Supporting Information Appendix (*SI Appendix*)

Liu and Koba et al. Nitrate is an important nitrogen source for Arctic tundra plants

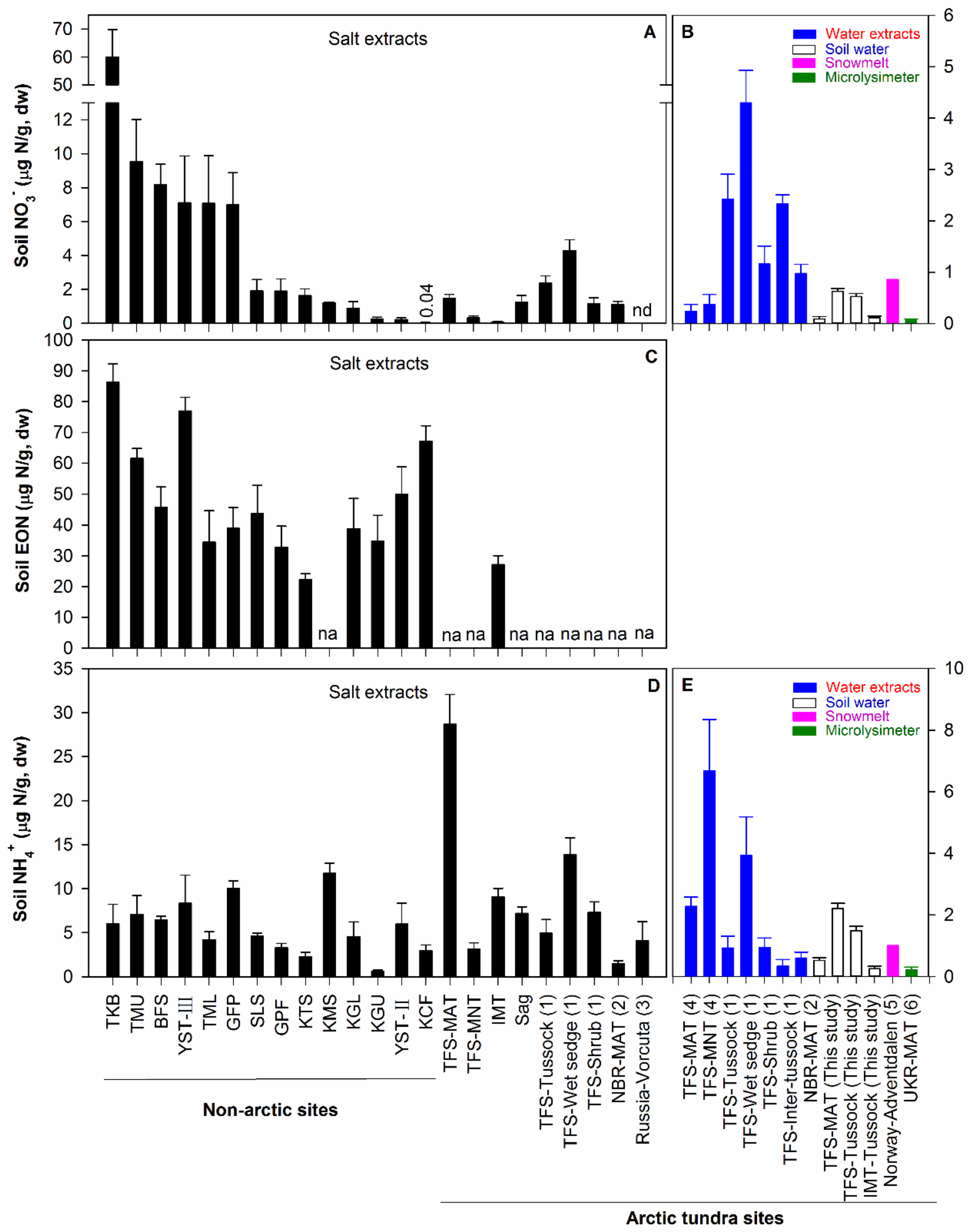


Fig. S1. Concentrations of NO_3^- (A, B), extractable organic N (EON) (C), NH_4^+ (D, E) in salt extracts, water extracts, soil water, snowmelt and microlysimeter of soils across Arctic tundra and non-arctic ecosystems. Mean ± Standard Error (SE) are shown. "nd" indicates not detected, "na" indicates not available or not measured. Data above the bar shows mean values. Salt-extractable N in soil at Toolik Field Station Moist Acidic Tundra (TFS-MAT, n = 135) and Toolik Field Station Moist Nonacidic Tundra (TFS-MNT, n = 54) was analyzed in June−August from 1990 to 2006 and from 1998 to 2006, respectively. Soil water of TFS-MAT (n = 4 for 1 site) was sampled in August 2012; soil water of TFS-Tussock (n = 1073 for NH_4^+ and n = 1060 for NO_3^- from 14 sites at Toolik Field Station) and IMT-Tussock (n = 690 for NH_4^+ and n = 576 for NO_3^- from 13 sites at Imnavait Creek) was sampled in June−August from 1988 to 2011. TFS-NBR stands for Toolik Field Station near the Northern Brooks Range, and UKR stands for the Upper Kuparuk River, Alaska. Data for SAG (n = 150, from 1987 to 2005) were downloaded from the Arctic LTER database (http://arc-lter.ecosystems.mbl.edu/). Other data of N in soil extracts (salt (K_2SO_4) or water extracts) and soil solutions (n = 4−60) were cited from corresponding references (reference numbers are in the parentheses).

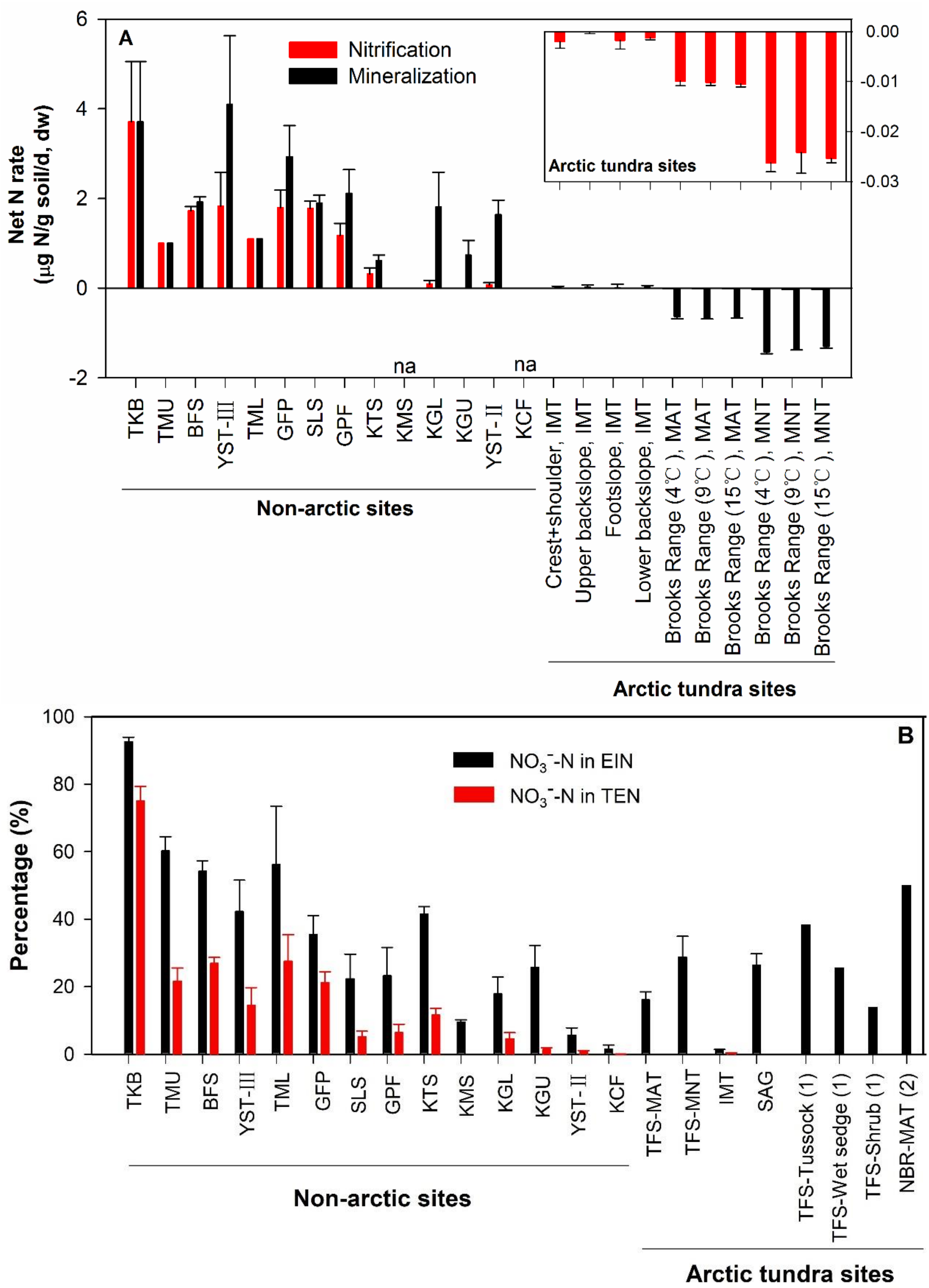


Fig. S2. Net N rates of nitrification and mineralization (A), and percentages of NO_3^--N in salt-extractable inorganic N (EIN) or in total salt-extractable N (TEN) (B), of soils across the Arctic tundra and non-arctic ecosystems. Mean ± SE are shown. In panel A, data of IMT were expressed as g N/m^2/growing season, while those of the Brooks Range around TFS were cited from (7). In panel B, EIN is the sum of NH_4^+-N and NO_3^--N, and TEN is the sum of EIN and EON (extractable organic N) and the reference numbers for the data in Arctic tundra sites are in the parentheses.

