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Carbon–nitrogen interactions in European forests and semi-natural vegetation – Part 1: Fluxes and budgets of carbon, nitrogen and greenhouse gases from ecosystem monitoring and modelling

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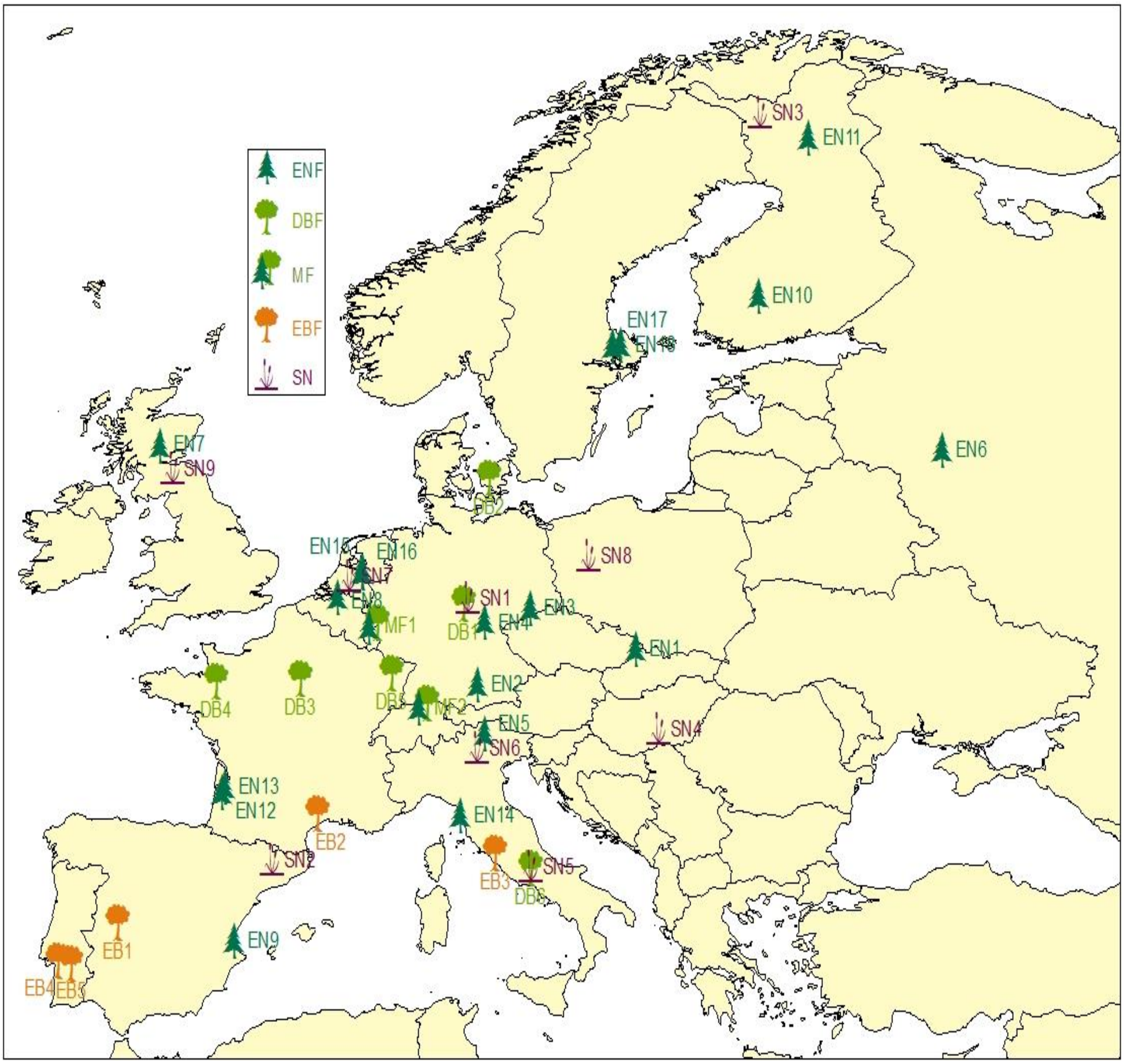

Figure S1. Geographical distribution of NitroEurope nitrogen deposition monitoring sites. Key: ENF: evergreen needle leaf forest; DBF: deciduous broadleaf forest; MF: mixed deciduous/needle leaf forest; EBF: Mediterranean evergreen broadleaf forest; SN: short semi-natural vegetation.

