Supplement of Biogeosciences, 16, 2771–2793, 2019
https://doi.org/10.5194/bg-16-2771-2019-supplement

Biogeosciences Open Access EGU

Supplement of

Decadal fates and impacts of nitrogen additions on temperate forest carbon storage: a data–model comparison

Susan J. Cheng et al.

Correspondence to: Susan J. Cheng (sjc265@cornell.edu)

Supplementary Information

Table S1: Published ^{15}N recovery measurements (%) and CLM5-simulated N recoveries (%) for each site and experiment, including for both open (Open CLM) and closed (Closed CLM) N cycle configurations. A .csv file with data from this table is available at https://doi.org/10.5281/zenodo.2772160.

Site	Years Since Tracer Application	Foliage	Wood	Bark	Fine Roots	Coarse Roots	Ground Plants	Organic Soil	Mineral Soil	Total Plant*	Total Soil	Open CLM Plant	Closed CLM Plant	Open CLM Soil	Closed CLM Soil
Arnot[a,b]	1	1.9	0.6	1.0	2.5	4.9	NA	13.7	45.3	10.9	59.0	50	65	26	33
	6	1.6	1.5	1.2	1.8	2.1	NA	5.9	56.5	8.2	62.4	16	24	63	73
Harvard BDT[c,d,e]	1	1.2	0.6	0.5	4.6	NA	NA	81.9	11.1	6.8	92.9	47	63	25	32
	8	3.8	2.1	1.7	4.2	NA	NA	73.9	15.7	11.8	89.6	14	23	56	71
	17	available upon request to site PI										14	20	48	72
Harvard BDT Fertilized[c,d,e]	1	5.9	2.9	1.6	13.7	NA	NA	44.6	27.4	24.0	72.0	31	29	26	31
	8	3.1	3.1	2.2	3.1	NA	NA	55.4	16.0	11.5	71.4	21	20	34	35
	17	available upon request to site PI										14	15	33	34
Harvard NET[c,d,e]	1	1.0	0.1	0.2	2.3	NA	NA	60.0	8.8	3.6	68.7	38	49	51	49
	8	2.9	1.3	0.6	3.4	NA	NA	56.2	31.9	8.1	88.1	24	24	58	72
	17	available upon request to site PI										18	16	60	78
Harvard NET Fertilized[c,d,e]	1	9.6	0.4	0.9	8.7	NA	NA	33.9	15.2	19.7	49.1	29	36	26	40
	8	6.1	1.1	0.9	5.1	NA	NA	34.9	24.3	13.2	59.2	20	26	31	43
	17	available upon request to site PI										16	20	32	45
Alptal[f,g,h]	1	2.3	3.0	with wood	6.6	0.4	19.0	25.6	19.6	12.3	45.2	39	44	52	50
	3	0.9	1.0	with wood	3.3	1.8	20.5	22.5	7.3	6.9	29.8	30	34	58	59
	9	3.7	2.6	2.3	3.1	1.1	3.8	42.6	13.3	12.8	55.9	29	19	9	70
Alptal Fertilized[f,g,h]	2	4.6	3.0	0.8	with organic soil	NA	5.0	55.0	21.0	8.4	76.0	36	45	54	51
	7	6.9	3.9	0.8	2.6	1.4	1.5	29.3	15.4	15.6	44.7	30	37	55	55
	14	5.0	4.4	2.0	2.7	1.2	0.9	39.6	18.9	15.3	58.5	24	31	53	59
Klosterhede[i]	1	9.9	3.3	0.4	6.9	7.0	20.1	41.5	10.4	27.4	51.8	32	47	52	50

	17	12.0	4.6	1.2	3.4	2.3	0.2	61.6	3.8	23.5	65.4	11	19	45	70
Klosterhede Fertilized[i]	1	16.8	6.3	0.7	11.2	10.7	3.2	23.9	22.5	45.8	46.4	38	63	52	34
	17	12.7	3.8	1.1	2.7	4.4	0.0	36.7	11.5	24.7	48.2	24	25	47	46
Bear Brook Fertilized[j]	3	2.4	9.1	NA	NA	NA	NA	NA	NA	11.4	23.3	40	35	27	37
Gårdsjön Fertilized[k]	2	NA	NA	NA	NA	NA	NA	NA	NA	28.0	82.0	39	47	43	37
Aber Low Fertilization[l]	3	NA	NA	NA	NA	NA	NA	17.0	15.0	32.0	32.0	49	56	29	33
Aber High Fertilization[l]	3	NA	NA	NA	NA	NA	NA	11.0	15.0	20.0	26.0	32	35	21	25

*plant recovery from field recoveries excludes ground vegetation.