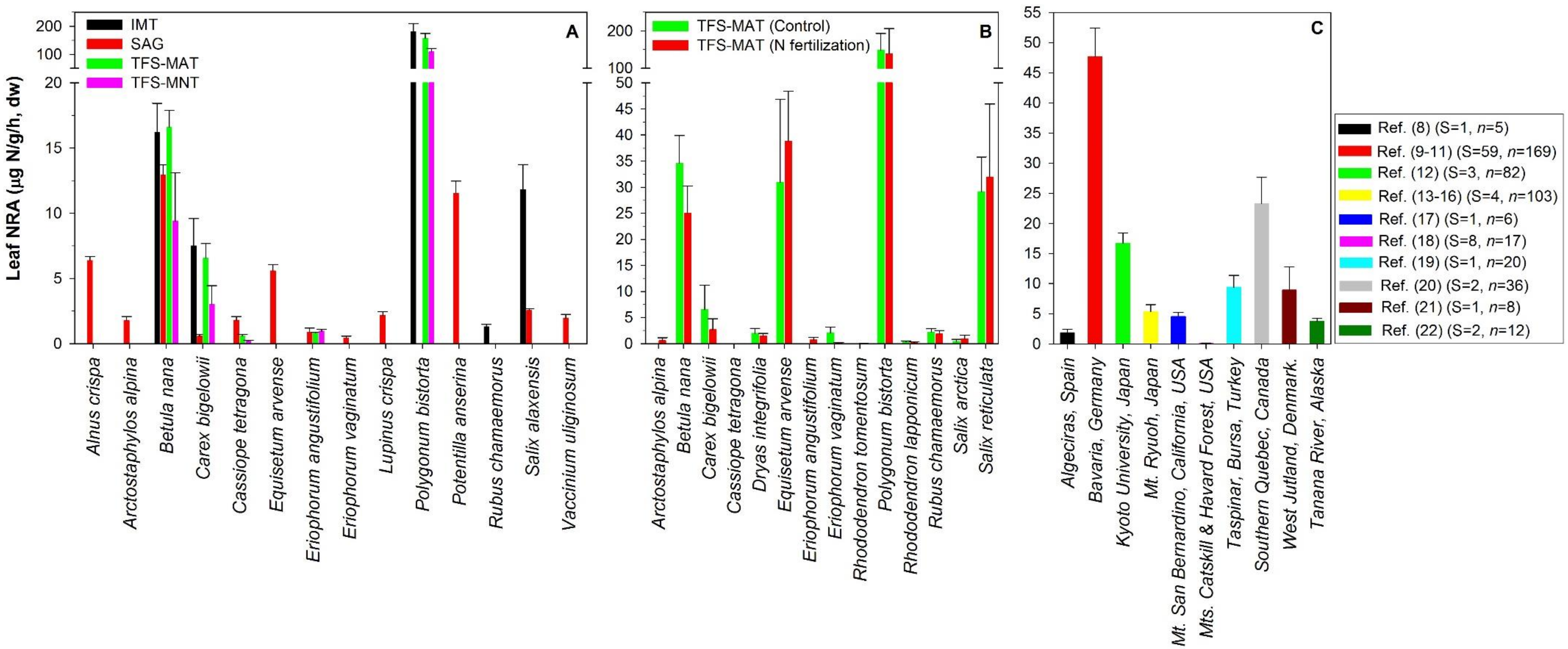


Fig. S3. Leaf nitrate reductase activities (NRA) of (A, B) tundra plants in northern Alaska and (C) terrestrial plants at lower latitude regions. Mean ± SE are shown. In panel A, the bars of IMT showed averages across ecosystems including crest, upper backslope, lower water tracks, lower non-water track, and footslope at Imnavait Creek (n = 9−15 for each species). The bars of SAG showed averages across ecosystems types along the Sagavanirktok River toposequence (n = 4−79; cited from (23)). n = 5 for TFS-MAT or TFS-MNT. In panel B, Control and N fertilization denote the control and N-fertilization plots at TFS-MAT, respectively (n = 3−5). In panel C, bars are average values for total sample number (n) of studied plant species (S is the species number) reported at each site.

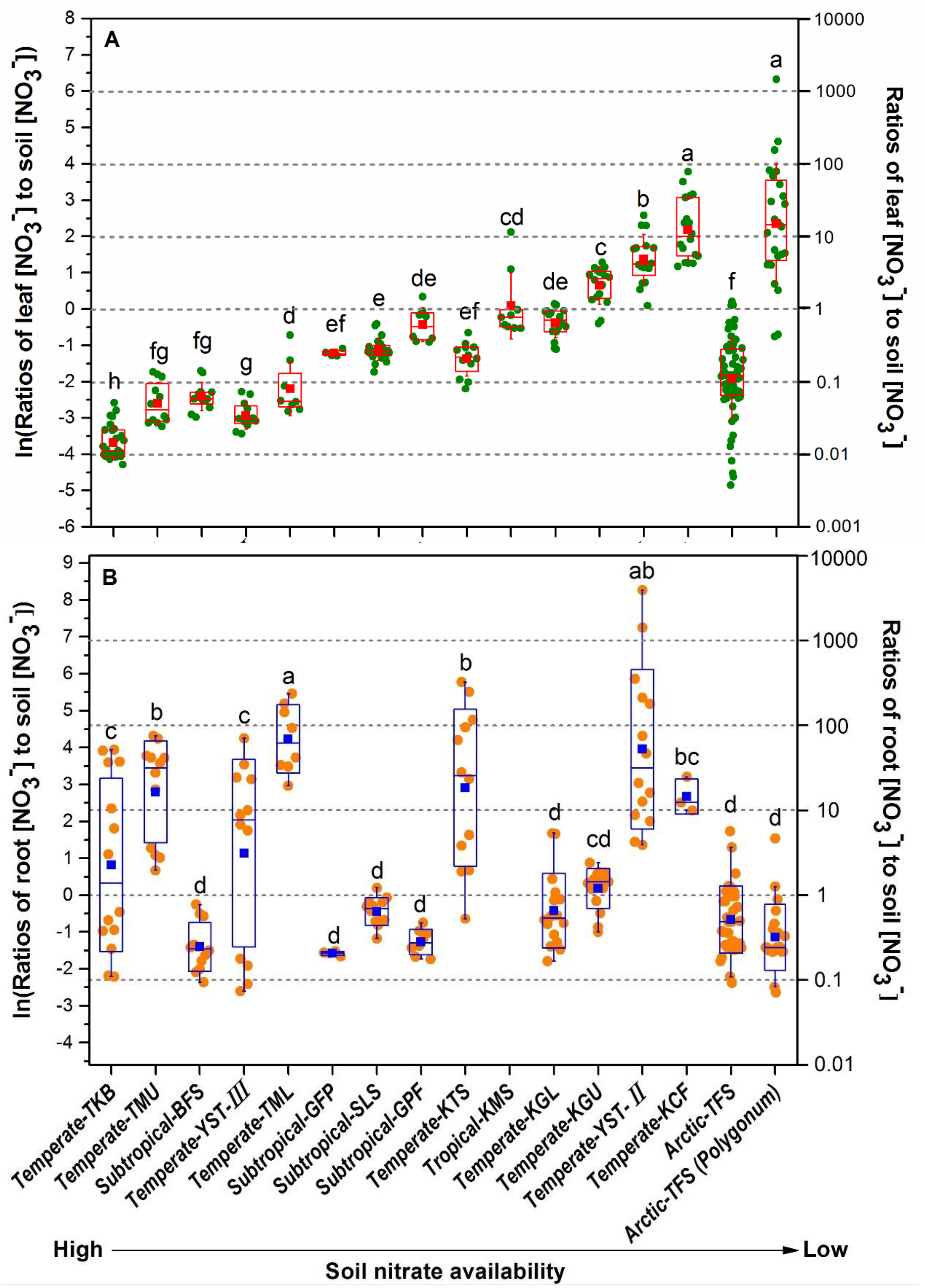
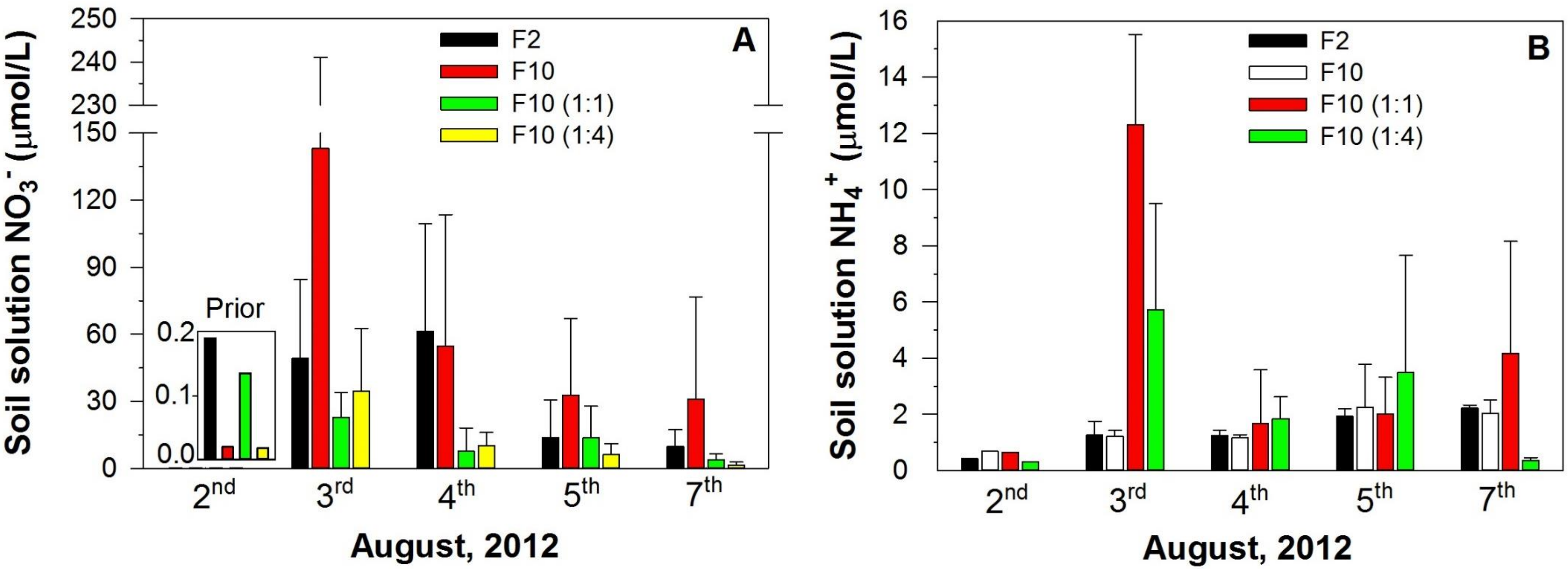


Fig. S4. Ratios of (A) leaf NO_3^- concentrations ($[NO_3^-]$) to soil $[NO_3^-]$ and (B) root $[NO_3^-]$ to soil $[NO_3^-]$ across different plants and ecosystems. Concentrations in the unit of µg-N/g dry plant or soil and mean concentrations of soil $[NO_3^-]$ (Fig. S2a) were used for calculating the ratios. The box encompasses the 25^{th}–75^{th} percentiles, whiskers are the Standard Deviation (SD) values. The line and square in each box mark the median and mean values of plants at each site, respectively. Different letters above the boxes mark significant differences at the level of $P < 0.05$.