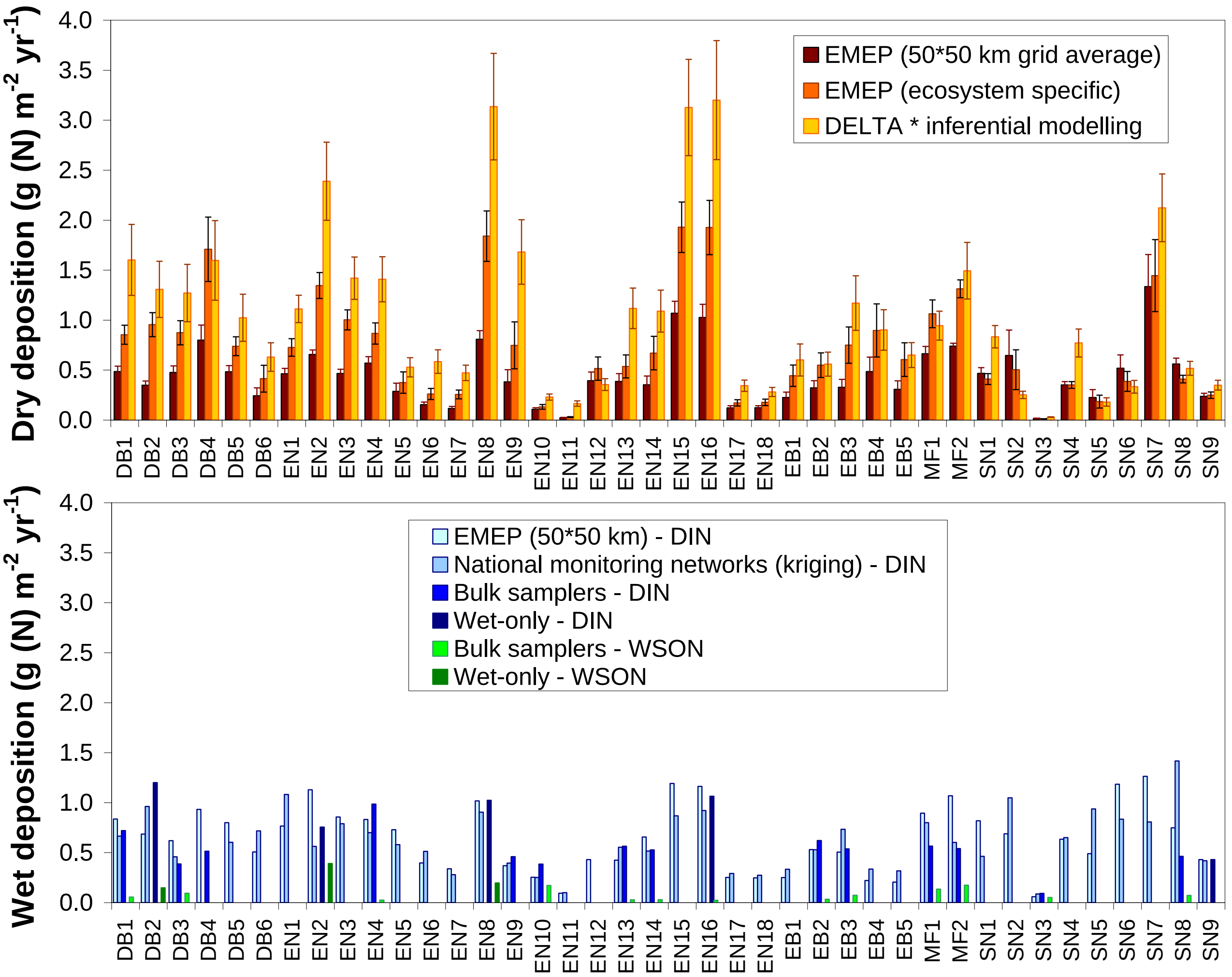

Figure S2. Comparison of annual dry and wet atmospheric inorganic nitrogen deposition estimates at the 31 forest (DB, EN, EB, MF) and 9 short semi-natural (SN) monitoring sites of this study, obtained using different methods and data sources. Top panel: dry deposition estimates from i) grid-average modelled outputs of the European-scale EMEP chemistry and transport model (Simpson et al., 2012) taken from the 50*50 km grid cells corresponding to each site (average and standard deviation for the years 2007-2010); ii) ecosystem-specific EMEP modelled dry deposition within each grid; and iii) inferential ensemble modelling estimates (in-situ atmospheric DELTA-Nr measurements coupled to several dry deposition models applied at the ecosystem scale; Flechard et al., 2011). Lower panel: dissolved inorganic (DIN) or water- soluble organic (WSON) N_r wet deposition estimates from i) modelled EMEP 50*50 km gridded outputs (average for the years 2007-2010); ii) spatial interpolation by kriging of rainfall concentration data from national and continental networks of precipitation monitors, scaled for local rainfall; iii) bulk precipitation samplers installed at 13 sites of the NEU network; iv) wet-only precipitation samplers at 6 sites.

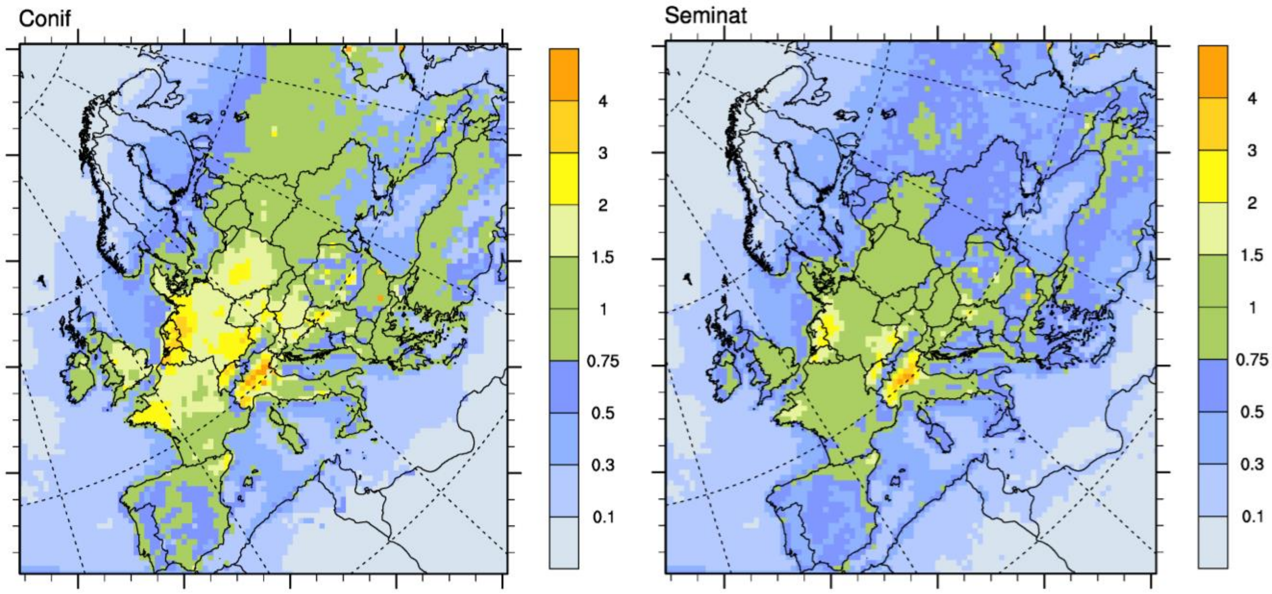

Figure S3. Comparison of total atmospheric nitrogen deposition (g (N) m^{-2} yr^{-1}) to coniferous forests (left) and to semi-natural vegetation (right), modelled by the EMEP chemical transport model (year 2010). The difference is mainly due to dry deposition, which is larger over forests due to larger surface roughness, which generates faster vertical turbulent transfer and larger deposition velocities.

