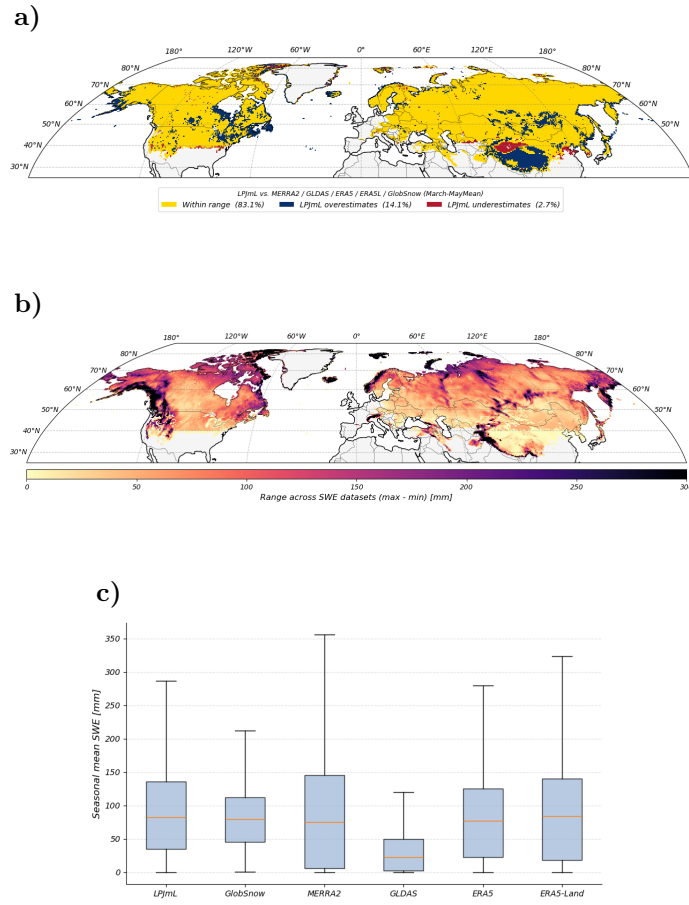
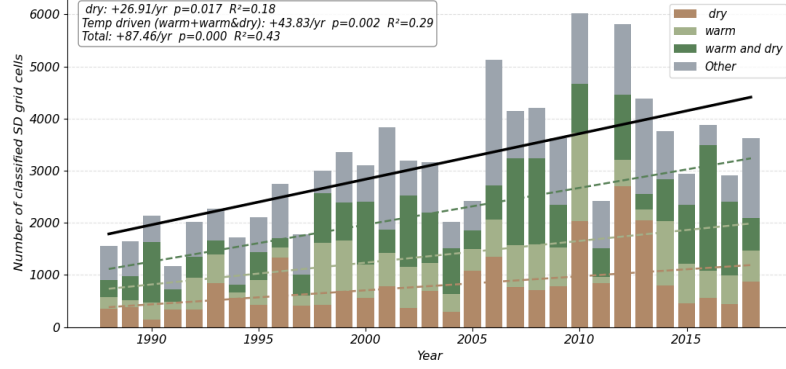


## Supplementary information

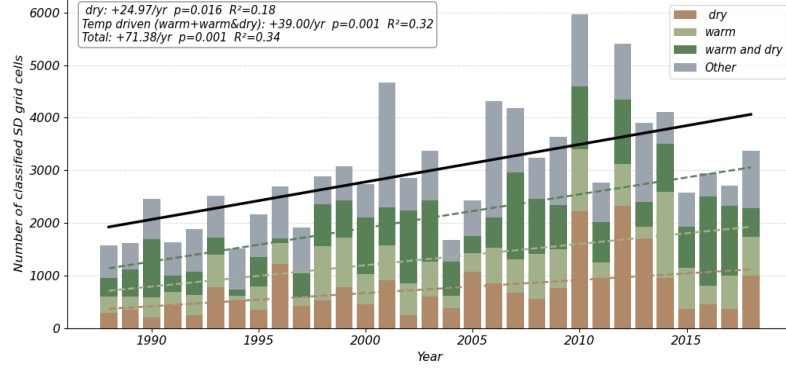


**Fig. S1:** (a) March-May seasonal mean agreement between LPJmL and a range of snow products: GLDAS, MERRA2, GlobSnow, ERA5, and ERA5-Land (see Methods). 83.1% of the LPJmL grid cells fall within the dataset range, with disagreement observed in complex topographic regions. In 14.1% of the grid cells, LPJmL overestimates SWE, whereas it underestimates it only in 2.7% of the grid cells. (b) SWE seasonal spread between the snow products, not including LPJmL. The large spread is concentrated in mountainous regions, indicating higher disagreement there. (c) Boxplot comparing SWE from the reference snow products and LPJmL.

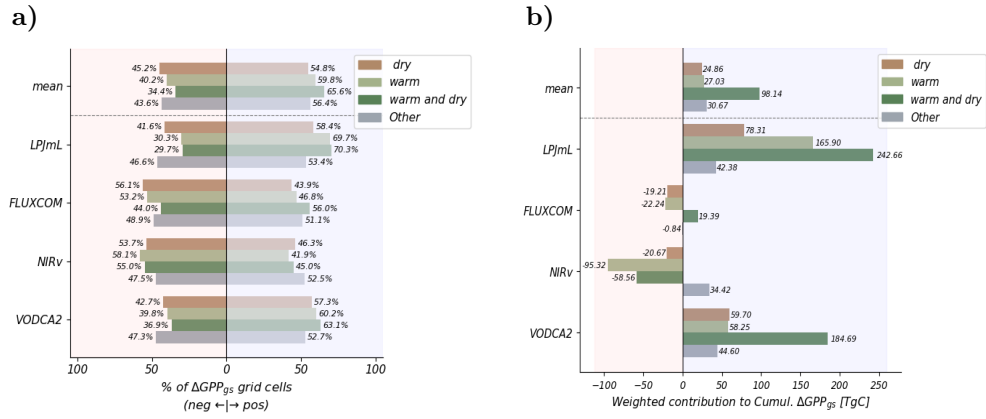
### a) LPJmL



### b) ERA5-Land

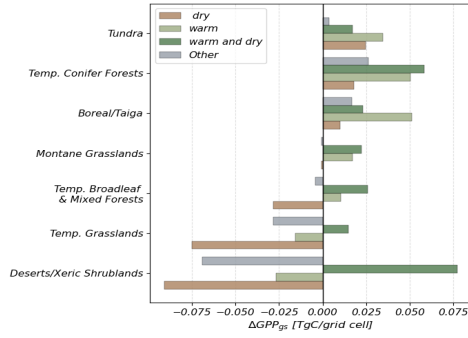


**Fig. S2:** Number of snow drought events per year from 1988–2018. Snow droughts are divided into the following categories: dry ( $\text{SPI} < -0.7$  and  $T \leq 0.75$  percentile), warm ( $\text{SPI} \geq -0.7$  and  $T > 0.75$  percentile), dry and warm ( $\text{SPI} < -0.7$  and  $T > 0.75$  percentile) and other ( $\text{SPI} \geq -0.7$  and  $T \leq 0.75$  percentile), following similar definitions as in [79]. In recent decades, snow drought events have increased significantly ( $p < 0.05$ ), with temperature-driven (warm and warm-and-dry) snow droughts becoming more frequent than precipitation-driven (dry snow droughts).

