Table S1 Correlations between site characteristics and xylemand lysimeter water SOI. Spearman (rank) and Pearson correlation coefficients were calculated for relationships between site characteristics and site-mean xylem-water and soil-water SOI. Statistically significant correlations are indicated with bold fonts (p<0.05) and gray shading (p<0.01).

Site characteristics	Beech SOI		Spruce SOI		Oak SOI		Shallow soil SOI		Deep soil SOI	
	rank	Pearson	rank	Pearson	rank	Pearson	rank	Pearson	rank	Pearson
1. *Depth*	-0.11	-0.14	-0.21	-0.16	0.08	0.20	**-0.52**	**-0.60**	-0.23	-0.20
2. *PAWC*	**-0.27**	**-0.23**	-0.23	-0.20	0.04	0.12	-0.37	-0.40	-0.17	-0.21
3. *Stones*	**0.34**	**0.31**	**0.26**	0.15	0.06	0.06	0.34	0.36	0.01	-0.03
4. *Clay*	0.15	0.10	-0.02	-0.08	0.02	-0.08	-0.20	-0.15	0.10	0.16
5. *Root depth*	0.14	0.11	0.01	-0.04	0.28	**0.45**	-0.17	-0.07	**-0.61**	-0.34
6. *Root density*	0.14	0.20	**0.24**	**0.24**	-0.14	0.13	0.05	0.18	-0.27	-0.29
7. *Elevation*	**0.42**	**0.35**	**0.57**	**0.46**	-0.01	0.17	**0.41**	**0.51**	0.26	**0.37**
8. *Slope*	**0.42**	**0.33**	**0.40**	**0.35**	0.13	**0.35**	**0.48**	**0.63**	0.36	**0.42**
9. *Aspect*	**0.23**	**0.24**	-0.16	-0.02	0.20	0.21	-0.35	-0.26	-0.17	-0.07
10. *Mean T*	-0.12	-0.05	**-0.48**	**-0.36**	0.19	0.18	**-0.42**	**-0.50**	-0.29	**-0.38**
11. *Snow fraction*	0.12	0.05	**0.42**	**0.31**	-0.24	-0.21	**0.49**	**0.57**	0.32	**0.40**
12. *50-day P*	**0.22**	**0.21**	**0.25**	0.18	-0.25	-0.06	0.28	0.37	0.05	0.13
13. *2015 P*	**0.40**	**0.46**	**0.42**	**0.38**	0.05	**0.36**	0.32	**0.42**	0.25	0.26
14. *Annual P*	**0.50**	**0.67**	**0.51**	**0.54**	0.08	**0.53**	0.37	**0.41**	0.20	0.23
15. *Annual P - PET*	**0.49**	**0.65**	**0.53**	**0.55**	0.06	**0.47**	0.40	**0.41**	0.21	0.23
16. *Summer P*	**0.49**	**0.63**	**0.60**	**0.58**	0.07	**0.53**	0.28	0.33	0.18	0.17
17. *Summer P-PET*	**0.47**	**0.61**	**0.61**	**0.56**	0.05	**0.46**	0.29	0.35	0.15	0.18
18. *Summer 2015 P*	**0.39**	**0.53**	**0.46**	**0.46**	0.00	**0.34**	**0.41**	**0.48**	0.26	0.27
19. *Summer 2015P-PET*	**0.43**	**0.55**	**0.59**	**0.53**	0.09	**0.34**	**0.43**	**0.57**	0.22	0.30

1. *Depth* is the depth to the base of the soil pit, at the parent-material boundary (C horizon) (*Bodenkundliche Kartieranleitung*, 2005).

2. *PAWC* is the plant-available water capacity of the soils up to 100-cm depth, calculated as the depth-integrated water content at field capacity minus the depth-integrated water content at wilting point; wilting point and field capacity were predicted as a function of soil texture, bulk density and organic-matter content(*Bodenkundliche Kartieranleitung*, 2005).

3. S*tones* refers to the mean fractional volume of stones(*Bodenkundliche Kartieranleitung*, 2005)[2] for soil horizons up to 50-cm depth.

