

## Supplemental Information for:

### Disentangling the effects of geographic peripherality and habitat suitability on neutral and adaptive genetic variation in Swiss stone pine

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**TABLE S1 Details of the 24 *Pinus cembra* populations sampled in this study.** Latitude and longitude are given in decimal degrees (WGS84). Populations were classified as part of eastern or western Swiss lineages based on Figure 4a and in agreement with Gugerli et al. (2009).

Sample	Population	Lineage	Latitude [° N]	Longitude [° E]
CH-005	Chandolin	Western	46.255813	7.604929
CH-008	Forêt du Lapé	Western	46.550490	7.222450
CH-011	Avers	Eastern	46.462871	9.519770
CH-015	Tamangur	Eastern	46.667218	10.359082
CH-019	Arvengarten	Western	46.585674	7.965694
CH-023	Bergün	Eastern	46.625165	9.779599
CH-028	Ritom	Eastern	46.535492	8.701091
CH-032	Sex Carro	Western	46.149363	7.079443
CH-034	Val Medel	Eastern	46.628743	8.853013
CH-035	Lago Sfii	Western	46.263385	8.493403
CH-039	Selva Secca	Eastern	46.537602	8.815266
CH-045	Uerlicherblase	Western	46.504620	8.346339
CH-046	Fafleralp	Western	46.441491	7.850506
CH-052	Meder	Western	46.566919	8.294656
CH-053	Untersteinberg	Western	46.507595	7.880997
CH-113	Bürchen	Western	46.253461	7.811912
CH-150	God Giavagl	Eastern	46.515592	10.007648
EC-HJ	Davos	Eastern	46.802313	9.910626
EN-HJ	Rautialp	Eastern	47.066344	9.015172
ES-HJ	Celerina	Eastern	46.479570	9.876973
WC-HJ	Grengiols	Western	46.332396	8.147029
WN-HJ	Kandersteg	Western	46.438217	7.649997
WS-HJ	Zermatt	Western	46.025387	7.783483
WZ-HJ	Riederupalp	Western	46.384882	8.024687

**TABLE S2 Details of the environmental variables used to carry out species distribution modelling and environmental association analysis in *Pinus cembra* populations.**

Type	Abbre-viation	Variable	Description	Unit
Climate	Bio1	Yearly mean temperature	Yearly mean temperature. Average and STD of 1981-2010.	°C
	Bio2	Mean diurnal range	Mean diurnal range as the mean of monthly (max temp - min temp). Average of 1981-2010.	no unit
	Bio3	Isothermality	Isothermality assessed as $(BIO2/BIO7) \times 100$ . Average of 1981-2010.	no unit
	Bio4	Temperature seasonality	Temperature seasonality assessed as the standard deviation $\times 100$ . Average of 1981-2010.	°C
	Bio5	Max temperature of warmest month	Maximal temperature of warmest month. Average of 1981-2010.	°C
	Bio6	Min temperature of coldest month	Minimal temperature of coldest month. Average of 1981-2010.	°C
	Bio7	Temperature annual range	Temperature annual range assessed as BIO5 - BIO6. Average of 1981-2010.	°C
	Bio8	Mean temperature of wettest quarter	Mean temperature of wettest quarter. Average of 1981-2010.	°C
	Bio9	Mean temperature of driest quarter	Mean temperature of driest quarter. Average of 1981-2010.	°C
	Bio10	Mean temperature of warmest quarter	Mean temperature of warmest quarter. Average of 1981-2010.	°C
	Bio11	Mean temperature of coldest quarter	Mean temperature of coldest quarter. Average of 1981-2010.	°C
	Bio12	Yearly precipitation sum	Yearly precipitation sum. Average and STD of 1981-2010.	mm/year
	Bio13	Precipitation of wettest month	Precipitation of wettest month. Average of 1981-2010.	mm/month
	Bio14	Precipitation of driest month	Precipitation of driest month. Average of 1981-2010.	mm/month
	Bio15	Precipitation seasonality	Precipitation seasonality expressed as coefficient of variation. Average of 1981-2010.	no unit
	Bio16	Precipitation of wettest quarter	Precipitation of wettest quarter. Average of 1981-2010.	mm/quarter
	Bio17	Precipitation of driest quarter	Precipitation of driest quarter. Average of 1981-2010.	mm/quarter
	Bio18	Precipitation of warmest quarter	Precipitation of warmest quarter. Average of 1981-2010.	mm/quarter
	Bio19	Precipitation of coldest quarter	Precipitation of coldest quarter. Average of 1981-2010.	mm/quarter
Topography	t01_alt	Altitude	Altitude	m
	t02_slp	Slope	Slope	radians
	t03_eas	Eastness	Sine of aspect	radians
	t04_vcu	Profile curvature	Vertical curvature	radians/m
	t05_hcu	Horizontal curvature	Horizontal curvature	radians/m
	t06_ddg	Downslope distance gradient	Quantify downslope controls on local drainage	radians
	t07_mpi	Morphometric protection index	Represent the protection from the surrounding relief	no unit
	t08_tpi	Topographic position index	Difference between the elevation of a focal cell and the mean of its 8 surrounding cells	no unit
	t09_vrm	Vector ruggedness measure	Quantifies rugosity and topographic heterogeneity	no unit
	t10_vis	Visible sky	Ratio of the sky area over the obstructed area	no unit
	t11_svf	Sky-view factor	Ratio of the radiation received by a planar surface to the radiation emitted by the entire hemispheric environment	no unit
	t12_dfr	Potential diffuse solar radiation	Diffuse solar radiation in the growing season (May-October) without cloud correction	kwh/m <sup>2</sup>
	t13_dir	Potential direct solar radiation	Direct solar radiation in the growing season (May-October) without cloud correction	kwh/m <sup>2</sup>
	t14_twi	Topographic wetness index	Quantifies the hydrological processes	no unit
	t15_lan	Geomorphological landforms	Categorical variable consists of ten geomorphological landform classes	no unit

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**TABLE S3 Modules and parameters used to generate topographic variables (Table S2) from the digital elevation model.**

Abbreviation	Variable	Unit	Module	Parameters
t01_alt	Altitude	m	—	—
t02_slp	Slope	radians	<i>ta_morphometry 0</i>	method = 6, unit_slope = 0, unit_aspect = 0
t03_eas	Eastness	radians		
t04_vcu	Profile curvature	radians/m		
t05_hcu	Horizontal curvature	radians/m		
t06_ddg	Downslope distance gradient	gradient	<i>ta_morphometry 9</i>	distance = 10
t07_mpi	Morphometric protection index	no unit	<i>ta_morphometry 7</i>	radius = 1000
t08_tpi	Topographic position index	no unit	<i>ta_morphometry 18</i>	by default
t09_vrm	Vector ruggedness measure	no unit	<i>ta_morphometry 17</i>	radius = 1, no distance weighting
t10_vis	Visible sky	no unit	<i>ta_lighting 3</i>	radius = 1000, method = sectors, dlevel = 3, ndirs = 8
t11_svf	Sky-view factor	no unit		
t12_dfr	Potential diffuse solar radiation	kwh/m <sup>2</sup>	<i>ta_lighting 2</i>	solarconst = 1367, latitude = 46.089549, period = 2, hour_range_min = 0, hour_range_max = 24, hour_step = 0.5, days_step = 2, day = 2017-05-01, day_stop = 2017-10-30, method = 0, atmosphere = 12000
t13_dir	Potential direct solar radiation	kwh/m <sup>2</sup>		suction = 10, area_type = 1, slope_type = 1, slope_min = 0, slope_off = 0.10, slope_weight = 1
t14_twi	Topographic wetness index	no unit	<i>ta_hydrology 15</i>	dw_weighting = 0, dw_idw_power = 1, dw_idw_offset = 1, dw_bandwidth = 75
t15_lan	Geomorphological landforms	no unit	<i>ta_morphometry 19</i>	