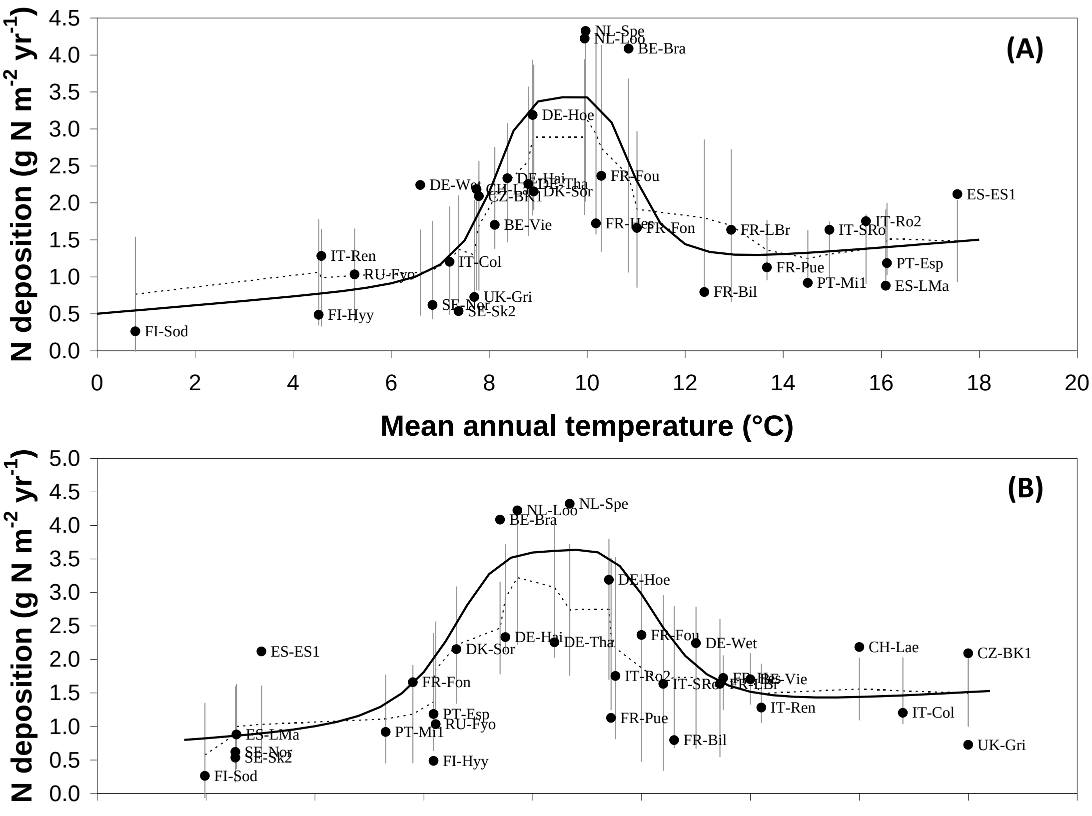

Figure S4. Spatial variations in measurement-based nitrogen deposition, plotted as a function of (A) mean annual temperature (MAT) and (B) mean annual precipitation (MAP). Temperature and precipitation are not direct determinants of N_{dep}, but the geographical occurrence of peak N_{dep} levels in mid-range for both MAT and MAP means that the relationship of forest productivity to N_{dep} cannot be considered independently of climate at the European scale. Dotted line: moving average +/- standard deviation; solid line: fitted bell-shaped function.

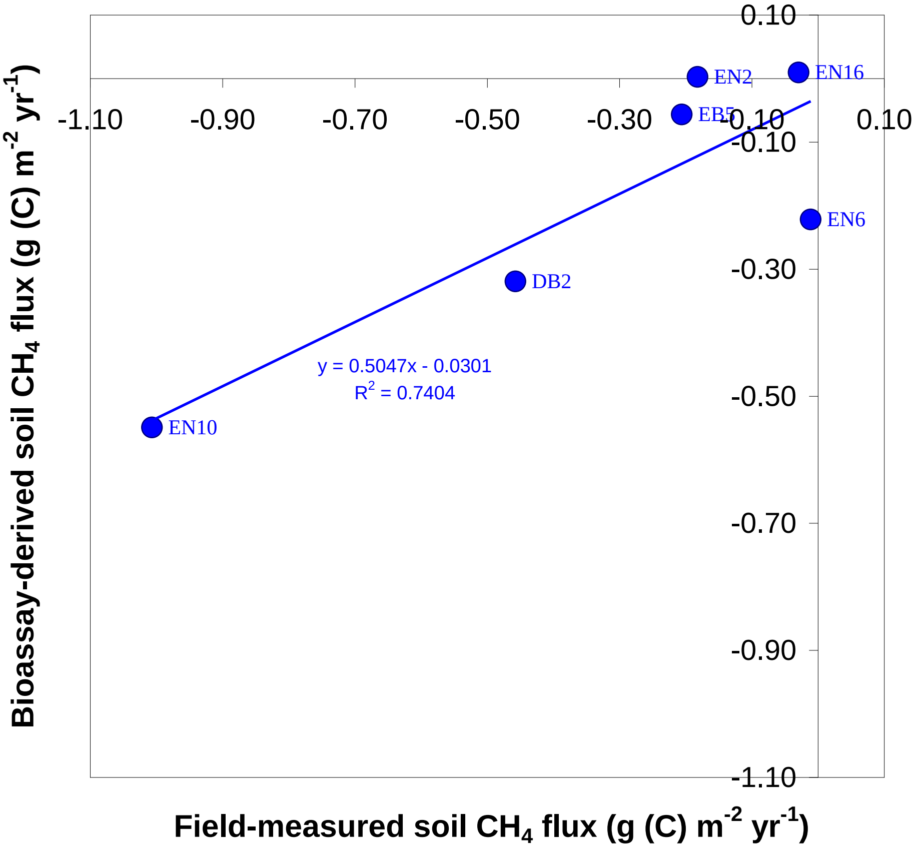

Figure S5. Comparison of net annual forest soil CH_4 fluxes calculated from field measurements using closed soil chambers and CH_4 flux values derived from laboratory-based bioassay experiments (see Methods for details).

Table S1. Selected references for the CarboEurope IP and NitroEurope IP monitoring sites included in this sudy.

