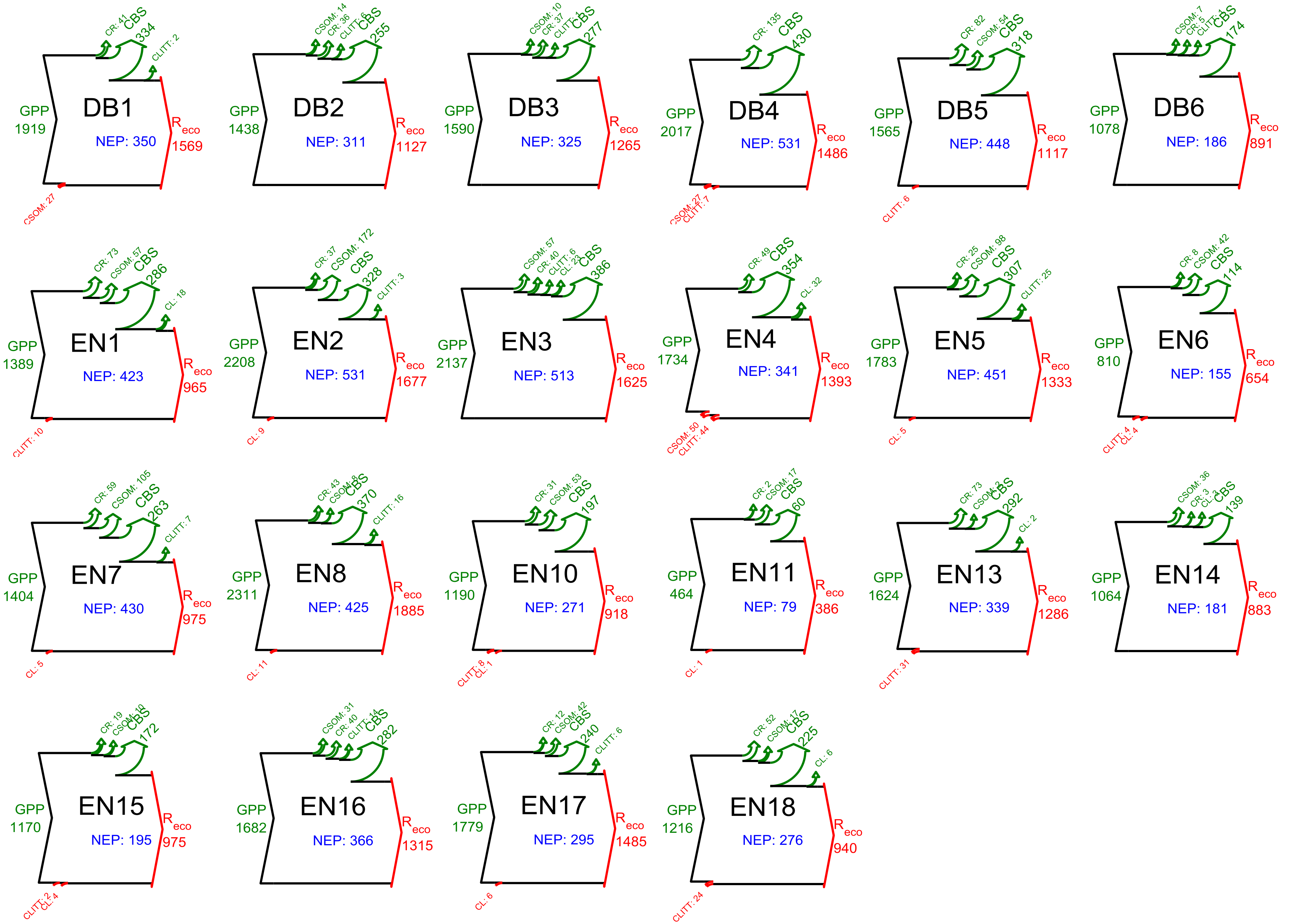


**Figure S1. Modelled (BASFOR) partitioning of C fluxes at deciduous broadleaf (DB) and coniferous evergreen needleleaf (EN) forests, and associated changes in C pools in soil organic matter (CSOM), roots (CR), litter layers (CLITT), branches and stems (CBS) and leaves (CL) (units g (C) $m^{-2}$ $yr^{-1}$). The simulations were run over the most recent 5-year period which did not include any thinning event ('5-yr' in the text). In this case (no disturbance, no export), NEP = NECB = d(CSOM+CR+CLITT+CBS+CL) / dt. Green indicates ecosystem C gain (photosynthesis and C pool increase), red denotes ecosystem C loss (respiration and C pool decrease). The sizes of the Sankey plots are not proportional to the C fluxes of the different study sites.**