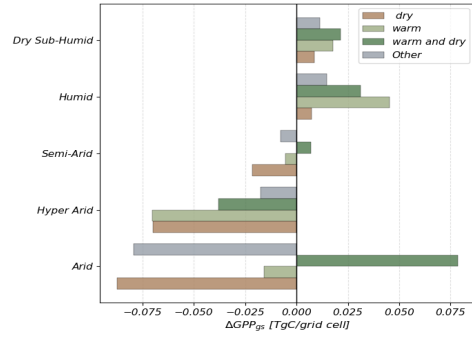


**Fig. S3:** (a) Percentages of grid cells with positive/negative  $\Delta GPP_{gs}$  according to snow drought types per dataset, and (b) their total cumulative  $\Delta GPP$  response. Although the percentages of positive and negative  $\Delta GPP_{gs}$  grid cells across the different snow drought types are similar, their cumulative anomalies indicate very different impacts on GPP, with warm-and-dry snow droughts showing the strongest positive response for all datasets (except NIRv).

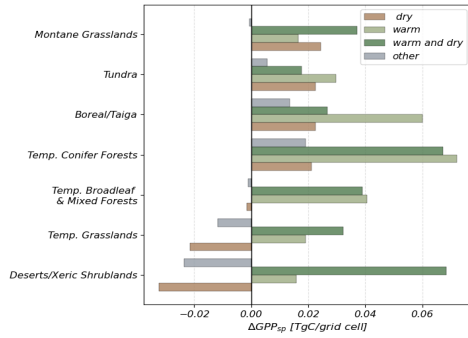
a)  $\Delta GPP_{gs}$  ecoregions



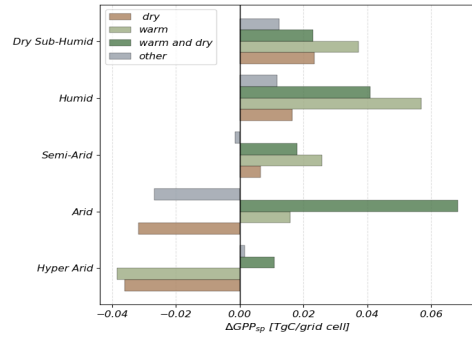
b)  $\Delta GPP_{gs}$  aridity index classes



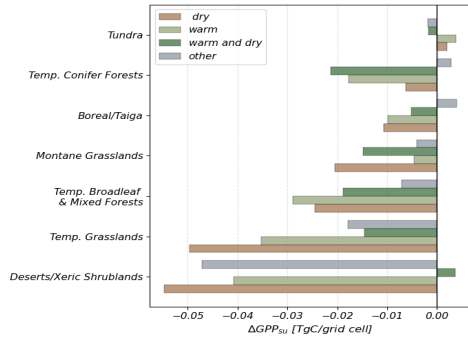
c)  $\Delta GPP_{sp}$  ecoregions



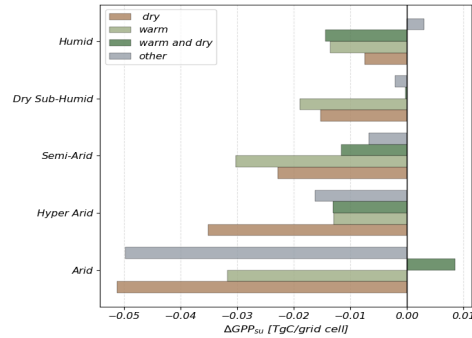
d)  $\Delta GPP_{sp}$  aridity index classes



e)  $\Delta GPP_{su}$  ecoregions

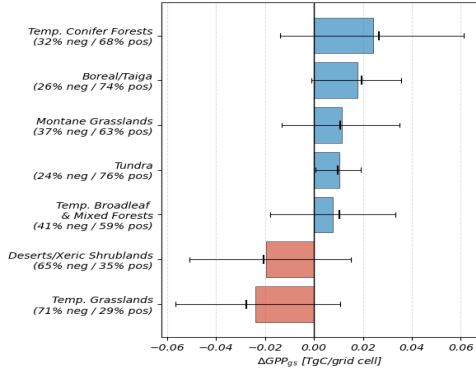


f)  $\Delta GPP_{su}$  aridity index classes

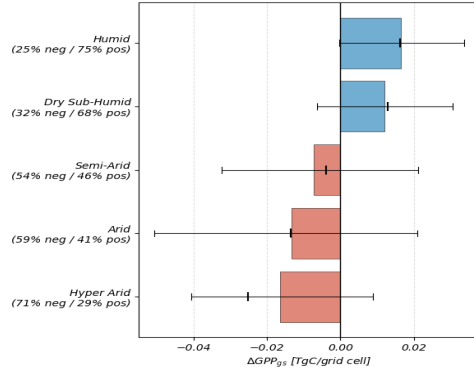


**Fig. S4:**  $\Delta GPP$  subdivided into types of snow droughts (dry, warm, dry and warm, and other) for ecoregions and aridity index classes. (a) and (b) show  $\Delta GPP_{gs}$ . Here, energy-limited regions (tundra, temperate conifer forests, boreal, montane grasslands, humid and dry sub-humid) all show a positive response to snow droughts. In most water-limited areas (deserts/xeric shrublands, temperate grasslands, semi-arid and arid regions), all snow drought types show a negative response, except for combined warm-and-dry types. Hyper-arid regions show a negative response for all snow drought types, and temperate broadleaf and mixed forests show a negative response for dry and other snow droughts, while showing positive responses from warm and warm-and-dry. (c) and (d) show  $\Delta GPP_{sp}$ , with warm, and warm-and-dry being positive for all regions except hyper-arid. Dry snow droughts already show a sign flip along the energy-water gradient. (e) and (f) show  $\Delta GPP_{su}$ , with the vast majority of snow drought types showing negative  $\Delta GPP$  in all regions. Some exceptions are observed, but they remain rather small in magnitude.