Site Name	Location, Country	PFT short name	Reference
DE-Hai	Hainich, Germany	DB1	Knohl et al. (2003)
DK-Sor	Sorø, Denmark	DB2	Pilegaard et al. (2003)
FR-Fon	Fontainebleau-Barbeau, France	DB3	Delpierre et al. (2016)
FR-Fgs	Fougères, France	DB4	Huet et al. (2004)
FR-Hes	Hesse, France	DB5	Granier et al. (2008)
IT-Col	Collelongo, Italy	DB6	Scartazza et al. (2004)
CZ-BK1	Bily Kriz, Czech Rep.	EN1	Sedlak et al. (2010)
DE-Hoe	Höglwald, Germany	EN2	Kreutzer et al. (2009)
DE-Tha	Tharandt, Germany	EN3	Grünwald and Bernhofer (2007)
DE-Wet	Wetzstein, Germany	EN4	Anthoni et al. (2004)
IT-Ren	Renon, Italy	EN5	Marcolla et al. (2005)
RU-Fyo	Fyodorovskoye, Russia	EN6	Milyukova et al. (2002)
UK-Gri	Griffin, UK	EN7	Clement et al. (2003)
BE-Bra	Brasschaat, Belgium	EN8	Neirynck et al. (2005)
ES-ES1	El Saler, Spain	EN9	Sanz et al. (2002)
FI-Hyy	Hyytiälä, Finland	EN10	Vesala et al. (2005)
FI-Sod	Sodankylä, Finland	EN11	Thum et al. (2008)
FR-Bil	Bilos, France	EN12	Moreaux et al. (2011)
FR-LBr	Le Bray, France	EN13	Rivalland et al. (2005)
IT-SRo	San Rossore, Italy	EN14	Chiesi et al. (2005)
NL-Loo	Loobos, Netherlands	EN15	Dolman et al. (2002)
NL-Spe	Speulderbos, Netherlands	EN16	Erisman et al. (1999)
SE-Nor	Norunda, Sweden	EN17	Grelle et al. (1999)
SE-Sk2	Skyttorp, Sweden	EN18	Lindroth et al. (2008)
ES-LMa	Las Majadas, Spain	EB1	Casals et al. (2009)
FR-Pue	Puechabon, France	EB2	Allard et al. (2008)
IT-Ro2	Roccarespampani, Italy	EB3	Tedeschi et al. (2006)
PT-Esp	Espirra, Portugal	EB4	Pereira et al. (2007)
PT-Mi1	Mitra, Portugal	EB5	Pereira et al. (2007)
BE-Vie	Vielsalm, Belgium	MF1	Aubinet et al. (2018)
CH-Lae	Lägeren, Switzerland	MF2	Ruehr et al. (2010)
DE-Meh	Mehrstedt, Germany	SN1	Don et al. (2009)
ES-VDA	Vall d'Alinya, Spain	SN2	Sebastià (2007)
FI-Lom	Lompolojänkkä, Finland	SN3	Aurela et al. (2009)
HU-Bug	Bugac, Hungary	SN4	Nagy et al. (2007)
IT-Amp	Amplero, Italy	SN5	Gavrichkova et al. (2010)
IT-MBo	Monte Bondone, Italy	SN6	Vescovo and Gianelle (2006)
NL-Hor	Horstemeer, Netherlands	SN7	Hendriks et al. (2007)
PL-wet	POLWET/Rzecin, Poland	SN8	Kowalska et al. (2013)
UK-AMo	Auchencorth Moss, UK	SN9	Flechard et al. (1998)

Table S2. Forest species composition and stand characteristics

Site Name	PFT [(1)] Short name	Dominant species	%	Secondary species	%	Density (year) trees ha^{-1}	Thinning (year) Fraction removed	DBH (year) cm	Basal area (year) $m^2 ha^{-1}$
DE-Hai	DB1	Fagus sylvatica	64	Fraxinus excelsior	27	330 (2003)		35 (2004)	34.2 (2000)
DK-Sor	DB2	Fagus sylvatica	80	Picea abies, Larix decidua	20	283 (2003)		38 (2002)	29.1 (2006)
FR-Fon	DB3	Quercus petraea	75	Carpinus betulus	20	410 (2007)		39 (2006)	27.5 (2006)
FR-Fgs	DB4	Fagus sylvatica	100			725 (2010)	26% (2010)	17.24 (2010)	15.3 (1997)
FR-Hes	DB5	Fagus sylvatica	90			2328 (2010)	25% (1999-2000)	9.554 (2008)	19.8 (2005)
IT-Col	DB6	Fagus sylvatica	100			825 (2007)		25 (2007)	40.6 (2007)
CZ-BK1	EN1	Picea abies	99			1440 (2008)		15.6 (2008)	27.4 (2008)
DE-Hoe	EN2	Picea abies	100			621 (2009)		41.3 (2009)	70.9 (2009)
DE-Tha	EN3	Picea abies	72	Pinus sylvestris	15	477 (1999)	15% (2002)	33 (1999)	35.8 (1999)
DE-Wet	EN4	Picea abies	100			410 (2004)		32.7 (2004)	35.7 (2004)
IT-Ren	EN5	Picea abies	85	Pinus cembra	12	270 (2000)		22 (2000)	29.0 (2000)
RU-Fyo	EN6	Picea abies	85	Betula pendula	15	558 (2011)		26.3 (2011)	30.5 (2011)
UK-Gri	EN7	Picea sitchensis	97	Pseudotsuga menziesii	2	2215 (1996)	20% (1996)	12.4 (2001)	31.2 (2001)
BE-Bra	EN8	Pinus sylvestris	55	Quercus robur	23	362 (2003)	30% (1999)	29.7 (2003)	28 (2001)
ES-ES1	EN9	Pinus halepensis	90	Pinus pinea	10	70 (2006)		31.8 (2006)	6.96 (2006)
FI-Hyy	EN10	Pinus sylvestris	75-100	Picea abies, Betula pubescens	5-15	2500 (2002)	25% (2002)	19.5 (2008)	24.0 (2008)
FI-Sod	EN11	Pinus sylvestris	95			2100 (2005)		18.5 (2000)	19.4 (2000)
FR-Bil	EN12	Pinus pinaster	100			1800 (2008)	88% (2008)	3.99 (2010)	
FR-LBr	EN13	Pinus pinaster	100			313 (2007)		33.6 (2007)	28.2 (2007)
IT-SRo	EN14	Pinus pinaster	84	Pinus pinea	12	565 (2005)		29 (2005)	39 (2003)
NL-Loo	EN15	Pinus sylvestris	89	Betula pendula	3	362 (2002)		28.9 (2008)	23.26 (2008)
NL-Spe	EN16	Pseudotsuga menziesii	100			612 (2010)	42%(1996)	31.46 (2010)	47.21(2010)
SE-Nor	EN17	Pinus sylvestris	63	Picea abies	33	600 (2000)		21.8 (2004)	41.7 (2004)
SE-Sk2	EN18	Pinus sylvestris	76	Picea abies	24	1023 (2006)		15.8 (2004)	22.3 (2005)
ES-LMa	EB1	Quercus ilex	100			25 (2009)		45 (2010)	4.1 (2006)
FR-Pue	EB2	Quercus ilex	95			6074 (2009)	15% (2005)	6.8 (2009)	33 (2009)
IT-Ro2	EB3	Quercus cerris	90	Quercus pubescens, Q. suber and Q. ilex	10	3300 (2007)		8.6 (2007)	22.8 (2007)
PT-Esp	EB4	Eucalyptus globulus	100			983 (2002)		9.9 (2002)	19.2 (2002)
PT-Mi1	EB5	Quercus ilex, Quercus suber	90			35-45 (2004)		34-42 (2005)	
BE-Vie	MF1	Fagus sylvatica	43	Pseudotsuga menziesii	37	230 (2007)		34 (2002)	33.72 (2002)
CH-Lae	MF2	Fagus sylvatica	25	Picea abies	21			36 (2010)	