4. *Clay* refers to the mean fractional clay content(*Bodenkundliche Kartieranleitung*, 2005)[2] for soil horizons up to 50-cm depth.

5-6. *Root density* is the mean quantitative root index for soil horizons up to 50-cm depth, calculated by converting the German soil survey's ordinal root indices (W1, W2, W3, W4, W5, W6)(*Bodenkundliche Kartieranleitung*, 2005)[2] to quantitative density values (1.5, 4, 8, 15.5, 35.5, and 50 roots cm^{-2}). *Root depth* was calculated as the density-weighted mean depth of roots, using the quantitative root density values.

7-9. *Elevation* was calculated for the pixel containing each site, using the 25-m digital elevation map.

8-9. *Slope* and *aspect* were measured in the field at each site, using a compass and clinometer.

9. *Aspect* was defined as the absolute deviation from north; sites with zero slope were assigned the intermediate value between north and south (90°).

10-19. Climate variables were calculated from site-specific data products from Meteotest (Bern, Switzerland).

12-13 and 16-19. For the 50-day precipitation and 2015 precipitation, values were calculated with respect to the site-specific sampling date.

14-16. Long-term climate variables—mean temperature (*Mean T*), total annual precipitation (*Annual P*), annual precipitation minus potential evapotranspiration (*Annual P − PET*), and fraction of precipitation as snow (*snow fraction*)—were based on 36-year means.

11. For *snow fraction*, we assumed that snow occurred when precipitation fell on days with mean temperatures below 0 °C.

15, 17, 19. Potential evapotranspiration was calculated using the Penman-Monteith approach (Meteotest, Bern, Switzerland).

Table S2 Multiple regression models of xylem water and lysimeter soil water SOI. An iterative stepwise model selection routine was used to determine which site characteristics were included (marked by *) to maximize R^2 while excluding predictor variables with component p-values < 0.05. This routine was applied using the "stepwiselm" function in MATLAB R2016B (Mathworks, Inc; Natick, MA, USA).

Site characteristics	Beech SOI	Spruce SOI	Oak SOI	Shallow soil SOI	Deep soil SOI
R^2	0.61	0.59	0.37	0.60	0.62
Number of sites	97	70	49	24	29
1. *Depth*				*	
2. *PAWC*					*
3. *Stones*					
4. *Clay*					*
5. *Root depth*			*		*
6. *Root density*					*
7. *Elevation*	*	*			
8. *Slope*				*	
9. *Aspect*	*				
10. *Mean T*	*				
11. *Snow fraction*					
12. *50-day P*		*			
13. *2015 P*					
14. *Annual P*			*		
15. *Annual P - PET*	*				
16. *Summer P*		*			
17. *Summer P-PET*					
18. *Summer 2015 P*					
19. *Summer 2015P-PET*		*			

1. *Depth* is the depth to the base of the soil pit, at the parent-material boundary (C horizon)(*Bodenkundliche Kartieranleitung*, 2005).

2. *PAWC* is the plant-available water capacity of the soils up to 100-cm depth, calculated as the depth-integrated water content at field capacity minus the depth-integrated water content at wilting point; wilting point and field capacity were predicted as a function of soil texture, bulk density and organic-matter content(*Bodenkundliche Kartieranleitung*, 2005).

3. S*tones* refers to the mean fractional volume of stones(*Bodenkundliche Kartieranleitung*, 2005)[2] for soil horizons up to 50-cm depth.

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15, 17, 19. Potential evapotranspiration was calculated using the Penman-Monteith approach (Meteotest, Bern, Switzerland).