**TABLE S4 Summary of the exome capture sequencing with trimming and mapping statistics from the 24 *Pinus cembra* populations studied.**

Sample	Sequencing ID	Raw read pairs	Read pairs after quality trimming	Percentage left	Read pairs mapped at Q20	Percentage left
CH-005	JFH-2-20	123,931,713	116,500,734	94.00%	75,248,862	64.59%
CH-008	JFH-2-21	113,733,160	107,235,656	94.29%	70,198,540	65.46%
CH-011	JFH-2-22	115,767,671	108,483,170	93.71%	66,538,353	61.34%
CH-015	AMJK-1-1	86,296,586	80,492,952	93.27%	49,241,062	61.17%
CH-019	AMJK-1-2	81,538,064	76,266,473	93.53%	46,627,716	61.14%
CH-023	AMJK-1-3	98,774,636	93,277,838	94.44%	55,884,701	59.91%
CH-028	AMJK-1-4	114,832,090	108,790,175	94.74%	72,443,182	66.59%
CH-032	AMJK-1-5	130,387,811	123,739,179	94.90%	75,542,908	61.05%
CH-034	AMJK-1-9	107,575,898	101,334,499	94.20%	64,802,939	63.95%
CH-035	AMJK-1-6	90,920,023	86,082,110	94.68%	54,958,688	63.84%
CH-039	AMJK-1-10	112,564,388	105,719,164	93.92%	65,378,162	61.84%
CH-045	AMJK-1-11	109,914,913	102,606,215	93.35%	63,887,921	62.27%
CH-046	AMJK-1-7	111,366,397	104,179,473	93.55%	65,520,099	62.89%
CH-052	AMJK-1-12	128,619,162	119,889,698	93.21%	70,736,593	59.00%
CH-053	AMJK-1-13	134,267,538	125,686,658	93.61%	77,459,378	61.63%
CH-113	JFH-2-23, AMJK-1-17	162,900,975	150,443,228	92.35%	89,106,435	59.23%
CH-150	AMJK-1-8	134,010,262	125,880,564	93.93%	81,941,110	65.09%
EC-HJ	20161116.A-EC-HJ-POOL	106,437,966	100,270,026	94.21%	64,871,565	64.70%
EN-HJ	JFH-1-1, AMJK-1-14	157,937,787	149,003,453	94.34%	98,280,810	65.96%
ES-HJ	JFH-2-1, AMJK-1-15	151,473,400	140,970,190	93.07%	94,387,258	66.96%
WC-HJ	JFH-1-4	108,773,448	103,251,500	94.92%	72,436,341	70.16%
WN-HJ	JFH-1-3	122,777,773	116,490,234	94.88%	83,874,974	72.00%
WS-HJ	JFH-1-2	158,670,982	151,698,425	95.61%	109,536,872	72.21%
WZ-HJ	JFH-2-2	127,075,751	119,632,844	94.14%	83,662,568	69.93%
Total		2,890,548,394	2,717,924,458	94.03%	1,752,567,037	64.48%

**TABLE S5 Estimates of geographic peripherality (GP) and habitat suitability (HS) for populations of *Pinus cembra*.** For HS, we inferred five species distribution models and used the weighted average ensemble; generalised linear model (GLM), generalised additive model (GAM), random forest (RF), artificial neural networks (ANN), and maximum-entropy (MAXENT). Standard deviation (SD) of the five models are also presented.

Sample	Species distribution models							Weighted average	SD
	GP	GLM	GAM	RF	ANN	MAXENT	Average		
CH-005	9.8044	0.9776	0.9794	0.8927	0.8714	0.7361	0.8914	0.8917	0.0891
CH-008	45.7757	0.8895	0.9236	0.8638	0.8289	0.6251	0.8262	0.8266	0.1052
CH-011	25.6534	0.8821	0.8494	0.7376	0.5203	0.3455	0.6670	0.6678	0.2047
CH-015	19.7895	0.8670	0.9187	0.8453	0.7149	0.5661	0.7824	0.7830	0.1273
CH-019	32.9146	0.9668	0.9643	0.7015	0.4563	0.6238	0.7425	0.7428	0.1986
CH-023	22.3163	0.9594	0.9341	0.6632	0.9556	0.4914	0.8007	0.8007	0.1906
CH-028	31.2558	0.8086	0.8743	0.7822	0.5728	0.3908	0.6857	0.6866	0.1787
CH-032	13.4928	0.8554	0.8836	0.7913	0.8032	0.5701	0.7807	0.7811	0.1106
CH-034	40.6676	0.6572	0.6485	0.4936	0.1372	0.3482	0.4569	0.4574	0.1960
CH-035	48.1395	0.2388	0.4187	0.2974	0.0539	0.2057	0.2429	0.2433	0.1191
CH-039	31.4677	0.7784	0.7557	0.6275	0.3943	0.3524	0.5817	0.5823	0.1782
CH-045	22.8520	0.8354	0.8974	0.6057	0.4101	0.3344	0.6166	0.6172	0.2232
CH-046	20.7735	0.9516	0.9803	0.6784	0.8404	0.6519	0.8205	0.8203	0.1355
CH-052	18.2334	0.7213	0.7304	0.4437	0.1682	0.2401	0.4607	0.4612	0.2346
CH-053	27.3578	0.9363	0.9364	0.8059	0.7173	0.5304	0.7852	0.7858	0.1521
CH-113	24.2265	0.9800	0.9817	0.9244	0.9968	0.8204	0.9407	0.9408	0.0650
CH-150	1.0000	0.9670	0.9714	0.8514	0.8995	0.6530	0.8685	0.8687	0.1166
EC-HJ	21.7646	0.7054	0.7770	0.4702	0.9009	0.3108	0.6328	0.6327	0.2136
EN-HJ	40.7928	0.9995	0.9960	0.6492	0.8080	0.9855	0.8876	0.8867	0.1393
ES-HJ	6.0388	0.9967	0.9988	0.8846	0.9871	0.7674	0.9269	0.9270	0.0904
WC-HJ	35.9979	0.9071	0.9330	0.7760	0.8475	0.4416	0.7810	0.7815	0.1781
WN-HJ	20.7381	0.9613	0.9826	0.8277	0.7202	0.6964	0.8376	0.8379	0.1185
WS-HJ	28.7244	0.9975	0.9962	0.9169	0.9943	0.7200	0.9250	0.9252	0.1070
WZ-HJ	25.9674	0.9286	0.9522	0.8676	0.9861	0.6419	0.8753	0.8755	0.1229

**TABLE S6 True skill statistics (TSS) of the different species distribution models (SDMs) averaged across 100 cross-validation repeats.** For abbreviations of SDMs see Table S5.

Model	TSS
GLM	0.889
GAM	0.890
RF	0.904
ANN	0.886
MAXENT	0.882
Average	0.890

**TABLE S7 Importance of environmental variables in the five species distribution models (SDMs) based on a permutation test.** Variables are ranked by their importance as expressed by average percentage per SDM. For abbreviations of SDMs see Table S5.

