Supplement

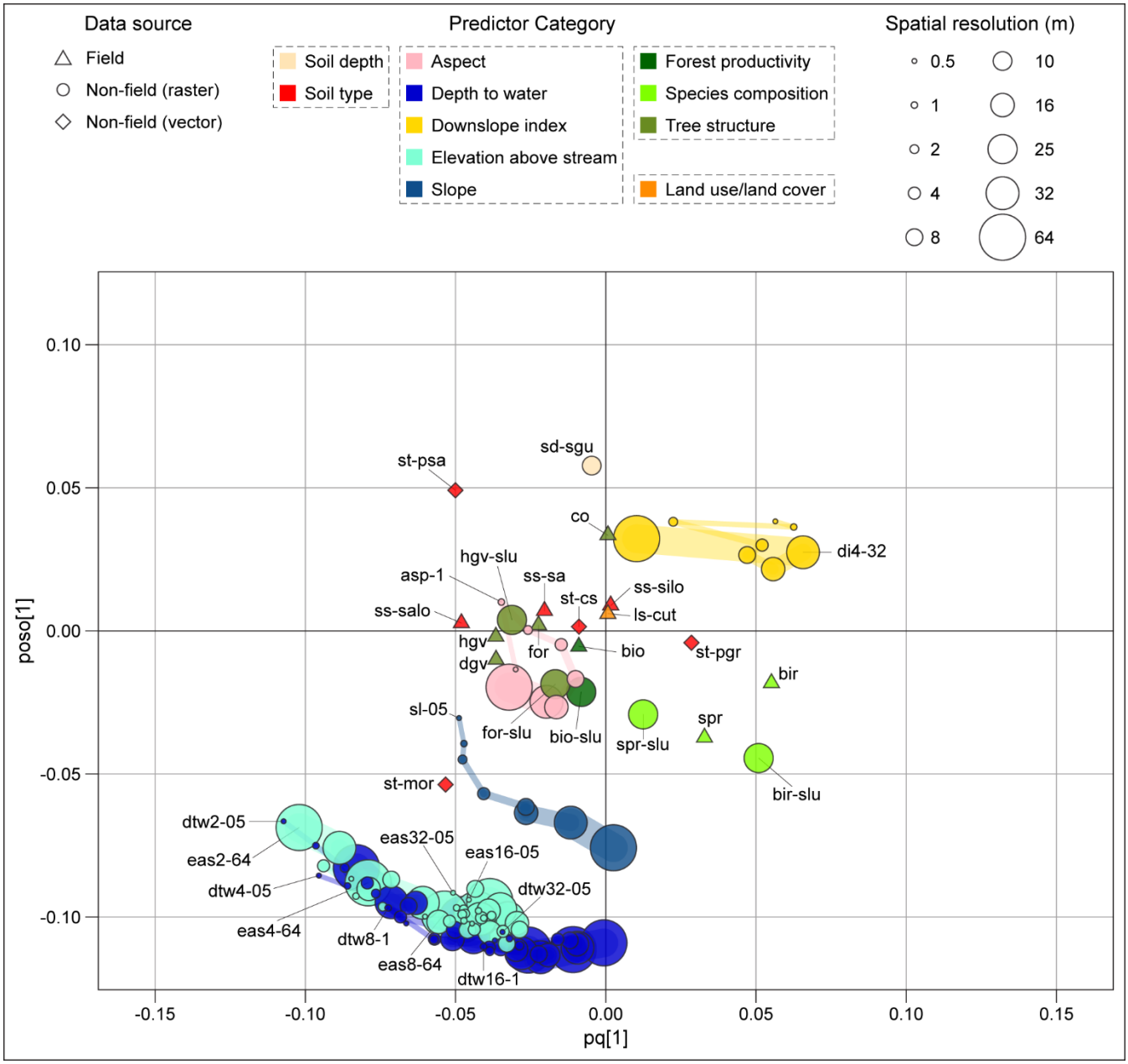

Figure S1. OPLS loading plot showing the relationship between a large array of "spatial" predictors, which vary spatially but remain constant over time, and the mean seasonal soil moisture (July 5 – October 4, 2022). Both the spatial predictors (X-variables) and the determinant (Y-variable) were gathered for 82 sites across the Krycklan catchment (Fig. 1 for the site locations). The spatial predictors, overall describing soil, topography, vegetation, and land use/land cover at each site (grey dotted boxes in the figure legend) were either directly measured in situ (symbolized by triangles) or estimated through remote sensing or modeling techniques (depicted as circles or rhombuses depending on

