Supplemental Material

Nitrogen deposition: How important is it for global terrestrial carbon uptake?

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Figure S1: CLM4 simulated global and annual mean changes of (a) soil mineral N and (b) soil mineral N per unit soil carbon relative to control (1N). Panel (a) shows the total amount of mineral nitrogen declines in the 2K warming cases, because the amount of soil organic matter (carbon) is smaller due to decline in ecosystem productivity. In 2xCO_2 cases, the overall increase in soil mineral N is due to CO_2 fertilization induced increase in ecosystem productivity but in the initial stages there is more demand for soil mineral N and hence there is a decline relative to 1N. Soil mineral N increases for N deposition cases 2N, 4N and 8N. Panel (b) shows that the soil mineral N per unit of soil carbon increases for 2K warming (red lines) and increased N deposition cases (blue lines) and also increases for 2xCO_2 (green line) cases. 2K warming causes increased decomposition and hence increased nitrogen mineralization per unit of soil carbon. In some 2xCO_2 cases (1N2xCO_2 and 2N2xCO_2), this quantity declines because of more N demand and larger soil carbon pools. A 57-year running average is applied to original annual mean data.

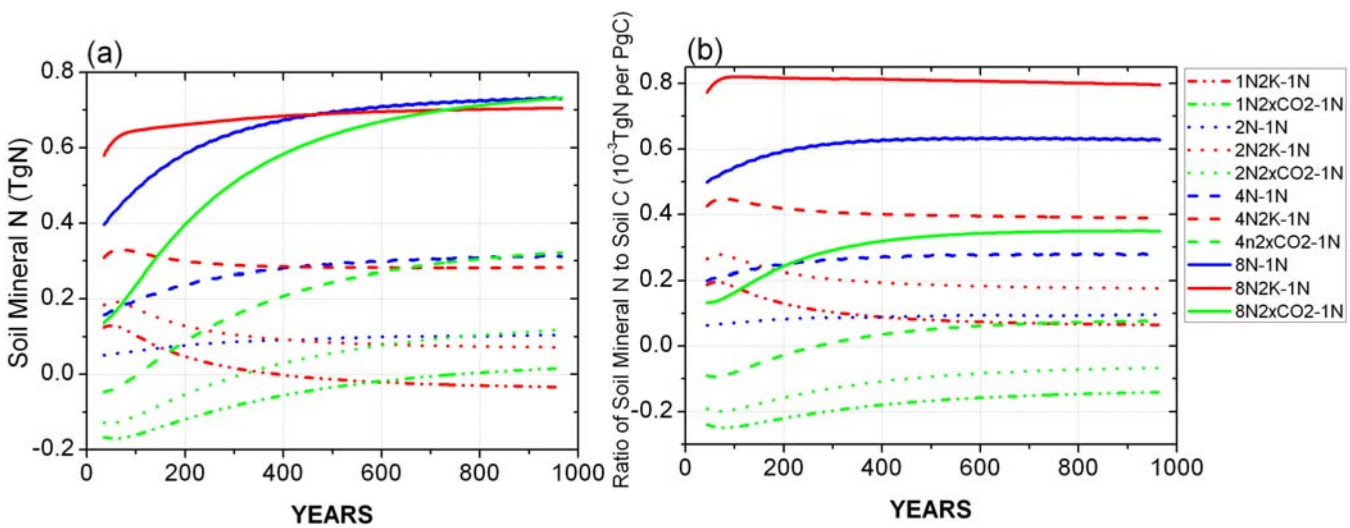

Figure S2: Terrestrial ecosystem carbon storage sensitivity to N deposition (δ_L) when N deposition is doubled from the pre-industrial (1850; left panel) and present day (2006; right panel) N deposition levels. Averages from last 100 years of 1000-year simulations are used for the calculation. These simulations show that the TEC sensitivity to N deposition at present day N deposition levels is slightly lower than the sensitivity at pre-industrial N deposition levels but the spatial distribution of sensitivity is similar.