NA: not available

[a]Goodale (2017)

[b]personal communication with C. Goodale

[c]Nadelhoffer et al. (1999b)

[d]Nadelhoffer et al. (2004)

[e]personal communication with K. Nadelhoffer

[f]Krause et al. (2012)

[g]personal communication with P. Schleppi

[h]Providoli et al. (2005) and Schleppi et al. (1999)

[i]Gundersen (1998)

[j]Nadelhoffer et al. (1999a)

[k]Nadelhoffer et al. (1999c)

[l]Tietema et al. (1998)

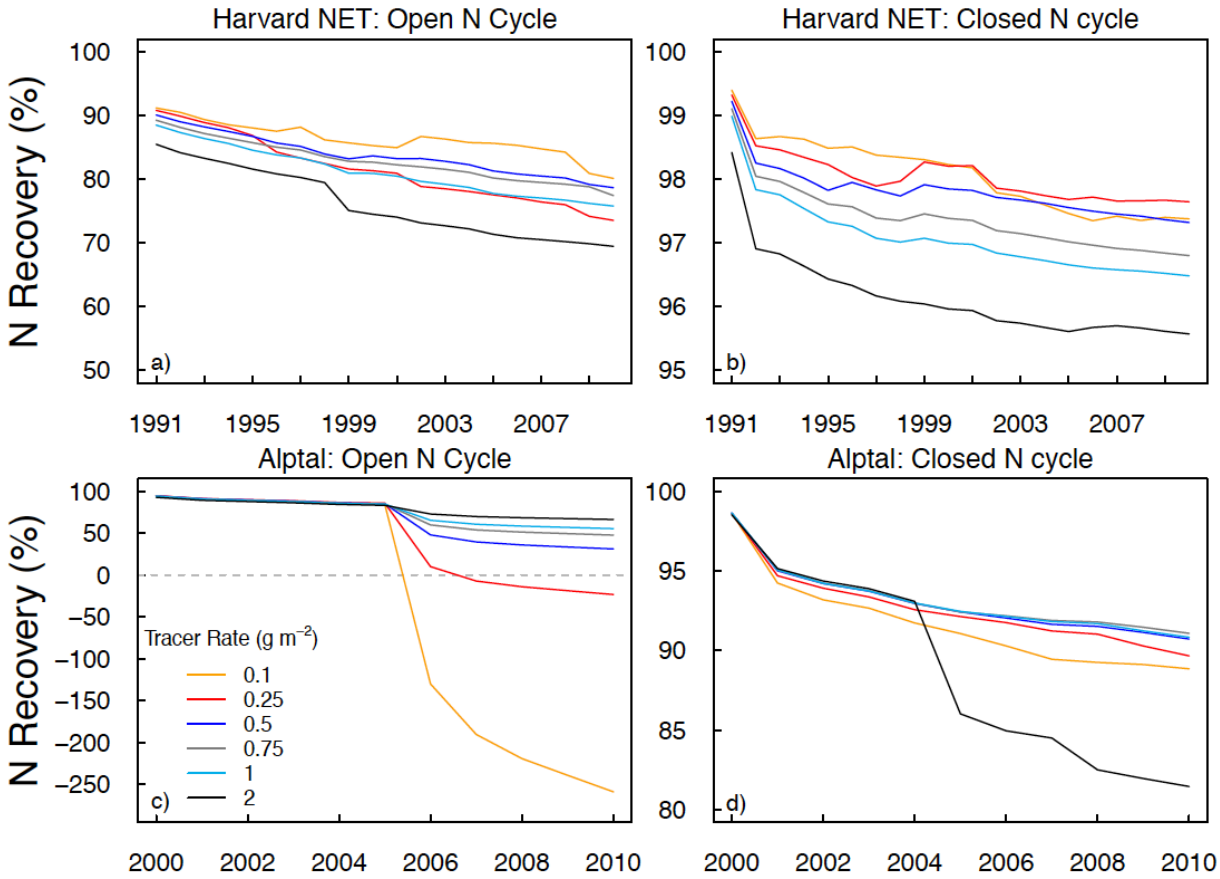

Figure S1: Results from a sensitivity study done at Harvard (a, b) needleleaf temperate tree (NET) plant functional type (PFT) and Alptal (c, d) on the amount of tracer that should be applied during the growing season (April-September) for both open and closed N cycles in CLM5.

