Interreg Project CE614

D.T2.2.1 Report on statistics of climate regimes with and among provenance delineation V.1

"Interreg CENTRAL EUROPE Project to improve conservation and sustainable utilization of forest tree diversity in climate change"

Content

Introduction

Existing provenance delineation systems in Central Europe are based on different methods depending on the countries specific needs and historic background. This results in very heterogeneous delineation systems, which are often based stronger on administrative boundaries than on climatic conditions. Therefore, e.g. in the case that there is a shortage in seed supply from a specific provenance region, it is very difficult to find alternate regions of provenance from other countries. Additionally, due to climate change trees will have to face novel climate regimes. Mean annual temperature e.g. will increase by around 2°C until the end of next century (Figure 1), and rainfall will vary. The use of seed material originating from places that today face the predicted climate regimes within the provenance regions of interest would enable to adapt forests to climate change. Within the frame of the project SUSTREE, we aimed at

1. Creating a tool that enables to find provenance regions which share a similar climate. This tool should serve as a first guide when trying to find alternate provenance regions at international level.
2. Creating a tool that enables to find seed sources which face the future predicted climate in a provenance region of interest. This tool should help to choose the right material when trying to adapt forests to climate change through assisted migration.

In this report we present an analysis based on bias-adjusted EURO-CORDEX climate data for Central European provenance regions, including present and future climates. We present maps of provenance regions sharing similar climate regimes now and in the future, and a tool that enables to link both climates. This is aimed to help practitioners in the choice of adequate seed material to adapt their forests to climate change.

Material and Methods

Tree species

Two species were included in the analysis, Norway Spruce (*Picea abies* (L.) H. Karst.) and Pedunculate Oak (*Quercus robur* L.). Species selection was based on the criteria (1) coverage of the spectrum vulnerability versus good adaptation capability to climate change, (2) importance of the species for forestry and (3) coverage of broad-leaved trees and conifers.

European provenance region shapefiles

For both species, shapefiles of the provenance regions of 6 participating countries (Poland, Germany, Check Republic, Slovakia, Austria and Hungary) were collected from the SUSTREE project partners. Additionally, shapefiles for the countries France, Switzerland, Slovenia and northern Italy (alpine region) were gathered (Figure 1, Table 3 and Table 4). There are two types of different provenance delineation systems within these countries:

1a) All species have the same provenance regions (AT, CH, CZ, IT, SL)
1b) Species or sets of species have distinct provenance regions (DE, FR, HU, PL, SK)
2a) The whole area of the country includes provenance regions (AT, CH, CZ, DE, HU, IT, PL, SL)
2b) Some regions within the country have no provenance region defined (also called “neutral zones”) (FR, SK)

All shapefiles were converted to the coordinate system WGS 84. Maps were plotted using the projection UTM zone 32N.

Climate Data

Bias- adjusted EURO-CORDEX climate data was used for the analysis. The available data from EURO-CORDEX with a 10 km resolution was statistically downscaled to a resolution of 1 km following the delta approach within the frame of the SUSTREE project. The resulting dataset consists of 83 raster files in Geotif format, each containing information on one climate variable, covering all of Europe (xmin: 32.65000, xmax: 6944167, ymin: 30.87892, ymax: 71.57893) in the coordinate system WGS 84. These 83 are available for the current climate (reference period 1961 – 1990), as well as for three future periods (2041 – 2060, 2061 – 2080 and 2081 – 2100), five pairs of regional-global climate models and two climate forcing scenarios (RCP 8.5 and RCP 4.5). In this analysis we focused the current climate (referred to as "present") and the climate model MPI-CSC-REMO2009, scenario RCP 4.5, with the time frame 2081 – 2100 (referred to as "future"). This future time period is expected to cover the biggest differences compared to the actual conditions and was therefore preferred. For details on the climate models, scenarios, climate indices and downscaling method and validation, see the readme-file "Bias-corrected historical and projected climate data for Europe" accompanying the downscaled SUSTREE climate data.

Data point grid

A grid with a resolution of 3 x 3 km was spanned over the area of investigation (Central Europe). The grid was cropped retaining only landmasses with forests based on a land-use map. The grid was then intersected with the climate data raster files (for all 83 climate variables, including present and future data), as well as with the shapefiles of the provenance regions. The resulting dataset contained a set of 93093 data points including coordinates, country, name of provenance region of spruce, name of provenance region of oak and a value for each 83 climatic variables, for the present and for the future.

Data analysis

All analyses were done with R version 3.4.0 and the packages raster, rgdal, factoextra, FactoMineR, cluster, clusterend, multcomp and networkD3. Maps were created with QGIS.

PCA

Using principal component analysis (PCA), the present 83 climate variables were reduced to 5 dimensions. The dimensions retained were based on their Eigenvalue, retaining only dimensions with an Eigenvalue bigger than 1. Within the same PCA, future climatic conditions were included as supplementary cases. The values of the 5 PCA dimensions were included to the original dataset and an average climate value was calculated for each provenance region.

Cluster analysis

After scaling the data, a distance matrix was created for the provenance regions using Euclidean distances. An agglomerative hierarchical clustering based on the Ward-method was applied for each the present and the future data. Ward was preferred against other methods, since it is based on the increase of a sum of squares error measure when agglomerating clusters and therefore creates the most homogeneous clusters. Results were checked with Hopkins statistics to ensure that the clustering was not random. The resulting dendrograms were cut in order to create 13 clusters of provenance regions with similar climatic conditions (Figure 2 and Figure 3).

Maps

Based on the cluster dendrograms, maps of clusters were created which show provenance regions sharing similar climates, both for present and future climatic conditions (Figure 4). The numbering of the clusters represents the order from left to right within the dendrograms. However, as the clustering for both trees was done separately, the present and future clusters are not related to each other, and especially the numbering cannot be compared.

Climate values within the clusters

To be able to compare the climate regime between each cluster, the values composing them were plotted in box-whisker plots (Figure 5). The corresponding values for the future clusters were also plotted within the same graphs. As mentioned above, the numbering of the clusters simply represents the order within the dendrogram, making it impossible to compare present and future clusters. Therefore, a distance matrix was created which condenses the 5 PCA axes values of each cluster and shows the distance between each pair of present and future cluster (Table 1 and Table 2). Using this distance matrix, it is possible to determine for each future provenance region in Figure 4, which is the present cluster that shares the most similar climate.

Results and Discussion

Two main tools were obtained from the statistical analysis of climate regimes of Central European provenance regions: maps of provenance regions of spruce and oak sharing similar climates for the present and the future (Figure 4), as well as corresponding distance matrices (Table 1 and Table 2) which link present and future climates, connecting the most similar ones.

The most noticeable groups for both species regarding the present climate are a big German/Polish cluster, a more continental Polish/Czech cluster, a cluster for the mid-elevations, a Pannonian-influenced cluster, a French Atlantic-influenced cluster, a Slovenian cluster and a set of alpine and pre-alpine clusters spanning from west to east (Figure 4).
At a first glance, the clusters for the future climate do not differ too much from the delineation of the present clusters. The biggest differences can be found in the alpine region, where the distinct bands from the present clusters are interrupted and distorted in the future clustering (Figure 4).
The clusters created have very distinct climate regimes based on the first five PCA-axes (Figure 5). PCA-axis 1 is strongly influenced by all temperature-related climate variables while PCA-axis 2 is more influenced by rainfall-related variables (Figure 6). Continentality has the biggest influence on PCA-axis 3. The climate regimes of the clusters show that there are clear changes between the present and the future clusters (Figure 5). PCA-axis 4 and 5 are influenced both by a mixture of rainfall- and temperature-related variables. The values for PCA-axis 1 are generally higher for the future clusters than for the present, highlighting the increase of temperature-related variables in the future. For PCA-axis 2, the pattern is not so clear, showing the general pattern that rainfall-related variables are not so easily predictable and may experience increases but also decreases in certain areas.

