Supplementary Materials

Table S1. Mean characteristics and location of declining (D) and non-declining (N) silver fir stands analyzed using two vegetation indices (NDVI, EVI).

Id	Name	Status	Elevation (m)	Latitude ºN	Longitude -ºW, +ºE	NDVI mean	NDVI SD	EVI mean	EVI SD
1	Paco de Ulló	D	948	42.7361131	-0.91086698	0.791476	0.045577	2.143932	0.196815
6	Lopetón	D	996	42.7619239	-0.84678275	0.769175	0.065823	2.072827	0.267934
7	Paco Ezpela Oeste	D	991	42.7556644	-0.85069466	0.790252	0.052024	2.10486	0.21229
8	Paco Ezpela Este	D	1179	42.7443833	-0.83563547	0.778427	0.048069	1.997564	0.191183
11	Bal de las Fuentes	D	982	42.7239143	-0.88109475	0.781901	0.053346	2.070854	0.214658
25	Labati	D	1199	42.7431708	-0.64990108	0.79282	0.051176	2.070904	0.184475
28	Laña	D	1232	42.7106572	-0.64441613	0.780649	0.058182	1.979146	0.22575
49	Albarún Oeste	D	1490	42.67584	-0.50226288	0.746831	0.056741	1.965662	0.765058
50	Albarún Este	D	1132	42.6386566	-0.5344729	0.767684	0.068528	2.043958	0.224912
51	Pacón de Acín	D	1355	42.610561	-0.51220082	0.756968	0.043281	1.903134	0.212555
52	Moscatuero	D	1464	42.6063707	-0.50365747	0.734547	0.037225	1.822817	0.1867
53	Paco de Guané	D	1348	42.6072899	-0.45631428	0.746035	0.049332	1.931948	0.205333
54	Barranco de San Salvador	D	1520	42.6138939	-0.44206825	0.71243	0.055348	1.747424	0.208831
55	Collado barranco de San Salvador	D	1441	42.6191266	-0.43609222	0.759612	0.052771	1.933838	0.251863
56	Bco. Carboneras	D	1509	42.5193732	-0.51814058	0.739649	0.051411	1.809026	0.227265
57	Cuculo Este	D	1195	42.5141897	-0.72545827	0.796977	0.064211	2.071004	0.197772
58	San Salvador	D	1372	42.5150506	-0.71741129	0.771236	0.072023	1.93056	0.240759
59	Oza Este-Ñetera	D	1134	42.5145665	-0.70854655	0.760969	0.055638	1.93424	0.197789
60	La Selba	D	1176	42.5216124	-0.70466171	0.767858	0.044291	1.927874	0.161912
62	Basari Burgui	D	787	42.7268304	-0.97043285	0.798	0.0493	2.201	0.1447
2	Maz	N	1417	42.8911018	-0.81407112	0.804936	0.085238	2.09959	0.310328
3	Gamueta	N	1426	42.8839015	-0.79440265	0.803751	0.077999	2.123368	0.295512
4	Las Eras	N	1323	42.8765528	-0.8075804	0.822574	0.090344	2.155042	0.298967
5	Bco. Marcón	N	1059	42.8176941	-0.82509547	0.818433	0.061867	2.210855	0.21555
9	Bal de Achá	N	921	42.7475897	-0.80768412	0.769494	0.049379	2.082984	0.26644
10	Bal de a Basa	N	1008	42.7280717	-0.88803085	0.803527	0.052445	2.099396	0.195986
12	Berrichú	N	928	42.7259794	-0.83424296	0.803625	0.05463	2.15374	0.216868
13	Oza Oeste-Tortiella	N	1252	42.8391556	-0.71617265	0.815176	0.055357	2.159332	0.288614