Variable	GLM	GAM	RF	ANN	MAXENT	Average
Bio1	58.20	45.62	49.80	29.45	68.04	50.22
Bio17	5.61	30.75	9.42	29.55	3.92	15.85
Bio4	9.92	6.87	5.53	8.42	7.26	7.60
Bio13	8.42	0.00	8.76	4.65	6.56	5.68
t06_ddg	9.14	5.47	2.65	4.58	5.26	5.42
Bio15	0.35	3.44	2.30	11.03	0.82	3.59
Bio3	0.54	0.67	2.36	7.29	5.32	3.24
Bio9	0.35	0.47	9.26	0.28	0.57	2.19
Bio8	0.12	0.00	8.08	0.61	0.78	1.92
t10_vis	2.88	2.41	0.61	2.14	0.45	1.70
t08_tpi	1.77	1.53	0.29	1.12	0.56	1.05
t03_eas	2.18	2.08	0.29	0.00	0.11	0.93
t13_dir	0.52	0.59	0.29	0.50	0.22	0.42
t09_vrm	0.00	0.09	0.29	0.31	0.11	0.16
t05_hcu	0.00	0.00	0.07	0.07	0.00	0.03

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**TABLE S8 Geographic distances ([km], lower triangle) and genetic differentiation ( $F_{ST}$ , upper triangle) among pairs of populations of *Pinus cembra* based on the full SNP set (SNP\_all).**

	CH-005	CH-008	CH-011	CH-015	CH-019	CH-023	CH-028	CH-032	CH-034	CH-035	CH-039	CH-045	CH-046	CH-052	CH-053	CH-113	CH-150	EC-HJ	EN-HJ	ES-HJ	WC-HJ	WN-HJ	WS-HJ	WZ-HJ
CH-005	–	-0.0516	0.0729	0.0670	0.0591	0.0679	0.0642	0.0372	0.0661	0.0571	0.0650	0.0579	0.0421	0.0703	0.0531	0.0315	0.0668	0.0698	0.1101	0.0557	0.0583	0.0439	0.0399	0.0481
CH-008	44.02	–	-0.0853	0.0761	0.0703	0.0779	0.0784	0.0451	0.0763	0.0688	0.0799	0.0713	0.0549	0.0830	0.0618	0.0422	0.0785	0.0823	0.1171	0.0676	0.0708	0.0504	0.0526	0.0567
CH-011	149.15	176.59	–	-0.0486	0.0595	0.0277	0.0448	0.0688	0.0324	0.0508	0.0426	0.0600	0.0679	0.0775	0.0640	0.0577	0.0366	0.0326	0.0781	0.0250	0.0738	0.0707	0.0680	0.0601
CH-015	216.44	240.63	68.24	–	-0.0569	0.0414	0.0461	0.0620	0.0441	0.0469	0.0468	0.0557	0.0633	0.0695	0.0600	0.0524	0.0301	0.0423	0.0914	0.0313	0.0696	0.0664	0.0644	0.0535
CH-019	45.97	57.12	120.02	183.51	–	-0.0559	0.0573	0.0584	0.0550	0.0531	0.0579	0.0529	0.0514	0.0640	0.0343	0.0455	0.0554	0.0555	0.0987	0.0448	0.0623	0.0561	0.0562	0.0439
CH-023	172.08	196.14	26.88	44.61	139.04	–	-0.0405	0.0633	0.0340	0.0443	0.0403	0.0545	0.0638	0.0711	0.0592	0.0542	0.0318	0.0304	0.0797	0.0227	0.0685	0.0672	0.0640	0.0559
CH-028	89.85	113.42	63.36	127.87	56.66	83.26	–	-0.0597	0.0407	0.0459	0.0430	0.0534	0.0636	0.0732	0.0619	0.0524	0.0439	0.0450	0.0883	0.0336	0.0682	0.0664	0.0597	0.0545
CH-032	42.25	45.93	191.18	258.64	83.68	214.31	132.01	–	-0.0634	0.0546	0.0650	0.0569	0.0431	0.0720	0.0540	0.0314	0.0626	0.0682	0.1068	0.0544	0.0603	0.0400	0.0401	0.0488
CH-034	104.48	125.26	54.36	115.37	68.15	70.96	15.59	146.45	–	-0.0439	0.0375	0.0542	0.0618	0.0701	0.0578	0.0527	0.0346	0.0358	0.0831	0.0275	0.0684	0.0650	0.0643	0.0515
CH-035	68.51	102.81	82.04	150.17	54.12	106.70	34.20	109.85	49.12	–	-0.0481	0.0483	0.0530	0.0644	0.0526	0.0422	0.0439	0.0511	0.0899	0.0352	0.0601	0.0575	0.0545	0.0440
CH-039	98.21	122.18	54.71	119.16	65.36	74.55	8.76	140.42	10.54	39.27	–	-0.0576	0.0639	0.0737	0.0613	0.0525	0.0422	0.0437	0.0888	0.0324	0.0740	0.0667	0.0640	0.0564
CH-045	63.39	86.38	90.22	155.31	30.55	110.70	27.44	105.25	41.22	29.10	36.17	–	-0.0564	0.0648	0.0537	0.0437	0.0547	0.0604	0.0997	0.0450	0.0558	0.0588	0.0563	0.0419
CH-046	27.99	49.71	128.27	193.99	18.30	149.39	66.14	67.70	79.67	53.30	74.84	38.72	–	-0.0682	0.0469	0.0326	0.0646	0.0662	0.1039	0.0539	0.0544	0.0464	0.0408	0.0439
CH-052	63.31	82.24	94.72	158.52	25.30	113.97	31.36	104.41	43.33	37.04	40.06	7.98	36.83	–	-0.0640	0.0609	0.0699	0.0721	0.1120	0.0592	0.0716	0.0706	0.0711	0.0573
CH-053	35.13	50.75	125.93	190.74	10.84	146.15	63.00	73.45	75.73	54.37	71.76	35.72	7.71	32.41	–	-0.0413	0.0595	0.0619	0.0978	0.0485	0.0574	0.0550	0.0527	0.0461
CH-113	15.96	56.08	133.48	200.99	38.77	156.75	75.23	57.70	90.23	52.56	83.38	49.70	21.11	50.91	28.74	–	-0.0561	0.0580	0.0964	0.0445	0.0435	0.0344	0.0338	0.0358
CH-150	187.06	213.69	37.91	31.77	156.79	21.31	100.27	229.10	89.40	119.80	91.52	127.51	165.85	131.51	163.21	171.39	–	-0.0328	0.0835	0.0224	0.0698	0.0666	0.0637	0.0542
EC-HJ	187.03	207.57	48.16	37.42	150.70	22.09	97.19	229.20	83.13	124.13	88.83	124.23	162.80	126.36	158.77	172.18	32.73	–	-0.0855	0.0260	0.0751	0.0719	0.0653	0.0595
EN-HJ	140.59	148.36	77.37	111.66	96.27	76.19	63.70	179.94	50.19	97.78	60.73	80.67	112.88	78.14	106.57	129.02	97.42	74.24	–	-0.0751	0.1128	0.1052	0.1065	0.1018
ES-HJ	176.58	203.85	27.50	42.44	147.10	17.83	90.46	218.57	80.26	109.13	81.74	117.54	155.72	121.80	153.26	160.88	10.80	35.97	92.67	–	-0.0594	0.0561	0.0525	0.0443
WC-HJ	42.63	75.07	106.56	173.83	31.41	129.52	48.20	84.81	63.44	27.77	56.19	24.52	25.83	28.43	28.24	27.27	144.46	144.95	105.19	134.02	–	-0.0593	0.0577	0.0438
WN-HJ	20.57	35.12	143.68	209.30	29.25	164.69	81.42	54.44	94.69	67.76	90.15	53.99	15.41	51.51	19.34	24.02	181.25	177.81	125.52	171.13	40.00	–	-0.0453	0.0502
WS-HJ	29.09	72.64	142.46	210.70	63.84	167.55	90.64	56.17	106.21	60.90	97.80	68.71	46.54	71.93	54.12	25.45	179.89	184.94	149.37	169.13	44.19	47.03	–	-0.0491
WZ-HJ	35.37	64.31	115.25	181.83	22.77	137.32	54.59	77.43	69.11	38.54	63.06	28.07	14.80	28.97	17.55	21.95	153.04	151.78	107.11	142.75	11.08	29.41	44.08	–

**TABLE S9 Correlations between genetic diversity indices (PPL,  $H_e$ ,  $\pi$ , and  $\theta_W$ ) for both the full (SNP\_all, upper triangle) and overall neutral (SNP\_neutral\_overall, lower triangle) SNP datasets.** Given are Pearson's correlation coefficients  $r$ . Asterisks indicate significance at 0.05 (\*), 0.01 (\*\*), and 0.001 (\*\*\*) levels.