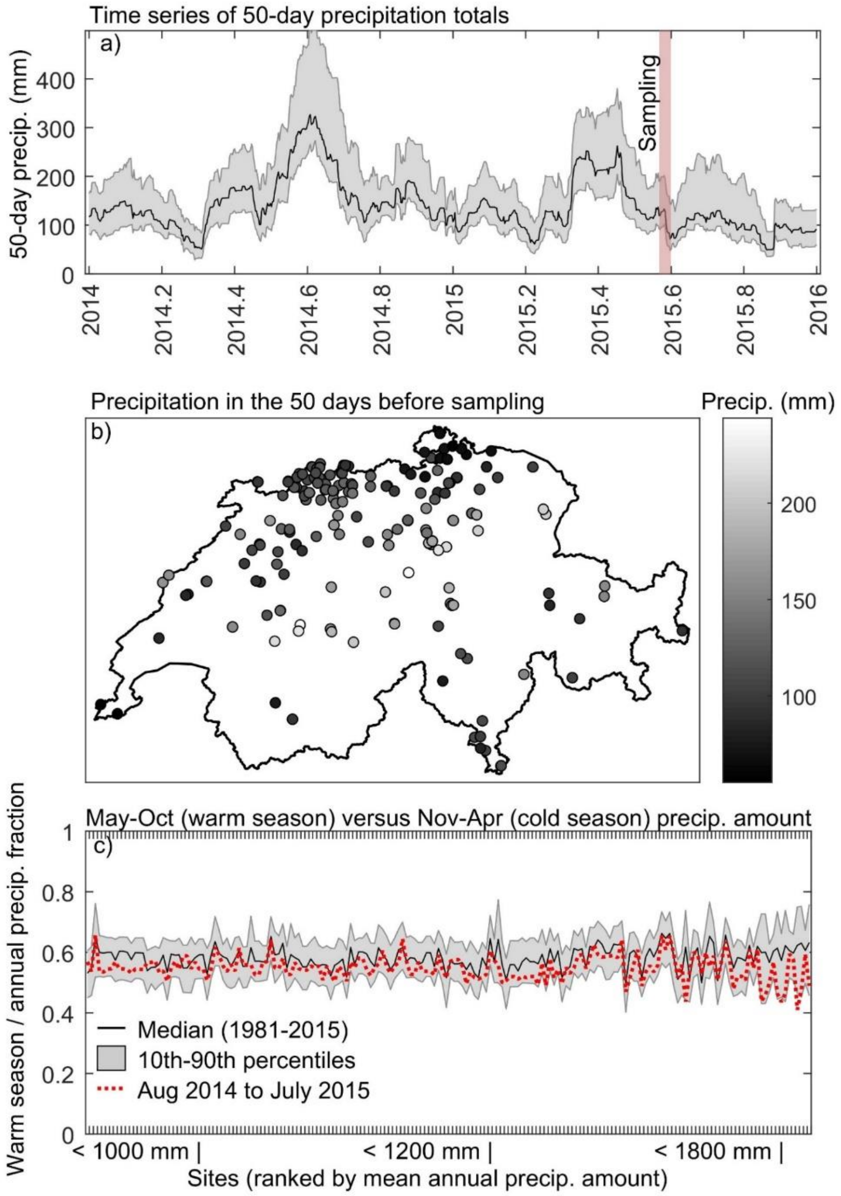

Figure S1 Precipitation amount at the study sites. a) Running total of precipitation for the fifty preceding days, calculated as a function of ending date. The xylem water sampling period is shown by the vertical red bar. Median values are indicated by the black line and the 10th to 90th percentiles are indicated by gray shading. b) Total precipitation for the 50 days prior to sample collection at each site. July of 2015, when xylem sampling began, was drier than usual (a), but all sites received summer precipitation. c) In Switzerland, slightly more (58% of annual) precipitation falls in the warmer months (i.e., May-October, when snow is uncommon) than in the colder months. In the year prior to the xylem sampling, 54% of precipitation fell in the warmer months.