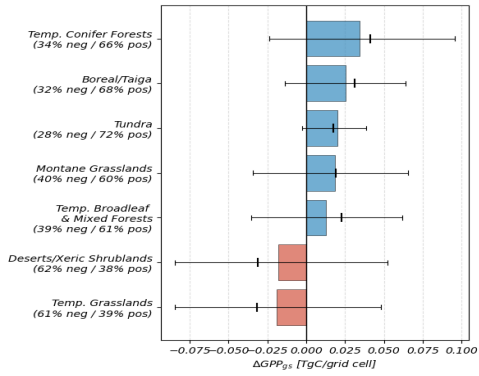
a)  $SWEI \leq -0.5$



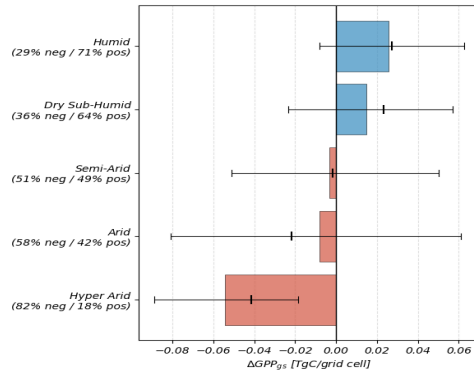
b)



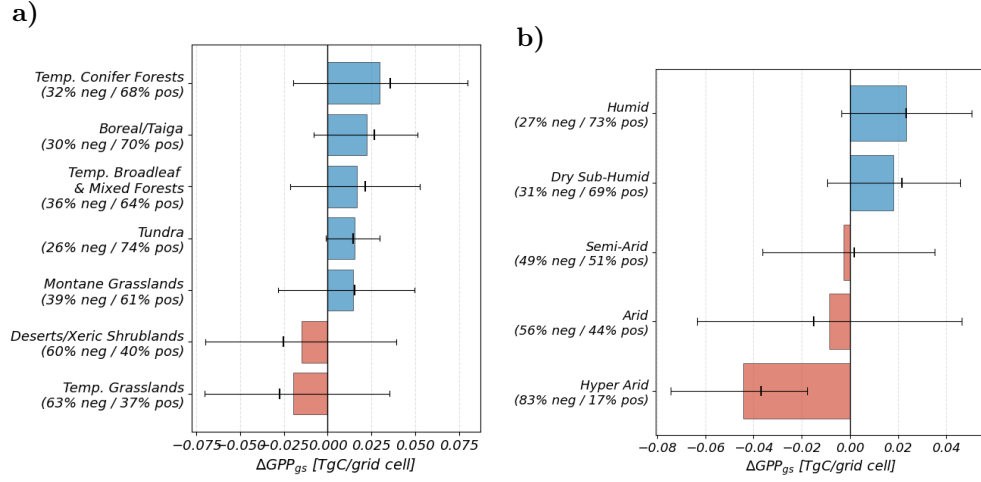
c)  $SWEI \leq -1.6$



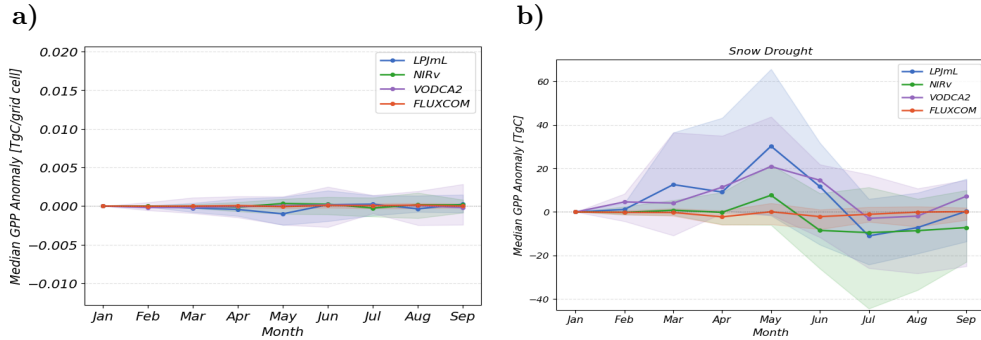
d)



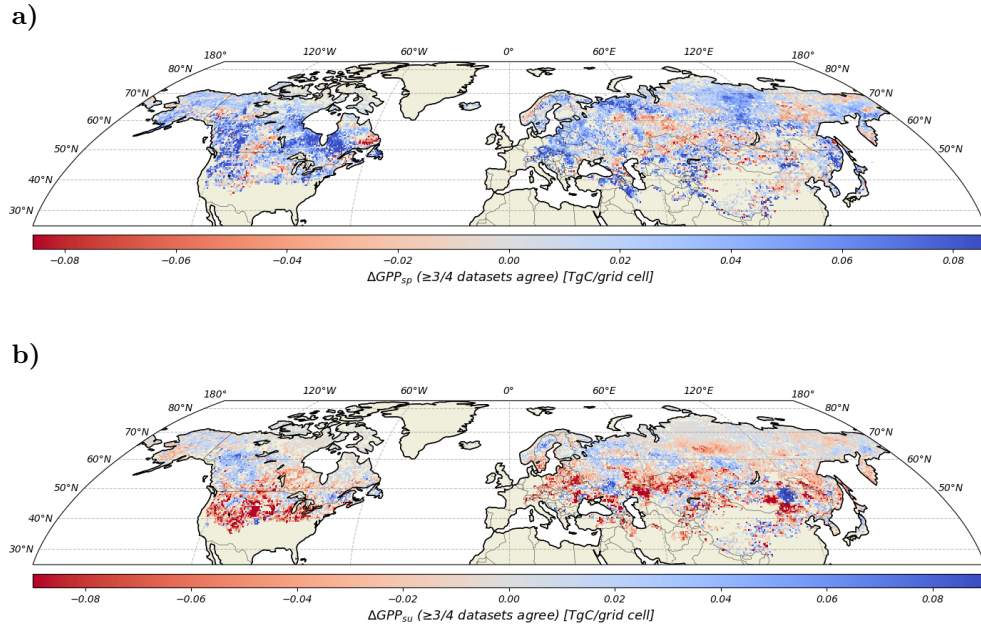
**Fig. S5:**  $\Delta GPP$  stratified by ecosystem and aridity. (a) and (b) show the results using  $SWEI \leq -0.5$ , corresponding to "abnormally dry" snow conditions. (c) and (d) show the same results with a  $SWEI \leq -1.6$ , corresponding to an extreme drought. The overall sign flip across water- and energy-limited regions remains despite a more or less strict  $SWEI$  threshold.