		Full SNP dataset			
		PPL	$H_e$	$\pi$	$\theta_W$
Overall neutral SNP dataset	PPL	—	0.866***	0.887***	0.990***
	$H_e$	0.891***	—	0.993***	0.898***
	$\pi$	0.875***	0.985***	—	0.914***
	$\theta_W$	0.988***	0.919***	0.912***	—

**TABLE S10** Tajima's *D* estimates for *Pinus cembra* populations for the full (SNP\_all) and overall neutral (SNP\_neutral\_overall) SNP set.

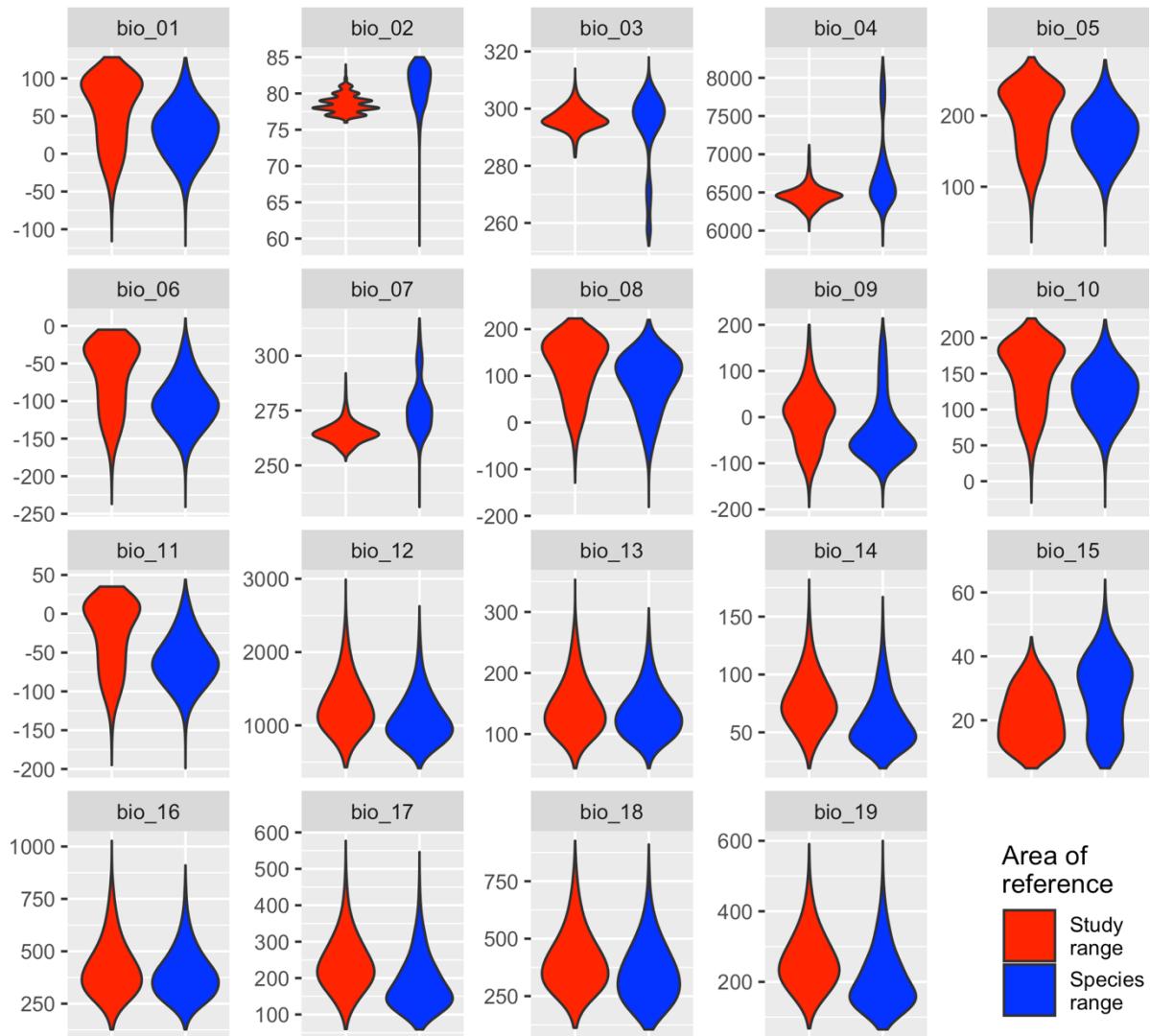
Sample	SNP_all	SNP_neutral_overall
CH-005	0.4167	0.7289
CH-008	0.4262	0.7244
CH-011	0.4048	0.7186
CH-015	0.4553	0.7421
CH-019	0.4145	0.7099
CH-023	0.4216	0.7386
CH-028	0.4507	0.7549
CH-032	0.4239	0.7258
CH-034	0.4111	0.6994
CH-035	0.4349	0.7462
CH-039	0.4429	0.7383
CH-045	0.4131	0.7238
CH-046	0.4036	0.7124
CH-052	0.4301	0.6901
CH-053	0.4472	0.7433
CH-113	0.3568	0.6845
CH-150	0.4080	0.7121
EC-HJ	0.3919	0.7062
EN-HJ	0.4414	0.6963
ES-HJ	0.3748	0.7020
WC-HJ	0.4162	0.7197
WN-HJ	0.3984	0.7016
WS-HJ	0.3564	0.6680
WZ-HJ	0.3793	0.6959
Average	0.4133	0.7160
Minimum	0.3564	0.6680
Maximum	0.4553	0.7549

**TABLE S11 Genomic inflation factors of latent factor mixed model (LFMM) analyses for  $K = 1–8$  and for each environmental variable.**