the dataset format). These predictors were organized into 18 color-coded categories (see Table 1; here only 11) to enhance plot readability. Gridded (i.e., raster) predictors are characterized by a certain spatial resolution, represented by the size of the circles. To visualize the effects of spatial resolution, guides connect loadings of the same variable moving from high to low resolutions, with the variable name visible only in correspondence of the optimal resolution (refer to Table 1 for variable labels). High positive and negative loadings on the predictive axis (pq[1]) represent variables that are positively and negatively correlated with the response variable (Y), with stronger correlation further way from the origin. The orthogonal axis (poso[1]) indicates how much of the variation for each variable was not correlated with the response variable (Y). This figure only shows the 23 least relevant predictors ($VIP_{predictive}$ smaller than 1, without asterisk in Table 1) as well as the less-performing layers (i.e., non-optimal user-defined thresholds) of three topographic indices (i.e., depth to water, downslope index, and elevation above stream).

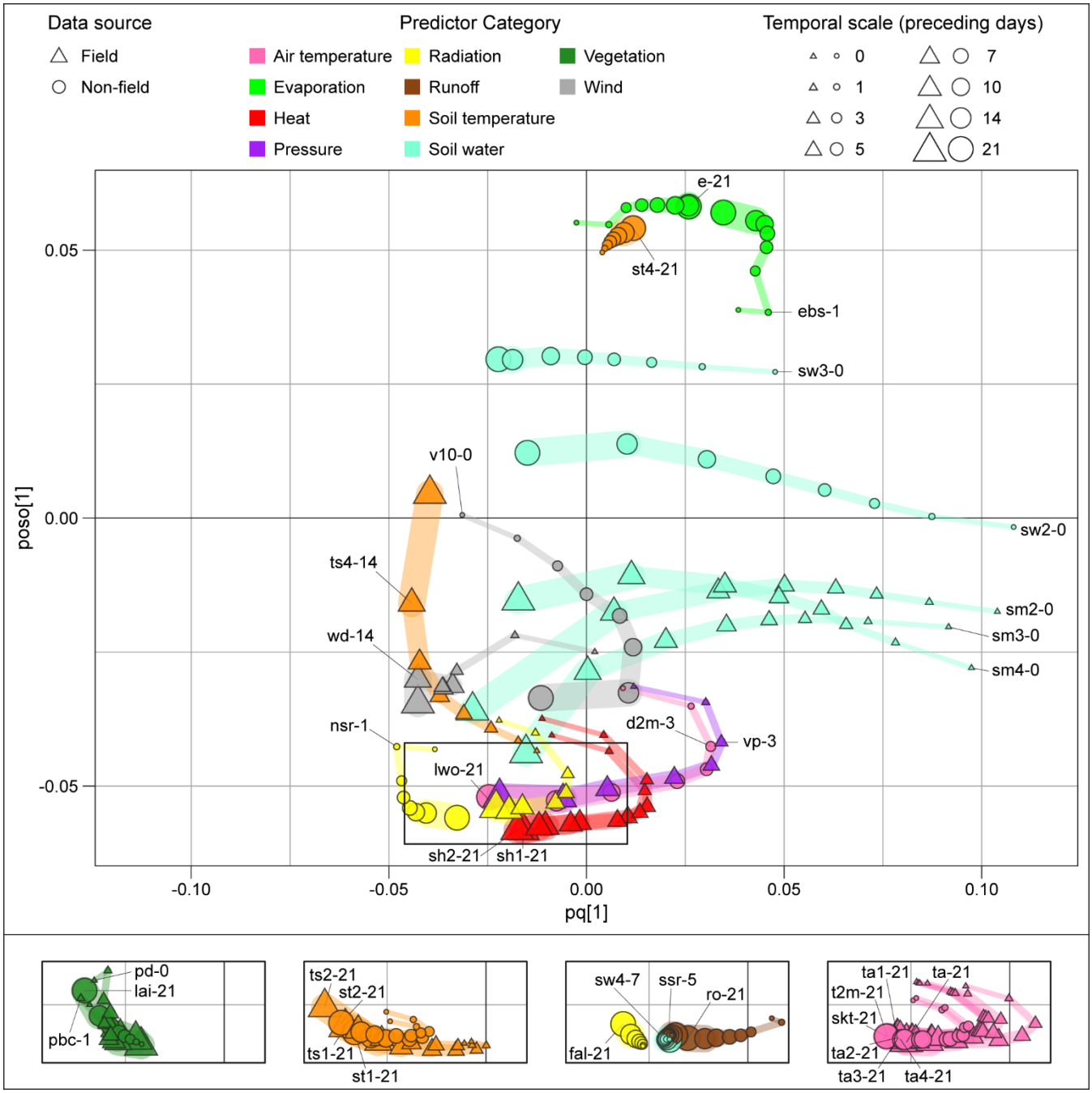

Figure S2. OPLS loading plot illustrating the relationship between a large array of "temporal" predictors, which do not vary spatially but change over time, and daily mean soil moisture (i.e., volumetric water content) averaged across 82 sites within the Krycklan catchment (refer to Fig. 1 for the site locations). Both the temporal predictors (X-variables) and the determinant (Y-variable) were aggregated at the daily temporal scale from July 5th to October 4th, 2022. The temporal predictors were either directly measured at the ICOS tower or at weather stations within Krycklan (symbolized by triangles) or extracted from the ERA5-Land dataset (depicted as circles). These predictors were organized into 12 color-coded categories (see Table 2; here only 10) to enhance plot readability. All predictors are characterized by a certain temporal scale, represented by the size of the triangles or circles. To visualize the effects of temporal scale, guides connect loadings of the

same variable moving from high to low scales, with the variable name visible only in correspondence of the optimal scale (refer to Table 2 for variable labels). High positive and negative loadings on the predictive axis (pq[1]) represent variables that are positively and negatively correlated with the response variable (Y), with stronger correlation further way from the origin. The orthogonal axis (poso[1]) indicates how much of the variation for each variable was not correlated with the response variable (Y). This figure only shows the 35 least relevant predictors ($VIP_{predictive}$ smaller than 1, without asterisk in Table 2). Because many variables that did not explain the temporal variability in soil moisture (including all air temperature predictors) clustered in the bottom- central part of the graphic, we quadruplicated that plot area (black rectangle box) to help visualize all overlapping loadings.