A
Soil solution NO3- (µmol/L)
F2
F10
F10 (1:1)
F10 (1:4)
Prior
August, 2012
2nd
3rd
4th
5th
7th
B
Soil solution NH4+ (µmol/L)
F2
F10
F10 (1:1)
F10 (1:4)
August, 2012
2nd
3rd
4th
5th
7th

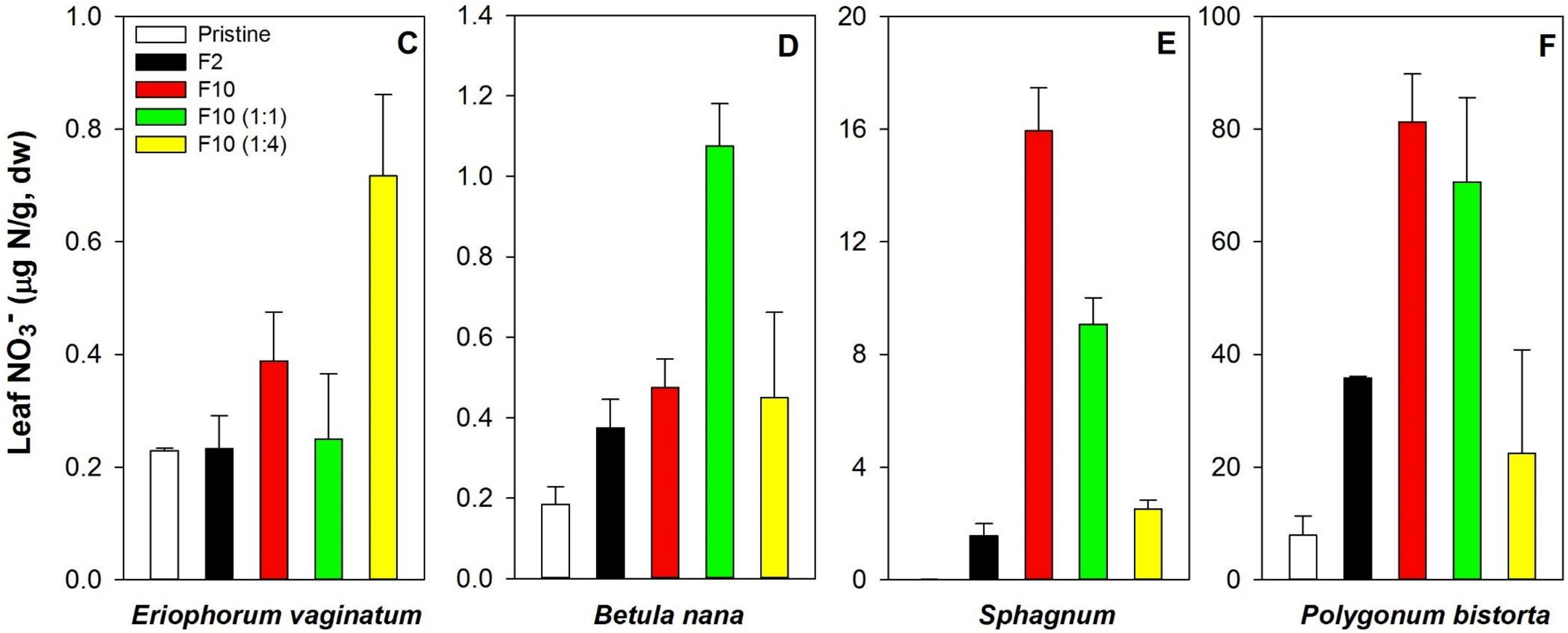
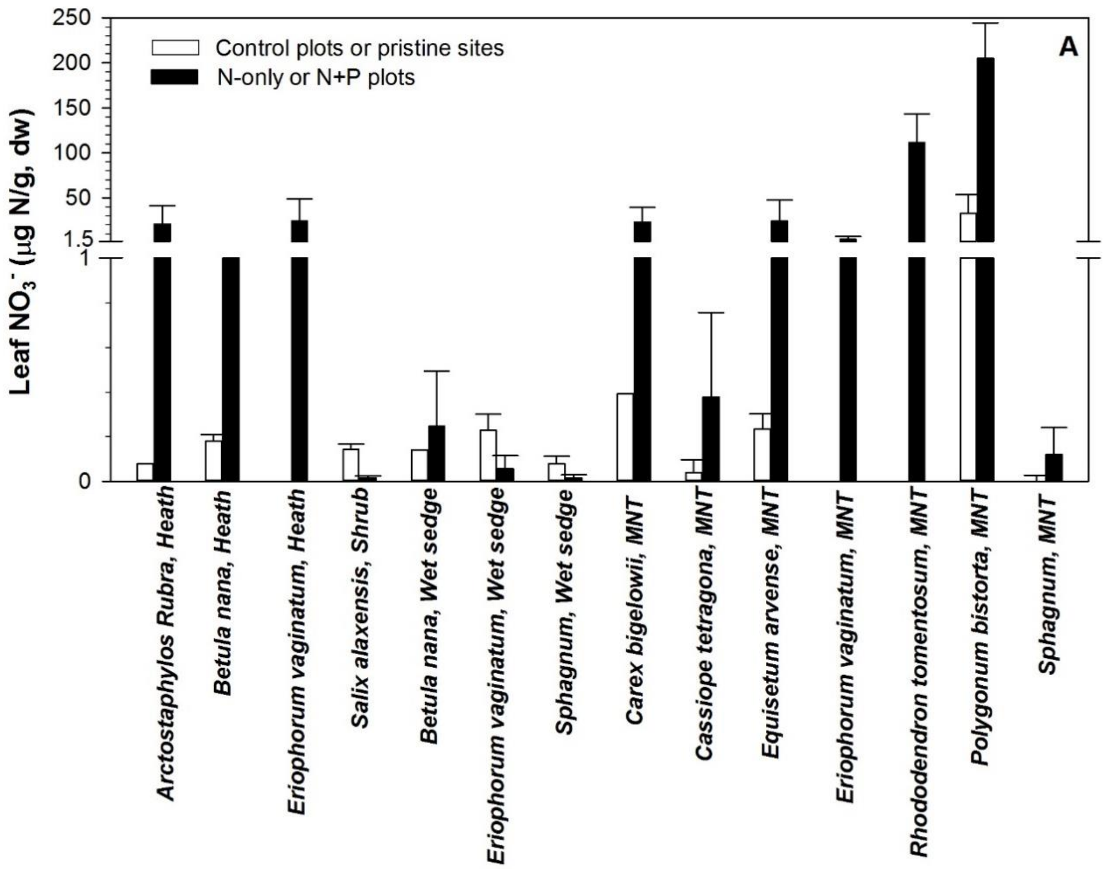
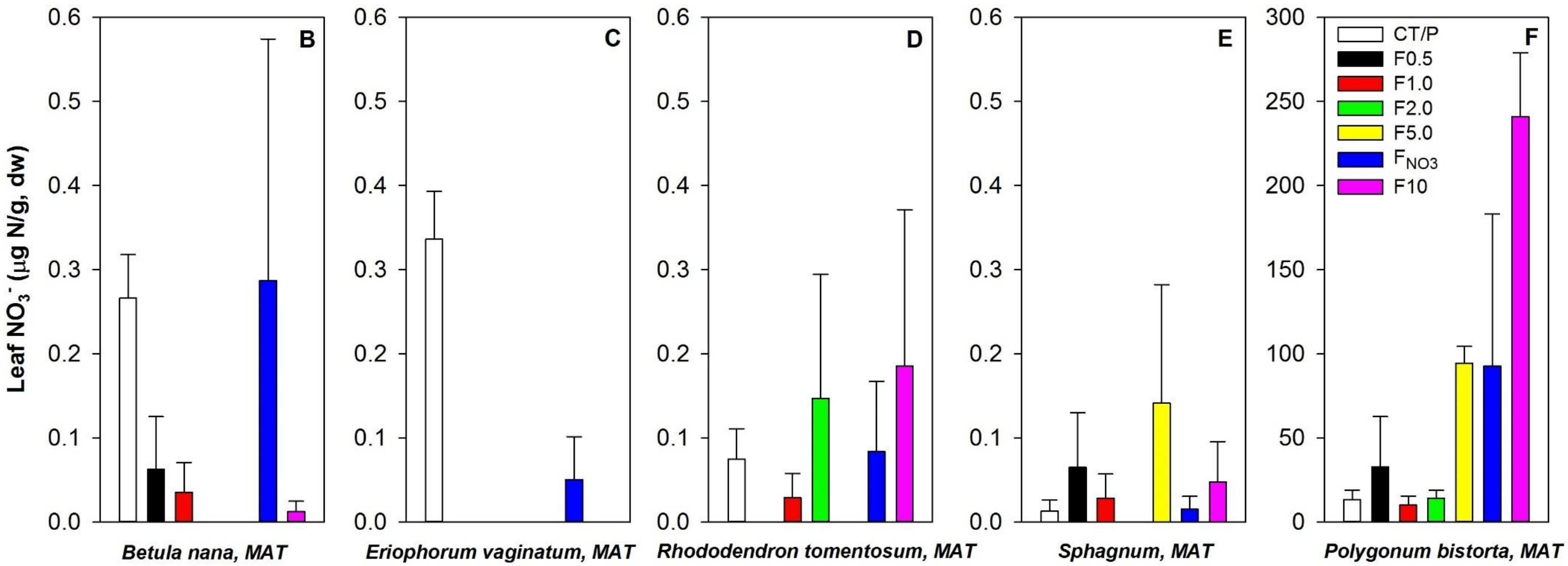