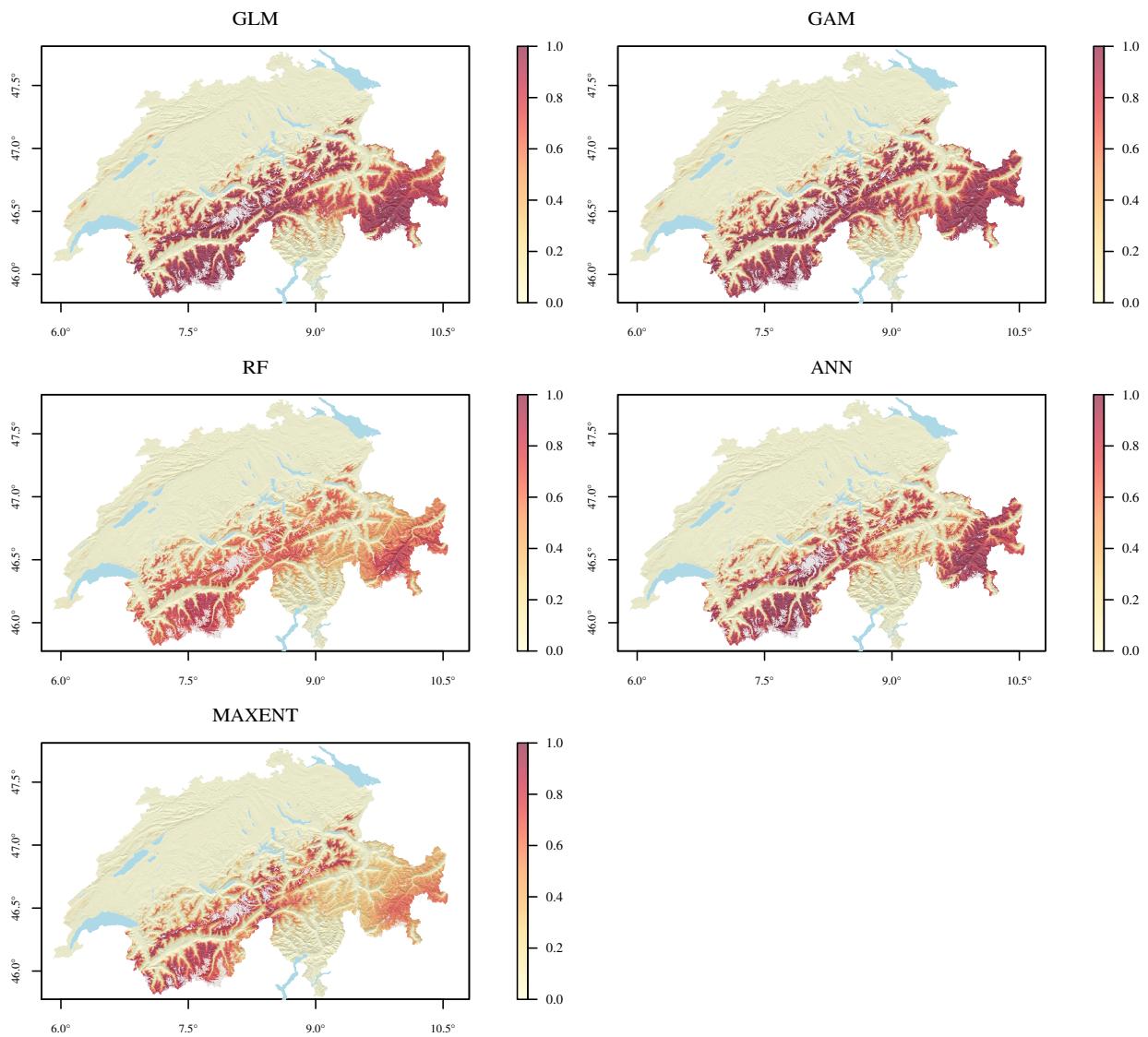
Variable	Abbreviation	K1	K2	K3	K4	K5	K6	K7	K8
Yearly mean temperature	Bio1	1.343	1.304	1.299	1.326	1.363	1.395	1.416	1.465
Mean diurnal range	Bio2	1.280	1.229	1.253	1.281	1.325	1.339	1.359	1.390
Isothermality	Bio3	1.153	1.175	1.198	1.228	1.256	1.281	1.307	1.286
Temperature seasonality	Bio4	2.268	2.336	1.984	2.046	2.046	2.076	2.124	2.164
Max temperature of warmest month	Bio5	1.027	1.078	1.115	1.140	1.176	1.194	1.234	1.256
Min temperature of coldest month	Bio6	1.492	1.492	1.419	1.450	1.489	1.527	1.562	1.589
Temperature annual range	Bio7	1.614	1.684	1.492	1.536	1.584	1.614	1.656	1.695
Mean temperature of wettest quarter	Bio8	1.481	1.581	1.508	1.542	1.594	1.637	1.636	1.678
Mean temperature of driest quarter	Bio9	1.417	1.471	1.321	1.358	1.350	1.374	1.394	1.432
Mean temperature of warmest quarter	Bio10	1.178	1.186	1.197	1.222	1.254	1.280	1.318	1.342
Mean temperature of coldest quarter	Bio11	1.513	1.525	1.433	1.458	1.507	1.546	1.586	1.608
Yearly precipitation sum	Bio12	1.580	1.636	1.608	1.648	1.644	1.688	1.708	1.743
Precipitation of wettest month	Bio13	1.575	1.632	1.616	1.662	1.626	1.661	1.695	1.694
Precipitation of driest month	Bio14	1.615	1.673	1.640	1.683	1.639	1.676	1.702	1.734
Precipitation seasonality	Bio15	1.404	1.396	1.400	1.433	1.468	1.510	1.530	1.549
Precipitation of wettest quarter	Bio16	1.594	1.644	1.672	1.725	1.674	1.721	1.745	1.764
Precipitation of driest quarter	Bio17	1.607	1.691	1.663	1.711	1.672	1.709	1.714	1.755
Precipitation of warmest quarter	Bio18	1.656	1.691	1.723	1.776	1.698	1.744	1.770	1.831
Precipitation of coldest quarter	Bio19	1.625	1.675	1.634	1.674	1.645	1.679	1.688	1.696
Altitude	t01_alt	1.338	1.345	1.341	1.370	1.399	1.425	1.459	1.485
Slope	t02_slp	1.093	1.086	1.115	1.147	1.170	1.201	1.206	1.230
Eastness	t03_eas	1.026	1.075	1.100	1.134	1.114	1.143	1.136	1.127
Profile curvature	t04_vcu	0.991	0.962	1.009	1.029	1.019	1.043	1.054	1.083
Horizontal curvature	t05_hcu	1.085	1.101	1.084	1.105	1.122	1.146	1.154	1.187
Downslope distance gradient	t06_ddg	1.167	1.071	1.115	1.136	1.166	1.188	1.205	1.227
Morphometric protection index	t07_mpi	1.343	1.360	1.293	1.333	1.317	1.350	1.351	1.376
Topographic position index	t08_tpi	1.139	1.066	1.102	1.139	1.163	1.186	1.218	1.248
Vector ruggedness measure	t09_vrm	1.075	1.054	1.060	1.091	1.124	1.150	1.175	1.187
Visible sky	t10_vis	1.258	1.244	1.220	1.249	1.236	1.271	1.304	1.327
Sky-view factor	t11_svf	1.220	1.250	1.239	1.274	1.278	1.317	1.291	1.309
Potential diffuse solar radiation	t12_dfr	1.287	1.303	1.263	1.305	1.263	1.287	1.331	1.349
Potential direct solar radiation	t13_dir	1.116	1.180	1.220	1.252	1.259	1.304	1.340	1.365
Topographic wetness index	t14_twi	1.109	1.158	1.201	1.232	1.206	1.233	1.260	1.260
Geomorphological landforms	t15_lan	0.980	1.014	1.051	1.075	1.082	1.097	1.114	1.145
Average		1.343	1.364	1.341	1.376	1.380	1.411	1.434	1.458

**TABLE S12 Comparison between variable importance in species distribution modelling (SDM, expressed in percent) and environmental association analysis (EAA).** For EAA, the effect size (averaged absolute  $\beta$  coefficient) for significant associations and for all associations, and the number of significant associations are given, as obtained from latent factor mixed model (LFMM; number of latent factors  $K = 3$ ).

Variable	Abbre-viation	LFMM			SDM	
		Number of significant SNPs	$\beta$ of significant associations	$\beta$ of all associations	Variable ranking	Variable importance in SDM (Average)
Yearly mean temperature	Bio1	1	0.020342	0.016244	1	50.22
Mean diurnal range	Bio2	1	0.026620	0.016020		
Isothermality	Bio3	0	NA	0.015720	7	3.24
Temperature seasonality	Bio4	88	0.061678	0.022763	3	7.60
Max temperature of warmest month	Bio5	2	0.075348	0.014437		
Min temperature of coldest month	Bio6	0	NA	0.017747		
Temperature annual range	Bio7	80	0.048714	0.018988		
Mean temperature of wettest quarter	Bio8	11	0.073336	0.017589	9	1.92
Mean temperature of driest quarter	Bio9	0	NA	0.016871	8	2.19
Mean temperature of warmest quarter	Bio10	3	0.038153	0.014999		
Mean temperature of coldest quarter	Bio11	0	NA	0.018064		
Yearly precipitation sum	Bio12	30	0.047382	0.017857		
Precipitation of wettest month	Bio13	73	0.054110	0.018131	4	5.68
Precipitation of driest month	Bio14	8	0.035212	0.018145		
Precipitation seasonality	Bio15	1	0.030602	0.018843	6	3.59
Precipitation of wettest quarter	Bio16	69	0.057304	0.018636		
Precipitation of driest quarter	Bio17	4	0.028507	0.018386	2	15.85
Precipitation of warmest quarter	Bio18	117	0.058823	0.019331		
Precipitation of coldest quarter	Bio19	0	NA	0.018001		
Altitude	t01_alt	1	0.019173	0.015830		
Slope	t02_slp	0	NA	0.014949		
Eastness	t03_eas	0	NA	0.014292	12	0.93
Profile curvature	t04_vcu	10	0.049985	0.014607		
Horizontal curvature	t05_hcu	35	0.038537	0.015003	15	0.03
Downslope distance gradient	t06_ddg	7	0.018065	0.015257	5	5.42
Morphometric protection index	t07_mpi	4	0.046253	0.016319		
Topographic position index	t08_tpi	8	0.056150	0.015081	11	1.05
Vector ruggedness measure	t09_vrm	55	0.042630	0.014895	14	0.16
Visible sky	t10_vis	1	0.056947	0.015650	10	1.70
Sky-view factor	t11_svf	8	0.056734	0.015575		
Potential diffuse solar radiation	t12_dfr	1	0.092668	0.015851		
Potential direct solar radiation	t13_dir	0	NA	0.015242	13	0.42
Topographic wetness index	t14_twi	3	0.048902	0.016077		
Geomorphological landforms	t15_lan	4	0.067515	0.014686		