14	Paco Astial	N	1295	42.8286046	-0.71817824	0.822679	0.061737	2.242442	0.85497
15	Oza Subordán	N	1203	42.8451075	-0.70980444	0.763551	0.067769	2.298357	2.183401
16	Paco de la Espata	N	1239	42.8347605	-0.70224316	0.801773	0.070095	2.210682	2.000385
17	Lo Jardín	N	1252	42.8263274	-0.70379824	0.825141	0.072249	2.46507	1.860044
18	Paco Romaceite	N	1100	42.8186164	-0.71096513	0.76581	0.09092	2.166856	1.220361
19	Corralones Oeste-Articuso	N	1262	42.7468548	-0.69823089	0.758078	0.078951	1.992654	0.259044
20	Corralones Este-Articuso	N	1323	42.7587522	-0.62979944	0.725708	0.079758	1.884857	0.445391
21	Corralones Sudoeste	N	1319	42.7573148	-0.62942138	0.803414	0.066919	2.299048	0.67142
22	Fuente del bosque	N	1242	42.7528714	-0.63229838	0.796779	0.065891	2.153605	0.179181
23	Cuangas	N	1254	42.7507493	-0.63161263	0.817733	0.053984	2.258123	0.252832
24	Bco. Cambrones	N	1366	42.7455116	-0.63219976	0.801057	0.051182	2.194511	0.361744
26	Labayo	N	1202	42.7375663	-0.6447466	0.789532	0.059411	2.172782	0.264395
27	Paco Mayor	N	1068	42.7291236	-0.65557542	0.738927	0.060155	1.880807	2.679661
29	Cozarrón	N	1378	42.7168526	-0.59747919	0.775998	0.062804	2.039881	0.256273
30	Fuen de Chamburro	N	1167	42.7035762	-0.61092147	0.760375	0.05993	2.0308	0.820636
31	Articazos	N	1455	42.7005032	-0.60308786	0.755018	0.053593	1.918553	0.206225
32	Barranco Abetar	N	1371	42.697294	-0.60370681	0.761561	0.052379	1.990261	0.268596
33	Plana Agustín	N	1380	42.6939157	-0.60428926	0.767515	0.047172	1.969902	0.223453
34	Terreraz	N	1476	42.6933585	-0.58708876	0.811525	0.044766	2.046833	0.163342
35	Solano de Lierde	N	1490	42.6806103	-0.57117158	0.724429	0.056147	1.854987	0.288152
36	Paco de Lierde	N	1288	42.6990025	-0.5474049	0.78084	0.075076	1.992262	0.242197
37	Canal Roya-Chiniprés	N	1384	42.6979481	-0.55202403	0.778348	0.052761	2.02264	0.201643
38	Pico del Águila Este	N	1390	42.7784978	-0.50221997	0.755125	0.062818	2.087597	0.245574
39	Col de Ladrones-Picaubé	N	1411	42.7608659	-0.51801654	0.802392	0.049196	2.256001	0.265203
40	Arañones	N	1456	42.7570506	-0.50511039	0.791158	0.06641	2.529467	1.280108
41	Samán-Ladera presa Este	N	1347	42.7502995	-0.50793737	0.789552	0.055655	2.657524	2.23018
42	Larrón bajo	N	1332	42.7396163	-0.51562196	0.745219	0.088577	3.242238	14.67348
43	Aguaré-Gabardito	N	1563	42.7379518	-0.51277635	0.75121	0.065809	2.395057	2.435593
44	Los Abetazos	N	1467	42.7215516	-0.53582377	0.799747	0.043474	2.054454	0.184301
45	Los Azuds 1 y 2	N	1436	42.7170914	-0.53794251	0.798651	0.041939	2.043563	0.185835
46	Los Forqués	N	1493	42.7023134	-0.51504761	0.725339	0.06102	2.031275	0.917043
47	Picerbera	N	1613	42.6857957	-0.4821531	0.694908	0.057773	1.916946	0.331107
48	La Selba	N	1462	42.6844028	-0.49022795	0.738287	0.067844	2.287182	1.249547
61	Paco Oroel	N	1396	42.5094955	-0.69971715	0.748863	0.068053	1.803939	0.203114

Table S2. Mean characteristics and location of declining (D) and non-declining (N) silver fir stands analyzed using dendrochronological methods. TRW is the mean tree-ring width for the period 1984-2000