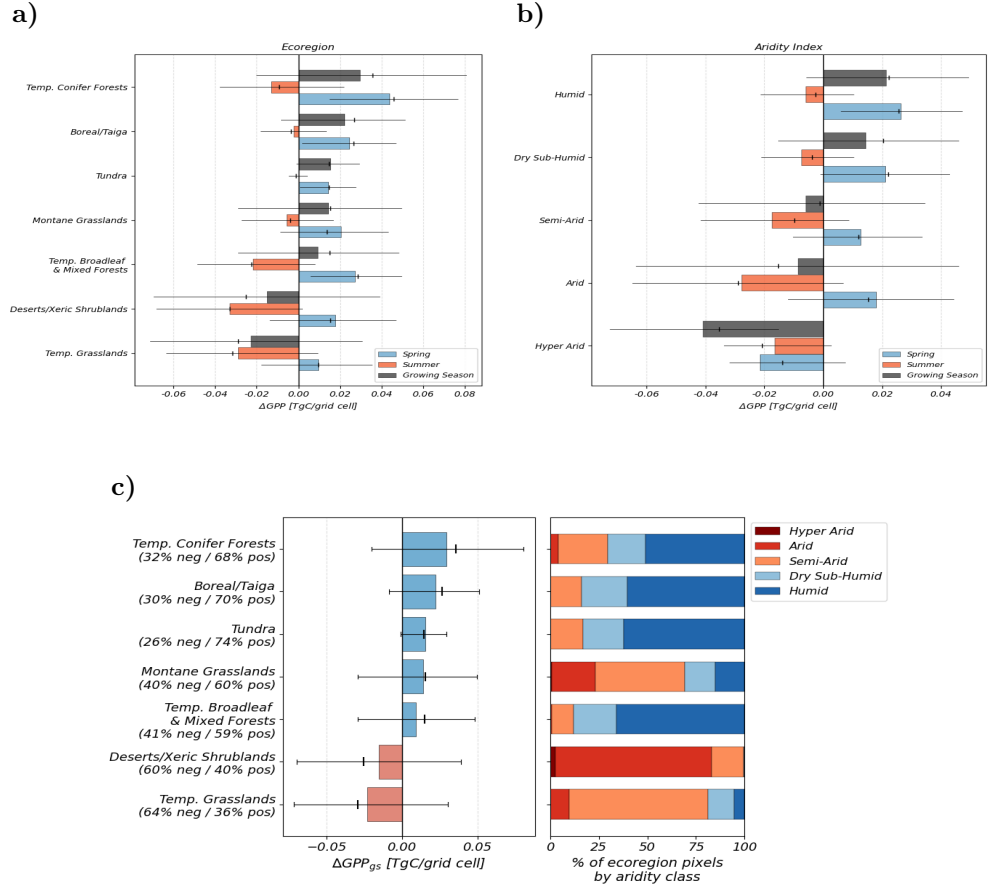
**Fig. S6:** Growing season  $\Delta\text{GPP}$  after removing croplands (based on MODIS 2016 land cover types [76]) stratified by (a) ecosystem and (b) aridity index class. Only grid cells where 3 of the 4 datasets agree are considered. Bars refer to the mean across all grid cells, whiskers denote the inter-quartile range, and the vertical black line represents the median across all grid cells of each group. We find that results remain consistent after masking cropland areas.



**Fig. S7:** (a) Seasonal evolution of GPP anomalies for normal conditions (no snow drought). As these conditions account for the majority of data points, GPP anomalies remain near zero throughout the year. (b) Cumulative seasonal evolution of GPP anomalies for years with snow drought conditions in winter.

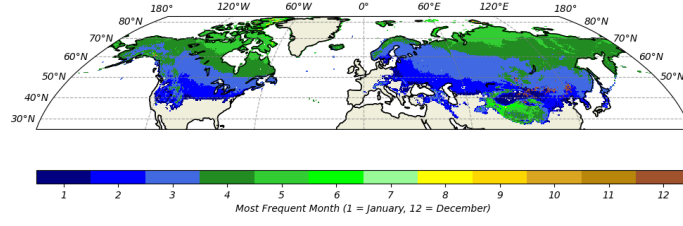


**Fig. S8:** Mean  $\Delta\text{GPP}$  per grid cell [ $\text{TgC}/\text{grid cell}$ ] over (a) spring and (b) summer across the four datasets. Only grid cells where at least 3 of the 4 datasets agree on the sign are shown.

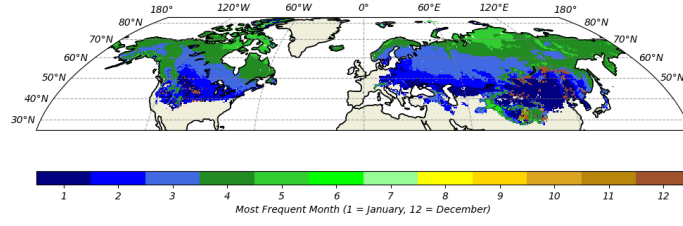


**Fig. S9:**  $\Delta\text{GPP}$  stratified by ecosystem and aridity. Only grid cells where 3 of the 4 datasets agree are considered (see Methods). Bars refer to the mean across all grid cells, whiskers denote the inter-quartile range, and the vertical black line represents the median across all grid cells of each group. (a) Total results are summarized for ecoregions and (b) aridity index. (c)  $\Delta\text{GPP}_{gs}$  for ecoregions, showing the percentage of ecoregion grid cells belonging to aridity index classes.