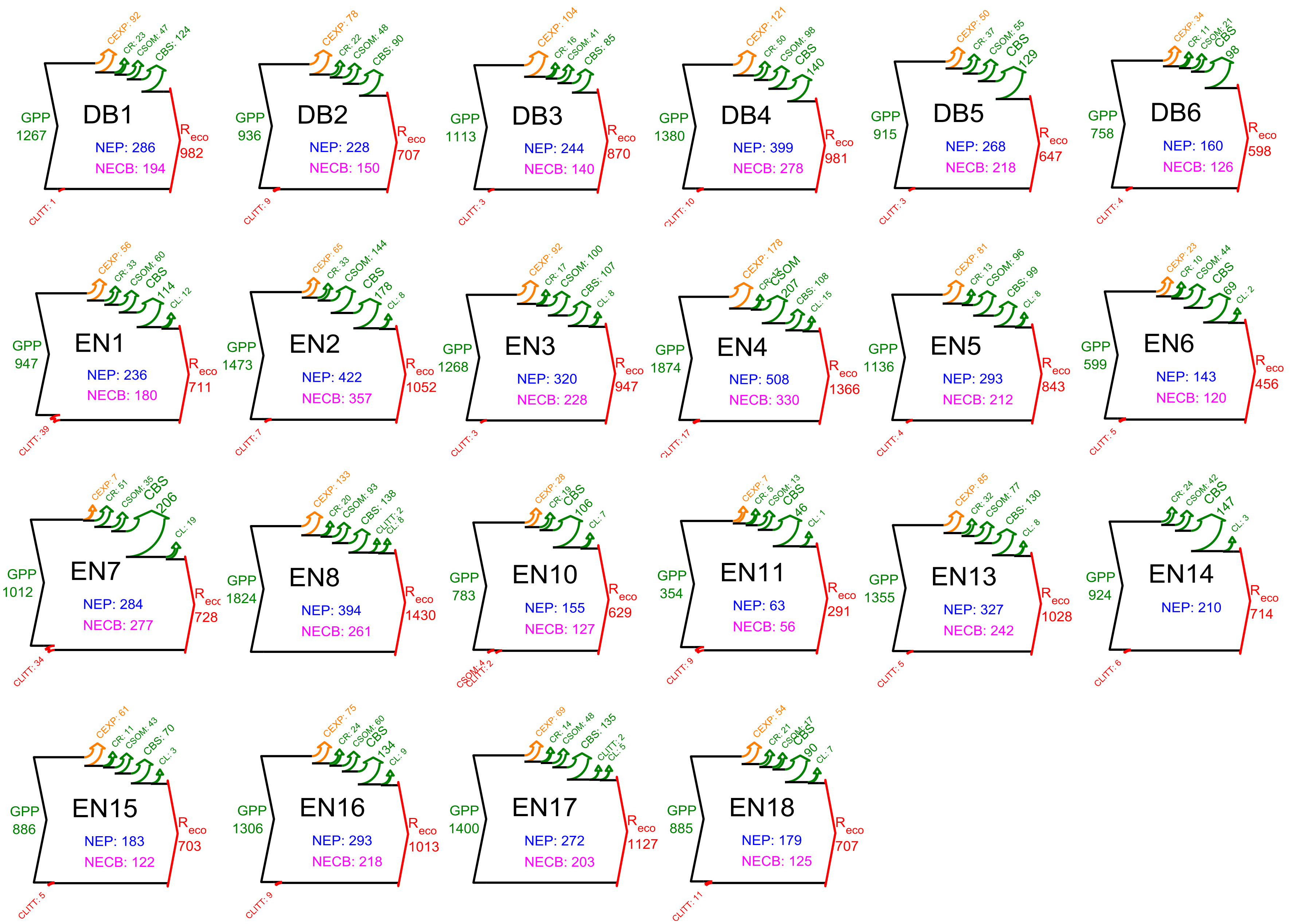


**Figure S2. Same as Fig. S1, but simulated over the whole time period since the forest was established ('lifetime' in the text), i.e. including C exports (CEXP) through all thinning/management events (units g (C) $m^{-2}$ $yr^{-1}$). In this case, NEP - CEXP = NECB = d(CSOM+CR+CLITT+CBS+CL) / dt. The sizes of the Sankey plots are not proportional to the C fluxes of the different study sites.**