Id	Name	Status	TRW (mm)	EVI 1984-2023	EVI 1984-2003	EVI 2004-2023	Dead trees 2000 (%)	Defoliation 1984-2003	Defoliation 2004-2023	Δ EVI	Δ Defoliation
1	Paco de Ulló	D	1.85	2.143	2.197	2.199	No data	No data	29	0.002	No data
3	Gamueta	N	2.19	2.123	2.277	2.275	0	0	2	-0.002	2
4	Las Eras	N	2.1	2.155	2.264	2.377	0	0	0	0.113	0
6	Lopetón	D	1.48	2.072	2.174	2.3	12	30	36	0.126	6
8	Paco Ezpela Este	D	1.68	1.997	2.033	2.096	11.3	46	65	0.063	19
12	Berrichú	N	2.44	2.153	2.196	2.24	0	0	15	0.044	15
13	Oza O.-Tortiella	N	2.44	2.159	2.242	2.26	5	12	17	0.018	5
21	Corralones SO	N	3.67	2.299	2.366	2.433	5	14	20	0.067	6
28	Laña	D	2.25	1.979	1.924	2.083	10	32	35	0.159	3
37	Canal Roya-Chiniprés	N	3.08	2.022	2.089	2.08	0	9	12	-0.009	3
45	Los Azuds 1 y 2	N	4.7	2.043	2.111	2.185	0	0	5	0.074	5
49	Albarún Oeste	D	1.98	1.965	2.171	2.044	2	20	37	-0.127	17
50	Albarún Este	D	1.31	2.043	2.146	2.058	0	0	45	-0.088	45
52	Moscatuero	D	No data	1.822	1.908	1.88	No data	No data	41	-0.028	No data
56	Bco. Carboneras	D	2.75	1.809	1.599	1.849	0	0	35	0.25	35
60	La Selba	D	2.37	1.927	1.866	1.937	0	0	No data	0.071	0