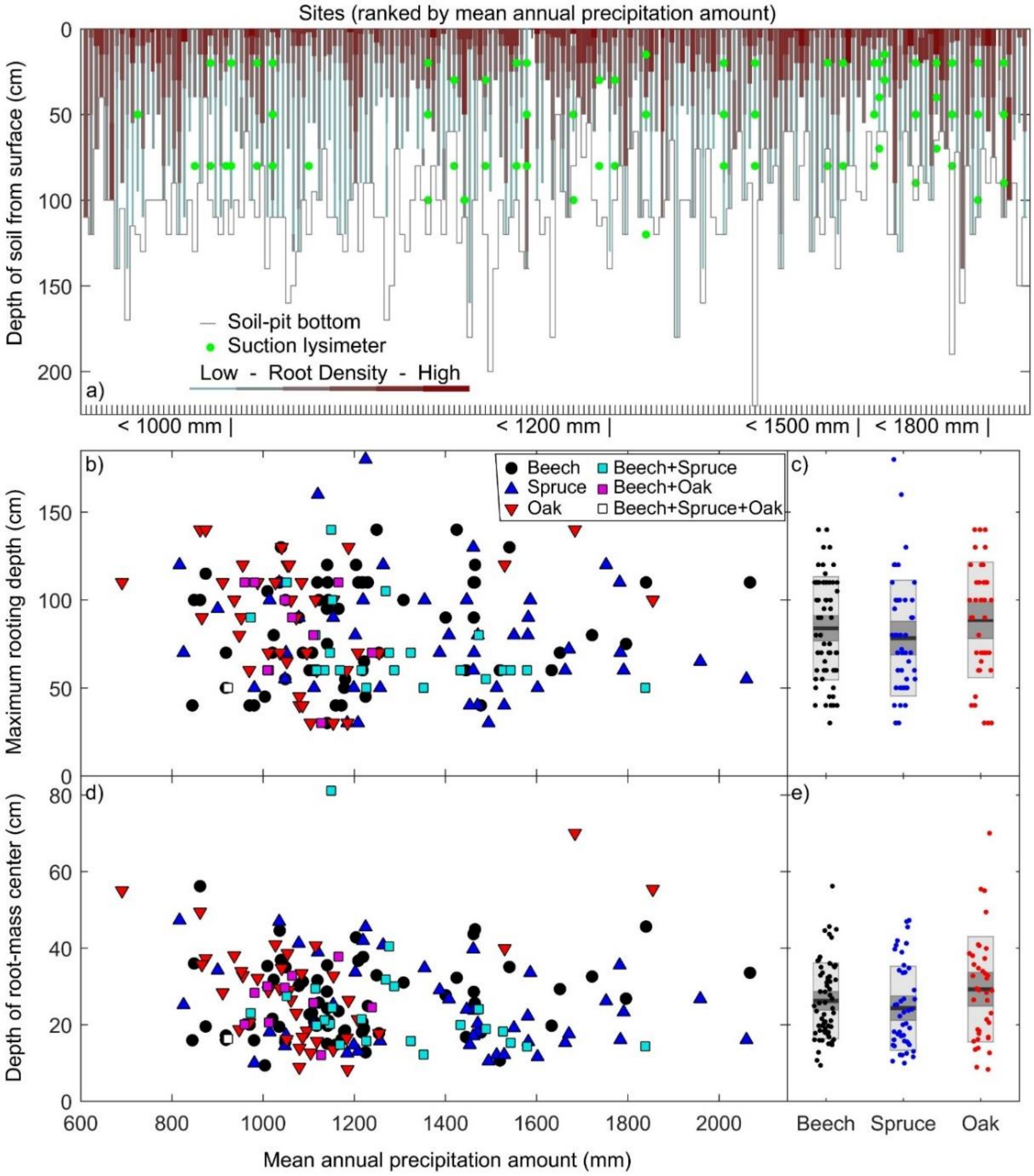

Figure S2 Soil, lysimeter, and root depths across the sites. (a) Soil depth was defined as the depth to the top of the C horizon, in accordance with German Soil Survey protocols[32]. High densities of roots mostly occurred in shallower soils (with density quantified on an ordinal scale from 0-6, in accordance with the German soil survey). (b, c) Maximum rooting depths were not well explained by mean annual precipitation ($R^2<0.01$, $p=0.22$). (d, e) Mean rooting depth, quantified as depth to root mass center, also was not linearly related to mean annual precipitation ($R^2<0.01$, $p=0.40$). Panels c and e show means (black line) ± one standard error (medium gray), and ± one standard deviation (light gray), of maximum (c) and mean (e) root depths, for the stands that only contained one of the study species; the data suggest that the three species have similar average rooting depths across the sampled sites. In one site, no root or soil data were collected (missing column in panel a).