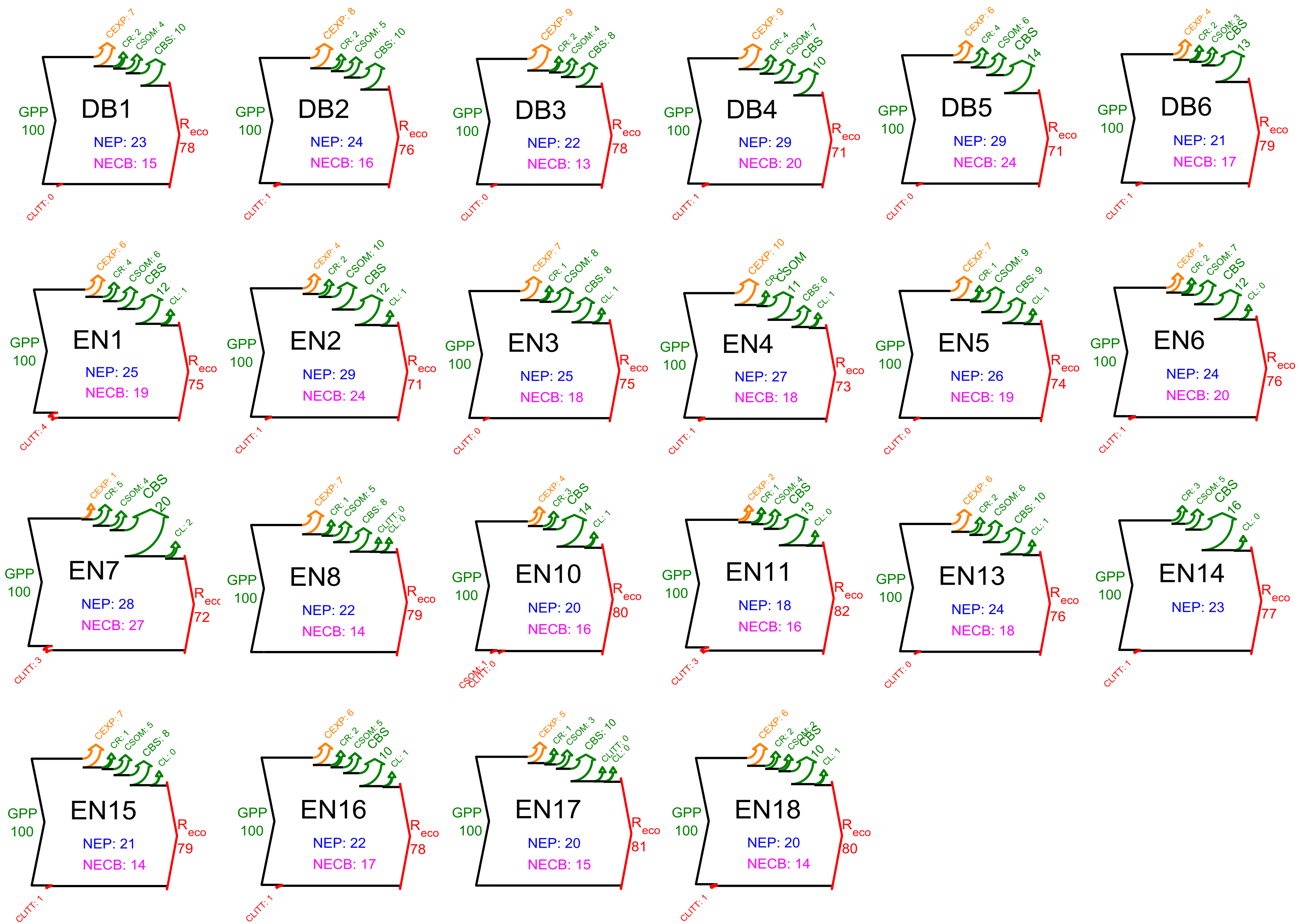


**Figure S3. Same as Fig. S2, but normalized to the mean lifetime GPP of each site (units % GPP). The NECB percentage value corresponds to the lifetime carbon sequestration efficiency (CSE). The sizes of the Sankey plots are not proportional to the C fluxes of the different study sites.**