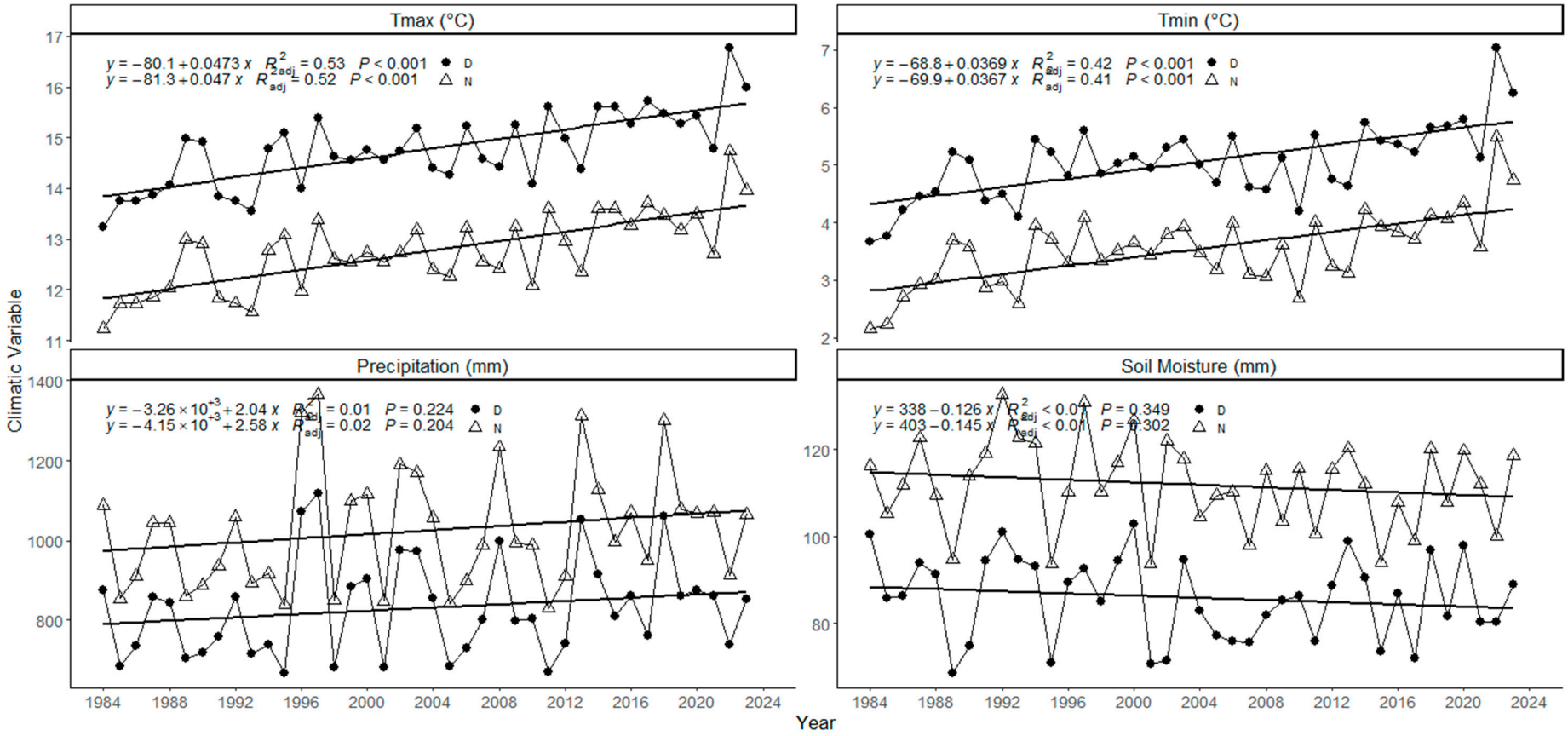

Figure S1. Long-term climatic trends for declining (D, black circles) and non-declining (N, white triangles) silver fir stands from 1984 to 2023. The panels show trends for maximum temperature (Tmax), minimum temperature (Tmin), precipitation, and soil moisture. Linear regressions are fitted for D and N stands, with corresponding equations, adjusted R^2 values, and *p* values displayed in each panel.

Table S3. Summary of Vapor Pressure Deficit (ANCOVA results).

Term	Estimate	Std. Error	t value	p-value	R2	adj_R2	
(Intercept)	-6.57674	1.216376	-5.40683	7.14E-07	0.629543		0.61492
year	0.003565	0.000607	5.872137	1.06E-07	0.629543		0.61492
Status	1.093436	1.720215	0.635639	0.526920972	0.629543		0.61492
year:Status	-0.00059	0.000859	-0.68407	0.496014198	0.629543		0.61492

Table S4. Summary of Cumulative Water Deficit (ANCOVA results).

Term	Estimate	Std. Error	t value	p-value	R2	adj_R2	
(Intercept)	-4505.29	1909.305	-2.35965	0.020860585	0.483534		0.463147
year	2.420127	0.952969	2.539566	0.013141281	0.483534		0.463147
Status	2156.663	2700.164	0.798716	0.426944371	0.483534		0.463147
year:Status	-1.13803	1.347701	-0.84442	0.401084016	0.483534		0.463147

Table S5. Summary of maximum temperature (ANCOVA results).

Term	Estimate	Std. Error	t value	p-value	R2	adj_R2	
(Intercept)	-80.0521	14.25717	-5.61486	3.07E-07	0.836243		0.829779
year	0.047324	0.007116	6.650419	3.97E-09	0.836243		0.829779
Status	-1.28794	20.16268	-0.06388	0.949235	0.836243		0.829779
year:Status	-0.00036	0.010064	-0.03597	0.971402	0.836243		0.829779

Table S6. Summary of minimum temperature (ANCOVA results).

Term	Estimate	Std. Error	t value	p-value	R2	adj_R2	
(Intercept)	-68.8218	13.7067	-5.02103	3.30E-06	0.760372		0.750913
year	0.036867	0.006841	5.388853	7.68E-07	0.760372		0.750913
Status	-1.11283	19.38421	-0.05741	0.954370156	0.760372		0.750913
year:Status	-0.0002	0.009675	-0.02062	0.983606496	0.760372		0.750913

Table S7. Summary of precipitation (ANCOVA results).