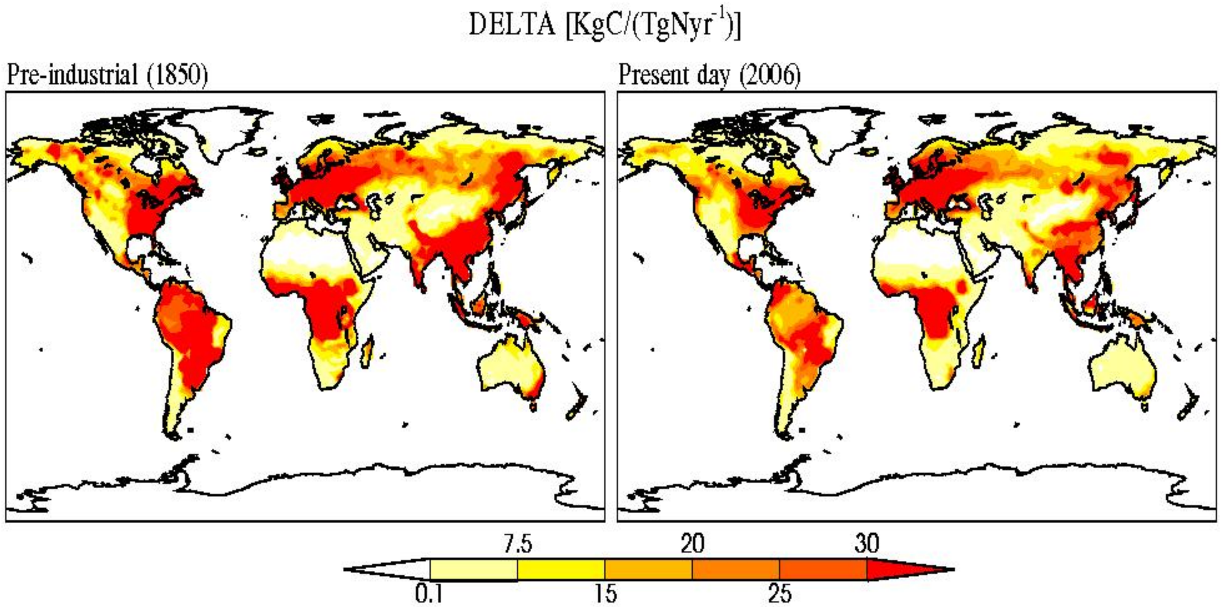

Figure S3: Spatial distribution of total ecosystem carbon (TEC) changes between the simulation with 2K warming (1N2K) and 1N (top left panel) and the simulation with 2K warming and an associated 6% increase in precipitation and13% change in specific humidity (1NPREC2K) and 1N (top right panel). The spatial pattern in the top two panels is similar indicating that the experiment 1N2K without the climate change related precipitation and water vapor changes is able to simulate the TEC changes associated with a 2K global mean warming very well. Bottom panel shows the percentage change in TEC between 1NPREC2K and 1N2K. It seen that regional changes are at most only ~10-15%. Averages from last 100 years of 1000-year simulations are used for the calculation.

