Supporting information for the research paper

Impacts of enhanced nitrogen deposition and soil acidification on biomass production and nitrogen leaching in Chinese fir plantations

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1. Sources of calibration data

A detailed description of FORECAST calibration data requirements can be found in Kimmins et al. (1999). Data for model calibration on Chinese fir growth were derived and compiled by Bi et al. (2007) from literature and field studies from sites with climates similar to that of the central area of Chinese fir plantations in the subtropical region, (Fujian, Zhejiang and Hunan provinces see below, Table S.1). Given the fact that the data came from several studies, care was taken to ensure that selected data were from comparable sites (i.e. climate, soil and topographic factors).

The input data were from sites covering the observed range of Chinese fir plantations, qualitatively described as poor, medium and good. The sites were scaled quantitatively by site index as 17, 21 and 27 (from poor to good, based on top height in m at age 50 years) to represent a relative index of tree growth required for extrapolation within the model. We assume in these simulations that the range in tree growth data reflects primarily the range in site nutrient availability within the climatic area from which the data came (Kimmins et al., 1999). Data describing nutrients in precipitation, slope seepage, mineral soil cation and anion exchange capacities, humus mass, nutrient concentrations in litterfall, litter decomposition rates, and other ecosystem variables were derived from Ding and Chen (1995), Huang et al. (2000), Liao et al. (1999, 2000), Liu et al. (1991), Tian and Zhao (1989), Tian et al. (1989), Yang et al. (2000) and Zhou et al. (1991). The tree data on biomass, mortality and stand density, tree height and canopy height, and nutrient concentrations of live tissues were based on values reported by Lin et al. (1996), Liu (1998), Pan et al. (1983), Tian et al. (1989), Wu (1984), Xiao et al. (1999), Yang et al. (1998, 1999), Zhong and Hsiung (1993), and Zhou (1994, 1999) for similar Chinese fir plantations. Data for herb and shrub biomass, height, tissue nutrient concentrations and other relevant data for understory vegetation came from Fan et al. (2001), Lin et al. (2001), Xiang et al. (2003), and Yan et al. (2003). Detailed field data on belowground minor vegetation biomass were not available, and were thus estimated from aboveground biomass (Bi et al. 2007).

Nitrogen cycling in FORECAST is based on a mass balance approach where N can exist in three distinct pools: (1) the plant biomass pool; (2) the available soil nutrient pool, and (3) the soil organic matter/forest floor pool. Inputs and outputs of N to the ecosystem are simulated in a fourstage process for each annual time step (Figure S.1). The “available N” pool in FORECAST can be assimilated to represent the interchangeable N present in the soil during one year as NH4+ , NO3- or labile organic N fractions with turnover rates shorter than 1 year. Effects of atmospheric pollution are simulated using a semi-empirical approach (Figure S.2). N deposition is simulated as a constant annual N flux that directly reaches the soil solution and is incorporated into the available N pool. No mechanistic representation of H+ or S cycles is included in the soil model. Rather, the observed empirical effects of different rain pHs on soil and vegetation are used to modify the related parameters in the model.

Data to simulate the effects of acid rain were based on Li (2010), Lu (2010) and Liu et al. (2010b) greenhouse experiments carried out at Zhejiang Agriculture and Forestry University, from where the full reports can be obtained (Table S.2). In these experiments, 2-year old seedlings were planted in the greenhouse in 2007 and irrigated for three years with sprinkles. The artificial acid rain was created with H_2SO_4 (98%) and HNO_3 (75%) at the volume ratio of 8:1, diluted in water into spay solutions to adjust the rain pHs to 2.5, 4.0, 5.6 and 7.0. The experiments measured the seasonal and annual variations of photosynthesis, chlorophyll fluorescence, chlorophyll content, saplings height, diameter, and biomass; soil pH, CEC, nitrates and ammonium content, SOM, leaf litter monthly decomposition rates and C/N ratio. The irrigation experiment lasted until the trees were 5-year old. At this age the trees were already 5-meter tall and able to produce flowers and seeds, and therefore could be considered young adults (Orwa et al. 2009). As a consequence, the results were considered as representative of the response of the trees to acid rain during the whole rotation (20 years).