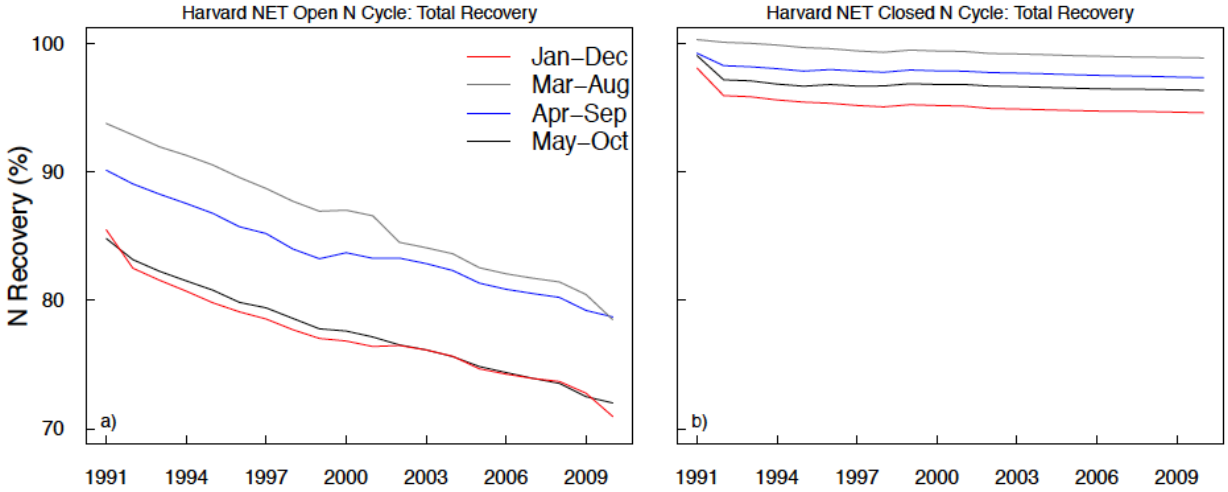

Figure S2: Results from the sensitivity study at Harvard needleleaf evergreen tree (NET) plant functional type (PFT) on the timing of applying 0.5 g N m^{-2} into the ecosystem under a) an open N cycle and b) a closed N cycle in CLM5.

Table S2: Turnover time of N in plant, soil, and total ecosystem pools in CLM5 for ecosystems with open and closed N cycles. Values shown are averaged across the last 20 years of the 1850 spinup simulation and for the last 20 years of the historical simulation. Turnover time is calculated a) for plants as the plant stock divided by losses from litterfall, b) for soils as the soil stock divided by losses from plant uptake, denitrification, leaching, and runoff, and c) for the ecosystem as the ecosystem stock divided by losses from denitrification, leaching, and runoff.

	1850		Last 20 Years	
	Open N cycle (years)	**Closed N cycle (years)**	**Open N cycle (years)**	**Closed N cycle (years)**
Plants				
Harvard BDT	29	30	17.6	18.0
Harvard NET	72	72	53.6	56.8
Arnot	29	30	23.7	24.5
Aber	72	71	42.6	42.0
Alptal	73	71	64.1	58.5
Bear Brook	29	30	19.4	20.5
Klosterhede	72	73	58.0	55.1
Gårdsjön	73	73	58.9	59.0
Soil				
Harvard BDT	93	114	70	95
Harvard NET	115	137	100	132
Arnot	143	170	122	158
Aber	131	161	95	101
Alptal	184	217	146	152
Bear Brook	117	136	93	114
Klosterhede	111	130	92	98
Gårdsjön	137	151	111	128
Ecosystem				
Harvard BDT	501	7142	578	6914
Harvard NET	679	5238	1597	16236
Arnot	57	10606	1065	12319
Aber	658	3557	441	1430
Alptal	2023	47976	1067	3127
Bear Brook	836	7019	888	6727
Klosterhede	596	6902	542	2775
Gårdsjön	1084	7787	873	2903