How to read the maps

The first tool developed, maps of provenance regions with similar climates, should serve practitioners to find alternate seed sources when seed supply is limited in a provenance region of interest. While there are recommendations for this at national level, at international level this is not possible at the moment. To read the map, simply choose the region of provenance of interest and look in which cluster it lays. All other provenance regions laying within the same cluster share a similar climate based on the analysis performed here and may serve as potential alternate seed sources. However, this has to be regarded with caution: changing the number of clusters may lead to totally different results (see methods and caveats section). Therefore, the maps should only be regarded as a help to find potentially suitable provenance regions, not as concrete recommendation. Another option is to take a look at the cluster dendrograms (Figure 2 and Figure 3). Each leaf represents a provenance region. Leaves are sorted in a matter that neighboring leaves are more similar in their climate regime to each other than to others. It is therefore possible to find out of the presented dendrograms the most similar provenance region to the one of interest.

How to read the table to find seed sources for the future

The second tool developed is the distance tables which help linking present and future clusters. This should help practitioners to find seed sources with trees adapted to the climate that will prevail in a region of interest. Remember that since the clusters within the dendrograms can be moved like parts of a mobile, their order is not strict and therefore the structure of both dendrograms cannot be compared in a 1:1 manner (see also methods and caveats section). However, from the different climate regimes within each cluster, it is possible to create a distance matrix which shows which present cluster is most similar to which future cluster. To read the tables, choose a provenance region of interest and look in the map for the future climate in which cluster it will be. Then go to the table and check which present cluster shares the most similar climate to the one in the future. Seed sources that are adapted to the future climate should be chosen from this cluster. The following example should illustrate the procedure.

Example

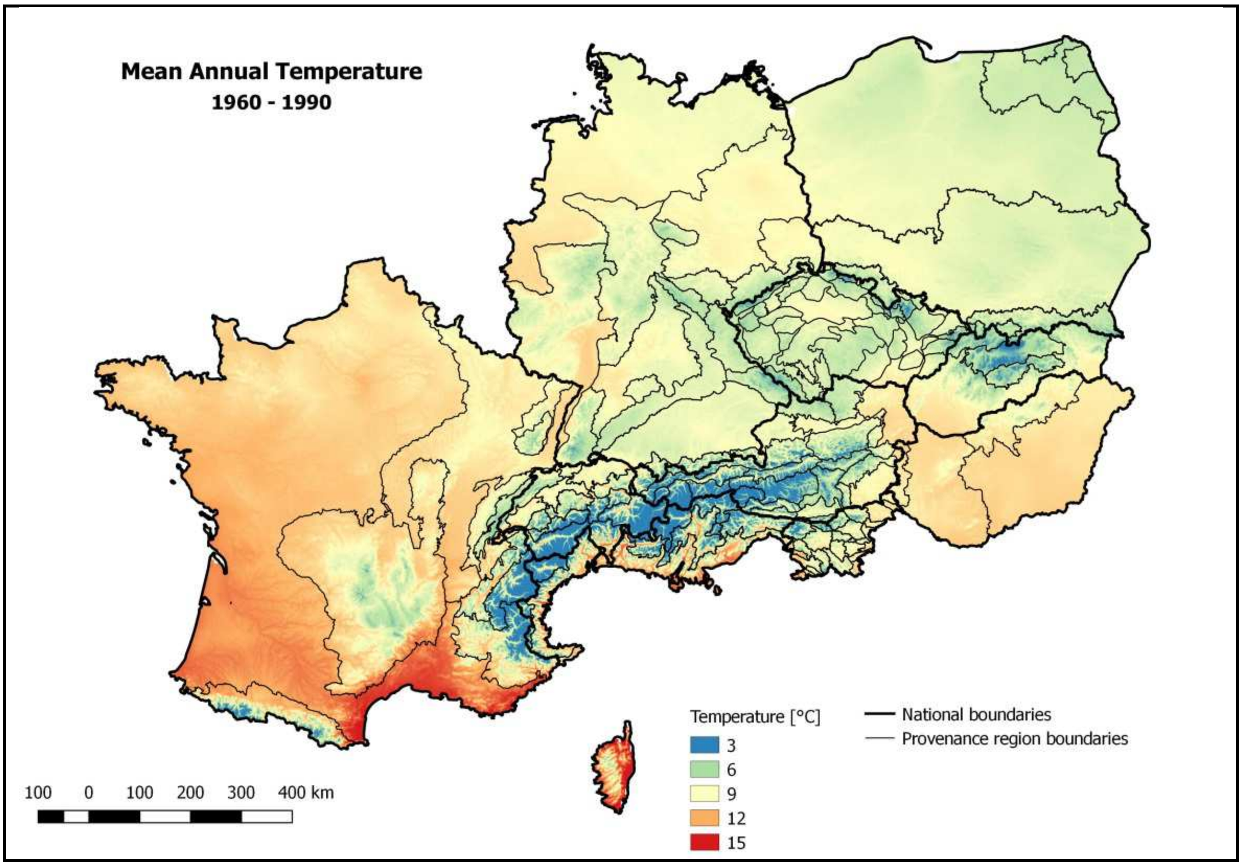
A practitioner wants to plant spruce seedlings with seeds adapted to the climate that his forest will face in the time period 2080 – 2100. His forest is located in Austria, provenance region number 7.1 (“Nördl. Alpenvorland – Westteil”), close to Salzburg. A look at the map for *Picea abies* – future climate (Figure 4) reveals that this provenance region will lie in cluster number 9. He then goes to Table 1, takes the line “Cluster # 9 – future”, and finds that the present cluster with the most similar climate to the one in the future is cluster number 13. So the seed material most adapted to future climates will be found somewhere in the Pannonian-influenced cluster.
Following this procedure it may happen that the best suitable seed source lies within the same cluster as the provenance region of interest.

Caveats

The results of this analysis are based on cluster statistics. While it is possible to say that leaves (provenance regions) of the dendrograms that are closer to each other share a more similar climatic regime than leaves farther away, it is not possible to say which leaves should be grouped together. There is no method to determine the “right” number of cluster and depending on the purpose of the clustering, bigger or smaller cluster may make more sense. We decided to group the trees into 13 cluster each (Figure 2 and Figure 3). The number of clusters was chosen based on the criteria of having the most similar number of leaves within each cluster of the dendrogram. Fewer groups would have led to some clusters being un-proportionally big, while more groups would have led to clusters containing only one or few provenance regions. So to sum up, the clusters presented here should not be regarded as a strict unit, and every decision should be taken cautiously and under consideration of the specific question asked.

Another consideration regarding cluster analysis is the ordering of clusters in the dendrogram: The function hclust in R groups the subtree so that the tighter cluster is on the left (the last, i.e., most recent, merge of the left subtree is at a lower value than the last merge of the right subtree. This means that with a new dataset the ordering may be totally different. Also, every node within a dendrogram can be flipped (similar as the rods in a mobile, which can rotate). Therefore, the order of clusters between present and future climate cannot be compared. This is why we decided to use a distance matrix to link the present and the future climate regimes within the clusters.