2. References

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Table S.1. Values used to calibrate FORECAST most important parameters related to Chinese-fir. Decomposition rates indicate the mass loss in one year as a fraction of the initial mass at that year. See text for list of bibliographical sources for model calibration.

Parameter	Unit	Rich site	Poor site
Chinese fir parameters			
Nitrogen concentration in needles young / old / dead	%	1.53 / 1.36 / 1.13	1.21 / 1.11 / 0.93
Nitrogen concentration in stem sapwood / heartwood	%	0.14 / 0.03	0.12 / 0.03
Nitrogen concentration in bark live / dead	%	0.44 / 0.27	0.37 / 0.24
Nitrogen concentration in branches live / dead	%	0.67 / 0.52	0.55 / 0.47
Nitrogen concentration in root sapwood / heartwood	%	0.37 / 0.06	0.35 / 0.06
Nitrogen concentration in fine roots live / dead	%	1.17 / 0.97	0.96 / 0.79
Shading by maximum foliage biomass	% of full light	8	30
Soil parameters			
Soil volume occupied at maximum fine root biomass	%	100	95
Efficiency of N root capture	%	98	100
Retention time for young / old foliage / dead branches	years	1 / 2 / 40	1 / 2 / 40
Fine roots turnover	$year^{-1}$	0.95	1.35
Nitrogen concentration in slow / fast humus	%	2.75 / 1.20	2.75 / 1.20
Decomposition rate slow / fast humus	% $year^{-1}$	0.17 / 3.00	0.17 / 3.00
CEC soil (CEC humus) / AEC [3]	kg N ha^{-1}	90.0 (0.2) / 7.0	70.0 (0.2) / 5.0
Decomposition rates			
Sapwood (by litter age)	% $year^{-1}$	1-10 years (0.4); 11-15 years (10.0); 16-25 years (15.0); 25-40 years (10.0); >40 years (2.0)	
Heartwood	% $year^{-1}$	1-3 years (0.1); 4-15 years (2.0); 15-20 years (12.0); 20-40 years (9.0); >40 years (2.0)	
Bark	% $year^{-1}$	1-5 years (2.0); 6-20 years (12.0); 20-40 years (20.0); >40 years (4.0)	
Branches and large roots	% $year^{-1}$	1-5 years (10.0); 6-10 years (45.0); 11-15 years (35.0); >15 years (4.0)	
Needles (poor site)	% $year^{-1}$	1-2 years (20.0); 3-5 years (30.0); 6-10 years (40.0); >10 years (2.0)	
Needles (good site)	% $year^{-1}$	1-2 years (27.0); 3-5 years (30.0); 6-10 years (40.0) >10 years (3.0)	
Fine roots	% $year^{-1}$	1-2 years (30.0); 3-4 years (50.0); >4 years (9.0)	

Table S.2. Results of Li (2010), Liu (2010) and Liu et al. (2010b) experiments of N deposition and acid rain on Chinese fir. The values on this table show the relative average (across site qualities and N deposition rates) changes compared to the control acid rain pH (5.6) of four parameters that were directly used to modify each of these parameters in FORECAST for each simulation. Values are dimensionless and shown as proportions of the value for the control.