Term	Estimate	Std. Error	t value	p-value	R2	adj_R2	
(Intercept)	-3264.68	3671.386	-0.88922	0.376689	0.375928		0.351294
year	2.043597	1.832456	1.115223	0.268269	0.375928		0.351294
Status	-884.519	5192.124	-0.17036	0.865181	0.375928		0.351294
year:Status	0.538884	2.591484	0.207944	0.835829	0.375928		0.351294

Table S8. Summary of soil moisture (ANCOVA results).

Term	Estimate	Std. Error	t value	p-value	R2	adj_R2	
(Intercept)	337.7249	271.5945	1.243489	0.21751	0.650261		0.636456
year	-0.12574	0.135558	-0.92761	0.356546	0.650261		0.636456
Status	64.78133	384.0926	0.168661	0.866512	0.650261		0.636456
year:Status	-0.0193	0.191708	-0.10066	0.920084	0.650261		0.636456

Table S9. Relevant results of climatic variables (means) and t tests between declining (D) and non-declining (N) stands.

Variable	D	N	test p-value	95% Confidence Interval of the Difference (Lower)	95% Confidence Interval of the Difference (Upper)
Vapor Pressure Deficit (kPa)	0.57	0.48	<0.01	0.06	0.11
Cumulative Water Deficit (mm)	343.44	220.06	<0.01	91.15	155.60
Maximum temperature (ºC)	14.76	12.75	<0.01	1.68	2.35
Minimum temperature (ºC)	5.04	3.53	<0.01	1.22	1.80
Precipitation (mm)	829.66	1024.80	<0.01	-255.19	-135.08
Soil Moisture	85.79	111.91	<0.01	-30.52	-21.71