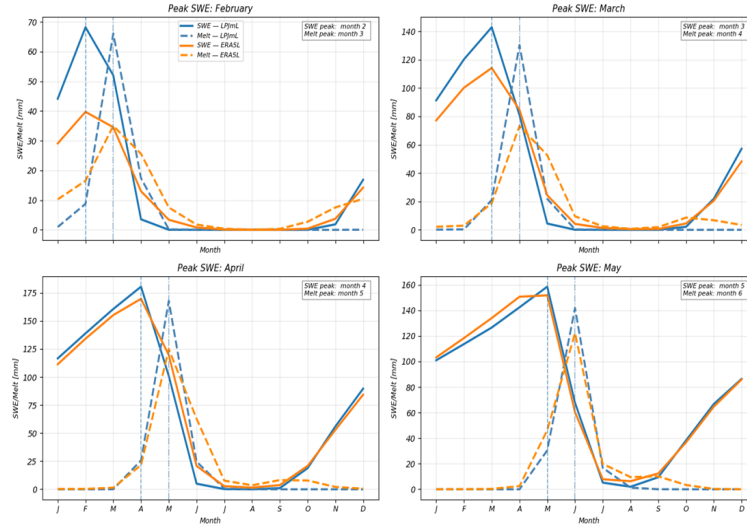
a) LPJmL



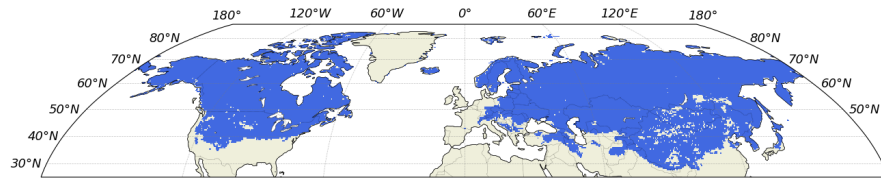
b) ERA5-Land



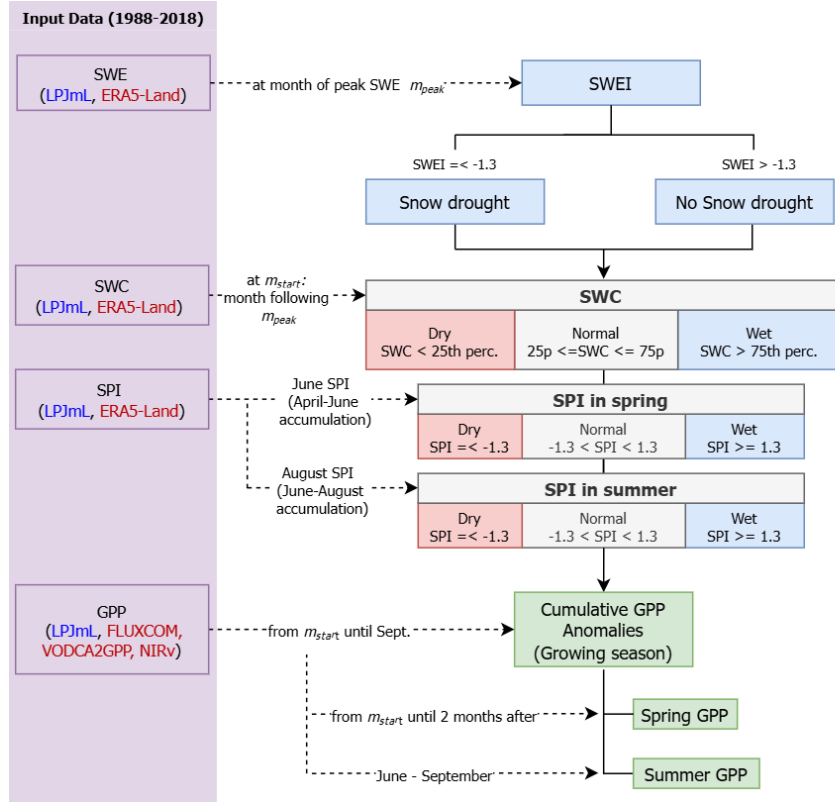
c)



**Fig. S10:** Spatial distribution of the modal month of peak Snow Water Equivalent (SWE) across the Northern Hemisphere, derived from (a) LPJmL (b) ERA5-Land over the 1988–2018 study period. Each grid cell is assigned the month in which peak SWE most frequently occurs across years. The domain is restricted to grid cells where SWE exceeds the minimum threshold required for snow drought classification (see Methods). Blue tones indicate early-season peak months (January–March), characteristic of lower-latitude areas, while green tones indicate mid-season peaks (April–May), typical of continental interiors and boreal regions. (c) Long-term mean annual cycle of Snow Water Equivalent (SWE, solid lines) and snowmelt (dashed lines) from LPJmL (blue) and ERA5-Land (orange). Each panel shows the modal month of peak SWE across grid cells: February (top left), March (top right), April (bottom left), and May (bottom right). Vertical dashed lines indicate the month of peak SWE (left line) and peak snowmelt (right line) for each group. All values represent spatial averages over grid cells assigned to each peak-month class, computed over the 1988–2018 study period.



**Fig. S11:** Valid pixel mask used for the analysis. Blue shading indicates grid cells that satisfy the following criteria: (1) passing the snow threshold test in both the LPJmL and ERA5-Land snow water equivalent (SWE) products, defined as having a non-zero three-month cumulative SWE sum in at least 75% of years between 1988-2018 (See Methods), (2) located outside Greenland, and (3) having a physically plausible modal peak SWE month in the LPJmL peak-month classification, excluding 0.96% of threshold-passing pixels. For ERA5-Land, the excluded pixels constitute a different set, covering 2.33% of the threshold-passing domain and exhibiting a similar spatial distribution.



**Fig. S12:** Analysis workflow. The purple column shows the input data for each analyzed variable (SWEI, SWC, SPI, GPP). Datasets in blue and red illustrate which datasets were used together when looking at the different variables (either all of LPJmL variables or all of the ERA5-Land variables in combination with the three GPP datasets). SWEI was obtained from SWE dataset and evaluated at the modal peak SWE month per grid cell. SWC was evaluated one month later, when melt usually peaks in LPJmL and ERA5-Land. SPI was calculated from precipitation data and evaluated in spring (April–June) and summer (June–August accumulation). GPP anomalies were aggregated over the growing season (from the month after peak SWE month until September), spring (the month after peak SWE plus the two following months), and summer (June–September).