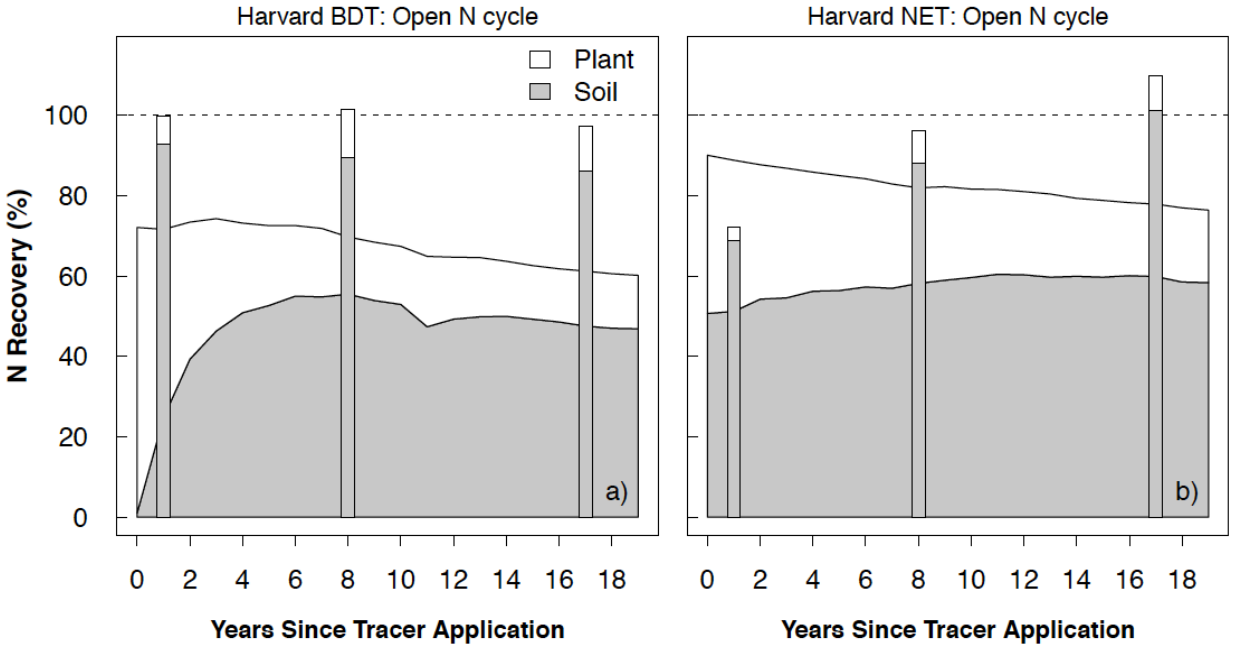

Figure S3: Modeled recovery of N additions in plant and soil pools at Harvard Forest under open N cycling and ambient N deposition for a) broadleaf deciduous tree (BDT) and b) needleleaf evergreen tree (NET) plant functional types (PFT). Thin, stacked bars represent observations. Recovery is calculated as the difference in stock size between a baseline simulation and a simulation with a "tracer" added as 0.5 g m^{-2} between April-September in the first year a ^{15}N tracer was applied in the field (see Methods).