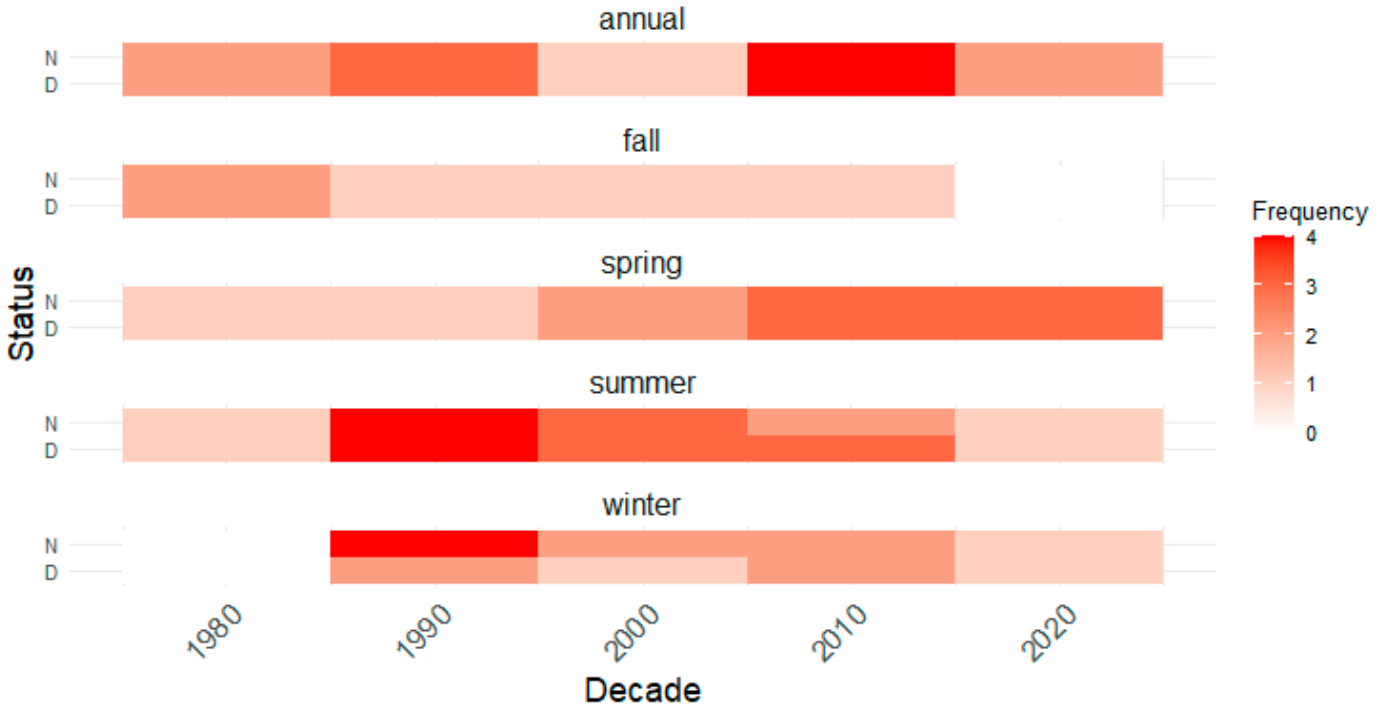

Figure S2. Drought event frequency by decade for declining (D) and non-declining (N) silver fir stands in the hydrological year by decades from 1985 to 2024. The heatmap shows the frequency of drought events, defined as SPEI values below -1 on the drought index, across the year and different seasons (fall, spring, summer, and winter) for N and D stands. The 1980s and 2020s cover only five years.