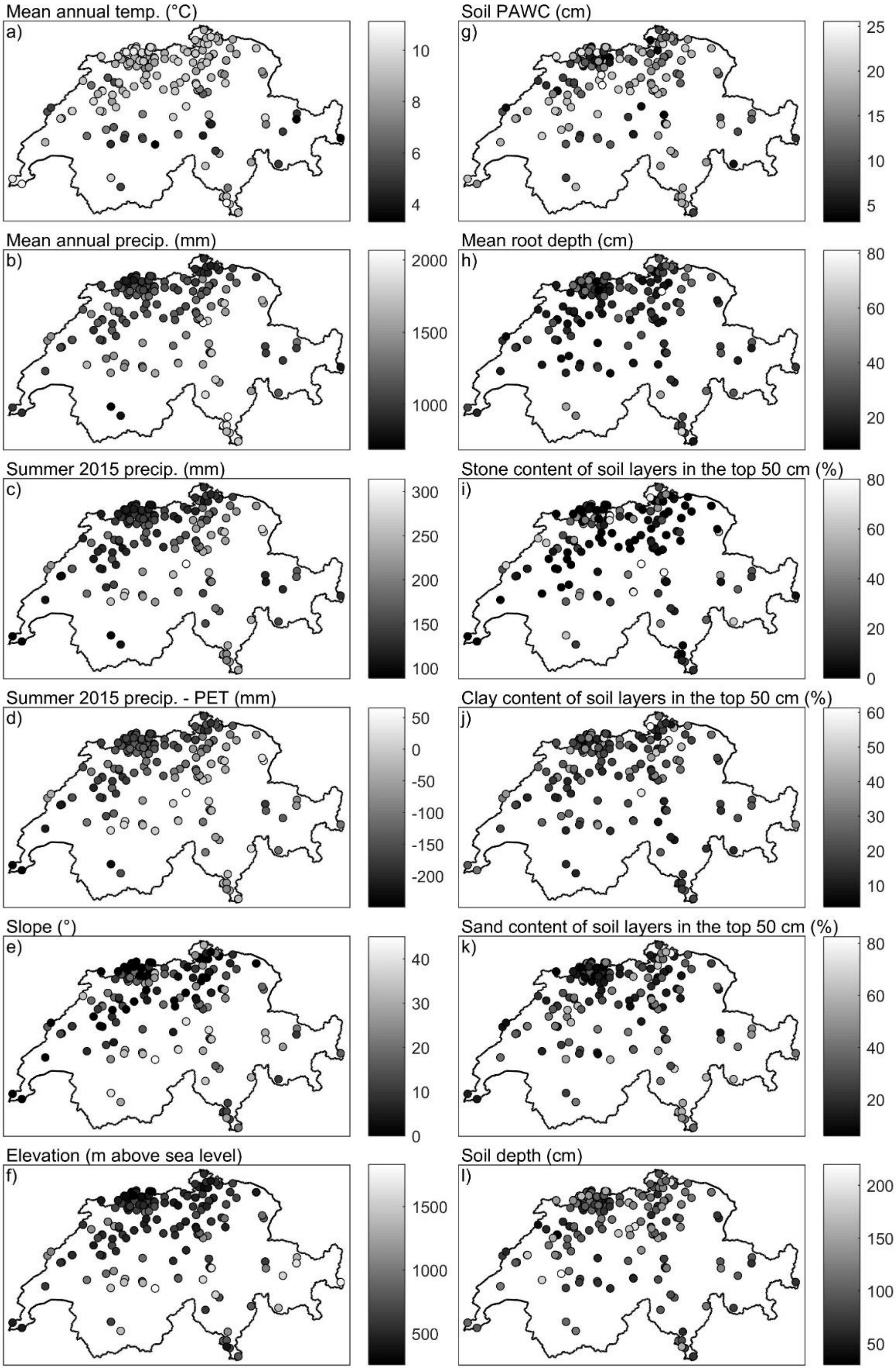

Figure S3 Mapped distributions of selected site characteristics for the 182 study sites. Panels (a-d) describe interpolated climatic data. In panel (c-d), summer is defined as June and July only, because the xylem sampling was late July through early August. In panel (d), PET is estimated by the Penman-Monteith approach. Panel (e) is the ground surface slope, measured at each site. Panel (f) is measured from a 25-m elevation map. Panels (g-l) are derived from soil-pit measurements. Soil PAWC (g) is the plant-available water capacity of the soils and root depth (h) is the depth of root-mass center, calculated from soil-pit metrics. See Table S 1 section for further details on the metrics.