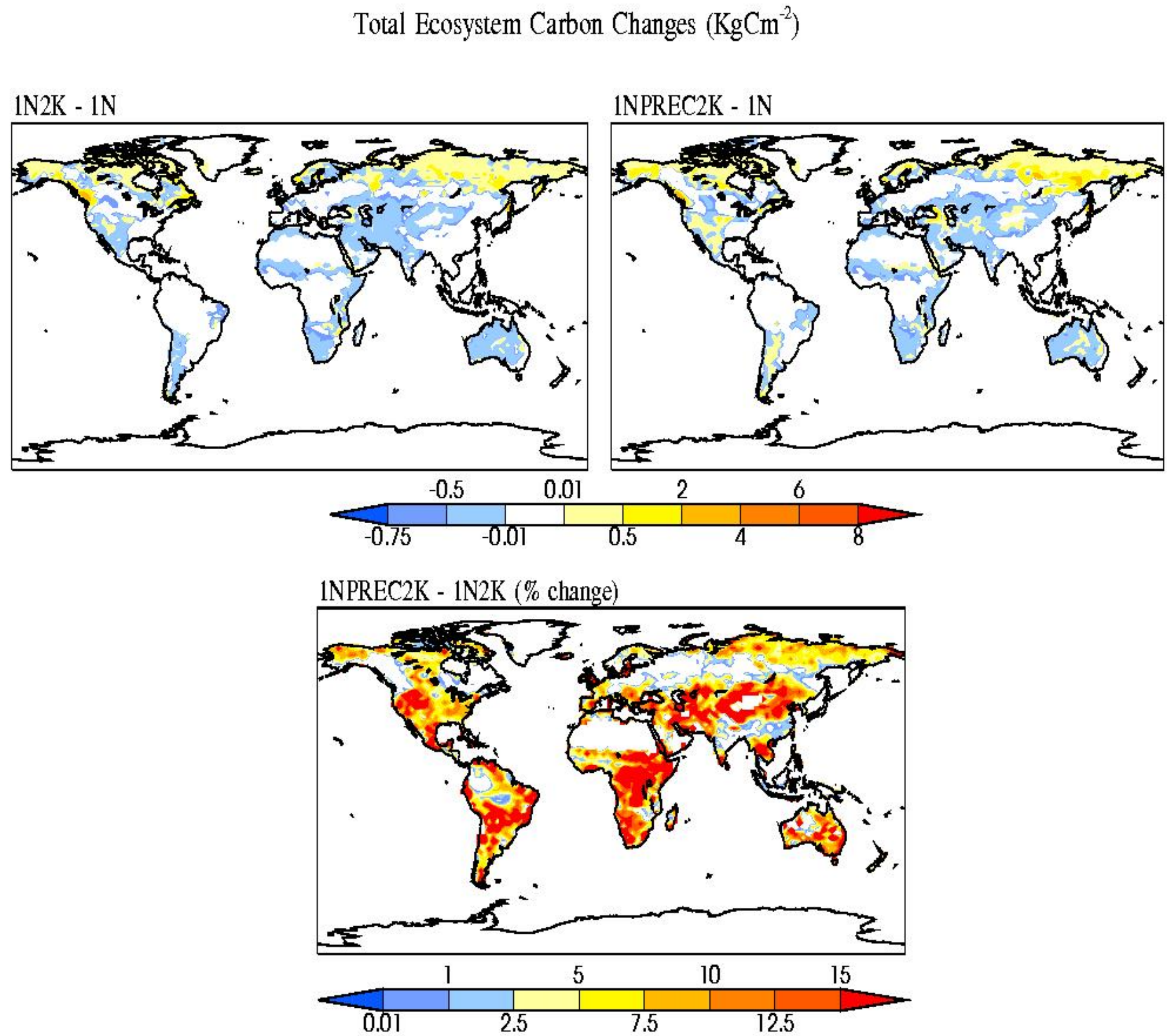

Figure S4. Simulated land-mean Leaf Area Index (LAI), canopy transpiration, evapotranspiration, total runoff (subsurface drainage + surface runoff) in 1N, 2N, 4N, 8N, 1N2K and 1N2xCO2 experiments. Increased N deposition leads to increased LAI which in turn causes increased canopy transpiration and land surface evapotranspiration and consequently decreased total runoff. The magnitudes of these land surface hydrological changes are small even for large increases in N deposition: when N deposition is increased eight fold (8N - 1N), we find a 17% increase in LAI, 3.3% increase in transpiration, 1% increase in evapotranspiration and 2.7% decline in runoff. As illustrated in this figure, the hydrological changes from increased N deposition are much smaller than changes from CO_2-driect effect (net effects of transpiration reduction from closing of stomata and increased transpiration due to CO_2-fertilization induced LAI increase) (*Bala et al.*, 2012; *Betts et al.*, 1997; *Betts et al.*, 2007; *Cao et al.*, 2010; *Gopalakrishnan et al.*, 2011) or from climate warming (which triggers evaporative demand).