**Table S1:** Net  $\Delta$ GPP anomalies over the growing season [TgC/grid cell] ( $\geq 3/4$  datasets agree)

|                                | Mean   | Median | IQR               |
|--------------------------------|--------|--------|-------------------|
| — Ecoregions —                 |        |        |                   |
| Temp. Conifer Forests          | +0.030 | +0.036 | [-0.020   +0.081] |
| Boreal Forests / Taiga         | +0.022 | +0.027 | [-0.008   +0.051] |
| Tundra                         | +0.015 | +0.015 | [-0.001   +0.030] |
| Montane Grasslands             | +0.014 | +0.015 | [-0.029   +0.050] |
| Temp. Broadleaf & Mixed        | +0.009 | +0.015 | [-0.029   +0.048] |
| Deserts & Xeric Shrublands     | -0.015 | -0.025 | [-0.070   +0.039] |
| Temp. Grasslands, Sav. & Shrub | -0.023 | -0.029 | [-0.071   +0.031] |
| — Aridity Index —              |        |        |                   |
| Humid                          | +0.021 | +0.022 | [-0.006   +0.049] |
| Dry Sub-Humid                  | +0.014 | +0.020 | [-0.015   +0.046] |
| Semi-Arid                      | -0.006 | -0.001 | [-0.042   +0.034] |
| Arid                           | -0.009 | -0.015 | [-0.064   +0.046] |
| Hyper Arid                     | -0.041 | -0.035 | [-0.073   -0.015] |

**Table S2:** Mean difference of  $\Delta$ GPP [TgC/grid cell] in spring, summer, and the growing season, along with the Hedges' g, describing the corresponding effect size.

| Season         | Case        | Mean diff.     | Hedges' g     | Effect size  |
|----------------|-------------|----------------|---------------|--------------|
| Spring         | LPJmL       | 0.0363         | 0.6957        | medium       |
|                | FLUXCOM     | -0.0003        | 0.0586        | negligible   |
|                | NIRv        | 0.0015         | 0.0318        | negligible   |
|                | VODCA2      | 0.0261         | 0.6627        | medium       |
|                | <b>Mean</b> | <b>0.0214</b>  | <b>0.8805</b> | <b>large</b> |
| Summer         | LPJmL       | -0.0060        | 0.1546        | negligible   |
|                | FLUXCOM     | -0.0015        | 0.1567        | negligible   |
|                | NIRv        | -0.0151        | 0.2816        | small        |
|                | VODCA2      | -0.0079        | 0.1875        | negligible   |
|                | <b>Mean</b> | <b>-0.0107</b> | <b>0.4055</b> | <b>small</b> |
| Growing Season | LPJmL       | 0.0303         | 0.4528        | small        |
|                | FLUXCOM     | -0.0021        | 0.1745        | negligible   |
|                | NIRv        | -0.0142        | 0.1876        | negligible   |
|                | VODCA2      | 0.0178         | 0.2892        | small        |
|                | <b>Mean</b> | <b>0.0110</b>  | <b>0.2850</b> | <b>small</b> |

**Table S3:** Net  $\Delta$ GPP anomalies per grid cell [TgC/grid cell] in spring ( $\geq 3/4$  datasets agree)

|                                | Mean   | Median | IQR               |
|--------------------------------|--------|--------|-------------------|
| — Ecoregions —                 |        |        |                   |
| Temp. Conifer Forests          | +0.044 | +0.046 | [+0.015   +0.077] |
| Temp. Broadleaf & Mixed        | +0.027 | +0.029 | [+0.006   +0.050] |
| Boreal Forests / Taiga         | +0.024 | +0.027 | [+0.002   +0.047] |
| Montane Grasslands             | +0.021 | +0.014 | [-0.009   +0.043] |
| Deserts & Xeric Shrublands     | +0.018 | +0.016 | [-0.014   +0.047] |
| Tundra                         | +0.015 | +0.015 | [+0.001   +0.028] |
| Temp. Grasslands, Sav. & Shrub | +0.010 | +0.010 | [-0.018   +0.035] |
| — Aridity Index —              |        |        |                   |
| Humid                          | +0.026 | +0.026 | [+0.006   +0.047] |
| Dry Sub-Humid                  | +0.021 | +0.022 | [-0.001   +0.043] |
| Arid                           | +0.018 | +0.015 | [-0.012   +0.044] |
| Semi-Arid                      | +0.013 | +0.012 | [-0.010   +0.034] |
| Hyper Arid                     | -0.022 | -0.014 | [-0.032   +0.007] |

**Table S4:** Net  $\Delta$ GPP anomalies per grid cell [TgC/grid cell] in summer ( $\geq 3/4$  datasets agree)

|                                | Mean   | Median | IQR               |
|--------------------------------|--------|--------|-------------------|
| — Ecoregions —                 |        |        |                   |
| Tundra                         | +0.000 | -0.001 | [-0.005   +0.004] |
| Boreal Forests / Taiga         | -0.002 | -0.004 | [-0.018   +0.014] |
| Montane Grasslands             | -0.005 | -0.004 | [-0.027   +0.017] |
| Temp. Conifer Forests          | -0.013 | -0.009 | [-0.038   +0.022] |
| Temp. Broadleaf & Mixed        | -0.022 | -0.022 | [-0.049   +0.008] |
| Temp. Grasslands, Sav. & Shrub | -0.029 | -0.032 | [-0.064   +0.009] |
| Deserts & Xeric Shrublands     | -0.033 | -0.033 | [-0.068   +0.002] |
| — Aridity Index —              |        |        |                   |
| Humid                          | -0.006 | -0.003 | [-0.021   +0.010] |
| Dry Sub-Humid                  | -0.007 | -0.004 | [-0.021   +0.010] |
| Hyper Arid                     | -0.017 | -0.021 | [-0.034   +0.003] |
| Semi-Arid                      | -0.017 | -0.010 | [-0.042   +0.009] |
| Arid                           | -0.028 | -0.029 | [-0.065   +0.007] |

**Table S5:** Mean  $\Delta$ GPP [TgC/grid cell] and Hedges' g effect size by ecoregion, season, and dataset, including the multi-dataset ensemble mean (pixels where  $\geq 3/4$  datasets agree on sign). Effect size color/weight: gray = negligible, plain = small, **bold blue** = medium, **bold red** = large.