Leaf NO_3^- (µg N/g, dw)
Pristine
F2
F10
F10 (1:1)
F10 (1:4)
C
D
E
F
Eriophorum vaginatum
Betula nana
Sphagnum
Polygonum bistorta

Fig. S5. Variations of NO_3^- and NH_4^+ in soil water (A, B), NO_3^- in plant leaves (C-F) prior to and after N additions at TFS-MAT in 2012. In panels A and B, mean ± SE values of replicate plots (*n* = 3, 1 m × 1 m plot size for each) are shown. From panel C to panel F, "pristine" indicated mean ± SE values of plant samples collected on 2nd August (*n* = 3 for each species), others showed mean ± SE values of plant samples collected on 3rd August (*n* = 1 for *Betula nana* and *Polygonum bistorta; n* = 3 for *Eriophorum vaginatum* and *Sphagnum*), 4th August (*n* = 1 for each species), 5th August (*n* = 1 for each species), 7th August (*n* = 1 for each species) (therefore, *n* = 4 for *Betula nana* and *Polygonum bistorta*, *n* = 6 for *Eriophorum vaginatum* and *Sphagnum*). F2 and F10 represent NO_3^- fertilizer additions of 2 g N/m^2 and 10 g N/m^2, respectively; F10 (1:1) and F10 (1:4) represent additions of 10 g N/m^2 with the NO_3^--N:NH_4^+-N of 1:1 and 1:4, respectively. NO_3^- and NH_4^+ were added as $NaNO_3$ and NH_4Cl, respectively.



A
Control plots or pristine sites
N-only or N+P plots
Leaf NO3- (μg N/g, dw)
250
200
150
100
50
1.5
1
0
Arctostaphylos Rubra, Heath
Betula nana, Heath
Eriophorum vaginatum, Heath
Salix alaxensis, Shrub
Betula nana, Wet sedge
Eriophorum vaginatum, Wet sedge
Sphagnum, Wet sedge
Carex bigelowii, MNT
Cassiope tetragona, MNT
Equisetum arvense, MNT
Eriophorum vaginatum, MNT
Rhododendron tomentosum, MNT
Polygonum bistorta, MNT
Sphagnum, MNT



Leaf NO3- (μg N/g, dw)
B
C
D
E
F
CT/P
F0.5
F1.0
F2.0
F5.0
FNO3
F10
Betula nana, MAT
Eriophorum vaginatum, MAT
Rhododendron tomentosum, MAT
Sphagnum, MAT
Polygonum bistorta, MAT

Fig. S6. Leaf NO_3^- concentrations of plants across different types of tundra ecosystems at TFS. CT/P represent samples collected from control plots or pristine sites out of the replicated block design. (A) Samples of N only (10 g N/m^2 as NH_4NO_3) and N+P (10 g N/m^2 as NH_4NO_3 + 5 g P/m^2 as triple superphosphate) were collected from the LTER plots of arctic heath (5 m × 20 m plot size), shrub (5 m × 10 m), wet sedge (5 m × 10 m), and MNT (moist non-acid tussock and or non-tussock tundra) (5 m × 20 m). (B-F) Samples of F0.5 (0.5 g N/m^2 as NH_4NO_3 + 0.25 g P/m^2 as triple superphosphate), F1 (1 g N/m^2 as NH_4NO_3 + 0.5 g P/m^2 as triple superphosphate), F2 (2 g N/m^2 as NH_4NO_3 + 1 g P/m^2 as triple superphosphate), F5 (5 g N/m^2 as NH_4NO_3 + 2.5 g P/m^2 as triple superphosphate), F_{NO3} (5 g N/m^2 as $NaNO_3$+ 2.5 g P/m^2 as triple superphosphate), and F10 (10 g N/m^2 as NH_4NO_3 + 5 g P/m^2 as triple superphosphate) were collected from plots of MAT (5 m × 20 m). Mean ± SE values were shown, *n* = 3-11 except for *Rhododendron tomentosum*, MNT (*n* = 2) and *Polygonum bistorta*, MNT (*n* = 2).

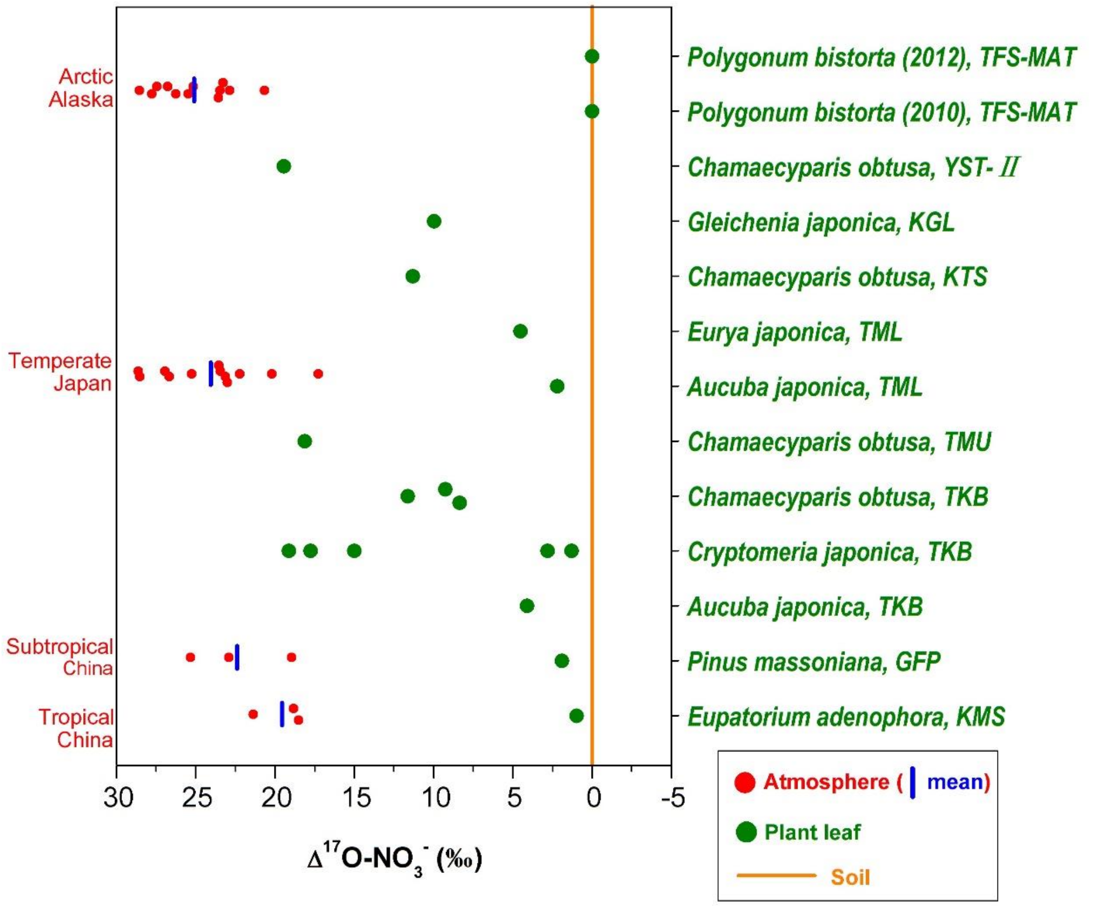
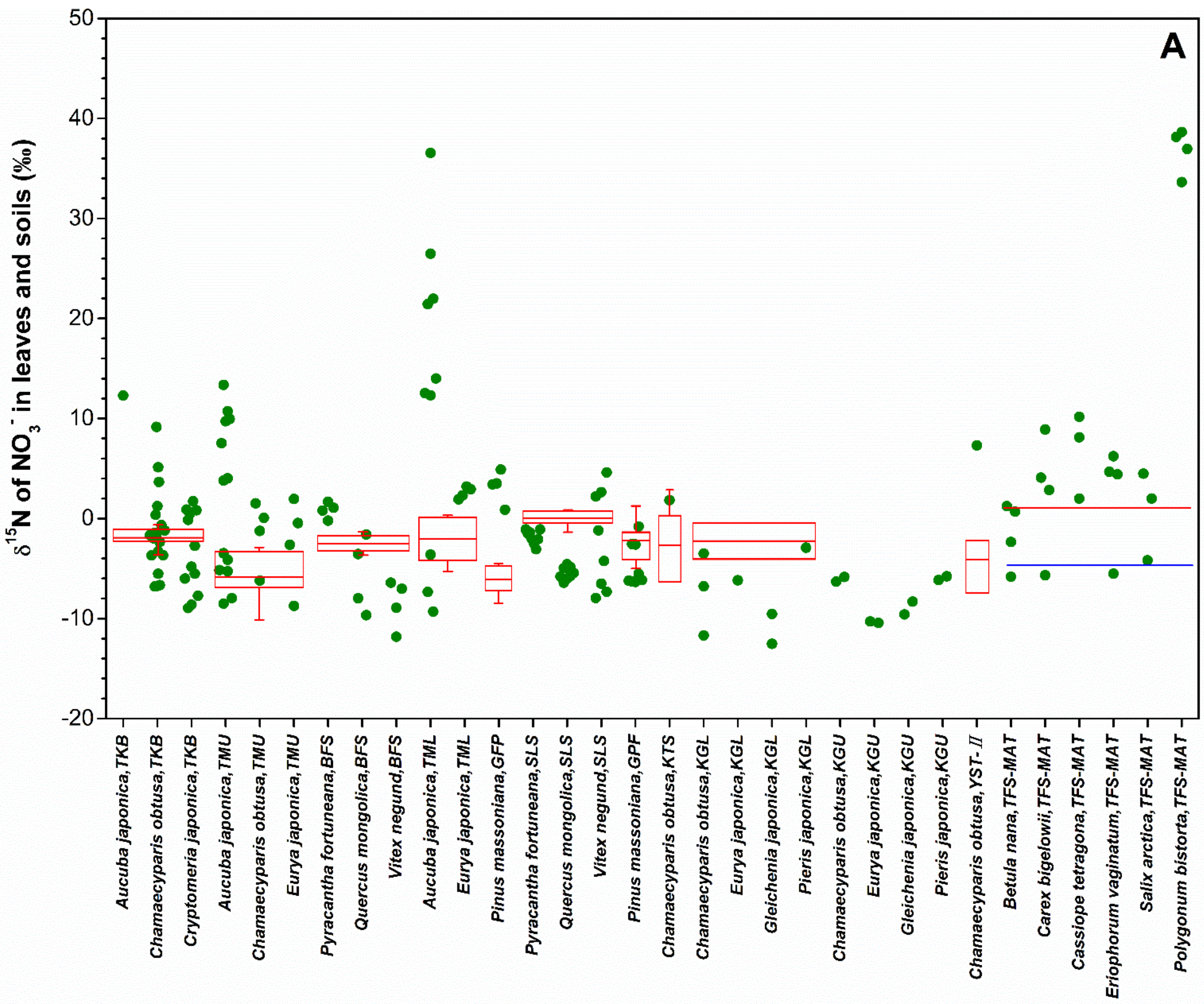