Figures and Tables



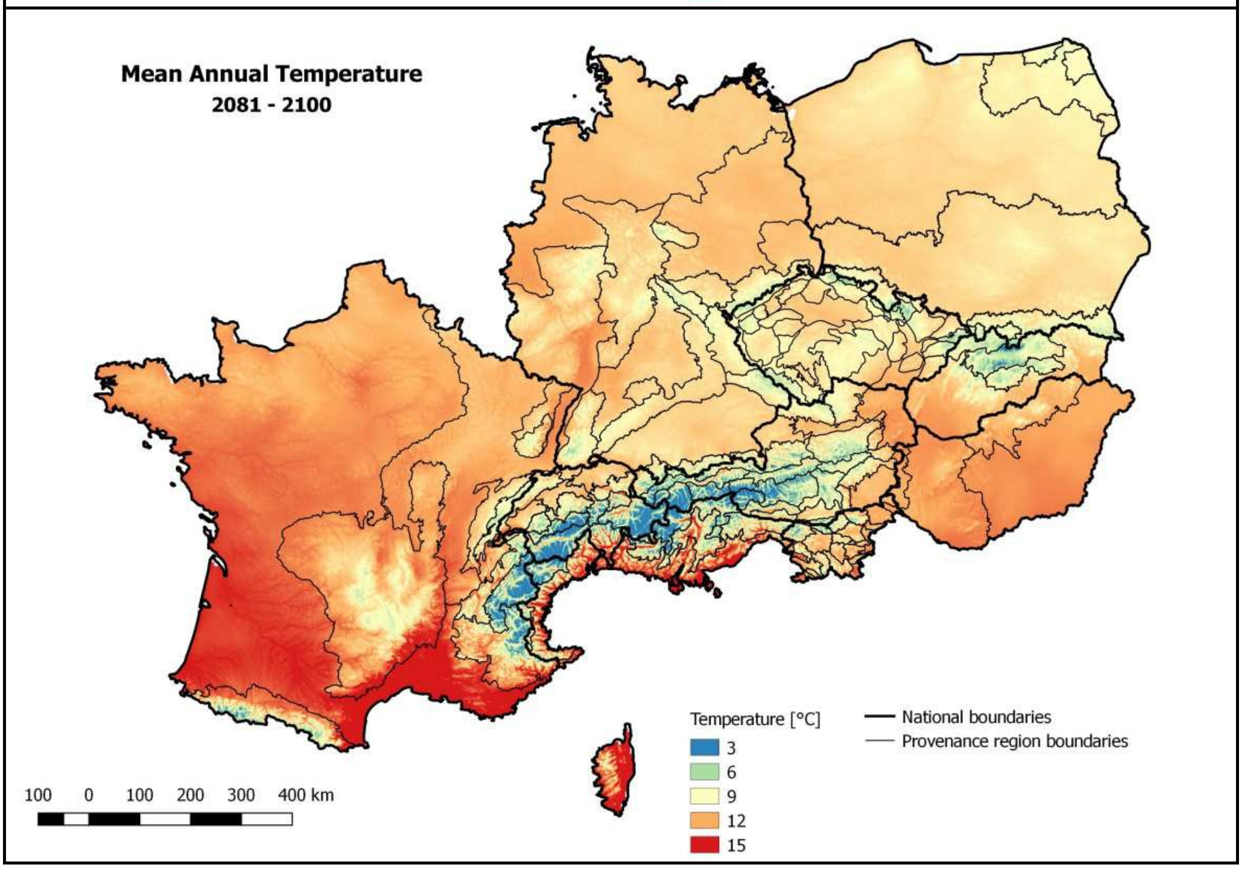


Figure 1: Mean annual temperature in Central Europe for present (reference period 1960 – 1990) and future (reference period 2081 – 2100) climatic conditions.

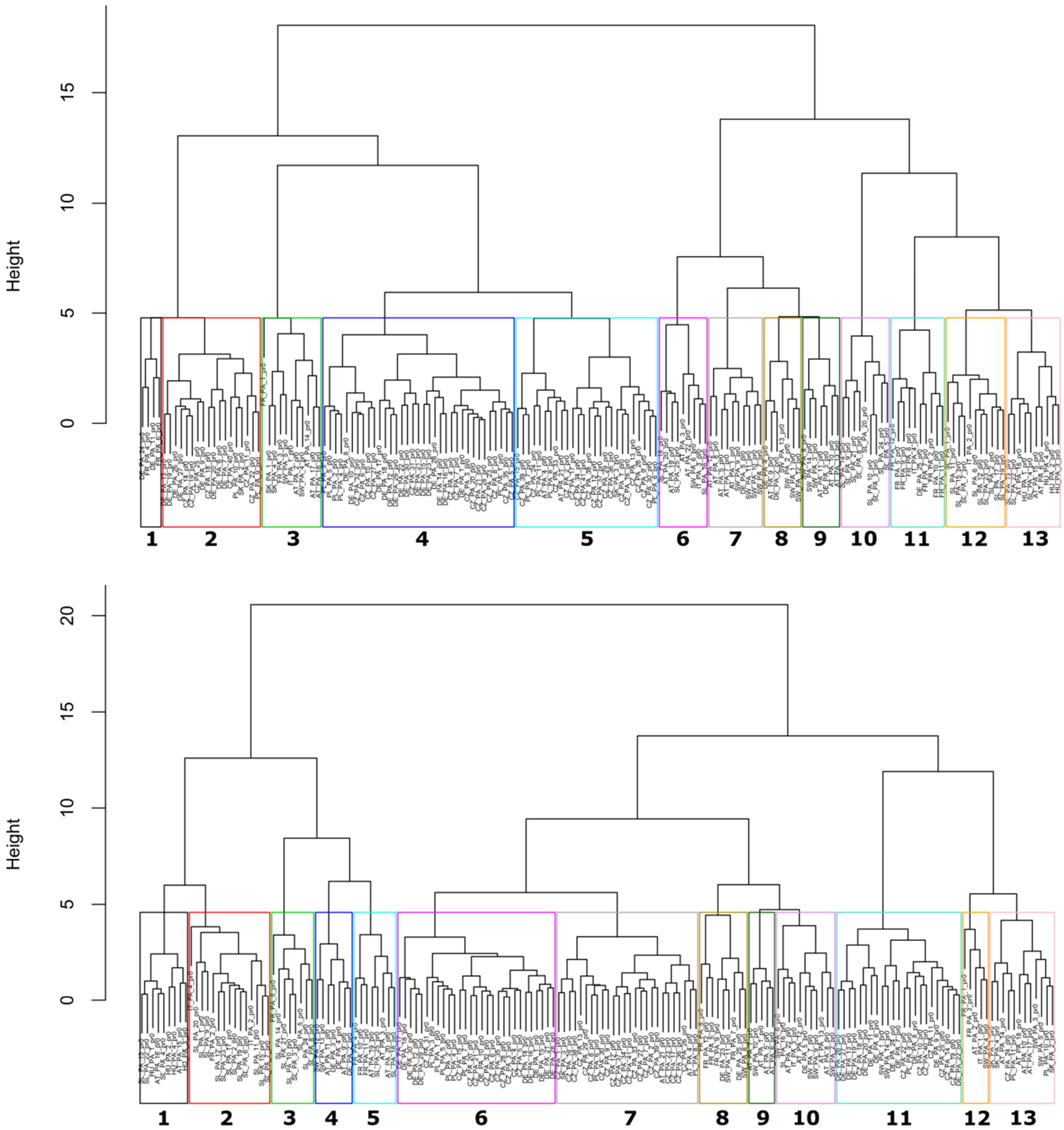


Figure 2: Cluster dendrograms of *Picea abies* for present (upper graph) and future (lower graph) conditions. The numbering of the clusters follows their order within the dendrogram. The code of the provenance regions (leaves) follows Table 3.