[(1)] PFT (plant functional types): DB: deciduous broadleaf forest; EN: evergreen needleleaf forest; EB: evergreen broadleaf forest; MF: mixed forest.

Table S3. Ecosystem carbon and nitrogen contents and C/N ratios at the sites included in this study.

Site Name	PFT Short name	Foliar N % DW	Foliar C % DW	Foliar C/N	Branches C/N	Stems C/N	Roots C/N	Topsoil C/N	Topsoil SOC gC/kg dry soil
DE-Hai	DB1	1.33	47.9	36	n.a.	n.a.	n.a.	12.0	64
DK-Sor	DB2	2.36	47.3	20	215 *	215 *	173	17.4	72
FR-Fon	DB3	2.18	49.0	22	n.a.	n.a.	n.a.	16.2	24
FR-Fgs	DB4	2.44	49.5	20	n.a.	n.a.	n.a.	17.6	18
FR-Hes	DB5	2.22	48.4	22	n.a.	n.a.	n.a.	10.2	n.a.
IT-Col	DB6	2.47	50.0	20	214	646	300[§] / 40[¶]	12.2	126
CZ-BK1	EN1	1.30	47.9	37	n.a.	n.a.	n.a.	20.4	175
DE-Hoe	EN2	1.50	45.0	30	259 *	259 *	261	23.0	102
DE-Tha	EN3	1.40	50.6	36	316	681	n.a.	18.5	333
DE-Wet	EN4	1.40	50.5	36	n.a.	n.a.	n.a.	20.3	425
IT-Ren	EN5	1.16	46.1	40	n.a.	n.a.	n.a.	23.4	240
RU-Fyo	EN6	1.17	49.8	42	n.a.	n.a.	n.a.	31.3	470
UK-Gri	EN7	0.90	48.6	54	n.a.	n.a.	n.a.	23.7	229
BE-Bra	EN8	1.76	48.6	28	n.a.	184***	n.a.	26.3	18
ES-ES1	EN9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	24.5	110
FI-Hyy	EN10	1.18	49.7	42	274 *	274 *	240	34.7	65
FI-Sod	EN11	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	41.7	30
FR-Bil	EN12	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
FR-LBr	EN13	1.18	53.6	45	n.a.	n.a.	n.a.	26.6	30
IT-SRo	EN14	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	35.9	n.a.
NL-Loo	EN15	1.55	47.3	30	n.a.	n.a.	n.a.	29.3	7
NL-Spe	EN16	1.82	47.6	26	169 *	169 *	121	24.8	156
SE-Nor	EN17	0.85	48.0	57	n.a.	n.a.	n.a.	28.0	367
SE-Sk2	EN18	0.99	48.0	49	n.a.	n.a.	n.a.	n.a.	n.a.
ES-LMa	EB1	1.32	47.0	36	n.a.	n.a.	n.a.	12.4	28
FR-Pue	EB2	1.23	47.0	38	n.a.	n.a.	n.a.	19.8	155
IT-Ro2	EB3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	15.2	92
PT-Esp	EB4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	22.9	18
PT-Mi1	EB5	1.5**	47.4**	32**	n.a.	n.a.	n.a.	13.9	12
BE-Vie	MF1	1.05	48.9	47	n.a.	n.a.	n.a.	17.0	84
CH-Lae	MF2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	13.7	82
DE-Meh	SN1	1.41	43.7	31	n.a.	n.a.	n.a.	9.9	24
ES-VDA	SN2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	12.7	67
FI-Lom	SN3	1.53	43.0	28	n.a.	n.a.	n.a.	34.3	476
HU-Bug	SN4	2.24	43.5	19	n.a.	n.a.	n.a.	10.3	86
IT-Amp	SN5	1.63	43.5	27	n.a.	n.a.	n.a.	12.0	67
IT-MBo	SN6	1.94	46.2	24	n.a.	n.a.	n.a.	14.3	107
NL-Hor	SN7	2.77	42.2	15	n.a.	n.a.	n.a.	n.a.	n.a.
PL-wet	SN8	1.11	44.1	40	n.a.	n.a.	n.a.	43.3	456
UK-AMo	SN9	1.04	48.7	47	n.a.	n.a.	n.a.	20.7	533

* Stems and branches pooled; ** Measured on an adjacent younger stand at PT-Mi3; ***Measured in 2015 at EN8; [§] Coarse roots; [¶] Fine roots.

Table S4. Soil physical properties at the sites included in this study.