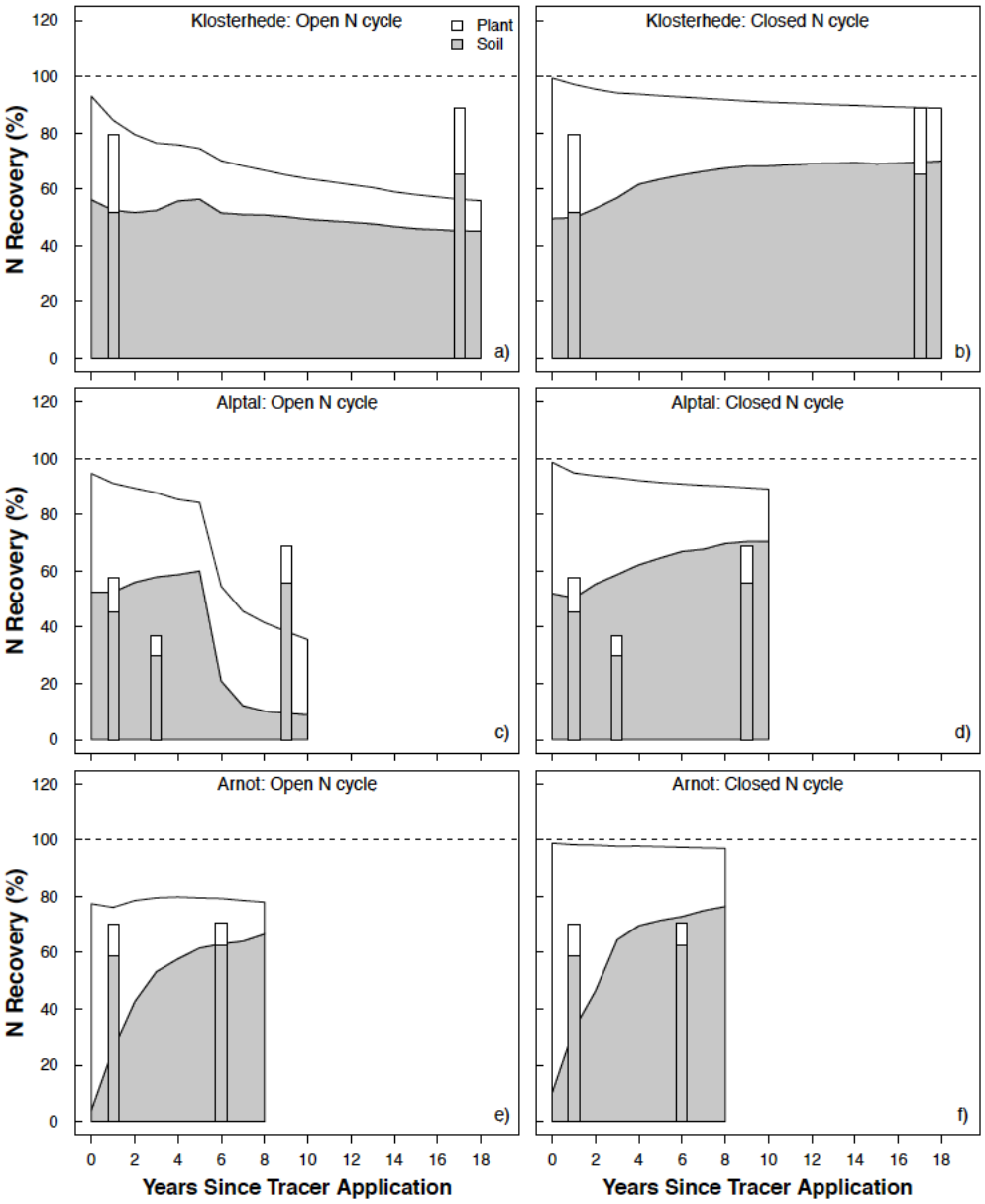

Figure S4: Modeled recovery of N additions in plant and soil pools in ecosystems with open and closed N cycles under ambient N deposition conditions. Thin, stacked bars represent observations. Recovery is calculated as the difference in stock size between a baseline simulation and a simulation with a "tracer" added as 0.5 g m^{-2} between April-September in the first year a ^{15}N tracer was applied in the field (see Methods).