Acid rain pH	**2.5**	**4.0**	**5.6**	**7.0**
N in anionic form in the soil solution	3.50	2.00	1	1.50
Soil CEC	0.75	0.87	1	1.01
Leaf litter decomposition rate	0.53	0.75	1	1.78
Fine root biomass	0.81	0.94	1	0.95

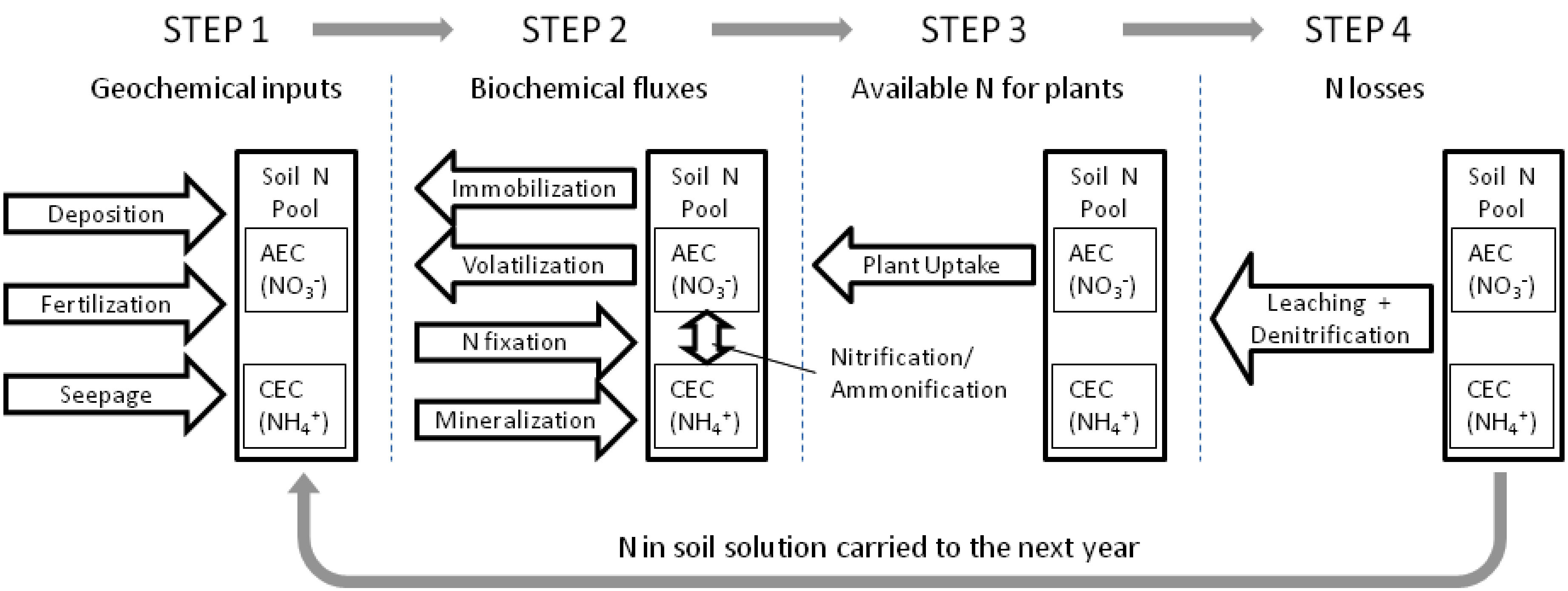

Figure S.1. Estimation of available N in FORECAST in each year. Step 1: geochemical inputs are calculated, with all the forms of N lumped together. Step 2: biochemical fluxes (the lumped N is divided into NH_4^+ and NO_3^- forms using the user-defined ration; denitrification is no explicitly simulated and it is assumed to be included in leaching). Step 3: Plants uptake the available N. Step 4: Soil N remaining for next time step is calculated by subtracting the remaining N from the soil CEC (for ammonium) or AEC (for nitrate): the excess is assumed to be lost via leaching (Kimmins et al. 1999).