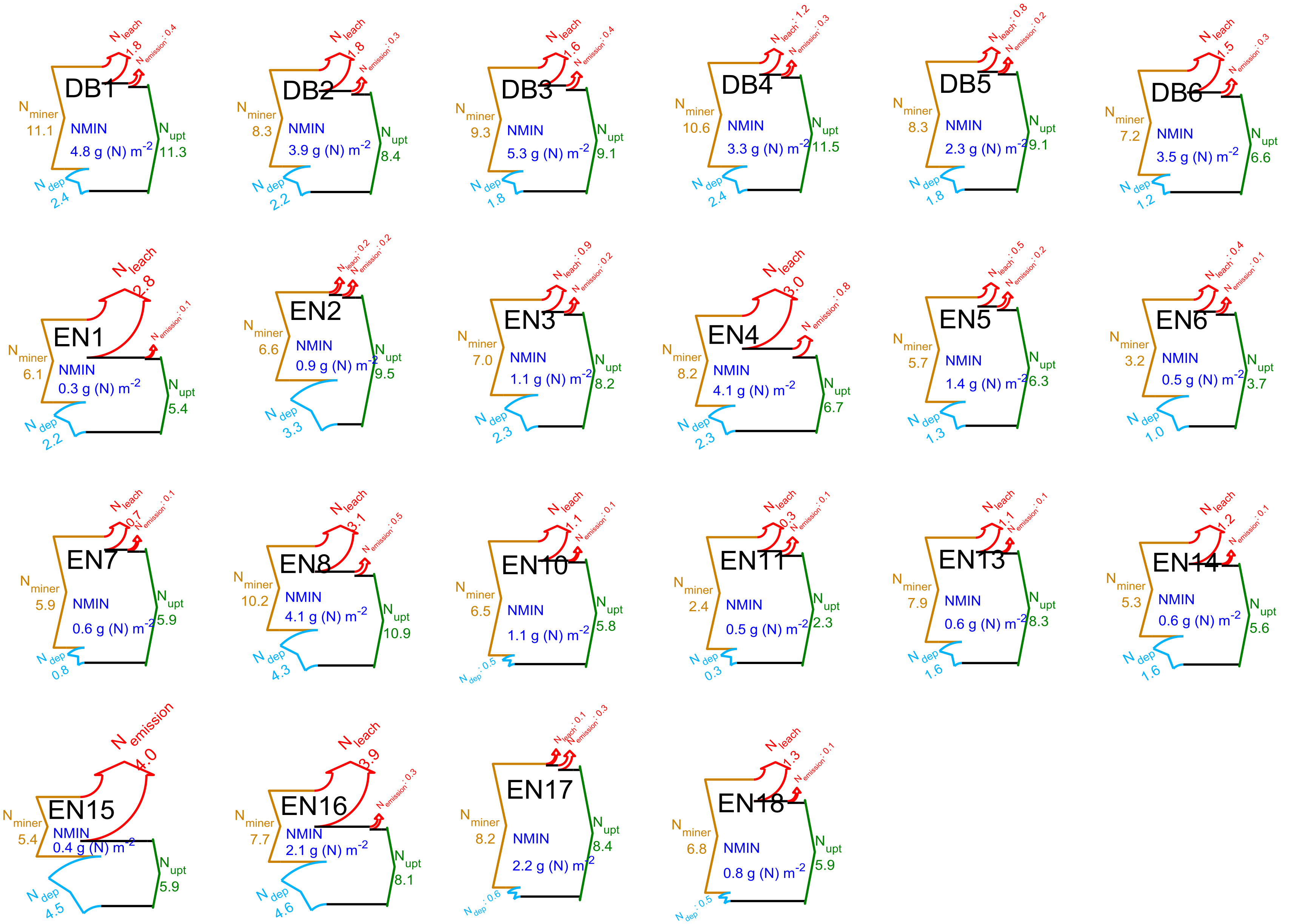


**Figure S4. Modelled (BASFOR) nitrogen budgets at deciduous broadleaf (DB) and coniferous evergreen needleleaf (EN) forests. The simulations were run over the most recent 5-year period which did not include any thinning event ('5-yr' in the text). The data show ecosystem SOM mineralisation ($N_{miner}$) and atmospheric Nr deposition ($N_{dep}$) (together making up $N_{supply}$), balanced by vegetation uptake ($N_{upt}$) and the sum of losses as dissolved N ($N_{leach}$) and gaseous NO + $N_2O$ ($N_{emission}$) (units: g (N) $m^{-2}$ $yr^{-1}$). NMIN indicates the mean size of the soil inorganic N pool (g (N) $m^{-2}$) over the modelling period. The sizes of the Sankey plots are not proportional to the N fluxes of the different study sites.**

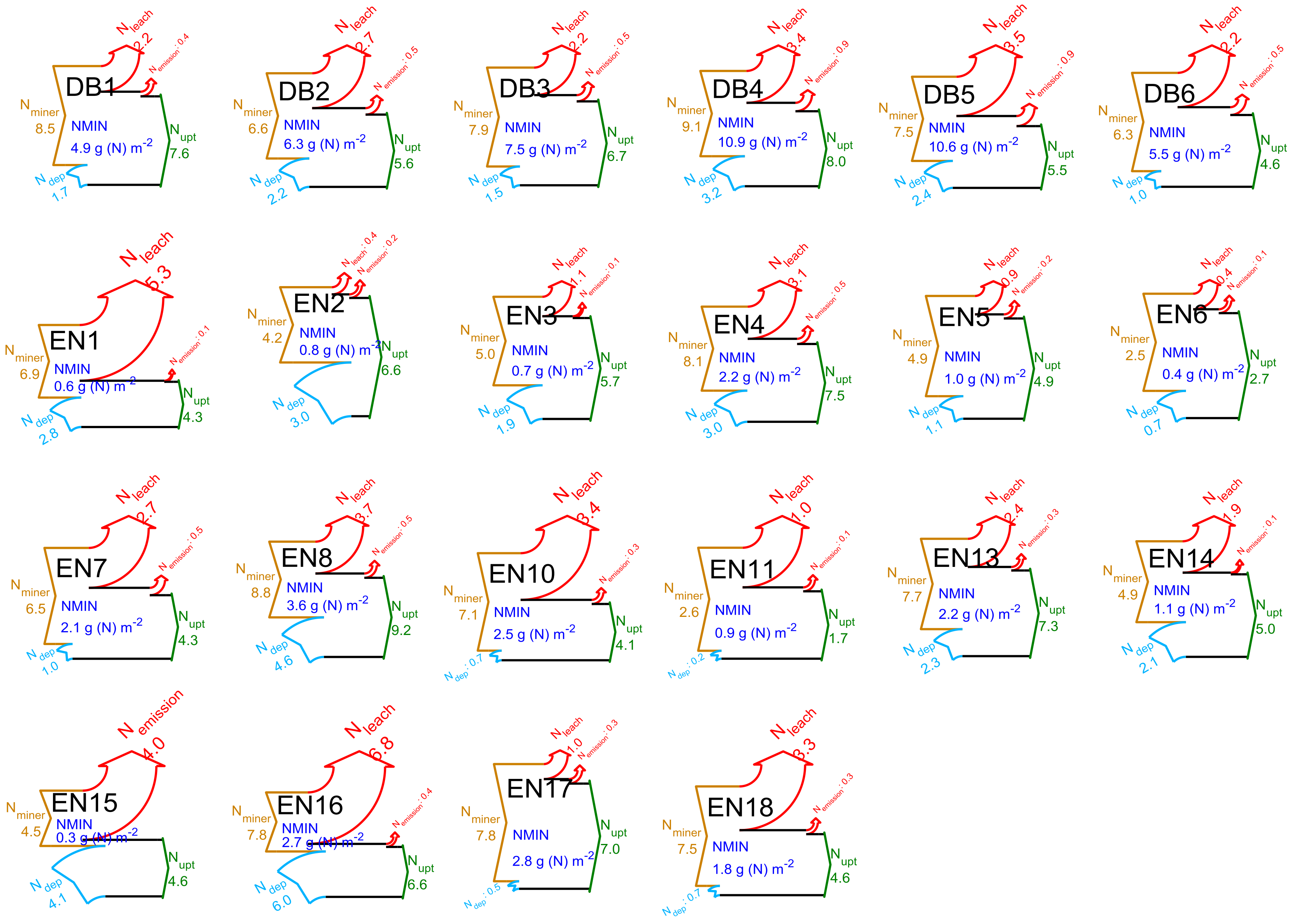


**Figure S5. Same as Fig. S4, but simulated over the whole time period since the forest was established ('lifetime' in the text) (units: g (N) m$^{-2}$ yr$^{-1}$, except for NMIN). The sizes of the Sankey plots are not proportional to the N fluxes of the different study sites.**