| Ecoregion                       | Season         | LPJmL           | FLUXCOM         | NIRv            | VODCA2          | Mean            |
|---------------------------------|----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Deserts/Xeric Shrublands        | Spring         | +0.0301         | -0.0024         | -0.0096         | +0.0232         | +0.0177         |
|                                 |                | 0.38 (s)        | 0.26 (s)        | 0.36 (s)        | <b>0.57 (m)</b> | <b>0.60 (m)</b> |
|                                 | Summer         | -0.0285         | -0.0004         | -0.0262         | -0.0205         | -0.0330         |
|                                 |                | 0.36 (s)        | 0.02 (n)        | <b>0.54 (m)</b> | 0.41 (s)        | <b>0.90 (l)</b> |
|                                 | Growing Season | +0.0005         | -0.0043         | -0.0384         | -0.0001         | -0.0151         |
|                                 |                | 0.00 (n)        | 0.17 (n)        | <b>0.73 (m)</b> | 0.00 (n)        | 0.27 (s)        |
| Temp. Grasslands, Sav. & Shrub  | Spring         | +0.0264         | -0.0021         | -0.0047         | +0.0143         | +0.0096         |
|                                 |                | 0.40 (s)        | 0.38 (s)        | 0.13 (n)        | 0.34 (s)        | 0.37 (s)        |
|                                 | Summer         | -0.0245         | -0.0049         | -0.0345         | -0.0315         | -0.0291         |
|                                 |                | 0.43 (s)        | 0.36 (s)        | 0.50 (s)        | 0.39 (s)        | <b>0.68 (m)</b> |
|                                 | Growing Season | +0.0013         | -0.0080         | -0.0402         | -0.0202         | -0.0228         |
|                                 |                | 0.01 (n)        | <b>0.50 (m)</b> | <b>0.56 (m)</b> | 0.21 (s)        | 0.45 (s)        |
| Temp. Broadleaf & Mixed Forests | Spring         | +0.0497         | +0.0022         | -0.0099         | +0.0438         | +0.0274         |
|                                 |                | <b>1.11 (l)</b> | 0.31 (s)        | 0.18 (n)        | <b>0.94 (l)</b> | <b>1.16 (l)</b> |
|                                 | Summer         | -0.0094         | -0.0057         | -0.0421         | -0.0096         | -0.0218         |
|                                 |                | 0.29 (s)        | 0.42 (s)        | <b>0.55 (m)</b> | 0.18 (n)        | <b>0.77 (m)</b> |
|                                 | Growing Season | +0.0414         | -0.0038         | -0.0539         | +0.0362         | +0.0093         |
|                                 |                | <b>0.78 (m)</b> | 0.24 (s)        | <b>0.57 (m)</b> | <b>0.51 (m)</b> | 0.25 (s)        |
| Montane Grasslands              | Spring         | +0.0372         | -0.0002         | -0.0163         | +0.0261         | +0.0206         |
|                                 |                | <b>0.61 (m)</b> | 0.04 (n)        | 0.20 (s)        | <b>0.56 (m)</b> | <b>0.62 (m)</b> |
|                                 | Summer         | +0.0007         | -0.0055         | -0.0119         | +0.0040         | -0.0054         |
|                                 |                | 0.02 (n)        | 0.48 (s)        | 0.14 (n)        | 0.10 (n)        | 0.19 (n)        |
|                                 | Growing Season | +0.0377         | -0.0064         | -0.0285         | +0.0310         | +0.0142         |
|                                 |                | 0.47 (s)        | 0.45 (s)        | 0.23 (s)        | 0.48 (s)        | 0.30 (s)        |
| Temp. Conifer Forests           | Spring         | +0.0653         | -0.0020         | -0.0031         | +0.0726         | +0.0438         |
|                                 |                | <b>1.06 (l)</b> | 0.26 (s)        | 0.04 (n)        | <b>1.23 (l)</b> | <b>1.38 (l)</b> |
|                                 | Summer         | -0.0070         | -0.0023         | -0.0382         | +0.0091         | -0.0129         |
|                                 |                | 0.13 (n)        | 0.27 (s)        | 0.48 (s)        | 0.23 (s)        | 0.43 (s)        |
|                                 | Growing Season | +0.0579         | -0.0043         | -0.0418         | +0.0815         | +0.0295         |
|                                 |                | <b>0.67 (m)</b> | 0.37 (s)        | 0.32 (s)        | <b>1.07 (l)</b> | <b>0.58 (m)</b> |
| Boreal/Taiga                    | Spring         | +0.0457         | -0.0004         | +0.0088         | +0.0257         | +0.0244         |
|                                 |                | <b>0.90 (l)</b> | 0.08 (n)        | 0.19 (n)        | <b>0.71 (m)</b> | <b>1.02 (l)</b> |
|                                 | Summer         | +0.0013         | +0.0004         | -0.0037         | -0.0069         | -0.0024         |
|                                 |                | 0.05 (n)        | 0.08 (n)        | 0.09 (n)        | 0.26 (s)        | 0.14 (n)        |
|                                 | Growing Season | +0.0470         | -0.0000         | +0.0050         | +0.0188         | +0.0223         |
|                                 |                | <b>0.81 (l)</b> | 0.00 (n)        | 0.07 (n)        | 0.40 (s)        | <b>0.71 (m)</b> |
| Tundra                          | Spring         | +0.0175         | +0.0004         | +0.0056         | +0.0167         | +0.0145         |
|                                 |                | <b>0.64 (m)</b> | 0.13 (n)        | 0.19 (n)        | <b>0.61 (m)</b> | <b>0.95 (l)</b> |
|                                 | Summer         | -0.0001         | -0.0001         | -0.0001         | +0.0016         | +0.0002         |
|                                 |                | 0.01 (n)        | 0.04 (n)        | 0.01 (n)        | 0.11 (n)        | 0.03 (n)        |
|                                 | Growing Season | +0.0174         | +0.0003         | +0.0055         | +0.0183         | +0.0154         |
|                                 |                | <b>0.55 (m)</b> | 0.09 (n)        | 0.15 (n)        | <b>0.56 (m)</b> | <b>0.81 (l)</b> |

**Table S6:** Mean  $\Delta$ GPP [TgC/grid cell] and Hedges' g effect size by aridity class, season, and dataset, including the multi-dataset ensemble mean (pixels where  $\geq 3/4$  datasets agree on sign). Effect size color/weight: gray = negligible, plain = small, **bold blue** = medium, **bold red** = large.

