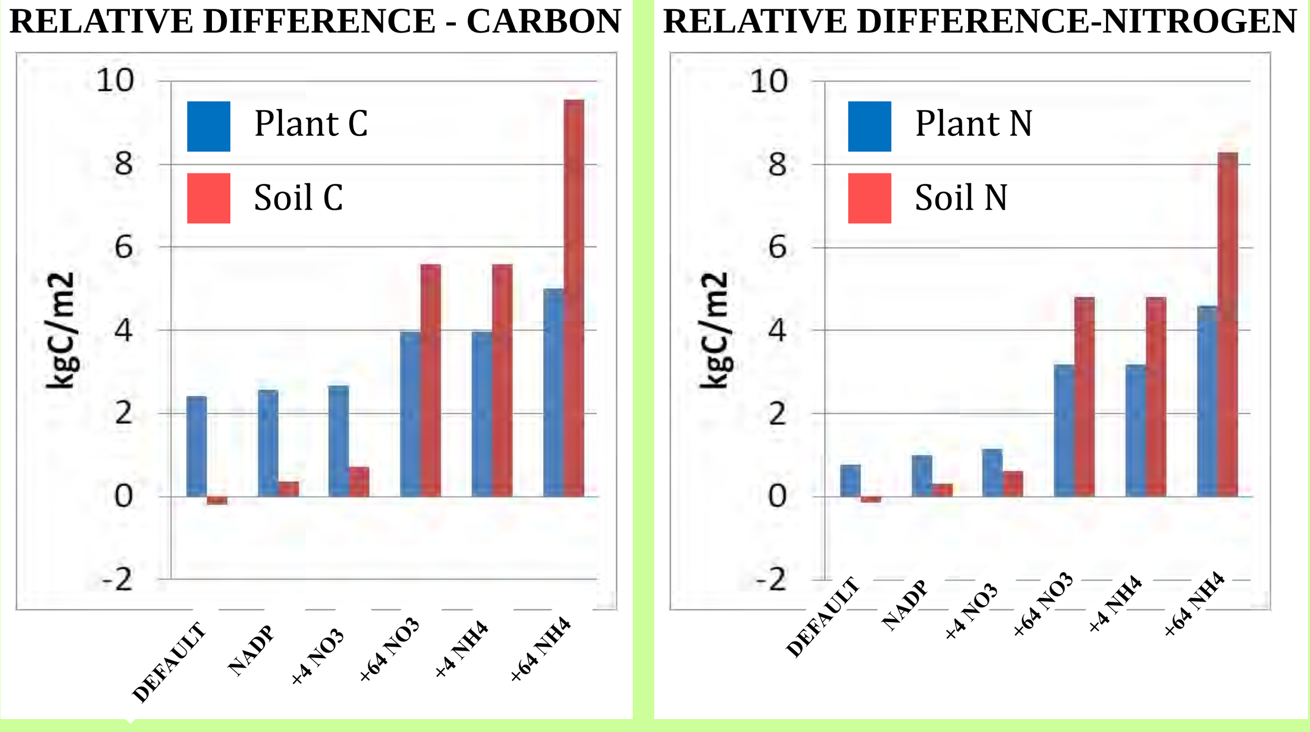


❖Increases in net primary productivity (NPP) are pronounced with 64 kg/ha/yr of both ammonium and nitrate deposition. These results are corroborated with the increases in plant C – more NPP coincides with more biomass.



❖ Bar plots are shown (above) of average annual N uptake and nitrification. There is an order of magnitude increase in nitrification for the largest addition of ammonium.

❖Streamflow nitrates (results not shown) result in an increase in the annual flux among the different experimental additions of ADN.



❖ Relative difference plots for carbon and nitrogen in plants (blue) and soil (red) comparing initial and final stores from simulation period.

❖ At lower rates of ADN, such as current NADP levels, more C and N are likely to be relatively contained in plants.

❖At higher rates of ADN, more C and N are stored in the soil. Looking at the elements separately, the soil compartment contains relatively more of each element than in plants (see top figures).

Discussion/Conclusions

❖ Using RHESSys and perturbed NADP data, nitrate and ammonium additions result in potential long-term C storage over the 20-year period.

❖These results also demonstrate that C and N in the plant and soil accumulate at faster rates with increased additions of ADN.

❖ Increases in net primary productivity (NPP) and positive trends in plant C indicate the HJ Andrews LTER site is N-limited because additional N results in more growth.

❖ In the output shown, positive trends for ammonium-added deposition had higher rates of change than the positive trends for added deposition via nitrates. Moreover, the amount of N exported to the stream are highest with the nitrate-added deposition. The mobility of nitrate in water may explain these two observations.

❖ The 20+ years simulated (1980-2003) may represent the growing stage of the forest, as indicated by positive trends (see Results). Therefore, results are interpreted within this context.

Future Work

❖ Running RHESSys over longer time periods to assess potential ecosystem response.

❖ Establishing correlations between certain output against ADN and/or climate data, such as temperature and precipitation.

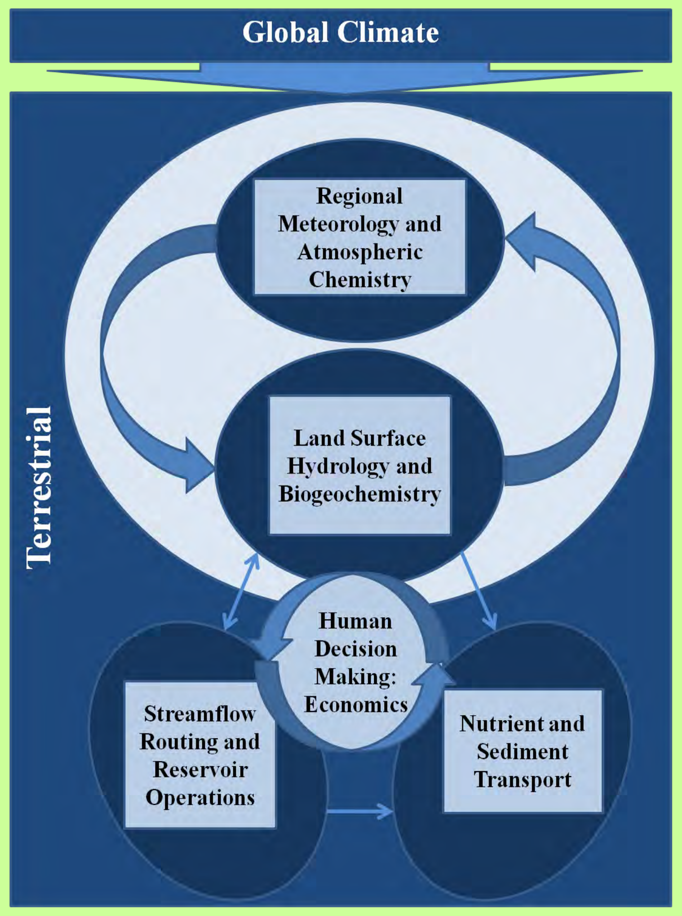
❖ Selecting sites where nitrogen addition experiments have taken place and comparing RHESSys output at these locations.

BioEarth

(http://www.cereo.wsu.edu/bioearth/)

❖This research also represents the first step in developing BioEarth, a regional Earth system model, by looking at the one-way linkages between the atmosphere and terrestrial biosphere.

❖The goal of BioEarth is to understand the interactions between land use and water and nutrient cycling under decadal-scale climate variability to inform decisions related to agricultural and natural resources management.



BioEarth Biosphere-relevant earth system model

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LAR Atmospheric Policy TRAJECTORY

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