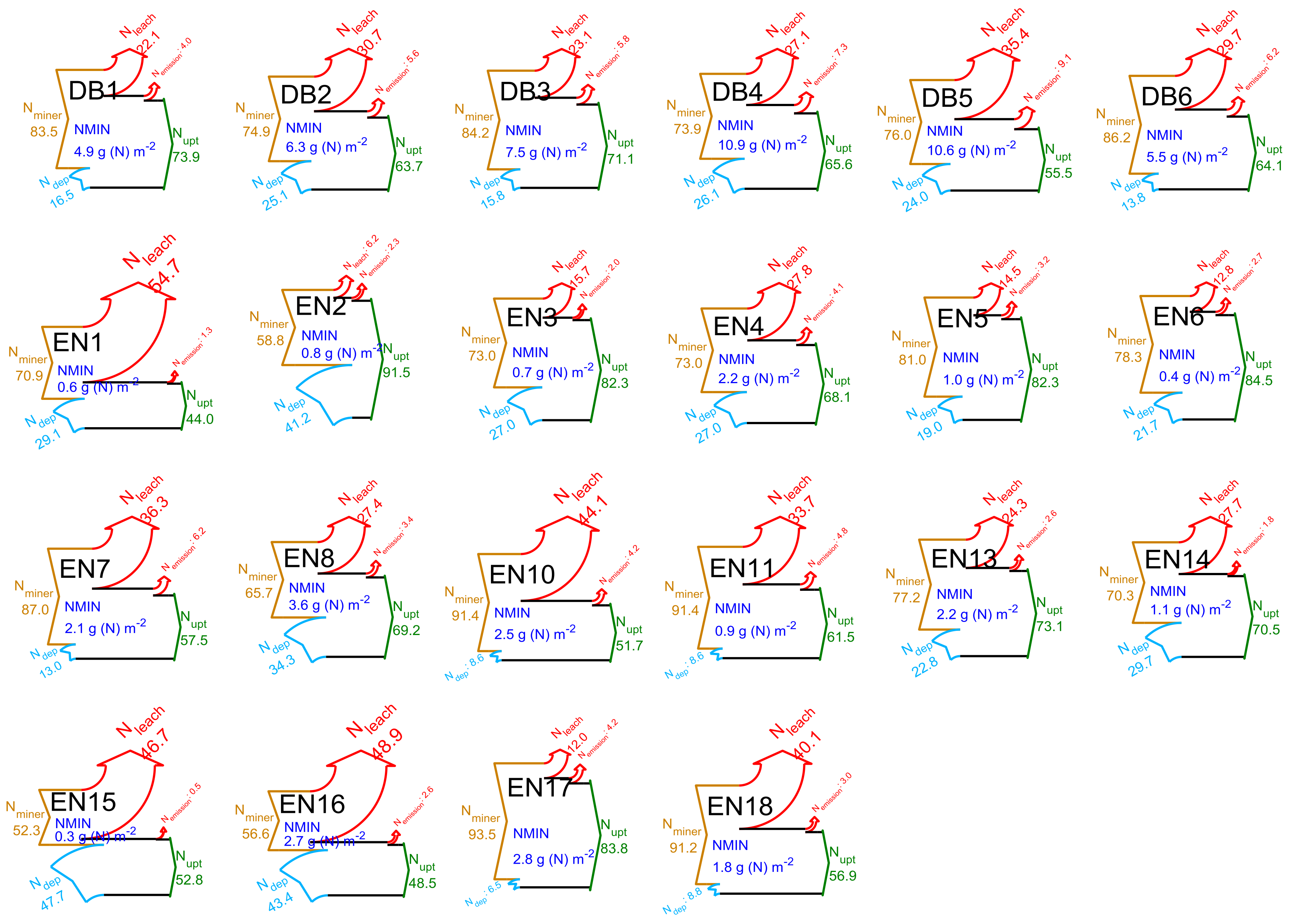


**Figure S6.** Same as Fig. S5, but fluxes are normalized and expressed as % of total $N_{supply}$ (= $N_{miner}$ + $N_{dep}$ = 100). The N uptake percentage value corresponds to the lifetime nitrogen use efficiency (NUE). The sizes of the Sankey plots are not proportional to the N fluxes of the different study sites.