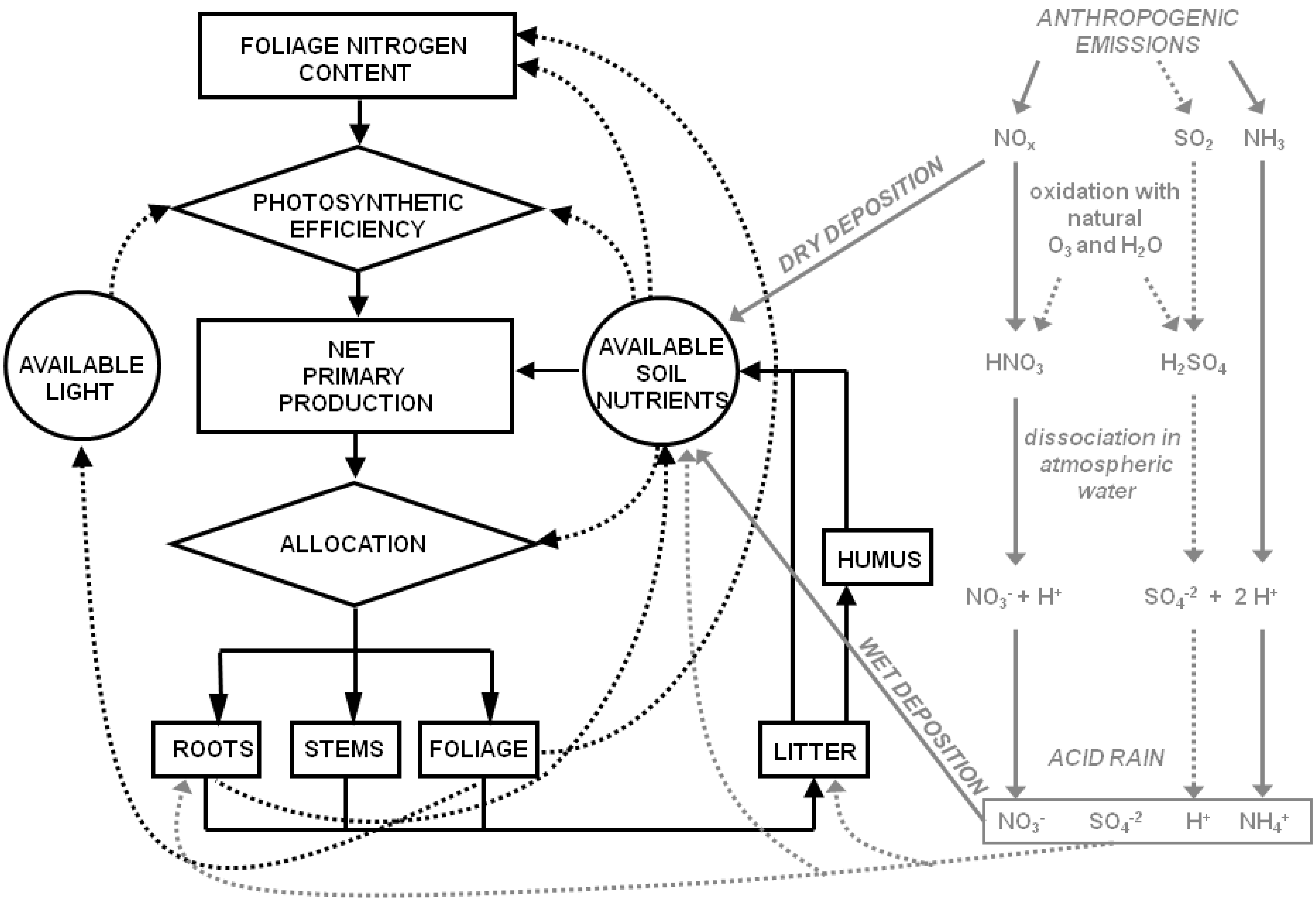

Figure S.2. Schematic representation of the key ecosystem processes and interactions (black dotted lines), the mass flows between the ecosystem pools (black solid lines) and the nutrient flows associated to atmospheric deposition (grey solid lines) represented in FORECAST. Dotted grey lines indicate the empirical effects of acid rain on Chinese fir included in the simulation as modifiers of calibration parameters (see text for a detailed description).