Site Name	PFT Short name	Depth m	Terrain slope °	Soil texture	Soil FAO class	Clay %	Sand %	Silt %	Φ_{WP} $m^3 m^{-3}$	Φ_{FC} $m^3 m^{-3}$	Φ_{SAT} $m^3 m^{-3}$	Topsoil pH
DE-Hai	DB1	0.48-0.71	2.5	Loamy clay	Dystric Cambisol	40	4	56	0.16	0.24	0.59	5.6
DK-Sor	DB2	0.70 - 0.85	0.0	Loamy sand	Stagnic Luvisol/Mollisol	15	51	34	0.09	0.20	0.46	3.4
FR-Fon	DB3	0.8	0.6	Loamy sand	Gleyic Luvisol	n.a.	n.a.	n.a.	0.09	0.20	0.30	3.8
FR-Fgs	DB4	0.4-1.5	1.1	Silty loam	Alocrisol/Neoluvisol	15	10	75	0.15	0.41	0.56	4.3
FR-Hes	DB5	1.45	1.4	Silty clay	Stagnic Luvisol	29	7	64	0.10	0.40	0.60	n.a.
IT-Col	DB6	0.3-1.5	n.a.	Silty clay	Humic Alisol	59	8	32	0.19	0.29	0.60	5.1
CZ-BK1	EN1	0.55	15.0	Loamy sand	Ferric Podzol	21	22	58	0.09	0.20	0.37	3.4
DE-Hoe	EN2	1	2.0	Sandy loam	Dystric Cambisol	5	64	31	0.18	0.27	0.37	3.1
DE-Tha	EN3	1.15	2.0	Silty loam	Dystric Cambisol	38	21	41	0.07	0.16	0.44	3
DE-Wet	EN4	0.44	n.a.	Sandy loam	Podzol	33	23	44	0.18	0.27	0.47	3.1
IT-Ren	EN5	0.5	11.0	Loamy sand	Haplic Podzol	11	55	34	0.14	0.34	0.61	4.9
RU-Fyo	EN6	0.3	1.0	Peat	Umbric Albeluvisol	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3.1
UK-Gri	EN7	1	5.0	Loamy clay	Haplic Podzol	n.a.	n.a.	n.a.	0.34	0.44	0.62	3.3
BE-Bra	EN8	2	0.2	Loamy sand	Albic Hypoluvic Arenosol	4	89	7	0.05	0.13	0.37	3.3
ES-ES1	EN9	2	0.0	Loamy sand	Arenosol	0	72	28	0.09	0.20	0.37	6.3
FI-Hyy	EN10	0.61	2.4	Loamy sand	Haplic podzol	9	61	18	0.08	0.55	0.57	3.6
FI-Sod	EN11	1.5	0.0	Loamy sand	Haplic podzol	0	94	4	0.11	0.26	0.47	3.3
FR-Bil	EN12	1	0.0	Pure sand	Umbric Podzol	2	98	0	0.04	0.17	0.44	n.a.
FR-LBr	EN13	1.2	3.6	Pure sand	Haplic Podzol	2	98	0	0.03	0.17	0.44	3.4
IT-SRo	EN14	0.5-3	0.0	Loamy sand	Regosol	4	93	3	0.05	0.09	0.38	n.a.
NL-Loo	EN15	1	0.0	Pure sand	Haplic Arenosol/Podzol	2	96	2	0.03	0.12	0.25	3.4
NL-Spe	EN16	1	2.0	Loamy sand	Haplic Podzol	1	70	29	0.09	0.20	0.37	2.9
SE-Nor	EN17	0.7	0.0	Silty sand	Dystric Regosol	5	65	30	0.05	0.17	0.40	3.2
SE-Sk2	EN18	1	0.0	Silty sand	Eutric Cambisol	n.a.	n.a.	n.a.	0.06	0.18	0.37	n.a.
ES-LMa	EB1	>0.8	2.9	Loamy sand	Stagnic Alisol	9	80	11	0.11	0.26	0.48	5.4
FR-Pue	EB2	0.5	0.0	Silty loam	Rhodo-chromic luvisol	39	26	35	0.22	0.35	0.42	6.6
IT-Ro2	EB3	0.5	0.0	Clayey sand	Chromic Luvisol/Cambisol	33	54	14	0.37	0.52	0.55	5.6
PT-Esp	EB4	0.65	0.0	Clayey loam	Dystric Cambisol	30	n.a.	n.a.	0.05	0.14	0.41	4.5
PT-Mi1	EB5	1	0.0	Loamy sand	Dystric Cambisol	6	89	5	0.05	0.14	0.37	5
BE-Vie	MF1	1.5	1.7	Sandy silt	Dystric Cambisol	18	27	55	0.19	0.34	0.44	3.4
CH-Lae	MF2	1	24.0	Clayey loam	Rendzic Leptosol	n.a.	n.a.	n.a.	0.26	0.36	0.41	5.9
DE-Meh	SN1	n.a.	n.a.	Clayey loam	Haplic Luvisol	31	2	67	0.31	0.43	0.50	7.2
ES-VDA	SN2	n.a.	n.a.	Loamy clay	Lithic Cryrendoll	n.a.	n.a.	n.a.	0.34	0.44	0.48	5.9
FI-Lom	SN3	n.a.	n.a.	Peat	Dystric Histosol	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	4.4
HU-Bug	SN4	n.a.	n.a.	Loamy sand	Chernozem	20	60	20	0.09	0.20	0.25	6.9
IT-Amp	SN5	n.a.	n.a.	Silty clay	Haplic Phaeozem	55	13	32	0.37	0.53	0.59	5.2
IT-MBo	SN6	n.a.	n.a.	Sandy loam	Humic Umbrisol	18	40	42	0.37	0.59	0.79	4.8
NL-Hor	SN7	n.a.	n.a.	Peat	Eutric Histosol	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
PL-wet	SN8	n.a.	n.a.	Peat	Haplic Podzol	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	4.9
UK-AMo	SN9	n.a.	n.a.	Peat	Dystric Cambisol	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3.4