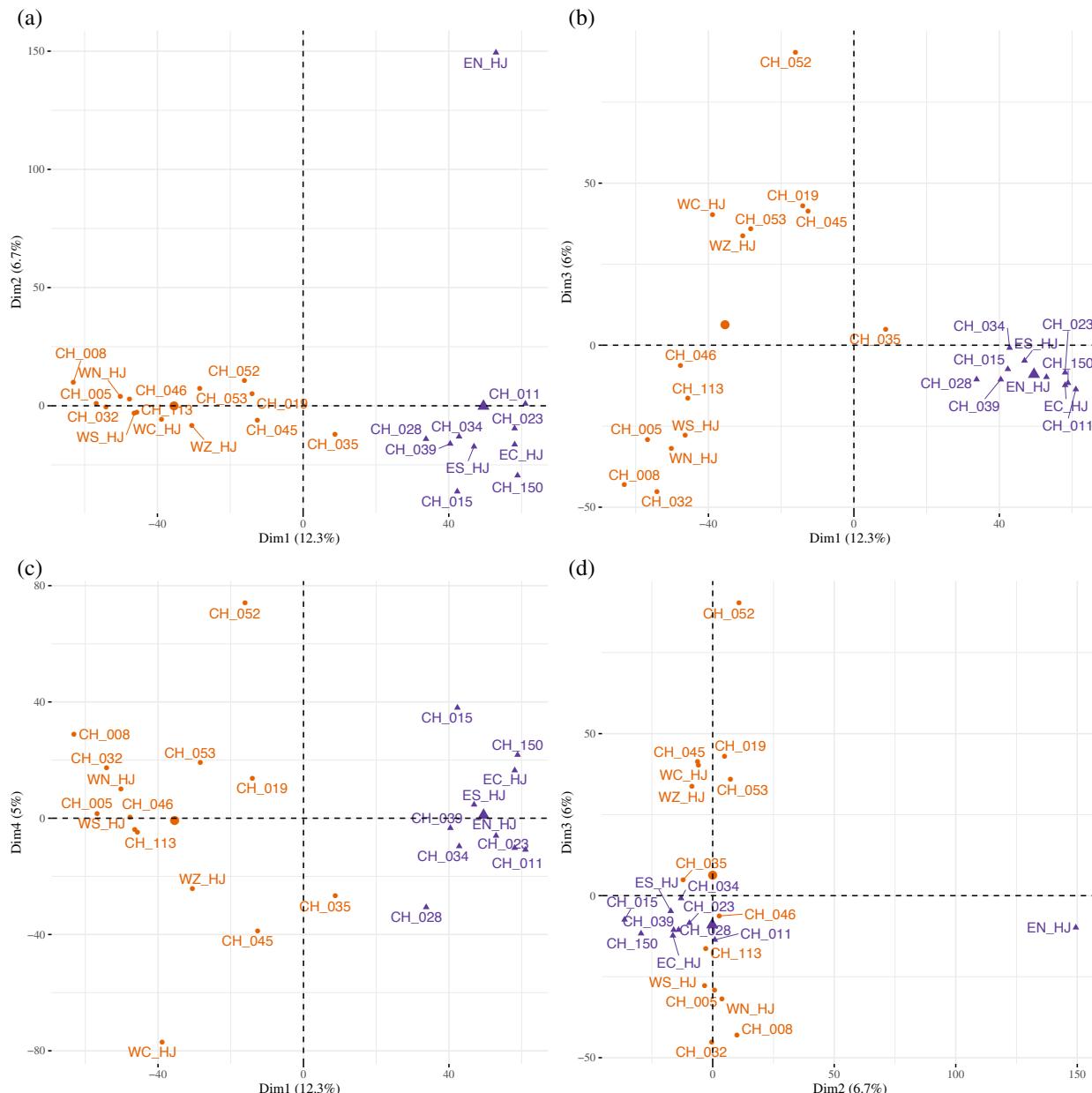


**FIGURE S1 Violin plots illustrating the distribution of environmental conditions in Switzerland (Study range, in red) and across the entire range of *Pinus cembra* (Species range, in blue) for 19 bioclimatic variables.** We extracted data for all 19 bioclimatic variables from the globally available CHELSA climate data (Karger et al., 2017) because climatic and topographic data we used in our study are not available across the entire range. Range boundaries for *P. cembra* follow Caudullo et al. (2017). Note that the following variables have been used in species distribution models, in decreasing importance (in %): bio\_01 (50%), bio\_17 (16%), bio\_04 (8%), bio\_13 (6%), bio\_15 (4%), bio\_03 (3%), bio\_09 (2%), bio\_08 (2%).

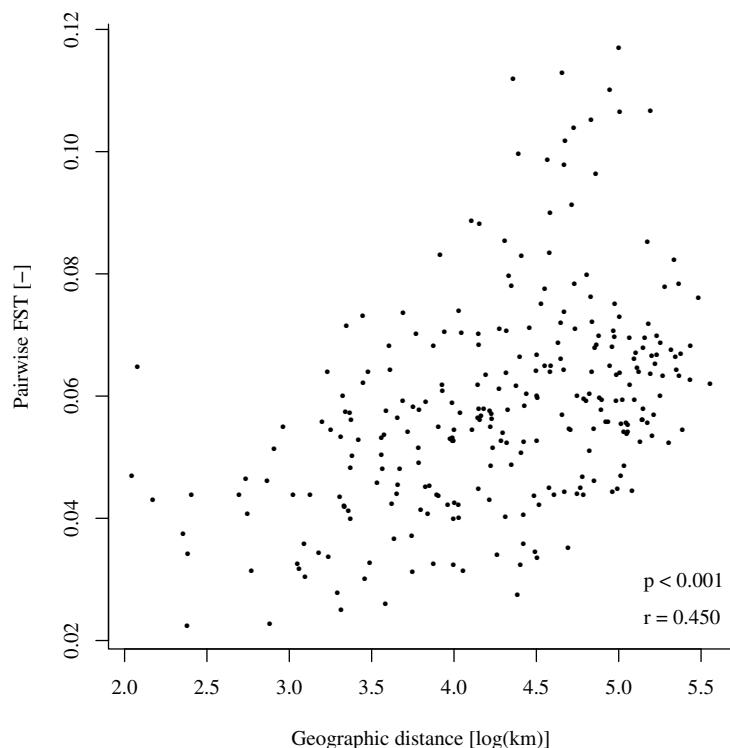


**FIGURE S2 Maps of the five individual species distribution models predicted for *Pinus cembra*.** Generalised linear model (GLM), generalised additive model (GAM), random forest (RF), artificial neural network (ANN), and maximum-entropy (MAXENT).