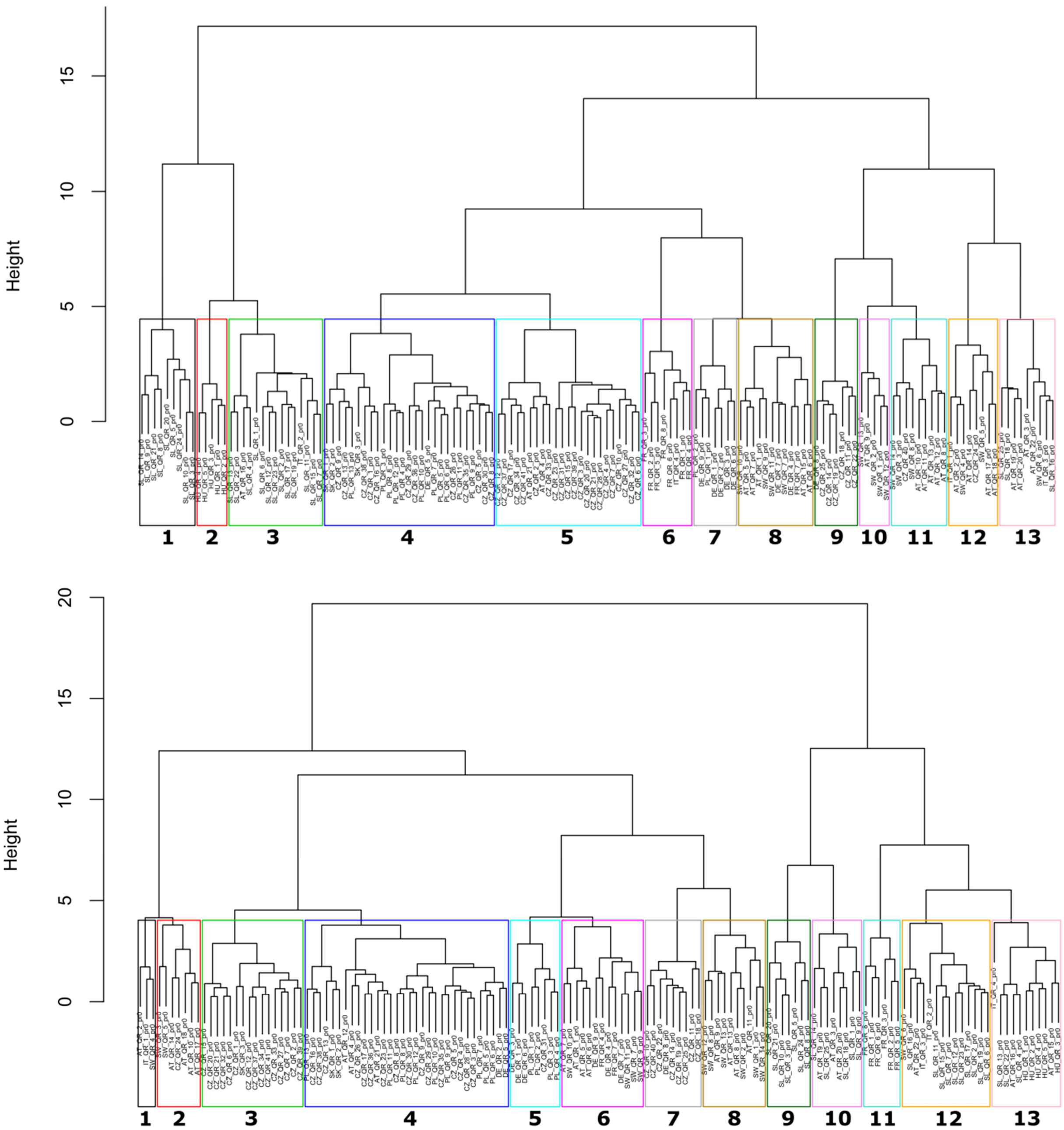


Figure 3: Cluster dendrograms of *Quercus robur* for present (upper graph) and future (lower graph) conditions. The numbering of the clusters follows their order within the dendrogram. The code of the provenance regions (leaves) follows Table 4.

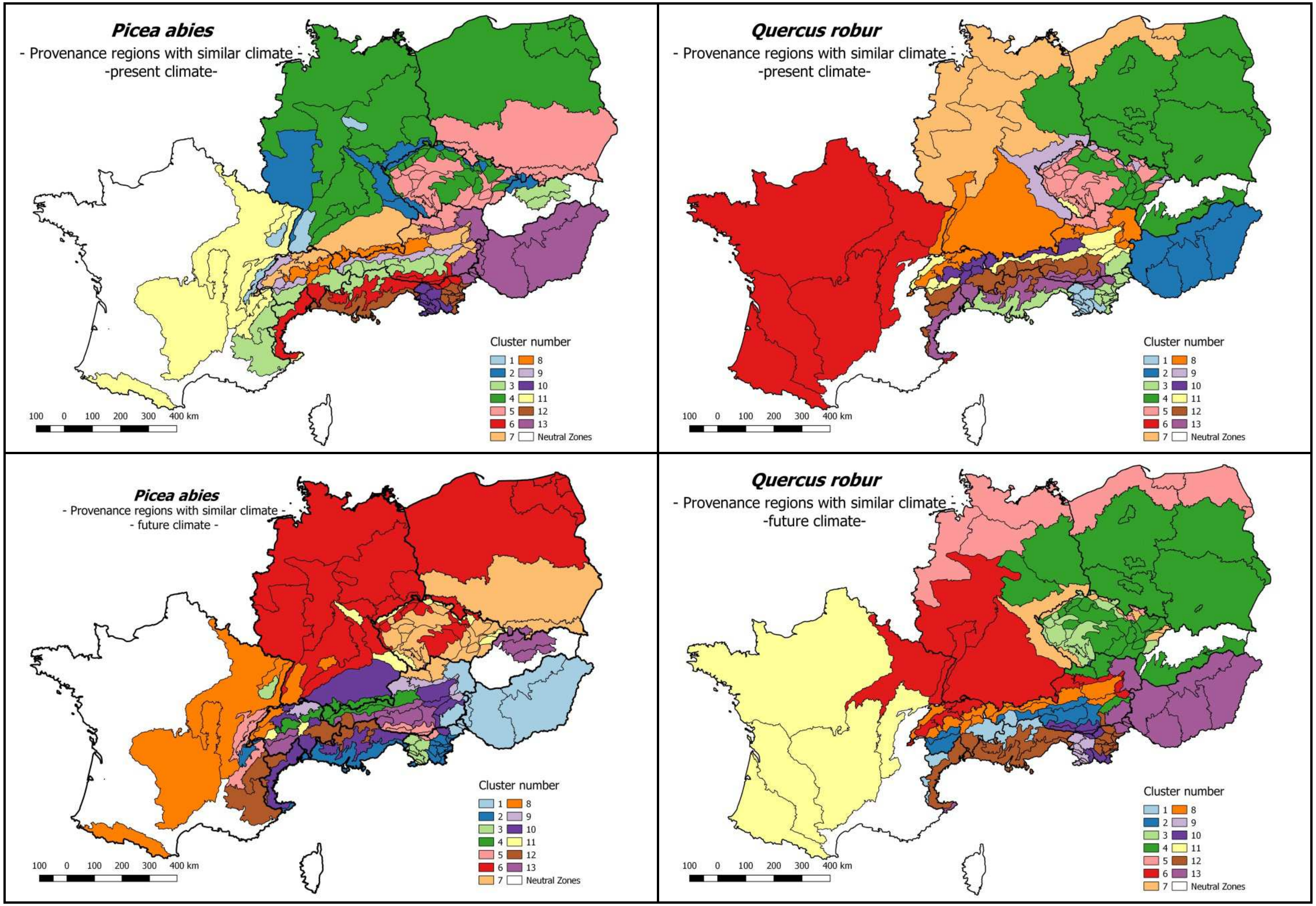


Figure 4: Maps of present (upper) and future (lower) provenance regions sharing similar climates for *Picea abies* (left) and *Quercus robur* (right).