Table S5. Site micro-climatological characteristics

Site Name	PFT Short name	MAT °C	GDD5[1] °C days	R_g[2] GJ m^{-2} yr^{-1}	MAP mm yr^{-1}	AET(EC)[3] mm yr^{-1}	AET=(Rn-H-G)/λ[4] mm yr^{-1}	PET[5] (Penman 1948) mm yr^{-1}	PET[6] (Penman-Monteith FAO) mm yr^{-1}	IWA1[7] AET/PET	IWA2[8] λE / (λE+H)	O3 AOT40[9] ppb hours
DE-Hai	DB1	8.4	1915	3.83	775	290	592	763	1029	0.33	0.59	16062
DK-Sor	DB2	8.9	1896	3.83	730	404	632	766	774	0.53	0.74	9318
FR-Fon	DB3	11.0	2535	4.25	690	628	689	876	1021	0.66	0.74	15470
FR-Fgs	DB4	10.3	2310	4.30	900	418	550	770	957	0.48	0.67	10049
FR-Hes	DB5	10.2	2347	4.28	975	276	836	945	961	0.29	0.68	18109
IT-Col	DB6	7.2	1596	5.65	1140	346	698	1034	1087	0.32	0.45	26492
CZ-BK1	EN1	7.8	2150	3.54	1200	294	513	790	1357	0.27	0.44	17814
DE-Hoe	EN2	8.9	2141	4.44	870	736	796	878	1245	0.69	0.68	20923
DE-Tha	EN3	8.8	2104	4.00	820	387	570	962	1708	0.29	0.50	17030
DE-Wet	EN4	6.6	1571	3.69	950	331	658	787	1218	0.36	0.61	16534
IT-Ren	EN5	4.6	1219	4.86	1010	629	197	867	1095	0.65	0.47	22229
RU-Fyo	EN6	5.3	1699	3.38	711	304	544	668	707	0.44	0.55	5814
UK-Gri	EN7	7.7	1444	2.78	1200	578	453	564	721	0.84	0.81	4591
BE-Bra	EN8	10.8	2402	3.79	850	305	433	915	815	0.35	0.48	10593
ES-ES1	EN9	17.6	4677	5.88	551	640	565	1252	1231	0.48	0.30	24709
FI-Hyy	EN10	3.8	1358	2.89	709	334	453	639	971	0.40	0.52	3329
FI-Sod	EN11	-0.4	905	2.76	527	245	-87	412	264	0.72	0.43	1083
FR-Bil	EN12	12.4	3053	4.61	930	628	582	1015	508	0.82	0.55	9647
FR-LBr	EN13	12.9	3142	4.48	972	689	677	1057	1148	0.62	0.60	12530
IT-SRo	EN14	14.9	3866	5.01	920	679	770	1192	1407	0.46	0.48	36194
NL-Loo	EN15	10.0	2232	3.70	786	579	847	925	534	0.79	0.61	7399
NL-Spe	EN16	10.0	2207	3.52	834	456	561	811	1634	0.37	0.60	7399
SE-Nor	EN17	6.8	1534	3.43	527	450	446	678	996	0.58	0.64	4258
SE-Sk2	EN18	7.4	1676	3.38	527	281	433	661	800	0.38	0.47	3741
ES-LMa	EB1	16.1	4309	6.01	528	558	880	1551	692	0.50	0.49	16116
FR-Pue	EB2	13.7	3385	5.23	872	397	622	1239	1123	0.34	0.43	20756
IT-Ro2	EB3	15.7	3876	5.81	876	507	835	1242	1424	0.37	0.60	29879
PT-Esp	EB4	16.1	4297	6.22	709	649	486	1771	1705	0.39	0.52	19437
PT-Mi1	EB5	14.5	3808	6.20	665	n.a.	n.a.	1365	1457	n.a.	n.a.	17076
BE-Vie	MF1	8.1	1752	3.63	1000	288	463	754	789	0.37	0.48	14750
CH-Lae	MF2	7.7	1836	4.53	1100	757	427	823	974	0.84	0.62	20927
DE-Meh	SN1	9.1	2081	3.56	547	235	482	740	609	0.35	0.56	15630
ES-VDA	SN2	6.4	1319	5.30	1064	440	615	884	537	0.62	0.62	18254
FI-Lom	SN3	-1.0	748	2.76	521	254	142	353	237	0.86	0.63	784
HU-Bug	SN4	10.7	2744	4.47	500	441	533	953	945	0.47	0.58	21047
IT-Amp	SN5	9.8	2722	5.27	1365	693	817	1105	899	0.69	0.68	26492
IT-MBo	SN6	5.1	1134	4.96	1189	480	616	639	503	0.85	0.76	29924
NL-Hor	SN7	10.8	2430	3.83	800	602	657	685	890	0.78	0.81	5568
PL-wet	SN8	8.5	2086	3.72	550	521	649	871	716	0.67	0.73	11809
UK-AMo	SN9	7.6	1430	2.83	1165	130	230	466	275	0.27	0.34	4174

[1] sum of growing degree days >5°C; [2] annual global radiation sum; [3] and [4] actual evapotranspiration from eddy covariance or from energy balance; [5] and [6] potential evapotranspiration from Penman 1948 or Penman-Monteith/FAO equations; [7] and [8] indices of water availability calculated from two different ratios; [9] accumulated O_3 exposure over 40-ppb threshold (EMEP model).

Table S6. Overview of available measured C, N and GHG flux data from the NEU and CEIP projects and from online databases and the literature. See Materials and Methods in the main body of the article for details.