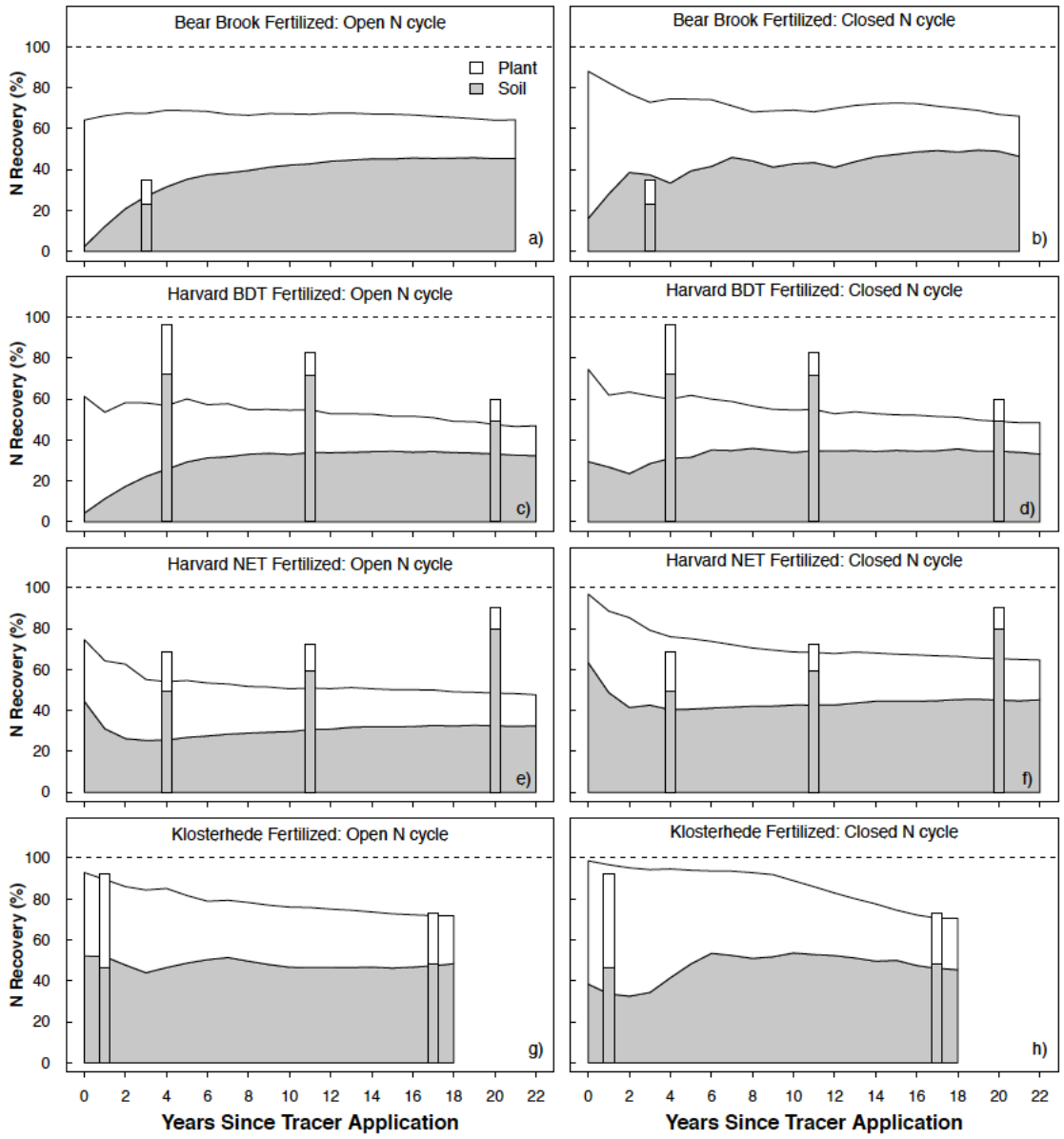

Figure S5: Modeled recovery of N additions in plant and soil pools of sites in ecosystems with open and closed N cycles compared to field measurements (thin, stacked bars) for sites under multi-year N fertilization. Recovery is calculated as the difference in stock size between a baseline simulation and a simulation with N fertilizer added into the soil mineral N pool between April-September (see Methods).