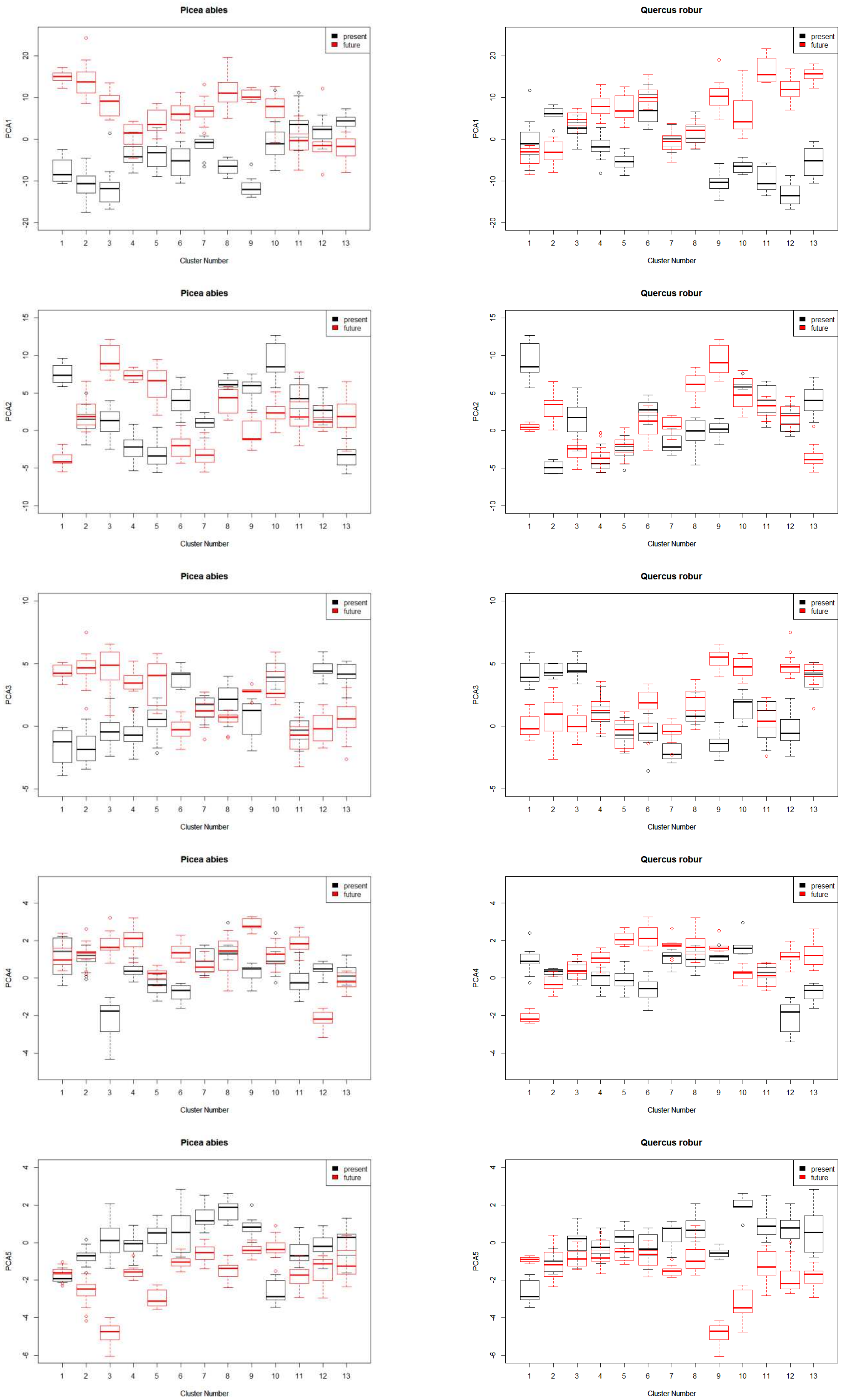


Figure 5: Present (black) and future (red) values of the five PCA-axis for *Picea abies* (left) and *Quercus robur* (right).

Table 1: Distance matrix between present and future clusters for *Picea abies*, sorted by their order in the dendrogram. To read the table, find in the map for the future clusters (Figure 4) the cluster for a provenance region of interest. Then find the red value representing the present cluster that has the most similar climate. For the provenance region of interest, the seeds best adapted for future climates can be found within this present cluster.

# Cluster	1 - present	2 - present	3 - present	4 - present	5 - present	6 - present	7 - present	8 - present	9 - present	10 - present	11 - present	12 - present	13 - present
1 – future	5.001	4.653	5.301	3.621	3.632	4.131	3.494	4.627	4.952	3.853	3.557	2.658	**1.967**
2 – future	4.311	4.602	5.395	4.062	4.222	3.976	3.781	4.368	4.707	2.488	3.278	**2.452**	2.844
3 – future	4.206	5.259	6.342	5.429	5.779	5.046	5.238	5.146	5.356	**2.043**	4.341	3.933	4.913
4 – future	2.711	3.369	4.757	3.608	3.967	3.165	2.921	2.569	3.110	**1.312**	2.736	2.102	3.367
5 – future	3.108	3.779	4.243	3.677	3.823	3.061	3.554	3.794	3.639	**1.164**	2.507	2.229	3.218
6 – future	3.197	2.555	4.017	**1.688**	2.312	3.735	2.275	3.535	3.495	3.780	2.130	2.817	2.382
7 – future	3.709	2.932	3.668	1.656	1.807	3.204	2.023	3.527	3.457	3.815	2.137	2.325	**1.494**
8 – future	2.844	3.166	4.357	2.787	3.252	3.600	2.731	3.404	3.518	2.763	**1.684**	2.557	2.944
9 – future	4.101	3.838	5.394	3.263	3.645	4.079	2.665	3.375	4.158	3.578	3.215	2.591	**2.571**
10 – future	3.440	3.340	4.198	2.735	2.851	2.609	1.881	2.568	3.093	2.537	2.089	**1.144**	1.810
11 – future	1.784	**1.759**	3.984	2.086	2.927	3.747	2.584	3.113	2.929	3.071	2.056	3.042	3.343
12 – future	3.532	3.266	**1.869**	2.680	2.413	2.889	3.437	4.367	3.268	3.973	2.149	3.360	3.369
13 – future	2.264	1.867	2.304	1.486	1.689	2.218	1.997	2.861	2.074	2.881	**1.101**	2.166	2.468

Table 2: Distance matrix between present and future clusters for *Quercus robur*, sorted by their order in the dendrogram. To read the table, follow the procedure described in the text and in Table 1.

# Cluster	1 - present	2 - present	3 - present	4 - present	5 - present	6 - present	7 - present	8 - present	9 - present	10 - present	11 - present	12 - present	13 - present
1 – future	4.112	3.432	3.125	2.284	2.130	2.120	3.138	3.093	3.019	4.248	2.701	1.618	2.497
2 – future	2.699	2.948	2.206	2.004	1.909	1.587	2.336	2.051	1.988	2.952	1.785	2.496	2.060
3 – future	3.799	2.055	2.417	1.171	1.599	1.865	1.490	1.535	2.211	3.546	2.844	3.528	3.218
4 – future	3.829	1.619	2.221	1.569	2.220	2.377	1.995	1.564	2.782	3.634	3.268	4.172	3.424
5 – future	4.025	2.848	3.043	2.407	2.620	2.727	1.658	1.843	2.501	3.397	3.371	4.680	4.098
6 – future	3.200	2.623	2.453	2.864	3.257	2.824	2.583	1.973	3.143	3.196	3.481	5.019	3.782
7 – future	3.154	3.012	2.848	2.266	2.295	2.516	1.711	1.923	1.538	3.002	2.653	4.003	3.531
8 – future	1.947	3.327	2.245	3.153	3.240	2.713	2.853	2.128	2.661	2.182	2.505	4.355	2.931
9 – future	2.219	4.737	4.329	5.567	6.035	5.013	5.892	5.210	5.593	5.551	5.641	6.819	5.182
10 – future	1.517	2.960	2.556	3.694	4.230	3.366	4.442	3.649	4.211	4.460	4.080	4.890	3.333
11 – future	3.305	3.084	2.838	3.066	3.345	1.579	2.996	2.721	3.688	4.053	3.683	4.469	3.634
12 – future	2.390	2.117	1.920	3.253	3.929	3.207	3.887	2.867	4.109	4.003	4.006	5.153	3.394
13 – future	3.808	1.688	2.663	3.091	3.932	3.581	3.802	3.055	4.365	4.761	4.668	5.581	4.253

Appendix

Table 3: Names, national codes and SUSTREE codes used for the provenance regions of *Picea abies*, sorted by country.