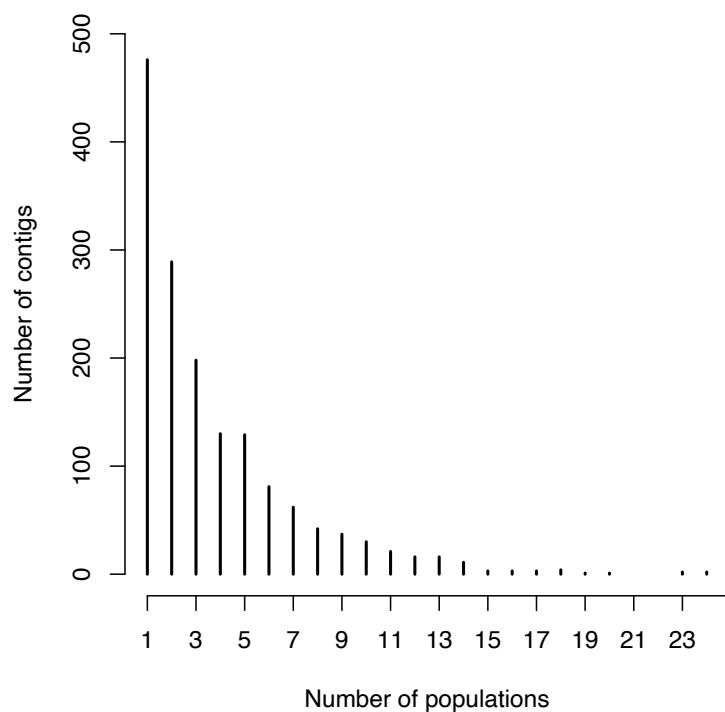
# MOLECULAR ECOLOGY



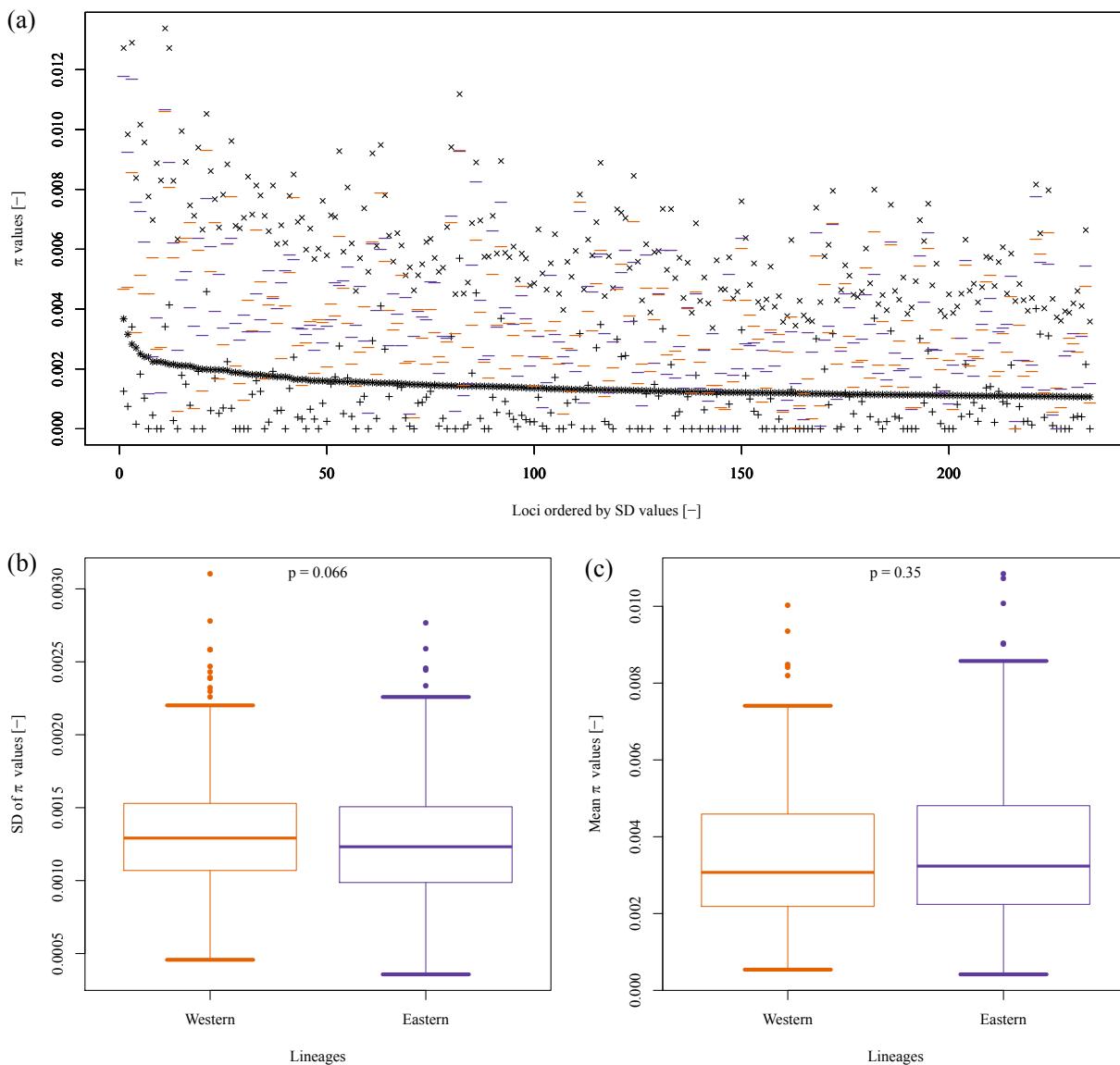
**FIGURE S3 Population genetic structure of *Pinus cembra* populations.** Panels (a)-(d) show the distribution of populations based on a principal component analysis, with various combinations of axes 1–4. Violet triangles and orange circles represent populations from eastern and western Swiss lineages, respectively; populations were classified based on Figure 4a and in agreement with Gugerli et al. (2009).



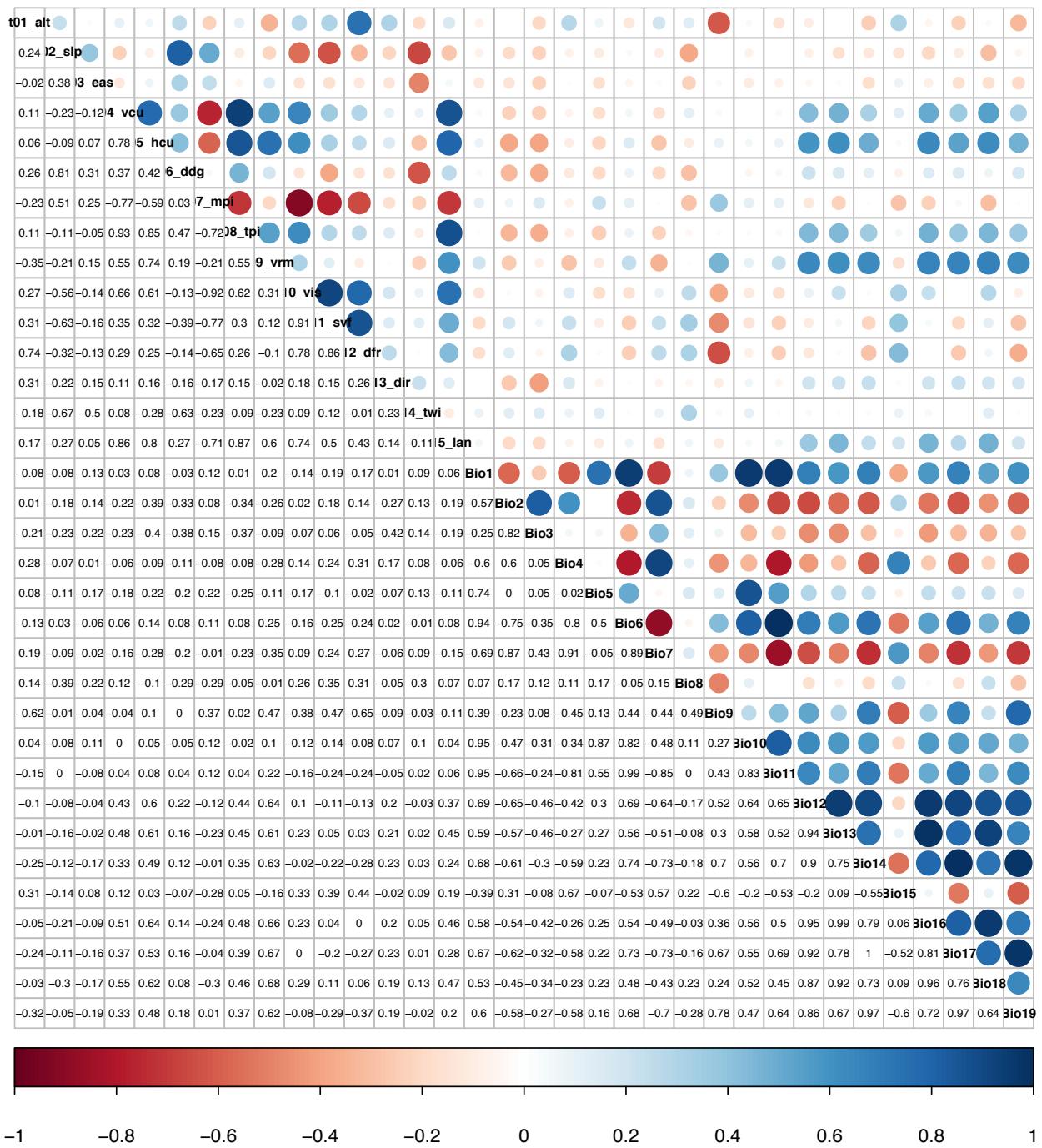
**FIGURE S4 Isolation by distance using a Mantel test.** For the test based on 999 permutations, geographic distances were ln-transformed and  $F_{ST}$  was linearised as  $F_{ST}/(1-F_{ST})$  following Rousset (1997).