**Table S1. Overview of ecosystem and climatic characteristics and inter-annual mean ecosystem/atmosphere exchange fluxes for forest and semi-natural short vegetation sites.**

| Site Name | Location, Country | PFT [(1)] Short name | Dominant vegetation | Forest age (2010) | $H_{max}$[(2)] m | $LAI_{max}$[(3)] $m^2\ m^{-2}$ | Lat. °N | Long. °E | Elevation m amsl[(4)] | MAT[(5)] °C | MAP[(6)] mm | $N_{dep}$[(7)] $g\ N\ m^{-2}\ yr^{-1}$ | GPP[(8)] $g\ C\ m^{-2}\ yr^{-1}$ | $R_{eco}$[(9)] $g\ C\ m^{-2}\ yr^{-1}$ | NEP[(10)] $g\ C\ m^{-2}\ yr^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DE-Hai | Hainich, Germany | DB1 | *Fagus sylvatica* | 142 | 23 | 4.0 | 51.079 | 10.452 | 430 | 8.4 | 775 | 2.3 | 1553 | 1074 | 479 |
| DK-Sor | Sorø, Denmark | DB2 | *Fagus sylvatica* | 91 | 31 | 4.6 | 55.487 | 11.646 | 40 | 8.9 | 730 | 2.2 | 1883 | 1581 | 301 |
| FR-Fon | Fontainebleau, France | DB3 | *Quercus robur, Quercus petraea* | 111 | 28 | 5.1 | 48.476 | 2.780 | 92 | 11.0 | 690 | 1.7 | 1850 | 1185 | 665 |
| FR-Fgs | Fougères, France | DB4 | *Fagus sylvatica* | 41 | 20 | 6.0 | 48.383 | -1.185 | 140 | 10.3 | 900 | 2.4 | 1725 | 1316 | 409 |
| FR-Hes | Hesse, France | DB5 | *Fagus sylvatica* | 45 | 16 | 6.7 | 48.674 | 7.066 | 300 | 10.2 | 975 | 1.7 | 1634 | 1187 | 446 |
| IT-Col | Collelongo, Italy | DB6 | *Fagus sylvatica* | 120 | 22 | 5.7 | 41.849 | 13.588 | 1560 | 7.2 | 1140 | 1.2 | 1425 | 776 | 650 |
| CZ-BK1 | Bily Kriz, Czech Rep. | EN1 | *Picea abies* | 33 | 13 | 9.8 | 49.503 | 18.538 | 908 | 7.8 | 1200 | 2.1 | 1548 | 767 | 781 |
| DE-Hoe | Höglwald, Germany | EN2 | *Picea abies* | 104 | 35 | 6.3 | 48.300 | 11.100 | 540 | 8.9 | 870 | 3.2 | 1856 | 1229 | 627 |
| DE-Tha | Tharandt, Germany | EN3 | *Picea abies* | 120 | 27 | 6.7 | 50.964 | 13.567 | 380 | 8.8 | 820 | 2.3 | 1997 | 1396 | 601 |
| DE-Wet | Wetzstein, Germany | EN4 | *Picea abies* | 56 | 22 | 7.1 | 50.453 | 11.458 | 785 | 6.6 | 950 | 2.2 | 1809 | 1767 | 43 |
| IT-Ren | Renon, Italy | EN5 | *Picea abies* | 111 | 29 | 5.1 | 46.588 | 11.435 | 1730 | 4.6 | 1010 | 1.3 | 1353 | 528 | 826 |
| RU-Fyo | Fyodorovskoye, Russia | EN6 | *Picea abies* | 190 | 21 | 2.8 | 56.462 | 32.922 | 265 | 5.3 | 711 | 1.0 | 1488 | 1559 | -70 |
| UK-Gri | Griffin, UK | EN7 | *Picea sitchensis* | 29 | 12 | 6.5 | 56.617 | -3.800 | 340 | 7.7 | 1200 | 0.7 | 989 | 677 | 311 |
| BE-Bra | Brasschaat, Belgium | EN8 | *Pinus sylvestris* | 82 | 21 | 1.9 | 51.309 | 4.521 | 16 | 10.8 | 850 | 4.1 | 1272 | 1149 | 123 |
| ES-ES1 | El Saler, Spain | EN9 | *Pinus halepensis* | 111 | 10 | 2.6 | 39.346 | -0.319 | 5 | 17.6 | 551 | 2.1 | 1552 | 960 | 593 |
| FI-Hyy | Hyytiälä, Finland | EN10 | *Pinus sylvestris* | 48 | 18 | 3.4 | 61.848 | 24.295 | 181 | 3.8 | 709 | 0.5 | 1114 | 845 | 268 |
| FI-Sod | Sodankylä, Finland | EN11 | *Pinus sylvestris* | 100 | 13 | 1.2 | 67.362 | 26.638 | 180 | -0.4 | 527 | 0.3 | 551 | 598 | -47 |
| FR-Bil | Bilos, France | EN12 | *Pinus pinaster* | 9 | 4 | 0.5 | 44.522 | -0.896 | 50 | 12.4 | 930 | 0.8 | 1178 | 989 | 189 |