Fig. S7. Δ^{17}O values of NO_3^- in plant leaves across different ecosystems. The Δ^{17}O of soil NO_3^- was assumed as zero. The Δ^{17}O values of atmospheric NO_3^- in arctic Alaska and tropical China were cited from that of snowpack NO_3^- (n = 12; (24)) in Barrow, Alaska and precipitation NO_3^- (n = 3) in Jianfengling forests of Hainan, tropical China (25), respectively. The Δ^{17}O of atmospheric NO_3^- in temperate Japan and subtropical China was based on that of precipitation NO_3^- in TML (n = 12) and Guiyang (n = 3) in this study. Full site information is given in Table S1.


A
δ15N of NO3- in leaves and soils (‰)
50
40
30
20
10
0
-10
-20
Aucuba japonica,TKB
Chamaecyparis obtusa,TKB
Cryptomeria japonica,TKB
Aucuba japonica,TMU
Chamaecyparis obtusa,TMU
Eurya japonica,TMU
Pyracantha fortuneana,BFS
Quercus mongolica,BFS
Vitex negund,BFS
Aucuba japonica,TML
Eurya japonica,TML
Pinus massoniana,GFP
Pyracantha fortuneana,SLS
Quercus mongolica,SLS
Vitex negund,SLS
Pinus massoniana,GPF
Chamaecyparis obtusa,KTS
Chamaecyparis obtusa,KGL
Eurya japonica,KGL
Gleichenia japonica,KGL
Pieris japonica,KGL
Chamaecyparis obtusa,KGU
Eurya japonica,KGU
Gleichenia japonica,KGU
Pieris japonica,KGU
Chamaecyparis obtusa,YST-Ⅱ
Betula nana,TFS-MAT
Carex bigelowii,TFS-MAT
Cassiope tetragona,TFS-MAT
Eriophorum vaginatum,TFS-MAT
Salix arctica,TFS-MAT
Polygonum bistorta,TFS-MAT

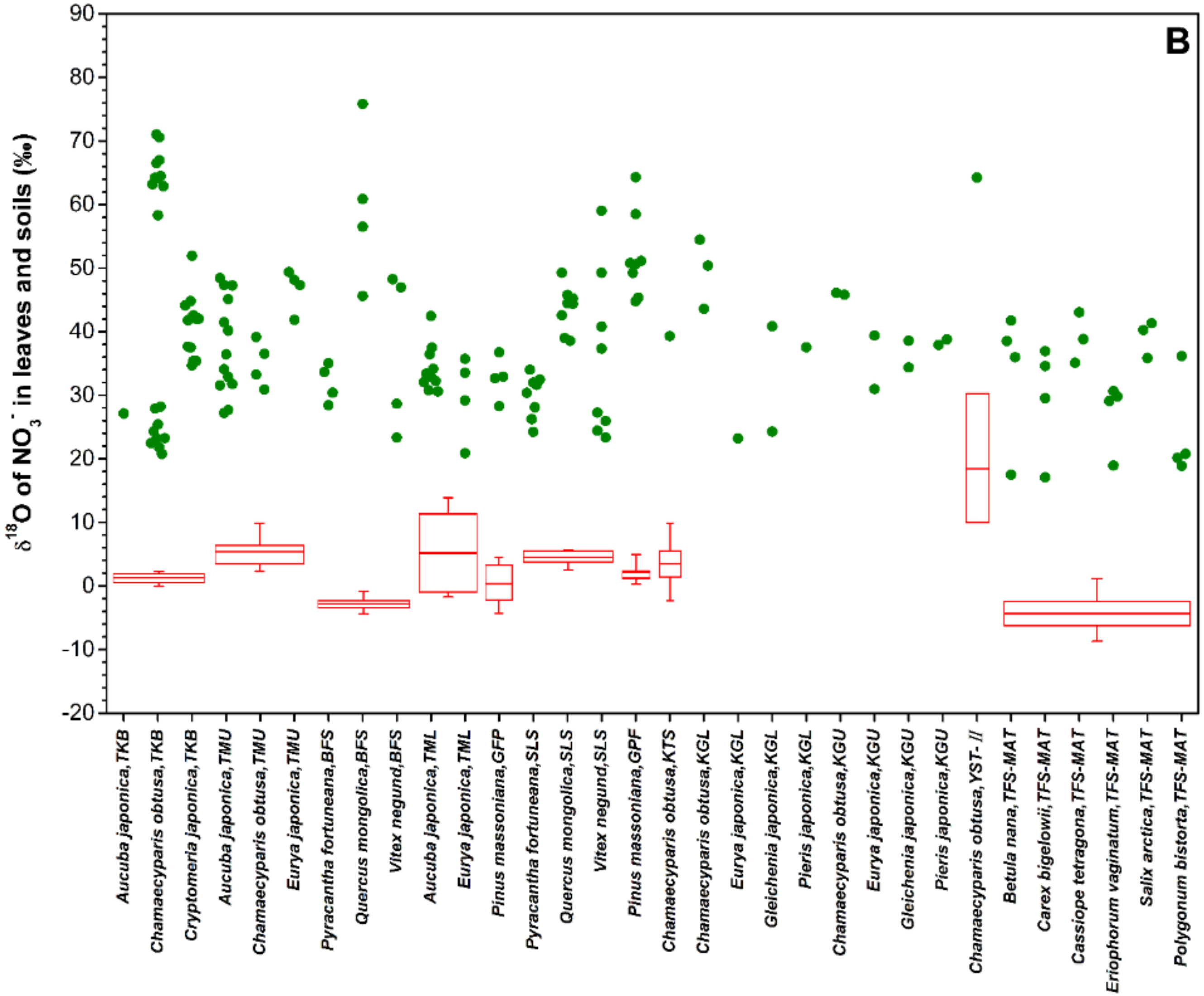

B
δ18O of NO3- in leaves and soils (‰)
90
80
70
60
50
40
30
20
10
0
-10
-20
Aucuba japonica,TKB
Chamaecyparis obtusa,TKB
Cryptomeria japonica,TKB
Aucuba japonica,TMU
Chamaecyparis obtusa,TMU
Eurya japonica,TMU
Pyracantha fortuneana,BFS
Quercus mongolica,BFS
Vitex negund,BFS
Aucuba japonica,TML
Eurya japonica,TML
Pinus massoniana,GFP
Pyracantha fortuneana,SLS
Quercus mongolica,SLS
Vitex negund,SLS
Pinus massoniana,GPF
Chamaecyparis obtusa,KTS
Chamaecyparis obtusa,KGL
Eurya japonica,KGL
Gleichenia japonica,KGL
Pieris japonica,KGL
Chamaecyparis obtusa,KGU
Eurya japonica,KGU
Gleichenia japonica,KGU
Pieris japonica,KGU
Chamaecyparis obtusa,YST- //
Betula nana, TFS-MAT
Carex bigelowii, TFS-MAT
Cassiope tetragona, TFS-MAT
Eriophorum vaginatum, TFS-MAT
Salix arctica, TFS-MAT
Polygonum bistorta, TFS-MAT

Fig. S8. $\delta^{15}N$ (A) and $\delta^{18}O$ (B) values of NO_3^- in plant leaves and soils across different ecosystems. Solid green circles stand for leaves (*n* = 1−40). Red boxes stand for soil extracts (*n* = 2−16). The box encompasses the 25^{th}–75^{th} percentiles; the solid line within each box and the upper and lower whisker of each box show the mean, maximum, and minimum values, respectively. Mean $\delta^{15}N$ of atmospheric NO_3^- (blue line in Panel A) and mean $\delta^{18}O$ of soil NO_3^- for tundra plants were cited from those measured at Barrow, Alaska (26).