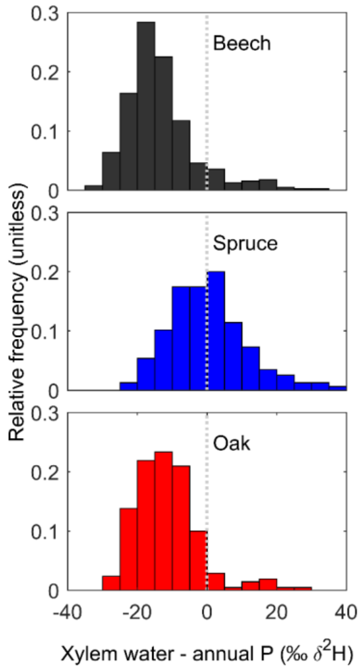

Figure S4 Distributions of measured δ^2H of tree xylem water across individuals, relative to the long-term, site-specific, volume-weighted, mean isotopic composition of precipitation (evaluated for 2007-2015). These are measured δ^2H values, not fractionation-compensated values (as shown in Fig. 2); thus, they reflect both the water origins and the effects of subsequent evaporative enrichment.

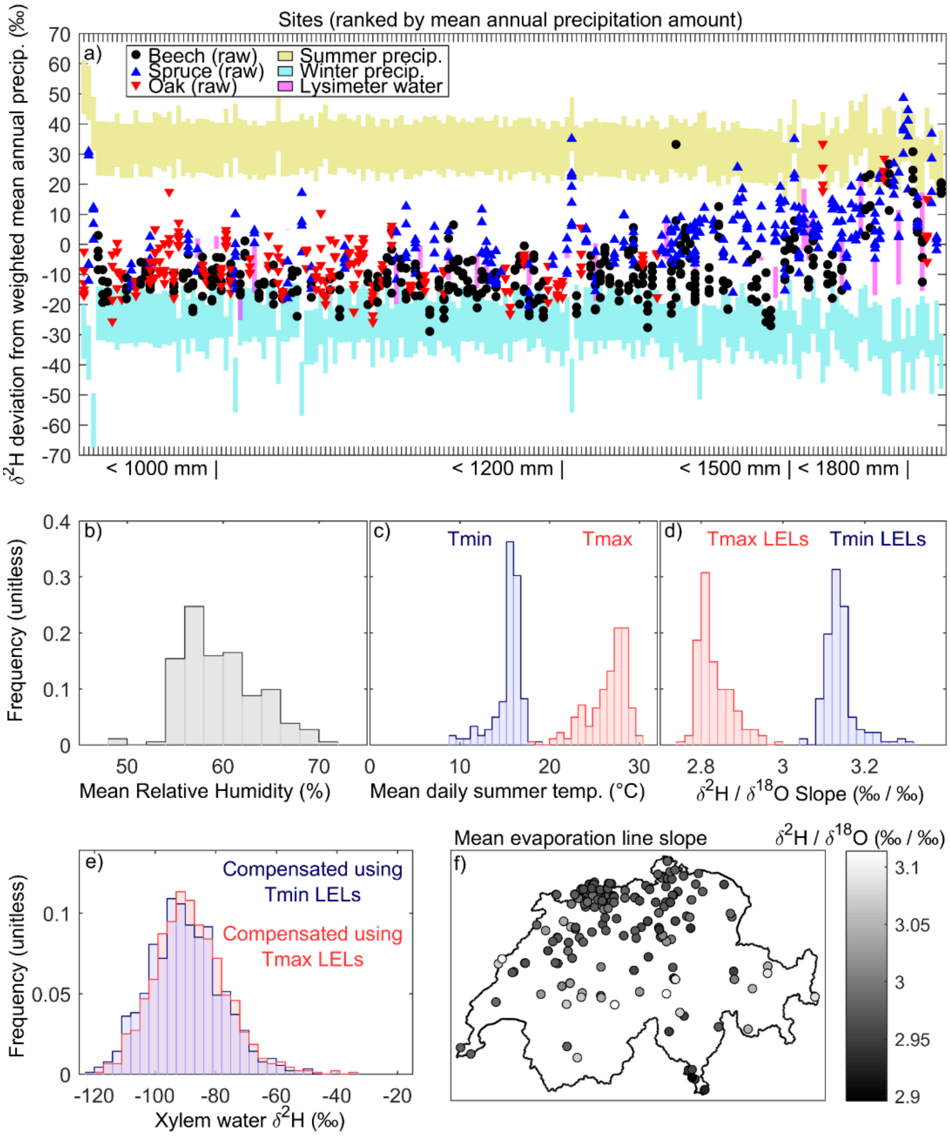

Figure S5 Effects of compensating for evaporative enrichment. Raw isotope ratios of xylem and lysimeter soil water compared to site-specific seasonal isotope cycles in precipitation (a); this panel mirrors Fig. 1, but uses raw, measured δ^2H values, instead of fractionation-compensated values (as used in Figs. 1-4 and panel e). The fractionation-compensated values of xylem and lysimeter soil water are based on deviations of those observations from local meteoric water lines (δ^2H versus δ^{18}O of precipitation), which we assumed diverged from original mixtures of precipitation, reflecting the lysimeter soil waters' seasonal origins, along local evaporation line slopes (LEL; see Methods for more details). LELs were modeled as a function of relative humidity and temperature at each site; distributions of 2015 summer mean humidity, and summer mean daily maximum (Tmax) and minimum temperature (Tmin) at each site, are shown in b and c. Site-specific LEL slopes were computed (d) from these climate input variables (b and c), using the Craig-Gordon approach (following Benettin et al.