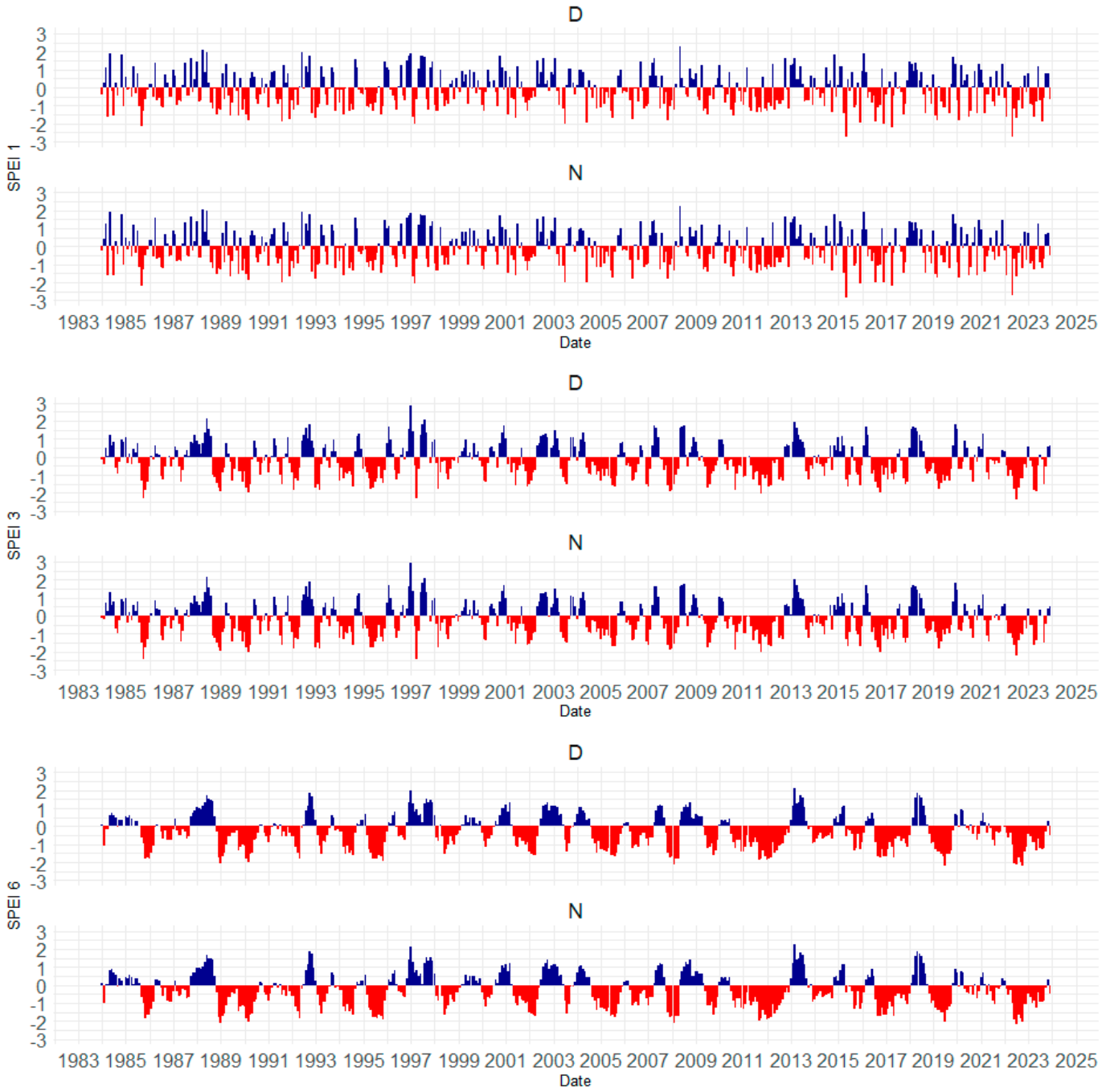

Figure S3. SPEI calculated at 1-, 3- and 6-month long scales in declining (D) and non-declining (N) silver fir stands.