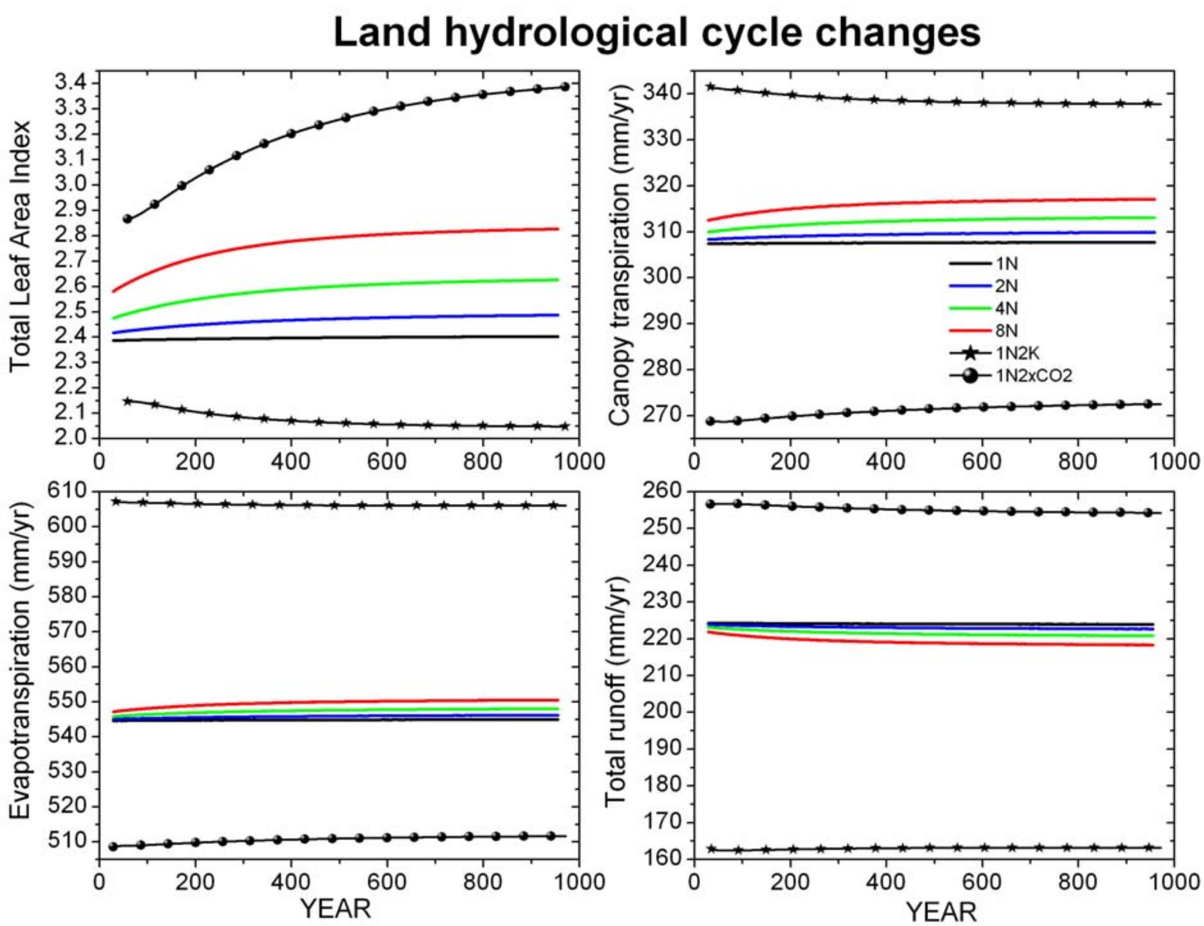

Table S1: Literature on the effects of N deposition on terrestrial productivity and carbon storage