| Aridity Class | Season | LPJmL           | FLUXCOM  | NIRv     | VODCA2          | Mean            |
|---------------|--------|-----------------|----------|----------|-----------------|-----------------|
| Hyper Arid    | Spring | -0.0152         | -0.0005  | +0.0144  | -0.0066         | -0.0216         |
|               |        | 0.36 (s)        | 0.20 (s) | 0.37 (s) | 0.38 (s)        | <b>0.63 (m)</b> |
|               | Summer | +0.0019         | -0.0038  | -0.0054  | -0.0029         | -0.0166         |
|               |        | 0.05 (n)        | 0.36 (s) | 0.05 (n) | 0.11 (n)        | <b>0.74 (m)</b> |
| Arid          | Spring | -0.0148         | -0.0052  | +0.0138  | -0.0084         | -0.0410         |
|               |        | 0.26 (s)        | 0.44 (s) | 0.19 (n) | 0.24 (s)        | <b>1.08 (l)</b> |
|               | Summer | +0.0379         | -0.0019  | -0.0086  | +0.0223         | +0.0180         |
|               |        | 0.48 (s)        | 0.23 (s) | 0.39 (s) | <b>0.60 (m)</b> | <b>0.62 (m)</b> |
| Semi-Arid     | Spring | -0.0282         | -0.0010  | -0.0142  | -0.0182         | -0.0278         |
|               |        | 0.35 (s)        | 0.06 (n) | 0.27 (s) | 0.32 (s)        | <b>0.66 (m)</b> |
|               | Summer | +0.0097         | -0.0045  | -0.0250  | +0.0003         | -0.0087         |
|               |        | 0.08 (n)        | 0.19 (n) | 0.45 (s) | 0.00 (n)        | 0.15 (n)        |
| Dry Sub-Humid | Spring | +0.0238         | -0.0022  | +0.0018  | +0.0192         | +0.0127         |
|               |        | 0.42 (s)        | 0.45 (s) | 0.05 (n) | 0.49 (s)        | <b>0.53 (m)</b> |
|               | Summer | -0.0088         | -0.0032  | -0.0221  | -0.0158         | -0.0174         |
|               |        | 0.20 (n)        | 0.30 (s) | 0.39 (s) | 0.28 (s)        | <b>0.54 (m)</b> |
| Humid         | Spring | +0.0147         | -0.0060  | -0.0208  | +0.0025         | -0.0059         |
|               |        | 0.19 (n)        | 0.46 (s) | 0.32 (s) | 0.03 (n)        | 0.14 (n)        |
|               | Summer | +0.0354         | -0.0014  | +0.0045  | +0.0302         | +0.0210         |
|               |        | <b>0.78 (m)</b> | 0.27 (s) | 0.10 (n) | <b>0.75 (m)</b> | <b>0.96 (l)</b> |
| Hyper Arid    | Spring | -0.0034         | -0.0019  | -0.0131  | -0.0038         | -0.0074         |
|               |        | 0.12 (n)        | 0.22 (s) | 0.28 (s) | 0.09 (n)        | 0.33 (s)        |
|               | Summer | +0.0322         | -0.0034  | -0.0092  | +0.0265         | +0.0142         |
|               |        | <b>0.59 (m)</b> | 0.32 (s) | 0.14 (n) | 0.44 (s)        | 0.43 (s)        |
| Arid          | Spring | +0.0435         | +0.0013  | +0.0014  | +0.0293         | +0.0262         |
|               |        | <b>0.96 (l)</b> | 0.23 (s) | 0.02 (n) | <b>0.74 (m)</b> | <b>1.09 (l)</b> |
|               | Summer | -0.0020         | -0.0006  | -0.0125  | -0.0040         | -0.0060         |
|               |        | 0.07 (n)        | 0.08 (n) | 0.23 (s) | 0.13 (n)        | 0.30 (s)        |
| Semi-Arid     | Spring | +0.0418         | +0.0007  | -0.0115  | +0.0257         | +0.0214         |
|               |        | <b>0.79 (m)</b> | 0.08 (n) | 0.13 (n) | 0.50 (s)        | <b>0.64 (m)</b> |

**Table S7:** Total  $\Delta$ GPP by ecoregion and aridity class [TgC], ensemble mean across the four GPP datasets. Rows sorted by descending mean value.

|                                 | Mean    | IQR                | Area [km <sup>2</sup> ] |
|---------------------------------|---------|--------------------|-------------------------|
| — Ecoregions —                  |         |                    |                         |
| Boreal Forests / Taiga          | +169.06 | [+33.71   +246.89] | 14,768,632              |
| Tundra                          | +60.77  | [+20.72   +106.73] | 7,185,482               |
| Temp. Conifer Forests           | +30.69  | [-16.23   +82.65]  | 2,761,283               |
| Temp. Broadleaf & Mixed Forests | +15.74  | [-49.97   +116.67] | 6,641,190               |
| Montane Grasslands              | +12.46  | [-9.94   +35.36]   | 3,097,087               |
| Deserts/Xeric Shrublands        | -13.60  | [-17.67   +0.11]   | 5,114,077               |
| Temp. Grasslands                | -50.75  | [-76.45   -17.37]  | 6,639,605               |
| — Aridity Index —               |         |                    |                         |
| Humid                           | +188.34 | [-26.28   +383.89] | 20,776,054              |
| Dry Sub-Humid                   | +58.68  | [-23.23   +138.68] | 8,258,755               |
| Hyper Arid                      | -1.90   | [-3.10   -0.62]    | 771,805                 |
| Arid                            | -5.87   | [-16.44   +6.19]   | 5,719,075               |
| Semi-Arid                       | -12.34  | [-58.21   +35.07]  | 11,750,207              |

**Table S8:** SWEI value classifications according to the US drought monitor. Adapted from [5].

| Classification | Description           | SWEI                           |
|----------------|-----------------------|--------------------------------|
| D4             | Exceptional Drought   | $\text{SWEI} \leq -2.0$        |
| D3             | Extreme Drought       | $-2.0 < \text{SWEI} \leq -1.6$ |
| D2             | Severe Drought        | $-1.6 < \text{SWEI} \leq -1.3$ |
| D1             | Moderate Drought      | $-1.3 < \text{SWEI} \leq -0.8$ |
| D0             | Abnormally Dry        | $-0.8 < \text{SWEI} \leq -0.5$ |
| NN             | Normal                | $-0.5 < \text{SWEI} < +0.5$    |
| W0             | Abnormally Wet        | $+0.5 \leq \text{SWEI} < +0.8$ |
| W1             | Moderate Wet Spell    | $+0.8 \leq \text{SWEI} < +1.3$ |
| W2             | Severe Wet Spell      | $+1.3 \leq \text{SWEI} < +1.6$ |
| W3             | Extreme Wet Spell     | $+1.6 \leq \text{SWEI} < +2.0$ |
| W4             | Exceptional Wet Spell | $\text{SWEI} \geq +2.0$        |

**Table S9:** Definitions of hydroclimatic and ecosystem variables used in the analysis.

| Variable             | Period considered                                                            |
|----------------------|------------------------------------------------------------------------------|
| SWE                  | Month of peak SWE                                                            |
| Spring precipitation | April–June accumulation (June SPI)                                           |
| Summer precipitation | June–August accumulation (August SPI)                                        |
| Spring SWC           | Month following peak SWE                                                     |
| Spring GPP           | from the month following peak SWE through the third month following peak SWE |
| Summer GPP           | June–September                                                               |
| Growing-season GPP   | from the month following peak SWE through September                          |