| FR-LBr | Le Bray, France | EN13 | *Pinus pinaster* | 41 | 22 | 1.9 | 44.717 | -0.769 | 61 | 12.9 | 972 | 1.6 | 1906 | 1479 | 427 |
| IT-SRo | San Rossore, Italy | EN14 | *Pinus pinaster* | 61 | 18 | 4.0 | 43.728 | 10.284 | 4 | 14.9 | 920 | 1.6 | 2256 | 1702 | 554 |
| NL-Loo | Loobos, Netherlands | EN15 | *Pinus sylvestris* | 101 | 18 | 1.5 | 52.168 | 5.744 | 25 | 10.0 | 786 | 4.2 | 1617 | 1141 | 476 |
| NL-Spe | Speulderbos, Netherlands | EN16 | *Pseudotsuga menziesii* | 51 | 32 | 7.5 | 52.252 | 5.691 | 52 | 10.0 | 834 | 4.3 | 1416 | 1015 | 401 |
| SE-Nor | Norunda, Sweden | EN17 | *Pinus sylvestris* | 112 | 28 | 4.6 | 60.083 | 17.467 | 45 | 6.8 | 527 | 0.6 | 1414 | 1356 | 58 |
| SE-Sk2 | Skyttorp, Sweden | EN18 | *Pinus sylvestris* | 39 | 16 | 3.2 | 60.129 | 17.840 | 55 | 7.4 | 527 | 0.5 | 1235 | 953 | 282 |
| ES-LMa | Las Majadas, Spain | EB1 | *Quercus ilex* | 111 | 8 | 0.6 | 39.941 | -5.773 | 258 | 16.1 | 528 | 0.9 | 1091 | 958 | 133 |
| FR-Pue | Puechabon, France | EB2 | *Quercus ilex* | 69 | 6 | 2.9 | 43.741 | 3.596 | 270 | 13.7 | 872 | 1.1 | 1309 | 1030 | 279 |
| IT-Ro2 | Roccarespampani, Italy | EB3 | *Quercus cerris* | 21 | 16 | 3.8 | 42.390 | 11.921 | 224 | 15.7 | 876 | 1.8 | 1707 | 886 | 821 |
| PT-Esp | Espirra, Portugal | EB4 | *Eucalyptus globulus* | 25 | 20 | 2.7 | 38.639 | -8.602 | 95 | 16.1 | 709 | 1.2 | 1473 | 1163 | 311 |
| PT-Mi1 | Mitra, Portugal | EB5 | *Quercus ilex, Quercus suber* | 91 | 8 | 3.4 | 38.541 | -8.000 | 264 | 14.5 | 665 | 0.9 | 870 | 817 | 53 |
| BE-Vie | Vielsalm, Belgium | MF1 | *Fagus sylvatica, Pseudotsuga menziesii* | 86 | 30 | 5.1 | 50.305 | 5.997 | 450 | 8.1 | 1000 | 1.7 | 1792 | 1247 | 545 |
| CH-Lae | Lägeren, Switzerland | MF2 | *Fagus sylvatica, Picea abies* | 111 | 30 | 3.6 | 47.478 | 8.365 | 689 | 7.7 | 1100 | 2.2 | 1448 | 757 | 692 |
| DE-Meh | Mehrstedt, Germany | SN1 | Afforestated grassland | n.a. | 0.5 | 2.9 | 51.276 | 10.657 | 293 | 9.1 | 547 | 1.5 | 1171 | 1175 | -4 |
| ES-VDA | Vall d'Alinya, Spain | SN2 | Upland grassland | n.a. | 0.1 | 1.4 | 42.152 | 1.448 | 1765 | 6.4 | 1064 | 1.2 | 669 | 528 | 140 |
| FI-Lom | Lompolojänkkä, Finland | SN3 | Peatland | n.a. | 0.4 | 1.0 | 67.998 | 24.209 | 269 | -1.0 | 521 | 0.1 | 377 | 345 | 32 |
| HU-Bug | Bugac, Hungary | SN4 | Semi-arid grassland | n.a. | 0.5 | 4.7 | 46.692 | 19.602 | 111 | 10.7 | 500 | 1.4 | 1044 | 918 | 126 |
| IT-Amp | Amplero, Italy | SN5 | Upland grassland | n.a. | 0.4 | 2.5 | 41.904 | 13.605 | 884 | 9.8 | 1365 | 0.9 | 1241 | 1028 | 213 |
| IT-MBo | Monte Bondone, Italy | SN6 | Upland grassland | n.a. | 0.3 | 2.5 | 46.029 | 11.083 | 1550 | 5.1 | 1189 | 1.7 | 1435 | 1347 | 89 |
| NL-Hor | Horstemeer, Netherlands | SN7 | Peatland | n.a. | 2.5 | 6.9 | 52.029 | 5.068 | -2 | 10.8 | 800 | 3.1 | 1584 | 1224 | 361 |
| PL-wet | POLWET/Rzecin, Poland | SN8 | Wetland (reeds, sedges, mosses) | n.a. | 2.1 | 4.9 | 52.762 | 16.309 | 54 | 8.5 | 550 | 1.4 | 937 | 642 | 295 |
| UK-AMo | Auchencorth Moss, UK | SN9 | Peatland | n.a. | 0.6 | 2.1 | 55.792 | -3.239 | 270 | 7.6 | 1165 | 0.8 | 786 | 705 | 81 |