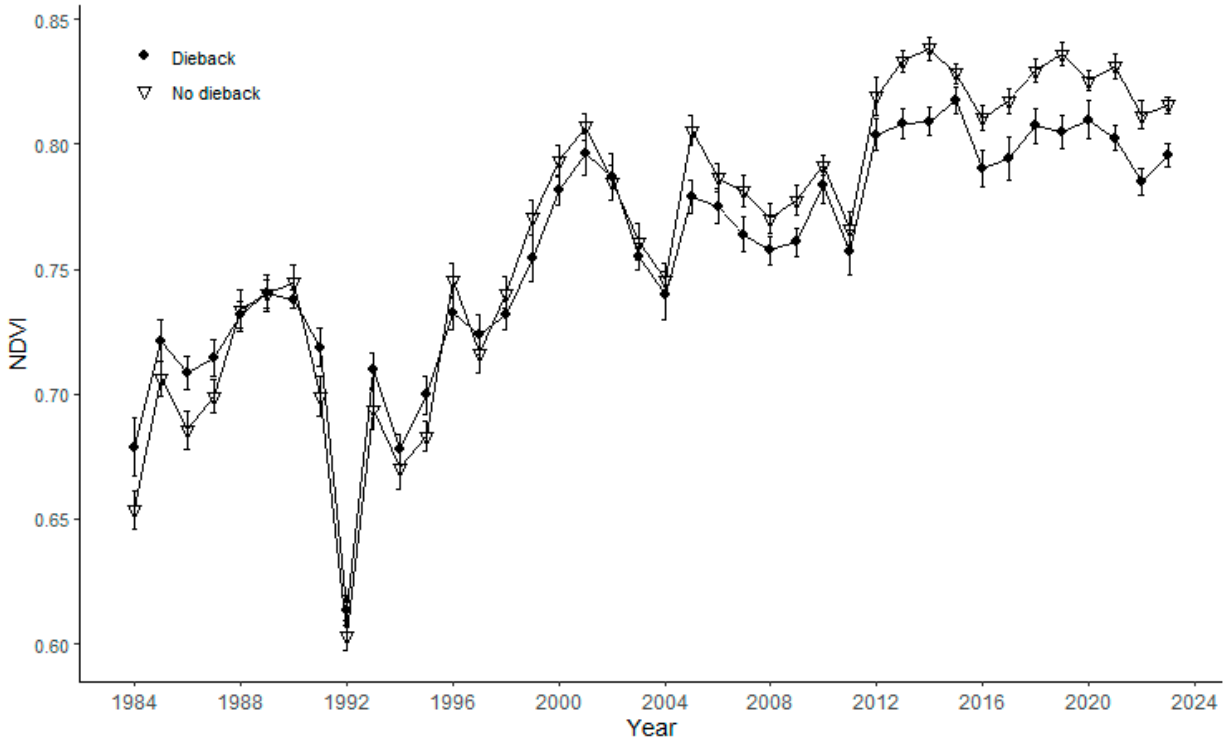

Figure S4. Long-term trends of NDVI (Normalized Difference Vegetation Index) for declining (Dieback, black circles) and non-declining (No dieback, open triangles) silver fir stands from 1984 to 2023. Error bars indicate the standard error for each year. No significant differences between the groups were observed.

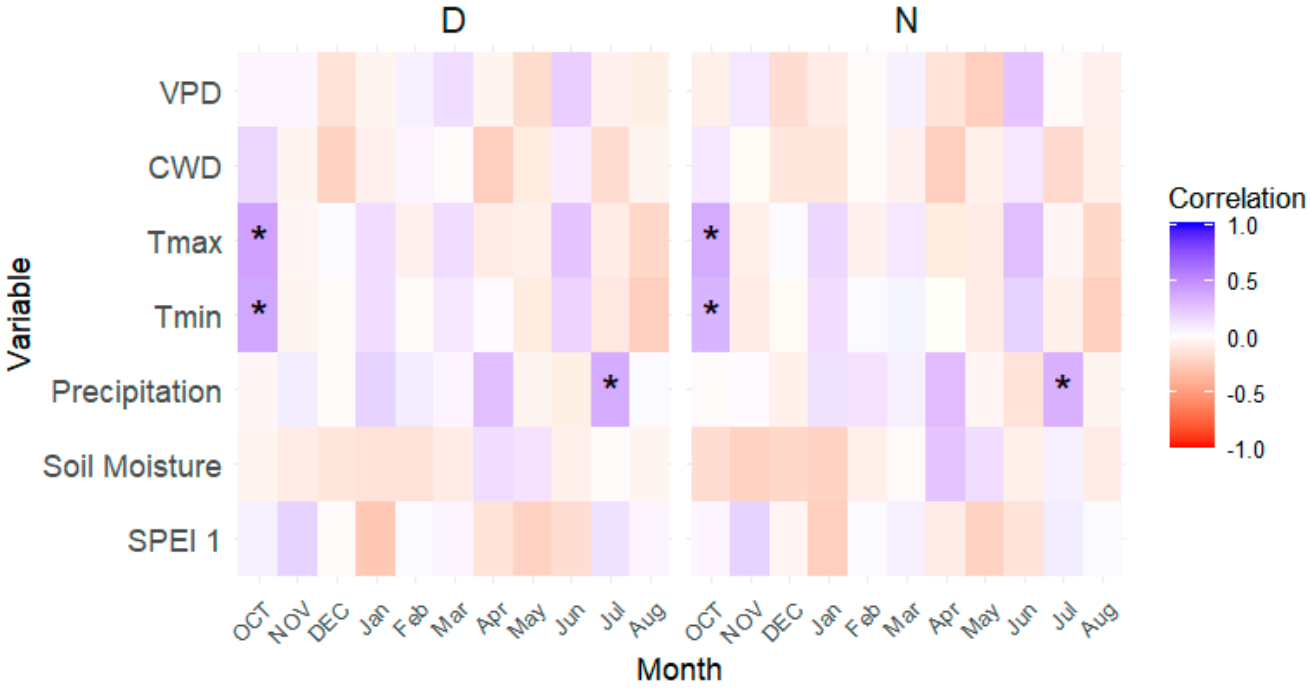

Figure S5. Monthly correlations calculated between the 1-month SPEI drought index and climatic variables (VPD, CWD, Tmax, Tmin, precipitation, soil moisture) and NDVI for declining (D) and non-declining (N) silver fir stands. Correlations were obtained from the previous October to the current (growth year) August. Significant correlations are marked with an asterisk (*) for $p < 0.05$.