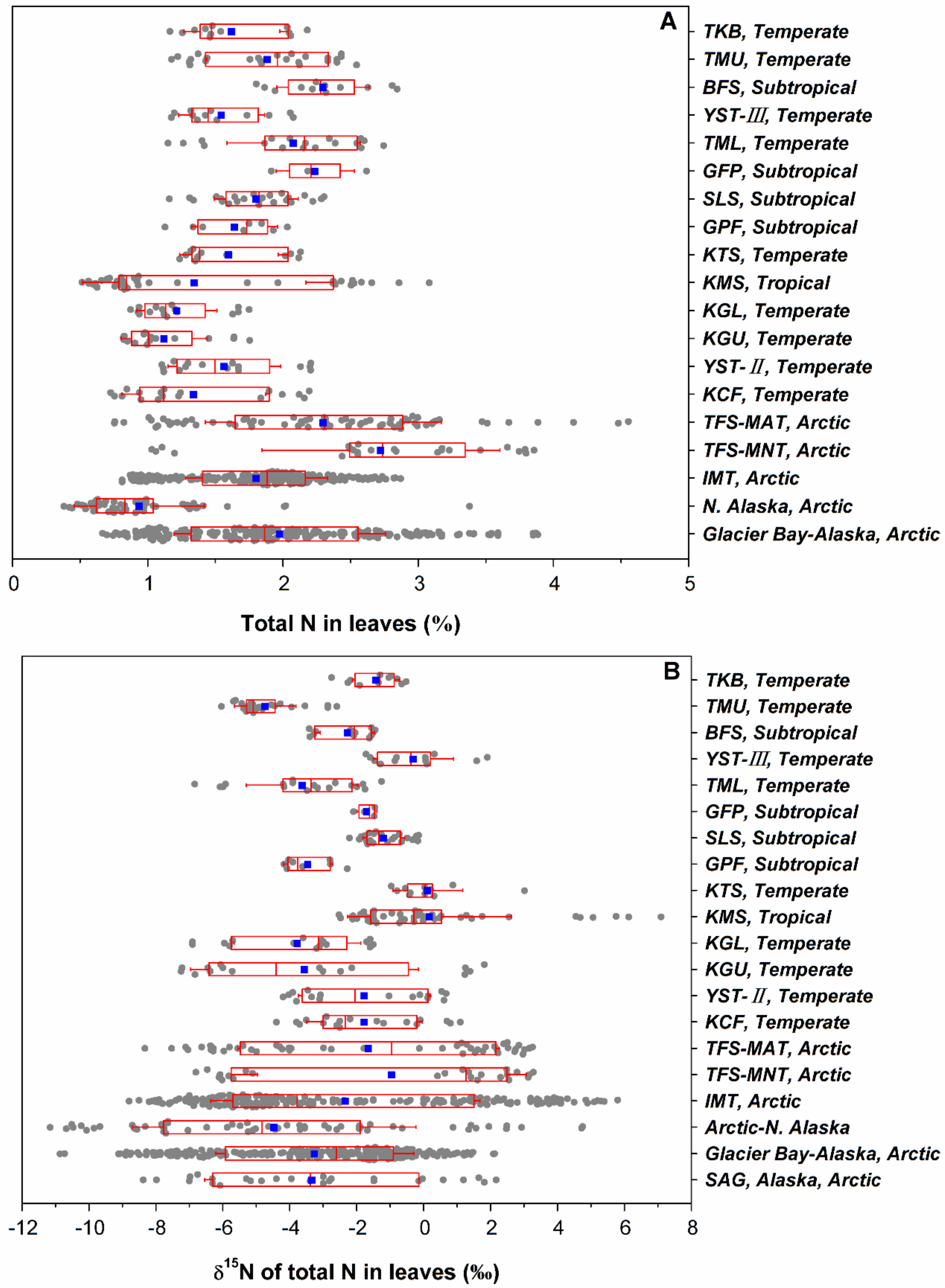


Fig. S9. Leaf total N concentrations (A) and total δ^{15}N values (B) of dominant plant species across Alaskan tundra sites and non-arctic sites. Dots around the boxes show replicate data at each site. The box encompasses the 25th–75th percentiles, whiskers are the SD values. The red line and blue square in each box mark the median and mean values, respectively. *N* ranged from 4 to 260 for each site. Data of plants at Glacier Bay, Alaska and northern Alaska (N. Alaska) were cited from (27) and (28), respectively.

Table S1. Descriptions of study sites, sample collections and analyses.

Site, region/Country	Site abbreviation	Climate	Latitude	Longitude	ME(m)	MT(°C)	MP(mm)
Mt. Kongming of Xishuangbanna, southwestern (SW) China	KMS	Tropical	21° 16' N	101° 6.0' E	1788	22.0	1600
Guiyang forest park of Guiyang city, SW China	GFP	Subtropical	26° 34' N	106° 45' E	1269	14.5	1100
Mt. Baofushan of Guiyang city, SW China	BFS	Subtropical	26° 34' N	106° 46' E	1230	14.5	1100
Guaijiu pine forest of Baiyi, Guiyang, SW China	GPF	Subtropical	26° 48' N	107° 1.0' E	1241	15.3	1100
Mt. Shilong of Baiyi, Guiyang, SW China	SLS	Subtropical	26° 48' N	107° 0.8' E	1329	15.3	1100
Kamigamo experimental forest of Kyoto Univ. (upperslope), western Japan	KGU	Temperate	35° 4.0' N	135° 46' E	220	15.0	1584
Kamigamo experimental forest of Kyoto Univ (lowerslope), western Japan	KGL	Temperate	35° 4.0' N	135° 46' E	200	15.0	1584
Kochi (Tsuno) forest, southern Japan	KCF	Temperate	33° 26' N	133° 01' E	710	13.1	3270
Field Museum Tama-Kyuryo (upperslope) of TUAT, central Japan	TMU	Temperate	35° 38' N	139° 23' E	110	14.8	1790
Field Museum Tama-Kyuryo (lowerslope) of TUAT, central Japan	TML	Temperate	35° 38' N	139° 23' E	100	14.8	1790
Tsukuba Forest Experimental Watershed, central Japan	TKB	Temperate	33° 10' N	140° 10' E	230	12.3	1390
Katsura forest, central Japan	KTS	Temperate	33° 31' N	140° 17' E	390	11.9	1350
Yasato forest-II, central Japan	YST-Ⅱ	Temperate	33° 17' N	140° 09' E	180	13.1	1440
Yasato forest-III, central Japan	YST-Ⅲ	Temperate	33° 19' N	140° 12' E	350	11.5	1460
Toolik field station (MAT), northern Alaska	TFS-MAT	Arctic	68° 38' N	149° 36' W	760	9.3*	180*
Toolik field station (MNT), northern Alaska	TFS-MNT	Arctic	68° 38' N	149° 36' W	760	9.3*	180*
Imnavait Creek, northern Alaska	IMT	Arctic	68° 36' N	149° 18' W	876	9.3*	180*
Sagavanirktok River Valley, northern Alaska	SAG	Arctic	68° 47' N	148° 52' W	552	9.3*	180*

* Data of June-August (Growing season). ME, mean elevation. MT, mean annual temperature. MP, mean annual precipitation. MAT, moist acidic tundra. MNT, moist non-acidic tundra.

(Continued, soil sampling and analysis)

Site	**Type, horizon (cm)**	**Sampling time**	**Replicate (*n*)**	**Mean pH (H_2O)**	**Measured N parameters**	**Methods and labs for inorganic N concentrations**	**Methods and labs for isotope analyses**
KMS	Lateritic, M (0–20)	November, 2011	5	4.6	Concentrations of (2N KCl)-extractable NO_3^- and NH_4^+	AutoAnalyzer III, SEAL Analytical GmbH, Germany; Xishuangbanna Tropical Botanical Garden, CAS	N.A
GFP	Yellow, A_0&M (0–10)	July, 2010	8	4.3	Concentrations and isotopes of (2N KCl)-extractable NO_3^-, NH_4^+, TEN&EON; Net rates of N mineralization and nitrification	The indophenol blue method followed by colorimetry for NH_4^+; AutoAnalyzer (TRAACS 800, Bran+Luebbe, Tokyo, Japan) for NO_3^- and TEN&EON; TUAT.	The denitrifier method; An IRMS (Finnigan Delta XP) coupled with Precon and GC (Agilent, HP6890); TUAT
BFS	Calcareous & Yellow, A_0&M (0–10)	July, 2010	8	6.9	Same as that of GFP	Same as that of GFP	Same as that of GFP
GPF	Yellow, A_0&M (0–10)	July, 2010	8	4.8	Same as that of GFP	Same as that of GFP	Same as that of GFP
SLS	Calcareous & Yellow, A_0&M (0–10)	July, 2010	8	6.3	Same as that of GFP	Same as that of GFP	Same as that of GFP
KGL	Cinnamon, A_0&M (0–20)	October, 2012	9	4.0	Concentrations of (0.5N K_2SO_4)-extractable	AutoAnalyzer (QuAAtro 2-HR, BL-Tech, Osaka, Japan); TUAT	The denitrifier method; An IRMS (model 20-22; Sercon Ltd) with the

					NO_3^-, NH_4^+, EON; Net rates of N mineralization and nitrification		same instrument setting and protocol as (29)
KGU	Cinnamon, A_0&M (0–20)	October, 2012	9	3.8	Same as that of KGL	Same as that of KGL	Same as that of KGL
KCF	Cinnamon, A_0&M (0–20)	September, 2013	9	N.A	Same as that of KGL	Same as that of KGL	Same as that of KGL
TMU	Cinnamon, A_0&M (0–20)	September, 2012	9	3.7	Concentrations and isotopes of (0.5N K_2SO_4)-extractable NO_3^-, NH_4^+, EON; Net rates of N mineralization and nitrification	Same as that of KGL	Same as that of KGL
TML	Cinnamon, M (0–10)	September, 2012 for soil extractions; November, 2011 to April, 2012 for soil solutions at depths of 15, 30, 50cm, respectively	3	3.7	Same as that of TMU See Table S1	Same as that of KGL	Same as that of KGL
TKB	Cinnamon, A_0&M (0–20)	Septemb er, 2012	9	4.5	Same as that of TMU	Same as that of KGL	Same as that of KGL
KTS	Cinnamon, M (0–20)	September, 2012	6	4.7	Same as that of TMU	Same as that of KGL	Same as that of KGL