Reference	Geography	Species/ Ecosystem	N deposition	Increase in productivity
(*Nilsson and Wiklund*, 1992)	Sweden, Skogaby experiment	Norway Spruce	100 Kg N/ha/Yr	31% increase in dry matter
(*Moller*, 1992)	Sweden	Spruce	150 Kg N/ha	10.1 m^3/ha
(*Moller*, 1992)	sweden	Pine	150 Kg N/ha	13.5 m^3/ha
(*Pettersson*, 1994)	Sweden	Forest ecosystem	140-150 Kg N/ha/yr	20-50% increase in growth
(*Lemus et al.*, 2008)	US	Switch grass	56, 112, 224 Kg/N/ha	An average of 3.6 tons/ha increase in biomass yield
(*Solberg et al.*, 2009)	Europe wide -363 monitoring plots over15 years	5 Species	1 Kg N/ha/yr	>1% increase in volume
(*de Vries*, 2009)	Europe wide - field and modelling study	Total Ecosystem carbon	1 Kg N	30-70 Kg C
(*de Vries et al.*, 2009)	Europe wide	Forest- above ground biomass	1 Kg N/ha/yr	15-40 KgC/ha/yr
(*de Vries et al.*, 2009)	Europe wide	Forest-soils	1 Kg N/ha/yr	5-35 KgC/ha/yr
(*Laubhann et al.*, 2009)	Europe wide	Forests	1 Kg N/ha/yr	21-26 KgC/ha/yr
(*Jacobson and Pettersson*, 2010)	Sweden	Scots Pine and Norway Spruce	1 Kg N/ha/yr	17-35 Kg C/ha/Yr
(*Thomas et al.*, 2010)	US	24 most common species	1 Kg N	61 Kg C of above ground biomass
(*Lu et al.*, 2012)	China	Nationwide estimation	1 Kg N	0-21 Kg C

Table S2: Coefficients and time constants of exponential fits ($\Delta TEC = A_0 - A_1 \text{ Exp } [-t/\tau_1] - A_2 \text{ Exp } [-t/\tau_2]$) with two time constants for changes in TEC in all experiments relative to 1N**.** A_0 is an estimate of the steady-state change in C storage under each scenario. The fit is constrained to go through $\Delta TEC = 0$ at t=0.

Relative to 1N	A_0 (PgC)	A_1 (PgC)	A_2 (PgC)	τ_1 (years)	τ_2 (years)	RMSE (PgC)
2N	72.6	11.9	60.7	64.0	340.3	0.2
4N	190.3	36.8	153.5	64.0	310.6	0.4
8N	360.5	93.0	267.5	65.2	283.1	0.9
1N2K	-306.8	-134.0	-172.8	35.3	254.8	4.0
2N2K	-247.9	-124.6	-123.3	34.7	216.9	4.2
4N2K	-153.5	-92.1	-61.4	31.8	97.9	4.7
8N2K	-3.2	-87.6	84.4	34.9	440.4	5.2
1N2xCO2	665.4	140.4	525.0	26.7	361.0	3.1
2N2xCO2	756.7	147.0	609.6	27.4	344.1	3.3
4N2xCO2	909.3	162.9	746.4	29.1	315.5	3.6
8N2xCO2	1138.5	204.0	934.4	33.4	276.9	4.4

Table S3: Testing the linearity of the effects due to climate warming, CO_2-fertilization and N deposition in our model simulations. Global and annual mean terrestrial carbon (TEC) changes relative to control simulation for the last 100years of the 1000 year simulations are listed. Unit for TEC change is PgC in all columns.

N deposition levels	**Test of linearity for Warming and N deposition effects**				
	Warming effect (1N2K-1N) (a)	N deposition effect (*x*N-1N)* (b)	Combined effect (*x*N2K-1N)	Sum of the effects (a)+(b)	Interaction term†
2N	-303.4	69.0	-246.8	-234.4	-12.4
4N	-303.4	183.5	-152.0	-120.0	-32.0
8N	-303.4	352.0	-13.2	48.6	-61.8
	Test of linearity for CO_2 fertilization and N deposition effects				
	CO_2-fertilization effect (1N2xCO2-1N) (a)	N deposition effect (*x*N-1N) (b)	Combined effect (*x*N2xCO2-1N)	Sum of the effects (a)+(b)	Interaction term
2N	627.7	68.9	718.5	696.6	19.9
4N	627.7	183.5	873.4	811.2	62.2
8N	627.7	352.0	1110.4	979.7	130.7

**x* takes on the value of 2, 4, 8 for 2N, 4N and 8N respectively.

† Interaction term is difference between combined effect and sum of effects.

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