Country	National Name	National Code	SUSTREE Code
AT	Innenalpen - kontinentale Kernzone	1.1	AT_PA_2
AT	Subkontinentale Innenalpen - Westteil	1.2	AT_PA_18
AT	Subkontinentale Innenalpen - Ostteil	1.3	AT_PA_17
AT	Nördliche Zwischenalpen - Westteil	2.1	AT_PA_11
AT	Nördliche Zwischenalpen - Ostteil	2.2	AT_PA_10
AT	Östliche Zwischenalpen - Nordteil	3.1	AT_PA_13
AT	Östliche Zwischenalpen - Südteil	3.2	AT_PA_14
AT	Südliche Zwischenalpen	3.3	AT_PA_20
AT	Nördliche Randalpen - Westteil	4.1	AT_PA_9
AT	Nördliche Randalpen - Ostteil	4.2	AT_PA_8
AT	Niederösterreichischer Alpenostrand (Thermenalpen)	5.1	AT_PA_5
AT	Bucklige Welt	5.2	AT_PA_1
AT	Ost- und Mittelsteirisches Bergland	5.3	AT_PA_12
AT	Weststeirisches Bergland	5.4	AT_PA_22
AT	Südliche Randgebirge	6.1	AT_PA_19
AT	Klagenfurter Becken	6.2	AT_PA_3
AT	Nördl. Alpenvorland - Westteil	7.1	AT_PA_7
AT	Nördl. Alpenvorland - Ostteil	7.2	AT_PA_6
AT	Pannonisches Tief- und Hügelland	8.1	AT_PA_15
AT	Subillyrisches Hügel- und Terrassenland	8.2	AT_PA_16
AT	Mühlviertel	9.1	AT_PA_4
AT	Waldviertel	9.2	AT_PA_21
CH	Jura West	1	SW_PA_8
CH	Jura Ost	2	SW_PA_7
CH	Mittelland West	3	SW_PA_11
CH	Mittelland Mitte	4	SW_PA_9
CH	Mittelland Ost	5	SW_PA_10
CH	Voralpen West	6	SW_PA_14
CH	Voralpen Mitte	7	SW_PA_12
CH	Voralpen Ost	8	SW_PA_13
CH	Alpen Nordwest	9	SW_PA_3
CH	Alpen Mitte	10	SW_PA_1
CH	Alpen Nordost	11	SW_PA_2
CH	Alpen Südwest	12	SW_PA_5
CH	Alpen Südost	13	SW_PA_4
CH	Alpensüdseite	14	SW_PA_6
CZ	Krušné hory	1	CZ_PA_19
CZ	Podkrušnohorské pánve	2	CZ_PA_28
CZ	Karlovarská vrchovina	3	CZ_PA_15
CZ	Doupovské hory	4	CZ_PA_7
CZ	České středohoří	5	CZ_PA_3
CZ	Západočeská pahorkatina	6	CZ_PA_41
CZ	Brdská vrchovina	7	CZ_PA_2
CZ	Křivoklátsko a český kras	8	CZ_PA_17
CZ	Rakovnicko-kladenská pahorkatina	9	CZ_PA_34
CZ	Středočeská pahorkatina	10	CZ_PA_37

CZ	Český les	11	CZ_PA_6
CZ	Předhoří šumavy a Novohradských hor	12	CZ_PA_33
CZ	Šumava	13	CZ_PA_40
CZ	Novohradské hory	14	CZ_PA_24
CZ	Jihočeské pánve	15	CZ_PA_12
CZ	Českomoravská vrchovina	16	CZ_PA_4
CZ	Polabí	17	CZ_PA_29
CZ	Severočeská pískovcová plošina a Český ráj	18	CZ_PA_35
CZ	Lužická pískovcová vrchovina	19	CZ_PA_21
CZ	Lužická pahorkatina	20	CZ_PA_20
CZ	Jizerské hory a Ještěd	21	CZ_PA_14
CZ	Krkonoše	22	CZ_PA_18
CZ	Podkrkonoší	23	CZ_PA_27
CZ	Sudetské mezihoří	24	CZ_PA_39
CZ	Orlické hory	25	CZ_PA_25
CZ	Předhoří Orlických hor	26	CZ_PA_32
CZ	Hrubý Jeseník	27	CZ_PA_11
CZ	Předhoří Hrubého Jeseníku	28	CZ_PA_31
CZ	Nízký Jeseník	29	CZ_PA_23
CZ	Drahanská vrchovina	30	CZ_PA_8
CZ	Českomoravské mezihoří	31	CZ_PA_5
CZ	Slezská nížina	32	CZ_PA_36
CZ	Předhoří Českomoravské vrchoviny	33	CZ_PA_30
CZ	Hornomoravský úval	34	CZ_PA_9
CZ	Jihomoravské úvaly	35	CZ_PA_13
CZ	Středomoravské Karpaty	36	CZ_PA_38
CZ	Kelečská pahorkatina	37	CZ_PA_16
CZ	Bílé Karpaty a Vizovické vrchy	38	CZ_PA_1
CZ	Podbeskydská pahorkatina	39	CZ_PA_26
CZ	Moravskoslezské Beskydy	40	CZ_PA_22
CZ	Hostýnsko-vsetínská vrchovinam a Javorníky	41	CZ_PA_10
DE	Norddeutsches Tiefland	840 01	DE_PA_17
DE	Mittel- und Ostdeutsches Tiefland außer Niederlausitz	840 02	DE_PA_14
DE	Niederlausitz	840 03	DE_PA_16
DE	Rheinisches und Saarpfälzer Bergland sowie Oberrheingraben, kolline Stufe	840 04	DE_PA_18
DE	Rheinisches und Saarpfälzer Bergland sowie Oberrheingraben, montane Stufe	840 05	DE_PA_19
DE	Weser- und Hessisches Bergland, kolline Stufe	840 06	DE_PA_29
DE	Weser- und Hessisches Bergland, montane Stufe	840 07	DE_PA_30
DE	Harz, kolline Stufe	840 08	DE_PA_12
DE	Harz, montane Stufe	840 09	DE_PA_13
DE	Harz, hochmontane Stufe	840 10	DE_PA_11
DE	Thüringer Wald und Frankenwald, kolline Stufe	840 11	DE_PA_27
DE	Thüringer Wald und Frankenwald, montane Stufe	840 12	DE_PA_26
DE	Vogtland und Ostthüringisches Hügelland	840 13	DE_PA_28
DE	Sächsisches Bergland, kolline Stufe	840 14	DE_PA_21
DE	Sächsisches Bergland, montane Stufe	840 15	DE_PA_22
DE	Sächsisches Bergland, hochmontane Stufe	840 16	DE_PA_20
DE	Neckarland und Fränkisches Hügelland	840 17	DE_PA_15
DE	Fichtelgebirge und Oberpfälzer Wald, submontane Stufe	840 18	DE_PA_10
DE	Fichtelgebirge und Oberpfälzer Wald, montane Stufe	840 19	DE_PA_9
DE	Bayerischer Wald, submontane Stufe	840 20	DE_PA_8
DE	Bayerischer Wald, montane Stufe	840 21	DE_PA_7
DE	Bayerischer Wald, hochmontane Stufe	840 22	DE_PA_6