Site	**PFT**	**CO_2 / NEE**	**Soil CO_2 efflux**	**R_{het}/R_{soil} ratio**	**DIC/DOC**	**Soil CH_4 flux**	**Soil core CH_4 flux**	**Soil N_2O flux**	**Soil core N_2O flux**	**Soil NO flux**	**Soil core NO flux**	**DIN leaching**	**Dry dep.**	**Wet dep.**	**Wet dep.**
Name	*Short name*	*EC flux N years*	*Field chamb.*	*Field exp.*	*Field exp.*	*EC/ field chamb.*	*Lab. bioassay*	*EC/ field chamb.*	*Lab. bioassay*	*Field chamb.*	*Lab. bioassay*	*Field exp.*	*DELTA * dep. model*	*Bulk/wet-only sampler*	*National network*
DE-Hai	DB1	4	**Y**	**Y**	**Y**	n	**Y**	n	**Y**	n	**Y**	**Y**	**Y**	**B**	**Y**
DK-Sor	DB2	6	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**W-O**	**Y**
FR-Fon	DB3	3	n	**Y**	n	n	**Y**	n	**Y**	n	**Y**	n	**Y**	**B**	**Y**
FR-Fou	DB4	7	**Y**	**Y**	n	n	n	n	n	n	n	**Y**	**Y**	**B**	n
FR-Hes	DB5	6	**Y**	**Y**	n	n	n	n	n	n	n	n	**Y**	n	**Y**
IT-Col	DB6	5	**Y**	**Y**	n	n	**Y**	n	**Y**	n	**Y**	n	**Y**	n	**Y**
CZ-BK1	EN1	6	n	n	n	n	**Y**	n	**Y**	n	**Y**	n	**Y**	n	**Y**
DE-Hoe	EN2	3	**Y**	n	n	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**W-O**	**Y**
DE-Tha	EN3	7	**Y**	n	n	n	**Y**	n	**Y**	n	**Y**	n	**Y**	n	**Y**
DE-Wet	EN4	5	**Y**	**Y**	**Y**	n	**Y**	n	**Y**	n	**Y**	**Y**	**Y**	**B**	**Y**
IT-Ren	EN5	7	**Y**	**Y**	n	n	**Y**	n	**Y**	n	**Y**	n	**Y**	n	**Y**
RU-Fyo	EN6	7	**Y**	**Y**	n	**Y**	**Y**	**Y**	**Y**	n	**Y**	n	**Y**	n	**Y**
UK-Gri	EN7	1	n	n	n	n	**Y**	n	**Y**	n	**Y**	n	**Y**	n	**Y**
BE-Bra	EN8	7	**Y**	**Y**	**Y**	n	**Y**	n	**Y**	n	**Y**	**Y**	**Y**	**W-O**	**Y**
ES-ES1	EN9	3	n	n	n	n	**Y**	n	**Y**	n	**Y**	n	**Y**	**B**	**Y**
FI-Hyy	EN10	6	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**B**	**Y**
FI-Sod	EN11	5	n	n	n	n	**Y**	n	**Y**	n	**Y**	n	**Y**	n	**Y**
FR-Bil	EN12	4	n	n	n	n	n	n	n	n	n	n	**Y**	n	n
FR-LBr	EN13	5	**Y**	n	n	n	**Y**	n	**Y**	n	**Y**	n	**Y**	**B**	**Y**
IT-SRo	EN14	7	**Y**	**Y**	n	n	n	**Y**	n	**Y**	n	n	**Y**	**B**	**Y**
NL-Loo	EN15	7	**Y**	**Y**	**Y**	n	**Y**	n	**Y**	n	**Y**	**Y**	**Y**	n	**Y**
NL-Spe	EN16	2	**Y**	n	n	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**	**W-O**	**Y**
SE-Nor	EN17	3	**Y**	**Y**	n	n	**Y**	n	**Y**	n	**Y**	n	**Y**	n	**Y**
SE-Sk2	EN18	1	**Y**	n	n	n	**Y**	n	**Y**	n	**Y**	n	**Y**	n	**Y**
ES-LMa	EB1	6	**Y**	n	n	n	**Y**	n	**Y**	n	**Y**	n	**Y**	n	**Y**
FR-Pue	EB2	6	**Y**	n	n	n	**Y**	n	**Y**	n	**Y**	n	**Y**	**B**	**Y**
IT-Ro2	EB3	7	**Y**	**Y**	n	n	**Y**	n	**Y**	n	**Y**	n	**Y**	**B**	**Y**
PT-Esp	EB4	7	**Y**	n	n	n	**Y**	n	**Y**	n	**Y**	n	**Y**	n	**Y**
PT-Mi1	EB5	3	**Y**	n	n	**Y**	**Y**	**Y**	**Y**	n	**Y**	n	**Y**	n	**Y**
BE-Vie	MF1	7	**Y**	n	n	n	**Y**	n	**Y**	n	**Y**	n	**Y**	**B**	**Y**
CH-Lae	MF2	5	**Y**	**Y**	n	n	**Y**	n	**Y**	n	**Y**	n	**Y**	**B**	**Y**
DE-Meh	SN1	3	n	n	n	n	**Y**	n	**Y**	n	**Y**	n	**Y**	n	**Y**
ES-VDA	SN2	5	n	n	n	n	**Y**	n	**Y**	n	**Y**	n	**Y**	n	**Y**
FI-Lom	SN3	3	n	n	n	**Y**	**Y**	**Y**	**Y**	n	**Y**	n	**Y**	**B**	**Y**
HU-Bug	SN4	5	n	n	n	**Y**	**Y**	**Y**	**Y**	n	**Y**	n	**Y**	n	**Y**
IT-Amp	SN5	3	n	n	n	n	**Y**	n	**Y**	n	**Y**	n	**Y**	n	**Y**
IT-MBo	SN6	5	n	n	n	n	**Y**	n	**Y**	n	**Y**	n	**Y**	n	**Y**
NL-Hor	SN7	4	n	n	**Y**	**Y**	n	n	n	n	n	n	**Y**	n	**Y**
PL-wet	SN8	4	n	n	n	**Y**	**Y**	**Y**	**Y**	n	**Y**	n	**Y**	**B**	**Y**
UK-AMo	SN9	6	n	n	**Y**	**Y**	**Y**	**Y**	**Y**	n	**Y**	n	**Y**	**W-O**	**Y**

Table S7. Published estimates of annual soil respiration fluxes and ratios of heterotrophic to total soil respiration (R_{het}/R_{soil}) for the forest sites of this study

Site	R_{soil} (g (C) m^{-2} yr^{-1})	R_{het}/R_{soil}	References
DB1	884	0.52	Kutsch et al. (2010), Knohl et al. (2008), Moyano et al. (2008)
DB2	740	0.61	Wu et al. (2013), Janssens and Pilegaard (2003)
DB3	na	0.77	Chemidlin Prevost-Boure et al. (2009)
DB4	na	0.46	Huet, S. (2004)
DB5	620	0.37	Epron et al. (1999a,b), Ngao et al. (2007, 2012)
DB6	879	0.29	Matteucci et al. (2000), Luyssaert et al. (2007)
EN1	na	na	
EN2	783	na	Luo et al. (2012)
EN3	na	na	
EN4	na	0.47	Moyano et al. (2008)
EN5	1015	0.58	Rodeghiero et al. (2005), Luyssaert et al. (2007)
EN6	765	0.38-0.62	Šantrůčková et al. (2010), Kurbatova et al. (2013)
EN7	na	na	
EN8	620	0.36	Curiel Yuste et al. (2005), Chiti et al. (2011)
EN9	na	na	
EN10	606	0.64	Kolari et al. (2009), Korhonen et al. (2009)
EN11	na	na	
EN12	na	na	
EN13	na	na	
EN14	872	0.74	Matteucci et al. (2015)
EN15	937	0.38	Kruit et al. (2003), Luyssaert et al. (2007)
EN16	653	na	Frumau et al. (2011)
EN17	1227	0.71	Moren et al. (2000), Widen and Majdi (2001)
EN18	na	na	
MF1	867	na	Longdoz et al. (2000)
MF2	888	0.54	Ruehr et al. (2010), Ruehr and Buchmann (2010)
EB1	561	na	Casals et al. (2009), Gimeno et al. (unpublished)
EB2	762	na	Misson et al. (unpublished)
EB3	904	0.77	Rey et al. (2002)
EB4	778	na	Luyssaert et al. (2007)
EB5	na	na	

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