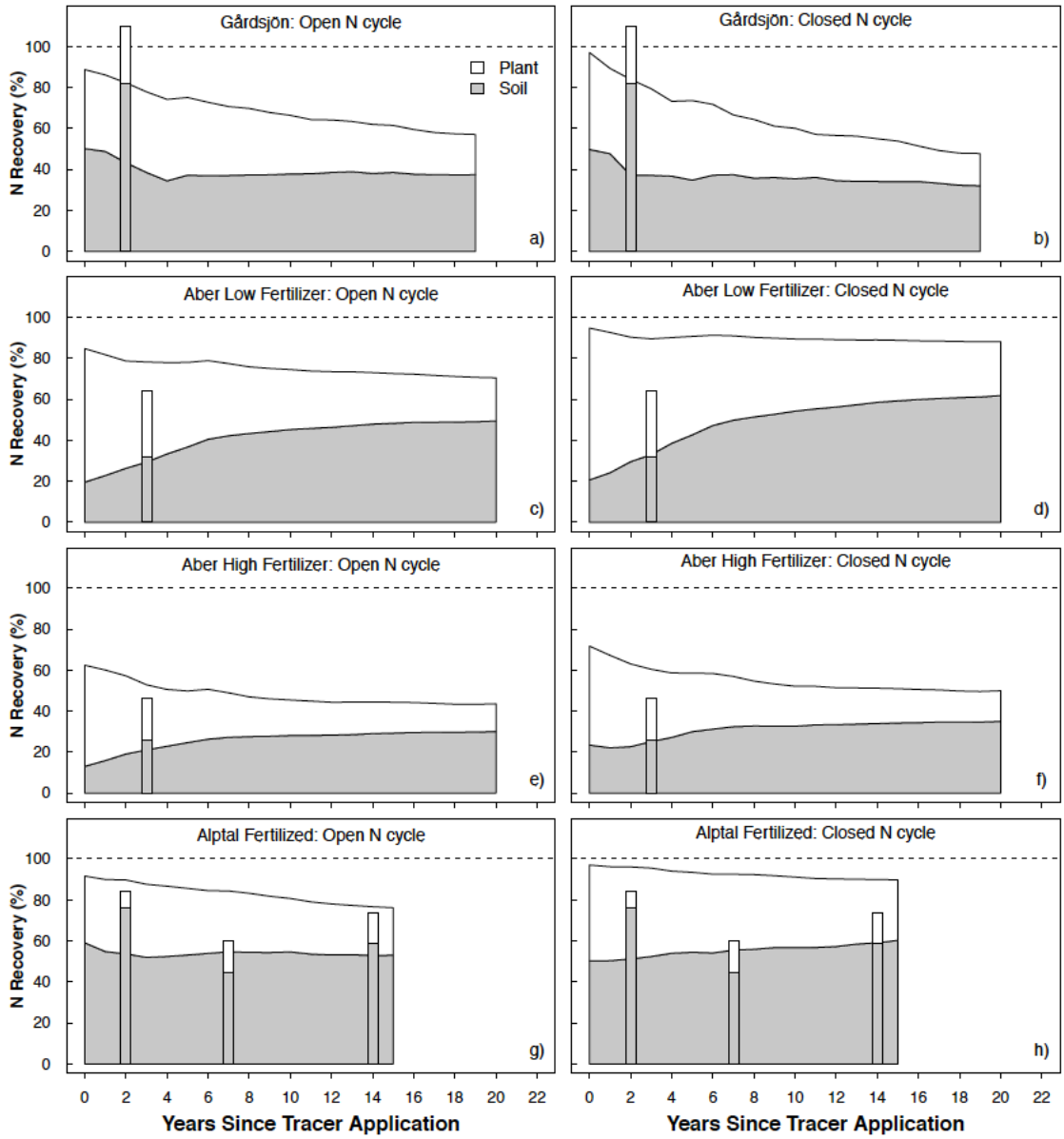

Figure S6: Modeled recovery of N additions in plant and soil pools of sites for ecosystems under closed and open N cycles compared to field measurements (thin, stacked bars) for sites under multi-year N fertilization. Recovery is calculated as the difference in stock size between a control simulation and a simulation with N fertilizer added into the soil mineral N pool between April-September (see Methods).

Table S3: C:N ratios of sub-pools for plants and soils as reported in literature. A .csv file with data from this table is available at https://doi.org/10.5281/zenodo.2772160.

Site	Foliage	Wood	Bark	Fine Roots	Coarse Roots	Organic Soil	Mineral Soil	Citations
Harvard BDT	25	338	126	50	NA	24	20	Nadelhoffer et al. (1999b); Nadelhoffer et al. (2004)
Harvard NET	42	337	253	41	NA	25	19	Nadelhoffer et al. (1999b); Nadelhoffer et al. (2004)
Arnot	35	638	154	47	109	39	9	Goodale (2017)
Alptal[a]	42	500	167	56	91	19	17	Providoli et al. (2005)
Klosterhede[b]	63	333	200	52	70	33	29	Emmett et al. (1998); Gundersen and Rasmussen (1995); Tietema et al. (1998); personal communication with P. Gundersen
Harvard BDT Fertilized	23	321	120	48	NA	21	23	Nadelhoffer et al. (1999b); Nadelhoffer et al. (2004)
Harvard NET Fertilized	35	409	253	24	NA	23	26	Nadelhoffer et al. (1999b); Nadelhoffer et al. (2004)
Bear Brook Fertilized	37	413	NA	NA	NA	23	19	Nadelhoffer et al. (1999a)
Gårdsjön	NA	NA	NA	NA	NA	32	31	Emmett et al. (1998)
Aber[b]	28	NA	NA	NA	NA	22	18	Emmett et al. (1998)
Mean ± 1 SD	37 ± 12	411 ± 110	182 ± 55	45 ± 10	90 ± 20	26 ± 6	21 ± 6	

NA: not available from literature

[a]C:N ratios of all plant subpools at Alptal were estimated by assuming 50% of biomass is carbon, and then dividing by the N concentration reported in the literature.