DE	Schwarzwald, submontane Stufe	840 23	DE_PA_25
DE	Schwarzwald, hochmontane Stufe	840 24	DE_PA_24
DE	Schwäbisch-Fränkischer Wald	840 25	DE_PA_23
DE	Alb	840 26	DE_PA_1
DE	Alpenvorland	840 27	DE_PA_5
DE	Alpen, submontane Stufe	840 28	DE_PA_4
DE	Alpen, montane Stufe	840 29	DE_PA_2
DE	Alpen, subalpine Stufe	840 30	DE_PA_3
FR	Nord-est (Northeast)	PAB201	FR_PA_9
FR	Massif Vosgien gréseux (Vosges standstone)	PAB202	FR_PA_7
FR	Massif Vosgien cristallin (crytalline Vosges)	PAB203	FR_PA_6
FR	Massif Central	PAB400	FR_PA_5
FR	Premier plateau du Jura (first plateau of Jura)	PAB501	FR_PA_11
FR	High Jura (high altitude)	PAB503	FR_PA_4
FR	Entre Jura et Savoie	PAB504	FR_PA_2
FR	Nothern Alpine foreland (high altitude)	PAB506	FR_PA_10
FR	High Alpes (mean altitude)	PAB507	FR_PA_3
FR	Alpes méridionales (southern Alps)	PAB509	FR_PA_1
FR	Pyrénées	PAB600	FR_PA_12
FR	neutral zone of Northwest	ZN1	FR_PA_8
HU	1	1	HU_PA_1
HU	2	2	HU_PA_2
HU	3	3	HU_PA_3
HU	4	4	HU_PA_4
IT	Regione Alpina Endalpica	100	IT_PA_1
IT	Regione Alpina Mesalpica	200	IT_PA_3
IT	Regione Alpina Esalpica	300	IT_PA_2
IT	Regione Oromediterranea	500	IT_PA_4
PL	Św10	Św10	PL_PA_1
PL	Św20	Św20	PL_PA_2
PL	Św21	Św21	PL_PA_3
PL	Św22	Św22	PL_PA_4
PL	Św23	Św23	PL_PA_5
PL	Św50	Św50	PL_PA_6
PL	Św71	Św71	PL_PA_7
PL	Św80	Św80	PL_PA_8
PL	Św81	Św81	PL_PA_9
PL	Św82	Św82	PL_PA_10
PL	Św83	Św83	PL_PA_11
SK	The Fatra - Tatric region	1	SK_PA_1
SK	The Kysuce - Orava region	2	SK_PA_2
SK	The region Pohronie - Hnilec	3	SK_PA_4
SK	The region out of spruce seed zones	4	SK_PA_3
SL	Julijske Alpe	11	SL_PA_8
SL	Zahodne Karavanke - Kamniške A	12	SL_PA_25
SL	Savinjske Alpe - Vzhodne Karav	13	SL_PA_18
SL	Pohorska	20	SL_PA_16
SL	Gorièko	31	SL_PA_4
SL	Murska ravan	32	SL_PA_13
SL	Slovenske gorice - Ptujsko pol	33	SL_PA_22
SL	Haloze - Dravinjske gorice	34	SL_PA_7
SL	Obsotelsko grièevje	35	SL_PA_15
SL	Krško - Bizeljsko grièevje	36	SL_PA_11
SL	Bela Krajina	37	SL_PA_1
SL	Škofjeloško hribovje - Savska	41	SL_PA_21

SL	Posavsko hribovje	42	SL_PA_17
SL	Savinjsko - Šaleško obmoèje	43	SL_PA_19
SL	Suha krajina - južno Zasavsko	51	SL_PA_23
SL	Mirnsko - Raduljsko hribovje	52	SL_PA_12
SL	Bohor	53	SL_PA_2
SL	Gorjanci	54	SL_PA_6
SL	Trnovski gozd	61	SL_PA_24
SL	Notranjsko - Snežniško pogorje	62	SL_PA_14
SL	Koèevsko - Ribniško pogorje	63	SL_PA_9
SL	Goriška Brda - Vipavska dolina	71	SL_PA_5
SL	Kras - Vremsko grièevje	72	SL_PA_10
SL	Brkini	73	SL_PA_3
SL	Šavrinsko grièevje	74	SL_PA_20

Table 4: Names, national codes and SUSTREE codes used for the provenance regions of *Quercus robur*, sorted by country.

Country	National Name	National Code	SUSTREE Code
AT	Innenalpen - kontinentale Kernzone	1.1	AT_QR_2
AT	Subkontinentale Innenalpen - Westteil	1.2	AT_QR_18
AT	Subkontinentale Innenalpen - Ostteil	1.3	AT_QR_17
AT	Nördliche Zwischenalpen - Westteil	2.1	AT_QR_11
AT	Nördliche Zwischenalpen - Ostteil	2.2	AT_QR_10
AT	Östliche Zwischenalpen - Nordteil	3.1	AT_QR_13
AT	Östliche Zwischenalpen - Südteil	3.2	AT_QR_14
AT	Südliche Zwischenalpen	3.3	AT_QR_20
AT	Nördliche Randalpen - Westteil	4.1	AT_QR_9
AT	Nördliche Randalpen - Ostteil	4.2	AT_QR_8
AT	Niederösterreichischer Alpenostrand (Thermenalpen)	5.1	AT_QR_5
AT	Bucklige Welt	5.2	AT_QR_1
AT	Ost- und Mittelsteirisches Bergland	5.3	AT_QR_12
AT	Weststeirisches Bergland	5.4	AT_QR_22
AT	Südliche Randgebirge	6.1	AT_QR_19
AT	Klagenfurter Becken	6.2	AT_QR_3
AT	Nördl. Alpenvorland - Westteil	7.1	AT_QR_7
AT	Nördl. Alpenvorland - Ostteil	7.2	AT_QR_6
AT	Pannonisches Tief- und Hügelland	8.1	AT_QR_15
AT	Subillyrisches Hügel- und Terrassenland	8.2	AT_QR_16
AT	Mühlviertel	9.1	AT_QR_4
AT	Waldviertel	9.2	AT_QR_21
CH	Jura West	1	SW_QR_8
CH	Jura Ost	2	SW_QR_7
CH	Mittelland West	3	SW_QR_11
CH	Mittelland Mitte	4	SW_QR_9
CH	Mittelland Ost	5	SW_QR_10
CH	Voralpen West	6	SW_QR_14
CH	Voralpen Mitte	7	SW_QR_12
CH	Voralpen Ost	8	SW_QR_13
CH	Alpen Nordwest	9	SW_QR_3
CH	Alpen Mitte	10	SW_QR_1
CH	Alpen Nordost	11	SW_QR_2
CH	Alpen Südwest	12	SW_QR_5
CH	Alpen Südost	13	SW_QR_4

CH	Alpensüdseite	14	SW_QR_6
CZ	Krušné hory	1	CZ_QR_19
CZ	Podkrušnohorské pánve	2	CZ_QR_28
CZ	Karlovarská vrchovina	3	CZ_QR_15
CZ	Doupovské hory	4	CZ_QR_7
CZ	České středohoří	5	CZ_QR_3
CZ	Západočeská pahorkatina	6	CZ_QR_41
CZ	Brdská vrchovina	7	CZ_QR_2
CZ	Křivoklátsko a český kras	8	CZ_QR_17
CZ	Rakovnicko-kladenská pahorkatina	9	CZ_QR_34
CZ	Středočeská pahorkatina	10	CZ_QR_37
CZ	Český les	11	CZ_QR_6
CZ	Předhoří šumavy a Novohradských hor	12	CZ_QR_33
CZ	Šumava	13	CZ_QR_40
CZ	Novohradské hory	14	CZ_QR_24
CZ	Jihočeské pánve	15	CZ_QR_12
CZ	Českomoravská vrchovina	16	CZ_QR_4
CZ	Polabí	17	CZ_QR_29
CZ	Severočeská pískovcová plošina a Český ráj	18	CZ_QR_35
CZ	Lužická pískovcová vrchovina	19	CZ_QR_21
CZ	Lužická pahorkatina	20	CZ_QR_20
CZ	Jizerské hory a Ještěd	21	CZ_QR_14
CZ	Krkonoše	22	CZ_QR_18
CZ	Podkrkonoší	23	CZ_QR_27
CZ	Sudetské mezihoří	24	CZ_QR_39
CZ	Orlické hory	25	CZ_QR_25
CZ	Předhoří Orlických hor	26	CZ_QR_32
CZ	Hrubý Jeseník	27	CZ_QR_11
CZ	Předhoří Hrubého Jeseníku	28	CZ_QR_31
CZ	Nízký Jeseník	29	CZ_QR_23
CZ	Drahanská vrchovina	30	CZ_QR_8
CZ	Českomoravské mezihoří	31	CZ_QR_5
CZ	Slezská nížina	32	CZ_QR_36
CZ	Předhoří Českomoravské vrchoviny	33	CZ_QR_30
CZ	Hornomoravský úval	34	CZ_QR_9
CZ	Jihomoravské úvaly	35	CZ_QR_13
CZ	Středomoravské Karpaty	36	CZ_QR_38
CZ	Kelečská pahorkatina	37	CZ_QR_16
CZ	Bílé Karpaty a Vizovické vrchy	38	CZ_QR_1
CZ	Podbeskydská pahorkatina	39	CZ_QR_26
CZ	Moravskoslezské Beskydy	40	CZ_QR_22
CZ	Hostýnsko-vsetínská vrchovinam a Javorníky	41	CZ_QR_10
DE	Niedersächsischer Küstenraum und Rheinisch-Westfälische Bucht	817 01	DE_QR_3
DE	Ostsee-Küstenraum	817 02	DE_QR_6
DE	Heide und Altmark	817 03	DE_QR_1
DE	Ostdeutsches Tiefland	817 04	DE_QR_5
DE	Mitteldeutsches Tief- und Hügelland	817 05	DE_QR_2
DE	Westdeutsches Bergland	817 06	DE_QR_9
DE	Oberrheingraben	817 07	DE_QR_4
DE	Südostdeutsches Hügel- und Bergland	817 08	DE_QR_8
DE	Süddeutsches Hügel- und Bergland sowie Alpen	817 09	DE_QR_7
FR	Nord-ouest	QRO100	FR_QR_3
FR	Plateaux du NE	QRO201	FR_QR_4
FR	Vallée du Rhin	QRO202	FR_QR_7