YST-II	Cinnamon, A_0&M (0–20)	September, 2012	9	4.9	Same as that of TMU	Same as that of KGL	Same as that of KGL
YST-III	Cinnamon, A_0&M (0–20)	September, 2012	9	4.2	Same as that of TMU	Same as that of KGL	Same as that of KGL
TFS-MAT	*Cryaquep*, A_0&M (0–15)	August, 1990-2006 July-August, 2012 (soil solutions only)	135	N.A	Same as that of KMS. See Table S1, Figs.S1&S2	Spectrophotometer and auto-analyzer; MBL	N.A
TFS-MNT	*Cryaquep*, A_0&M (0–15)	August, 1998-2006	54	N.A	Same as that of TFS-MAT	Same as that of TFS-MAT	N.A
IMT	*Cryaquep*, A_0&M (*)	July-August, 2000	93	N.A	Total N% and $\delta^{15}N$; Concentrations of (2N KCl)-extractable NO_3^-, NH_4^+, EON; $\delta^{15}N$-NH_4^+; Net rates of N mineralization and nitrification See Figs.S1 and S2	The buried-bag and field-incubation method (1st-July to 12th-August) for net N rates; Others same as that of TFS-MAT	EA-IRMS for total N% and $\delta^{15}N$. Diffusion method for $\delta^{15}N$-NH_4^+; MBL (30)
SAG	*Cryaquep*, A_0&M (0–15)	August, 1987-2005	151	N.A	Same as that of TFS-MAT	Same as that of TFS-MAT	N.A

*Samples were collected by each horizon (including Oa, Oe, Oe+a, Oi, Oi+a, Oi+e layers, if available and visible) along the landscape toposequence (crest and shoulder, footslope, lower backslope, upper backslope). Soils of tundra sites are histic pergelic cryaquepts overlying a silty mineral soil and permafrost. A_0, organic layer. M, mineral soil. EON, dissolved organic N (the difference between total dissolved N and (NO_3^-- plus NH_4^+-N)). CAS, Chinese Academy of Sciences; TUAT, Tokyo University of Agriculture and Technology. MBL, Marine Biology Laboratory. N.A, data not available. IRMS, isotope-ratio mass spectrometer.

(Continued, plant sampling and analysis)

Site	**Dominant vegetation**	**Organs collected (time)**	**Measured N parameters**	**Methods and labs for total N**	**Methods and labs for tissue NO_3^-**
KMS	Herbs, invaded by alien shrubberies	Mature leaves & fine roots (November, 2011)	Leaf total N & total $\delta^{15}N$; Leaf NO_3^- concentrations and $\Delta^{17}O$ values	EA (Flash2000) coupled with IRMS (MAT-253); IGCAS	The denitrifier method; A GC-ECD (GC-14B, Shimadzu) for concentrations
GFP	Conifer (P&S), mainly *Pinus*	Mature leaves & fine roots (July, 2010)	Total N&$\delta^{15}N$; Tissue NO_3^- concentrations & tissue NO_3^- isotopes	EA (Flash1112) coupled with IRMS (Delta-XP); TUAT	Same as that of KMS for concentrations; IRMS (Delta XP) coupled with Precon and GC (Agilent, HP6890) for $\delta^{15}N$ and $\delta^{18}O$; TUAT. Thermal decomposition coupled with an IRMS (Delta Plus Advantage) for $\Delta^{17}O$, UW.
BFS	Shrubbery (S), a mixture of Broadleaves & evergreen shrubs	Same as that of GFP	Same as that of GFP	Same as that of GFP	Same as that of GFP
GPF	Conifer (P&S), mainly *Pinus*	Same as that of GFP	Same as that of GFP	Same as that of GFP	Same as that of GFP

SLS	Shrubbery (S), mixed by broadleaves & evergreen shrubs	Same as that of GFP	Same as that of GFP	Same as that of GFP	Same as that of GFP
KGL	Conifer (P&S), mainly *Chamaecyparis obtusa*, with understories mixed by deciduous & evergreen shrubs	Same as that of GFP (October, 2012)	Total N & total $\delta^{15}N$; Tissue NO_3^- concentrations (all available) & tissue NO_3^- isotopes (available for leaf samples only)	Same as that of GFP	Same as that of KMS for concentrations and $\Delta^{17}O$. An IRMS (model 20-22; Sercon Ltd) with the same instrument setting and protocol as (29) for $\delta^{15}N$ and $\delta^{18}O$, TUAT.
KGU	Assembling that of KGL	Same as that of KGL	Same as that of KGL	Same as that of GFP	Same as that of KGL
KCF	Assembling that of KGL	Same as that of GFP (September, 2013)	Leaf total N & total $\delta^{15}N$; Leaf NO_3^- concentrations	Same as that of GFP	Same as that of KGL
TMU	Assembling that of KGL, but N-saturated	Mature leaves only for *Aucuba japonica* (November, 2011; March, June, November, 2012), Mature leaves & fine roots for all studying species (September, 2012)	Same as that of GFP	Same as that of GFP	Same as that of KGL
TML	With very few *C. obtusa*, but N-saturated	Same as that of TMU	Same as that of GFP	Same as that of GFP	Same as that of KGL
TKB	Assembling that of KGL	Mature leaves & fine roots (February, 2012 only for *C. obtusa* & *Cryptomeria japonica*; September, 2012 for *C. obtusa* & understories)	Same as that of KGL	Same as that of GFP	Same as that of KGL
KTS	Assembling that of KGL	Mature leaves & fine roots (September, 2012)	Same as that of KGL	Same as that of GFP	Same as that of KGL

YST-II	Assembling that of KGL	Same as that of KTS	Same as that of KGL	Same as that of GFP	Same as that of KGL
YST-III	Assembling that of KGL	Same as that of KTS	Leaf total N & total $\delta^{15}N$; Leaf NO_3^- concentrations	Same as that of GFP	Same as that of KGL
TFS-MAT	Acidic tundra, mainly as the grass of *Eriophorum*, mixed with few deciduous shrubs such as *Betula, Salix*; evergreen shrubs such as *Cassiope, Rhododendron;* forb such as *Polygonum*; sedge such as *Carex*; and *Sphagnum*	Leaves (August, 2001; August, 2010); Roots (June, 2010); Leaves & roots in short-term fertilizing plots (August, 2012); Leaves & roots at pristine/control sites and leaves in LTER blocks/plots (July-August, 2012)	Leaf N% and total $\delta^{15}N$ ratios (August, 2001); Leaf NRA (control and fertilizing plots); Tissue NO_3^- concentrations (all samples) & tissue NO_3^- isotopes (roots collected in 2007; Part of leaves collected in 2010 and 2012)	AutoAnalyzer III for NRA; EA-IRMS for total N, CER Kyoto University	A GC-ECD (GC-2014, Shimadzu) for plants collected from fertilizing plots. Others same as that of GFP
TFS-MNT-T	Non-acidic and tussock, mainly *Eriophorum, Carex, Cassiope, Polygonum,* Equisetum, *Sphagnum*	Leaves & roots at pristine/control sites and leaves only in LTER blocks/plots (July-August, 2012)	Leaf NRA (control and fertilizing plots); Tissue NO_3^- concentrations only.	Same as that of TFS-MAT	Same as that of TFS-MAT
TFS-MNT-NT	Non-acidic & non-tussock, assembling species of MNT-T	Leaves & roots at pristine/control sites and leaves only in LTER blocks/plots (July-August, 2012)	Tissue NO_3^- concentrations only	N.A	Same as that of TFS-MAT
TFS-Heath	Low productivity, mixed by *Betula, Arctous, Juniperus, Rhododendron, Vaccinium, Polygonum*	Leaves & roots at pristine/control sites and leaves only in LTER blocks/plots (July-August, 2012)	Tissue NO_3^- concentrations only	N.A	Same as that of TFS-MAT
TFS-Wet sedge	Mainly as the sedge, grass of *Eriophorum*, *Sphagnum*,	Leaves & roots at pristine/control sites and leaves	Tissue NO_3^- concentrations only	N.A	Same as that of TFS-MAT

	mixed with a few *Vaccinium* and *Betula* species	only in LTER blocks/plots (July-August, 2012)			
TFS-Shrub	High productivity, mainly as the deciduous shrub of *Salix*, mixed with *Sphagnum* and a very few other species	Leaves & roots at pristine/control sites and leaves only in LTER blocks/plots (July-August, 2012)	Tissue NO_3^- concentrations only	N.A	Same as that of TFS-MAT
IMT	Assembling species compositions of MAT	Leaves of plants at pristine sites along the landscape topsequence (Crest & shoulder, footslope, lower backslope, upper backslope) (July-August, 2001)	Leaf NRA (pristine sites); Leaf N% and total $\delta^{15}N$ ratios	EA-IRMS with a manual "cryoflow' system, MBL (30)	N.A

S, secondary; P, planted; M, mineral soil; O, organic layer; NRA, nitrate reductase activity. IGCAS, Institute of Geochemistry, Chinese Academy of Sciences. UA, University of Washington. N.A, data not available.

Table S2. Mean NO_3^- concentrations in leaves and roots (µg N/g, dw), total leaf N (%) and $\delta^{15}N$ (‰) in plants across arctic and non-arctic sites. Mean ± SE (number of replicate samples) are shown. n.a indicating data not available.