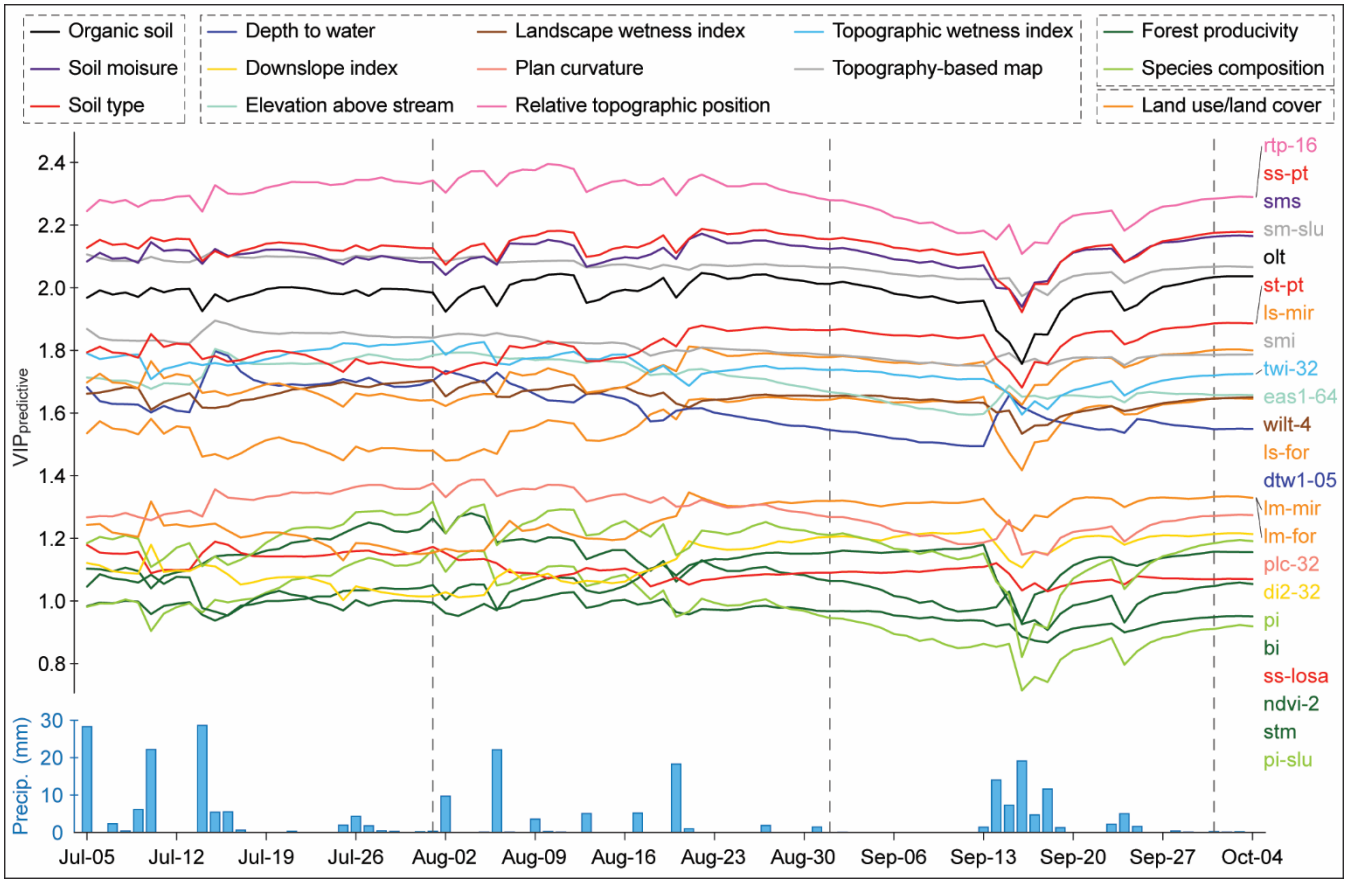

Figure S3. $VIP_{predictive}$ values of 92 spatial OPLS models generated using mean daily soil moisture over the study season (July 5th – October 4th, 2022) as the response variable (Y). The lower section of the figure displays the mean precipitation across Krycklan derived from weather stations (refer to Fig. 1 for their locations). The spatial predictors, overall describing soil, topography, vegetation, and land use/land cover at each site (grey dotted boxes in the figure legend), were organized into 18 color-coded categories (see Table 1; here only 14) to enhance plot readability. This graphic includes all 23 relevant predictors ($VIP_{predictive}$ greater than 1) identified in Fig. 3. Color-coded labels on the right side of the figure are ordered according to their $VIP_{predictive}$ on the last day of the study season (October 4, 2022), with a limited number of callouts (lines connecting time series to their corresponding labels) showed to reduce clutter.

Table S1. Results of the Mann-Kendall test for seasonal trends in soil moisture (July 5 – October 4, 2022) across 82 study plots. The table presents the p-value, Kendall's correlation coefficient (τ), Theil-Sen's slope, and the overall seasonal change in soil moisture (%). Study plots exhibiting significant positive trends (95% confidence interval) are highlighted in green (15), while those with significant negative trends are highlighted in purple (7). Refer to Fig. 2bc for details regarding location and daily time series plot associated with these trends.