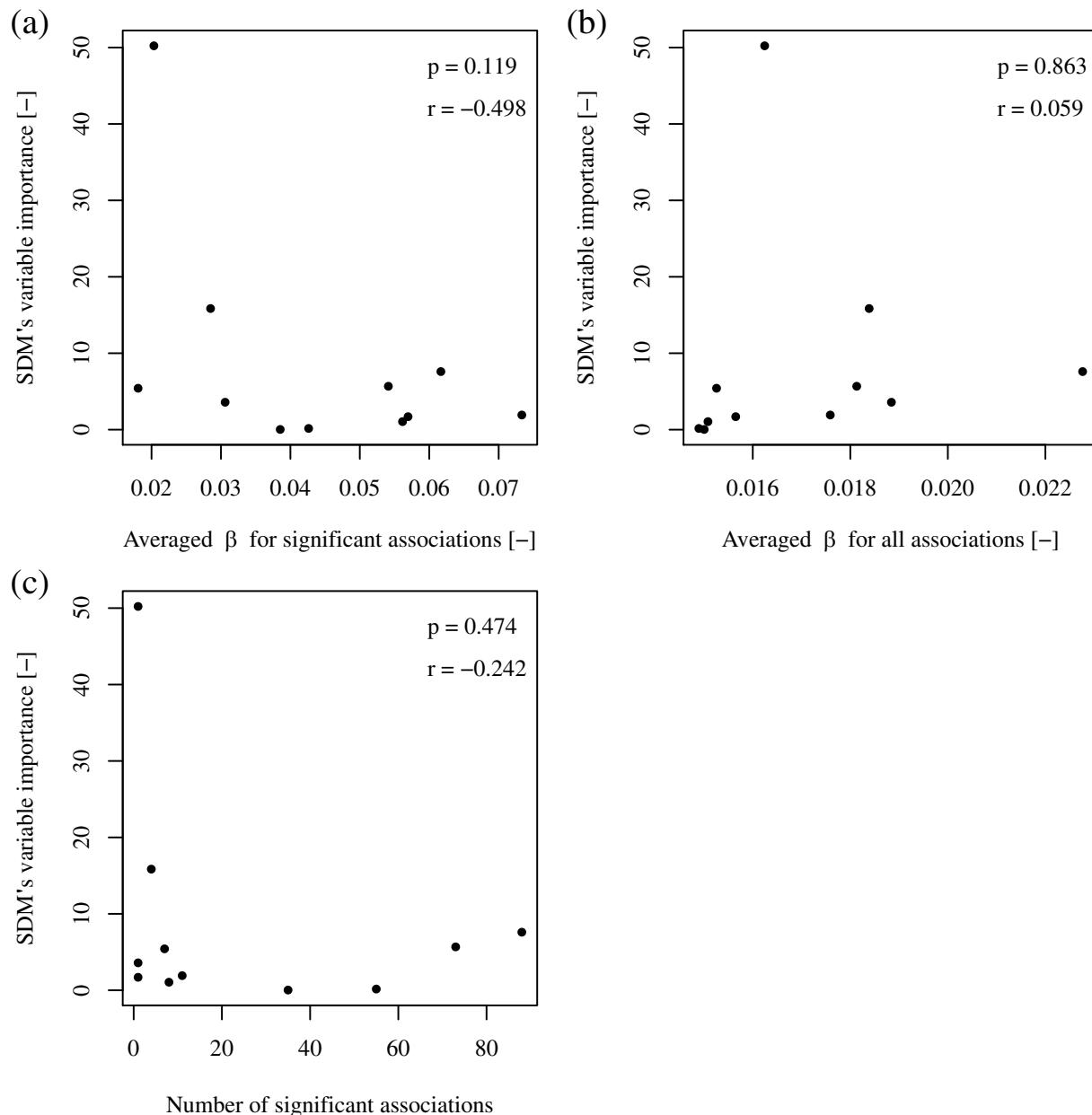
**FIGURE S5 Shared signatures of strong positive selection in *Pinus cembra*.** Number of contigs with a selection signature shared among populations using Tajima's  $D$ . Contigs were defined as being under positive selection if Tajima's  $D$  was below the 5% quantile of the population-specific distribution.



**FIGURE S6 Distribution of  $\pi$  values (a) for contigs above the 95% quantile of the standard deviation of  $\pi$ .** Stars represent the standard deviation values, plus the minimum values, crosses the maximum values, purple and orange horizontal bars the median values for the eastern and western lineages, respectively. Standard deviation (b) and mean (c) of  $\pi$  values are represented by lineage. Significance was calculated with a Wilcoxon test. Populations were classified as part of eastern or western Swiss lineages based on Figure 4a and in agreement with Gugerli et al. (2009).



**FIGURE S7 Correlation matrix of environmental variables used in association analysis.** Pearson's correlation coefficients  $r$  are presented (lower triangle), with warm (red) and cold (blue) colours (upper triangle) showing higher positive and negative correlations, respectively.



**FIGURE S8** Correlations between variable importance in species distribution modelling and environmental association analysis (EAA). Shown is the correlation with (a) the average effect size (averaged absolute  $\beta$  coefficient) for significant associations, (b) the average effect size for all associations, and (c) the number of significant associations in EAA.

## References

- Caudullo, G., Welk, E., & San-Miguel-Ayanz, J. (2017). Chorological maps for the main European woody species. *Data in Brief*, 12, 662–666. doi:10.1016/j.dib.2017.05.007
- Gugerli, F., Rüegg, M., & Vendramin, G. G. (2009). Gradual decline in genetic diversity in Swiss stone pine populations (*Pinus cembra*) across Switzerland suggests postglacial re-colonization into the Alps from a common eastern glacial refugium. *Botanica Helvetica*, 119(1), 13–22. doi:10.1007/s00035-009-0052-6
- Karger, D. N., Conrad, O., Böhner, J., Kawohl, T., Kreft, H., Soria-Auza, R. W., ... Kessler, M. (2017). Climatologies at high resolution for the earth's land surface areas. *Scientific Data*, 4, 1–20. doi:10.1038/sdata.2017.122
- Rousset, F. (1997). Genetic differentiation and estimation of gene flow from *F*-statistics under isolation by distance. *Genetics*, 145(4), 1219–1228. doi:10.1007/BF00341816