FR	Vallée de la Saône	QRO203	FR_QR_6
FR	Nord de la Garonne	QRO301	FR_QR_2
FR	Sud ouest	QRO361	FR_QR_5
FR	Massif Central	QRO421	FR_QR_1
FR	Zone neutralisée	ZN	FR_QR_8
HU	1	1	HU_QR_1
HU	2	2	HU_QR_2
HU	3	3	HU_QR_3
HU	4	4	HU_QR_4
HU	5	5	HU_QR_5
IT	Regione Alpina Endalpica	100	IT_QR_1
IT	Regione Alpina Mesalpica	200	IT_QR_3
IT	Regione Alpina Esalpica	300	IT_QR_2
IT	Regione Oromediterranea	500	IT_QR_4
PL	Dbs10	Dbs10	PL_QR_1
PL	Dbs11	Dbs11	PL_QR_2
PL	Dbs20	Dbs20	PL_QR_3
PL	Dbs21	Dbs21	PL_QR_4
PL	Dbs30	Dbs30	PL_QR_5
PL	Dbs31	Dbs31	PL_QR_6
PL	Dbs32	Dbs32	PL_QR_7
PL	Dbs40	Dbs40	PL_QR_8
PL	Dbs50	Dbs50	PL_QR_9
PL	Dbs51	Dbs51	PL_QR_10
PL	Dbs60	Dbs60	PL_QR_11
PL	Dbs61	Dbs61	PL_QR_12
PL	Dbs62	Dbs62	PL_QR_13
SK	The region of west Slovakia	1	SK_QR_2
SK	The region of east Slovakia	2	SK_QR_1
SK	The region out of English oak seed zones	3	SK_QR_3
SL	Julijske Alpe	11	SL_QR_8
SL	Zahodne Karavanke - Kamniške A	12	SL_QR_25
SL	Savinjske Alpe - Vzhodne Karav	13	SL_QR_18
SL	Pohorska	20	SL_QR_16
SL	Gorièko	31	SL_QR_4
SL	Murska ravan	32	SL_QR_13
SL	Slovenske gorice - Ptujsko pol	33	SL_QR_22
SL	Haloze - Dravinjske gorice	34	SL_QR_7
SL	Obsotelsko grièevje	35	SL_QR_15
SL	Krško - Bizeljsko grièevje	36	SL_QR_11
SL	Bela Krajina	37	SL_QR_1
SL	Škofjeloško hribovje - Savska	41	SL_QR_21
SL	Posavsko hribovje	42	SL_QR_17
SL	Savinjsko - Šaleško obmoèje	43	SL_QR_19
SL	Suha krajina - južno Zasavsko	51	SL_QR_23
SL	Mirnsko - Raduljsko hribovje	52	SL_QR_12
SL	Bohor	53	SL_QR_2
SL	Gorjanci	54	SL_QR_6
SL	Trnovski gozd	61	SL_QR_24
SL	Notranjsko - Snežniško pogorje	62	SL_QR_14
SL	Koèevsko - Ribniško pogorje	63	SL_QR_9
SL	Goriška Brda - Vipavska dolina	71	SL_QR_5
SL	Kras - Vremsko grièevje	72	SL_QR_10
SL	Brkini	73	SL_QR_3
SL	Šavrinsko grièevje	74	SL_QR_20

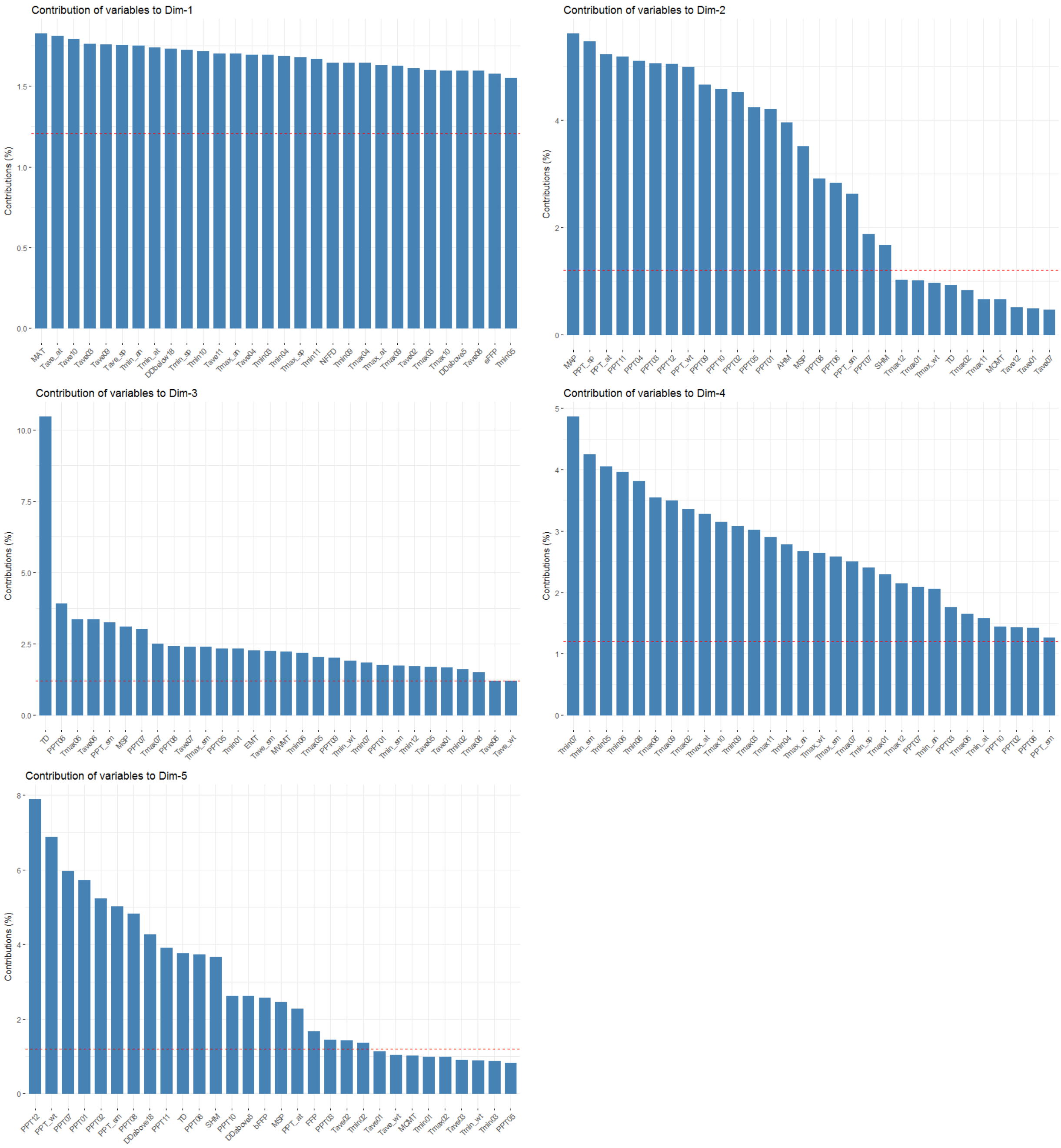


Figure 6: Contribution of variables to the first five PCA-axes. Only the first 30 variables are shown in the graphs. The red line represents the point at which a contribution can be considered important for a given axis.

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