[18]); Tmin and Tmax were used to constrain the range of reasonable expect LEL slope values, which were then used to compensate the 918 xylem sample values (e) for fractionation. The mean difference resulting from using the upper versus lower LEL slope was 1.5±0.7 ‰ δ^2H (mean ± standard deviation), with steeper slopes shifting xylem values towards further winter precipitation values. Throughout the paper, for fractionation compensation, we used site-specific LEL slopes that were an average of the slopes calculated at Tmin and Tmax (mapped in panel f).

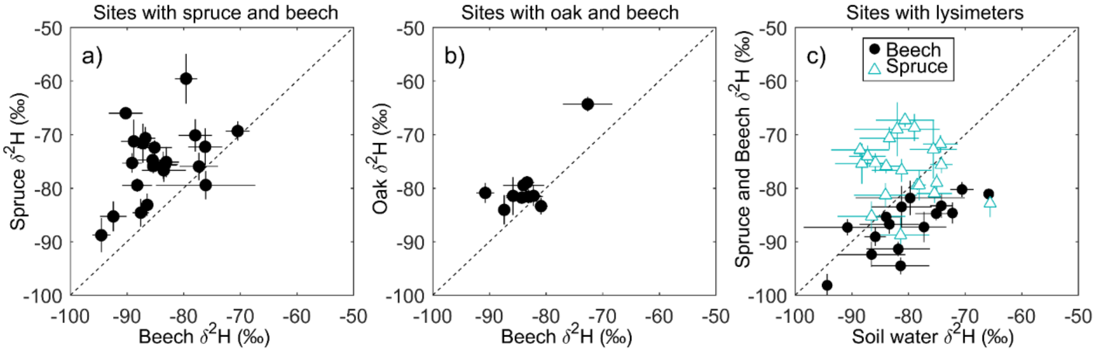

Figure S6 Pairwise comparisons of non-fractionation-compensated δ^2H for sites where a) spruce and beech are collocated, b), oak and beech are collocated, and c), trees and lysimeters are collocated. Symbols indicate means ± 1 standard error. A 1:1 line is plotted for reference, highlighting that (a) spruce used more summer-sourced water than beech, whereas (b) beech and oak used similar water supplies. Additionally, (c) spruce used water similar to soil water from lysimeters, unlike beech. These are measured δ^2H values, not fractionation-compensated values (as shown in Fig. 4); thus, they reflect both the water origins and the effects of subsequent evaporative enrichment.