Species, Site	Leaf NO_3^-	Root NO_3^-	Leaf N	Leaf $\delta^{15}N$
Aucuba japonica, TKB	2.1±0.2 (4)	2635.1±245.8 (4)	2.1±0.0 (4)	-1.1±0.2 (4)
Cryptomeria japonica, TKB	1.0±0.0 (6)	28.6±3.6 (4)	n.a	n.a
Chamaecyparis obtusa, TKB	2.1±0.3 (13)	316.9±310.3 (2)	1.5±0.0 (4)	-0.9±0.1 (4)
Eurya japonica, TKB	1.1±0.1 (4)	142.3±85.1 (4)	1.3±0.1 (4)	-2.3±0.2 (4)
Aucuba japonica, TMU	0.8±0.3 (4)	292.4±49.8 (4)	2.2±0.1 (17)	-4.7±0.2 (17)
Chamaecyparis obtusa, TMU	0.9±0.3 (4)	26.9±3.2 (4)	1.3±0.0 (4)	-4.7±0.4 (4)
Eurya japonica,TMU	0.8±0.2 (4)	546.4±83.2 (4)	1.3±0.1 (4)	-4.9±0.5 (4)
Pyracantha fortuneana, BFS	0.7±0.0 (4)	1.1±0.1 (4)	2.0±0.1 (4)	-1.5±0.0 (4)
Quercus mongolica, BFS	0.8±0.2 (4)	1.9±0.1 (4)	2.3±0.0 (4)	-3.3±0.0 (4)
Vitex negundo, BFS	0.9±0.2 (4)	4.5±0.9 (4)	2.6±0.2 (4)	-2.0±0.1 (4)
Aucuba japonica, YST-III	0.4±0.0 (4)	271.0±78.3 (4)	1.9±0.1 (4)	-0.6±0.4 (4)
Chamaecyparis obtusa, YST-III	0.4±0.1 (4)	0.9±0.2 (4)	1.3±0.0 (4)	-1.4±0.2 (4)
Eurya japonica, YST-III	0.5±0.1 (4)	55.5±6.8 (4)	1.4±0.0 (4)	1.0±0.5 (4)
Aucuba japonica, TML	1.5±0.7 (4)	1150.7±213.7 (4)	2.3±0.1 (14)	-2.9±0.3 (14)
Eurya japonica, TML	0.6±0.1 (4)	225.3±32.4 (4)	1.3±0.1 (4)	-6.2±0.2 (4)
Pinus massoniana, GFP	2.1±0.1 (4)	1.4±0.0 (4)	2.2±0.1 (4)	-1.7±0.1 (4)
Pyracantha fortuneana, SLS	0.6±0.0 (8)	0.8±0.1 (4)	2.0±0.1 (8)	-0.5±0.1 (8)
Quercus mongolica, SLS	0.7±0.1 (8)	1.3±0.1 (4)	1.5±0.1 (8)	-1.6±0.1 (8)
Vitex negundo, SLS	0.6±0.0 (8)	1.8±0.2 (4)	1.9±0.1 (8)	-1.4±0.2 (8)
Pinus massoniana, GPF	1.4±0.2 (8)	0.6±0.1 (8)	1.6±0.1 (8)	-3.5±0.3 (8)
Aucuba japonica, KTS	0.4±0.0 (4)	281.0±112.2 (4)	2.1±0.0 (4)	-0.4±0.2 (4)
Chamaecyparis obtusa, KTS	0.5±0.2 (4)	3.9±1.6 (4)	1.3±0.0 (4)	-0.2±0.3 (4)

Eurya japonica, KTS	0.5±0.1 (4)	87.9±40.2 (4)	1.4±0.1 (4)	0.9±0.7 (4)
Imperata cylindrical, KMS	0.9±0.1 (2)	n.a	0.8±0.0 (15)	-1.1±0.2 (15)
Sporobolus virginicus, KMS	0.7±0.0 (2)	n.a	0.7±0.0 (11)	-0.8±0.3 (11)
Terricolous mosses, KMS	1.2 (1)	n.a	0.8±0.0 (4)	-1.5±0.3 (4)
Eupatorium adenophora, KMS	3.8±2.2 (4)	n.a	2.5±0.1 (15)	2.6±0.7 (15)
Chamaecyparis obtusa, KGL	0.4±0.1 (4)	2.8±1.1 (4)	0.9±0.0 (4)	-3.9±0.7 (4)
Eurya japonica, KGL	0.6±0.1 (4)	0.7±0.2 (4)	1.1±0.0 (4)	-3.2±0.1 (4)
Pieris japonica, KGL	0.8±0.1 (4)	0.5±0.1 (4)	1.7±0.0 (4)	-1.6±0.0 (4)
Gleichenia japonica, KGL	0.9±0.1 (4)	0.3±0.1 (4)	1.2±0.0 (4)	-6.3±0.3 (4)
Chamaecyparis obtusa, KGU	0.3±0.1 (4)	0.4±0.0 (4)	0.8±0.0 (4)	-6.8±0.2 (4)
Eurya japonica, KGU	0.6±0.0 (4)	0.4±0.0 (4)	1.0±0.1 (4)	-2.7±0.2 (4)
Pieris japonica, KGU	0.5±0.1 (4)	0.4±0.1 (4)	1.0±0.0 (4)	1.4±0.1 (4)
Gleichenia japonica, KGU	0.8±0.1 (4)	0.1±0.0 (4)	1.6±0.1 (4)	-6.2±0.2 (4)
Aucuba japonica, YST-II	0.6±0.1 (4)	329.1±191.2 (4)	1.6±0.0 (4)	-3.4±0.3 (4)
Chamaecyparis obtusa, YST-II	2.2±0.3 (4)	1.7±0.5 (4)	1.2±0.1 (4)	-3.8±0.1 (4)
Eurya japonica, YST-II	0.5±0.1 (4)	18±7.7 (4)	1.3±0.0 (4)	-0.3±0.2 (4)
Hydrangea hirta, YST-II	1.1±0.1 (4)	2.6±1.0 (2)	2.2±0.0 (4)	0.5±0.1 (4)
Chamaecyparis obtusa, KCF	0.3±0.1 (6)	n.a	0.8±0.0 (6)	-3.3±0.3 (6)
Eurya japonica, KCF	0.2±0.0 (6)	n.a	1.1±0.0 (6)	0.1±0.4 (6)
Lindera triloba, KCF	0.9±0.2 (6)	0.6±0.2 (3)	2.0±0.1 (6)	-2.2±0.5 (6)
Arctostaphylos alpina, TFS-MAT	n.a	n.a	1.8±0.0 (3)	n.a
Betula nana, TFS-MAT	0.2±0.0 (3)	0.8±0.2 (6)	2.5±0.1 (9)	-6.4±0.4 (8)
Carex bigelowii, TFS-MAT	0.4±0.0 (3)	0.7±0.2 (7)	3.0±0.0 (8)	2.4±0.2 (8)
Cassiope tetragona, TFS-MAT	0.3±0.1 (4)	0.4 (1)	1.1±0.0 (8)	-4.6±0.4 (5)

Dryas integrifolia, TFS-MAT	n.a	n.a	1.6±0.1 (3)	n.a
Equisetum arvense, TFS-MAT	n.a	n.a	2.5±0.1 (3)	n.a
Eriophorum angustifolium, TFS-MAT	n.a	n.a	2.3±0.0 (3)	1.6±0.8 (9)
Eriophorum vaginatum, TFS-MAT	0.3±0.1 (6)	0.9±0.5 (3)	2.5±0.1 (8)	n.a
Rhododendron tomentosum, TFS-MAT	0.1±0.0 (3)	0.4 (1)	1.2±0.1 (3)	-6.1±0.6 (3)
Polygonum bistorta, TFS-MAT	13.5±5.5 (11)a	n.a	3.8±0.1 (13)	0.9±0.3 (6)
Rhododendron lapponicum, TFS-MAT	n.a	n.a	1.4±0.1 (3)	n.a
Rubus chamaemorus, TFS-MAT	n.a	n.a	3.0±0.1 (4)	1.5 (1)
Salix alaxensis, TFS-MAT	0.3±0.0 (3)	1.2±0.1 (4)	2.5±0.2 (3)	-3.0 (1)
Salix reticulata, TFS-MAT	n.a	n.a	1.9±0.2 (3)	n.a
Vaccinium uliginosum, TFS-MAT	n.a	n.a	2.2±0.1 (3)	-4.0 (1)
Vaccinium vitis-idaea, TFS-MAT	n.a	n.a	0.8±0.0 (3)	-7.1 (1)
Betula nana, TFS-MNT	n.a	n.a	2.6±0.1 (5)	-6.0±0.3 (5)
Sphagnum, TFS-MAT	0.0±0.0 (3)	n.a	n.a	n.a
Carex bigelowii, TFS-MNT	0.4 (1)	1.2 (1)	3.3±0.1 (5)	2.5±0.4 (5)
Cassiope tetragona, TFS-MNT	0.0±0.0 (4)		1.1±0.0 (4)	-5.9±0.2 (4)
Eriophorum vaginatum, TFS-MNT	0.2±0.0 (4)	0.4 (1)	2.6±0.1 (5)	2.5±0.1 (5)
Equisetum arvense, TFS-MNT	0.2±0.1 (5)	n.a	n.a	n.a
Polygonum bistorta, TFS-MNT	29.3±16.7 (10)b	0.5±0.1 (18)	n.a	1.1±0.2 (5)
Sphagnum, TFS-MNT	0.0±0.0 (6)	n.a	n.a	n.a
Arctostaphylos rubra, TFS-Heath	0.1 (1)	0.4 (1)	n.a	n.a
Betula nana, TFS-Heath	0.2±0.0 (3)	0.3 (1)	n.a	n.a
Juniperus communis, TFS-Heath	0.0 (1)	0.4 (1)	n.a	n.a
Rhododendron tomentosum, TFS-Heath	0.2 (1)	0.6 (1)	n.a	n.a
Polygonum bistorta, TFS-Heath	0.6±0.3 (3)	0.1±0.0 (3)	n.a	n.a
Vaccinium, TFS-Heath	0.1±0.1 (2)	1.8 (1)	n.a	n.a
Sphagnum, TFS-Shrub	0.1±0.0 (2)	n.a	n.a	n.a

Salix alaxensis, TFS-Shrub	0.1±0.0 (5)	0.4±0.1 (4)	n.a	n.a
Betula nana, TFS-Wet sedge	0.1 (1)	0.2 (1)	n.a	n.a
Vaccinium, TFS-Wet sedge	0.1 (1)	0.5 (1)	n.a	n.a
Eriophorum vaginatum, TFS-Wet sedge	0.2±0.1 (7)	0.6±0.2 (2)	n.a	n.a
Sphagnum, TFS-Wet sedge	0.1±0.0 (4)	n.a	n.a	n.a

a: Mininum=0.7, Maximum=65.8 (unit: μg N/g, dw);
b: Mininum=2.6, Maximun=177.1 (unit: μg N/g, dw).

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