[b]C:N ratios for foliage at Aber were estimated by assuming 50% of biomass is carbon, and then dividing by the N concentration reported in the literature.

References

Emmett, B. A., Kjønaas, O. J., Gundersen, P., Koopmans, C., Tietema, A., and Sleep, D.: Natural abundance of ^{15}N in forests across a nitrogen deposition gradient, Forest Ecology and Management, 101, 9-18, https://doi.org/10.1016/S0378-1127(97)00121-7, 1998.

Goodale, C. L.: Multiyear fate of a ^{15}N tracer in a mixed deciduous forest: retention, redistribution, and differences by mycorrhizal association, Global Change Biology, 23, 867-880, 10.1111/gcb.13483, 2017.

Gundersen, P., and Rasmussen, L.: Nitrogen mobility in a nitrogen limited forest at Klosterhede, Denmark, examined by NH4NO3 addition, Forest Ecology and Management, 71, 75-88, https://doi.org/10.1016/0378-1127(94)06085-W, 1995.

Gundersen, P.: Effects of enhanced nitrogen deposition in a spruce forest at Klosterhede, Denmark, examined by moderate NH_4NO_3 addition, Forest Ecology and Management, 101, 251-268, 10.1016/s0378-1127(97)00141-2, 1998.

Krause, K., Providoli, I., Currie, W. S., Bugmann, H., and Schleppi, P.: Long-term tracing of whole catchment ^{15}N additions in a mountain spruce forest: measurements and simulations with the TRACE model, Trees, 26, 1683-1702, 10.1007/s00468-012-0737-0, 2012.

Nadelhoffer, K., Downs, M., Fry, B., Magill, A., and Aber, J.: Controls on N retention and exports in a forested watershed, Environmental Monitoring and Assessment, 55, 187-210, 10.1023/A:1006190222768, 1999a.

Nadelhoffer, K. J., Downs, M. R., and Fry, B.: Sinks for ^{15}N-enriched additions to an oak forest and a red pine plantation Ecological Applications, 9, 72-86, 10.1890/1051-0761(1999)009[0072:SFNEAT]2.0.CO;2, 1999b.

Nadelhoffer, K. J., Emmett, B. A., Gundersen, P., Kjønaas, O. J., Koopmans, C. J., Schleppi, P., Tietema, A., and Wright, R. F.: Nitrogen deposition makes a minor contribution to carbon sequestration in temperate forests, Nature, 398, 145, 10.1038/18205, 1999c.

Nadelhoffer, K. J., Colman, B. P., Currie, W. S., Magill, A., and Aber, J. D.: Decadal-scale fates of ^{15}N tracers added to oak and pine stands under ambient and elevated N inputs at the Harvard Forest (USA), Forest Ecology and Management, 196, 89-107, https://doi.org/10.1016/j.foreco.2004.03.014, 2004.

Providoli, I., Bugmann, H., Siegwolf, R., Buchmann, N., and Schleppi, P.: Flow of deposited inorganic N in two gleysol-dominated mountain catchments traced with $^{15}NO_3^-$ and $^{15}NH_4^+$, Biogeochemistry, 76, 453-475, 10.1007/s10533-005-8124-1, 2005.

Schleppi, P., Bucher-Wallin, I., Siegwolf, R., Saurer, M., Muller, N., and Bucher, J. B.: Simulation of Increased Nitrogen Deposition to a Montane Forest Ecosystem: Partitioning of the Added 15N, in: Forest Growth Responses to the Pollution Climate of the 21st Century, edited by: Sheppard, L. J., and Cape, J. N., Springer Netherlands, Dordrecht, 129-134, 1999.

Tietema, A., Emmett, B. A., Gundersen, P., Kjønaas, O. J., and Koopmans, C. J.: The fate of ^{15}N-labelled nitrogen deposition in coniferous forest ecosystems, Forest Ecology and Management, 101, 19-27, https://doi.org/10.1016/S0378-1127(97)00123-0, 1998.