Plot ID	p value	Kendall's τ	Theil-Sen's slope	Seasonal change (%)
19	0.66851	-0.06	-0.010	-1.0
39	0.81263	0.04	0.008	0.7
68	0.00268	-0.39	-0.049	-4.5
74	0.95169	-0.01	-0.001	-0.1
78	0.80788	0.02	0.006	0.5
82	0.93293	0.01	0.002	0.2
89	0.42147	0.08	0.011	1.0
128	0.94508	0.01	0.001	0.0
143	0.02439	0.25	0.025	2.3
144	0.35714	0.11	0.015	1.4
145	0.05644	0.24	0.015	1.4
146	0.06576	0.19	0.028	2.6
160	0.00848	0.28	0.059	5.5
165	0.58739	0.06	0.011	1.0
166	0.27845	0.13	0.020	1.8
167	0.36520	0.12	0.021	2.0
168	0.22595	-0.18	-0.026	-2.4
169	0.00218	0.57	0.074	6.8
170	0.71165	-0.06	-0.009	-0.8
171	0.00303	-0.44	-0.031	-2.9
175	0.08875	-0.25	-0.025	-2.3
187	0.00085	0.39	0.059	5.4
188	0.43330	0.12	0.008	0.7
189	0.00061	0.33	0.084	7.7
190	0.00004	0.44	0.062	5.7
191	0.00757	0.26	0.027	2.5
192	0.12728	0.16	0.044	4.0
193	0.86099	0.02	0.003	0.3
194	0.49989	0.09	0.015	1.4
215	0.43426	-0.10	-0.006	-0.5
216	0.93496	0.01	0.001	0.1
217	0.00064	-0.38	-0.047	-4.3
218	0.58538	0.06	0.010	0.9
219	0.08877	0.21	0.026	2.4
220	0.89510	-0.02	-0.010	-1.0
221	0.33676	0.12	0.013	1.2

Plot ID	p value	Kendall's τ	Theil-Sen's slope	Seasonal change (%)
226	0.03561	0.23	0.023	2.1
241	0.01996	0.26	0.040	3.6
242	0.89854	-0.02	-0.001	0.0
243	0.00214	0.33	0.065	5.9
245	0.37990	0.10	0.011	1.0
246	0.32236	0.14	0.021	1.9
248	0.01925	-0.39	-0.060	-5.5
255	0.90654	-0.02	-0.005	-0.4
269	0.58623	0.09	0.013	1.2
270	0.03557	0.24	0.035	3.2
271	0.30117	0.14	0.024	2.2
272	0.22157	0.12	0.022	2.0
273	0.68938	-0.07	-0.016	-1.5
274	0.31230	-0.17	-0.060	-5.5
275	0.60222	-0.08	-0.011	-1.0
295	0.22107	0.14	0.034	3.1
297	0.46745	0.07	0.010	0.9
298	0.22518	-0.16	-0.044	-4.0
299	0.90341	-0.02	-0.002	-0.2
300	0.64646	-0.06	-0.012	-1.1
301	0.23379	0.14	0.026	2.4
302	0.25970	-0.17	-0.020	-1.9
303	0.73494	-0.06	-0.009	-0.8
307	0.77466	0.05	0.011	1.0
329	0.02465	-0.36	-0.035	-3.3
341	0.14689	0.12	0.004	0.4
347	0.90653	-0.02	-0.002	-0.2
378	0.23631	0.21	0.036	3.3
384	0.35964	-0.12	-0.007	-0.7
385	0.00000	0.52	0.062	5.7
401	0.80264	0.04	0.005	0.5
402	0.00000	0.54	0.111	10.2
409	0.08000	-0.24	-0.024	-2.2
418	0.43978	0.10	0.021	1.9
419	0.20376	0.17	0.018	1.7
420	0.03442	0.27	0.020	1.8
460	0.00726	-0.37	-0.027	-2.5
464	0.58583	-0.08	-0.006	-0.6
468	0.13493	-0.23	-0.041	-3.8

Plot ID	p value	Kendall's τ	Theil-Sen's slope	Seasonal change (%)
475	0.54698	-0.08	-0.019	-1.8
485	0.47148	-0.12	-0.007	-0.6
500	0.00797	-0.58	-0.091	-8.4
0001	0.89021	-0.01	-0.001	-0.1
0002	0.00742	0.28	0.046	4.3
S1	0.28067	0.15	0.019	1.7
S22	0.22290	0.14	0.017	1.5