[(1)] PFT (plant functional types): DB: deciduous broadleaf forest; EN: evergreen needleleaf coniferous forest; EB: evergreen broadleaf Mediterranean forest; MF: mixed deciduous/coniferous forest; SN: short semi-natural, including moorland, peatland, shrubland and unimproved/upland grassland; [(2)] maximum canopy height; [(3)] maximum leaf area index, defined as 1-sided or half of total; [(4)] above mean sea level; [(5)] mean annual temperature; [(6)] mean annual precipitation; [(7)] nitrogen deposition; [(8)] gross primary productivity; [(9)] ecosystem respiration; [(10)] net ecosystem productivity; n.a.: not available/ not applicable.

**Table S2. Procedure for the calculation of climate / soil standardization factors ($f_{CLIM}$ or $f_{SOIL}$) through BASFOR meta-modelling for the n=22 forest sites. The indices i and j stand for the site being modelled (i = 1..n), and for the scenarios being applied for climate data or for soil parameters (j=1..n), respectively. See main text and Eqs (10-15) for details.**

| **GPP(i,j)** | Site modelled i=1 | i=2 | i=3 | i=… | i=n-1 | i=n |
|---|---|---|---|---|---|---|
| Scenario j=1 | GPP(1,1) = $GPP_{base}(1)$ | GPP(2,1) | GPP(3,1) | … | GPP(n-1,1) | GPP(n,1) |
| j=2 | GPP(1,2) | GPP(2,2) = $GPP_{base}(2)$ | GPP(3,2) | … | GPP(n-1,2) | GPP(n,2) |
| j=3 | GPP(1,3) | GPP(2,3) | GPP(3,3) = $GPP_{base}(3)$ | … | GPP(n-1,3) | GPP(n,3) |
| j=… | … | … | … | GPP(i=j) = $GPP_{base}(i)$ | … | … |
| j=n-1 | GPP(1,n-1) | GPP(2,n-1) | GPP(3,n-1) | … | GPP(n-1,n-1) = $GPP_{base}(n-1)$ | GPP(n,n-1) |
| j=n | GPP(1,n) | GPP(2,n) | GPP(3,n) | … | GPP(n-1,n) | GPP(n,n) = $GPP_{base}(n)$ |

| **X(i,j) = GPP(i,j) / $GPP_{base}$(i)** | Site modelled i=1 | i=2 | i=3 | i=… | i=n-1 | i=n | **Mean $\overline{X(j)}$** |
|---|---|---|---|---|---|---|---|
| Scenario j=1 | 1 | GPP(2,1) / $GPP_{base}(2)$ | GPP(3,1) / $GPP_{base}(3)$ | … | GPP(n-1,1) / $GPP_{base}(n-1)$ | GPP(n,1) / $GPP_{base}(n)$ | $\overline{X(1)}$ |
| j=2 | GPP(1,2) / $GPP_{base}(1)$ | 1 | GPP(3,2) / $GPP_{base}(3)$ | … | GPP(n-1,2) / $GPP_{base}(n-1)$ | GPP(n,2) / $GPP_{base}(n)$ | $\overline{X(2)}$ |
| j=3 | GPP(1,3) / $GPP_{base}(1)$ | GPP(2,3) / $GPP_{base}(2)$ | 1 | … | GPP(n-1,3) / $GPP_{base}(n-1)$ | GPP(n,3) / $GPP_{base}(n)$ | $\overline{X(3)}$ |
| j=… | … | … | … | 1 | … | … | **…** |
| j=n-1 | GPP(1,n-1) / $GPP_{base}(1)$ | GPP(2,n-1) / $GPP_{base}(2)$ | GPP(3,n-1) / $GPP_{base}(3)$ | … | 1 | GPP(n,n-1) / $GPP_{base}(n)$ | $\overline{X(n-1)}$ |
| j=n | GPP(1,n) / $GPP_{base}(1)$ | GPP(2,n) / $GPP_{base}(2)$ | GPP(3,n) / $GPP_{base}(3)$ | … | GPP(n-1,n) / $GPP_{base}(n-1)$ | 1 | $\overline{X(n)}$ |

| **$X_{norm}$(i,j) = X(i,j) / $\overline{X(j)}$** | Site modelled i=1 | i=2 | i=3 | i=… | i=n-1 | i=n |
|---|---|---|---|---|---|---|
| Scenario j=1 | X(1,1) / X(1) | X(2,1) / X(1) | X(3,1) / X(1) | ... | X(n-1,1) / X(1) | X(n,1) / X(1) |
| j=2 | X(1,2) / X(2) | X(2,2) / X(2) | X(3,2) / X(2) | ... | X(n-1,2) / X(2) | X(n,2) / X(2) |
| j=3 | X(1,3) / X(3) | X(2,3) / X(3) | X(3,3) / X(3) | ... | X(n-1,3) / X(3) | X(n,3) / X(3) |
| j=… | ... | ... | ... | X(i,j) / X(j) | ... | ... |
| j=n-1 | X(1,n-1) / X(n-1) | X(2,n-1) / X(n-1) | X(3,n-1) / X(n-1) | ... | X(n-1,n-1) / X(n-1) | X(n,n-1) / X(n-1) |
| j=n | X(1,n) / X(n) | X(2,n) / X(n) | X(3,n) / X(n) | ... | X(n-1,n) / X(n) | X(n,n) / X(n) |
| | | | | | | |
| **f(i) = mean $\overline{X_{norm}(i)}$** | **f(1) = $\overline{X_{norm}(1)}$** | **f(2) = $\overline{X_{norm}(2)}$** | **f(3) = $\overline{X_{norm}(3)}$** | **…** | **f(n-1) = $\overline{X_{norm}(n-1)}$** | **f(n) = $\overline{X_{norm}(n)}$** |