Interreg
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North-West Europe
MigFoRest

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WP1 - Joint Strategy to implement assisted migration (AM) in North-West Europe

Selection of provenances for AM

List of suitable provenances to implement AM in North-West Europe, except Ireland

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Introduction

The aim of this activity is to provide a list of up to 30 suitable provenances (including priorities and alternatives) across all species with a justification and concrete description of the basic material (seed source, seed stand, seed orchard) or reproductive material (stored seeds, saplings) to be used. This document contains the aim and methodologies applied for selection of the provenances. Additional Excel document “List of suitable provenances to implement AM in NWE” provides the list of the provenances with the explanations for the criteria that have been used.

The concept of assisted migration is based on choosing species and provenances that have grown for generations in contexts that are more restrictive from a hydric and temperature point of view than the target sites. It is generally accepted that southern and/or mediterranean species and provenances fall into this category. However, this is not always the case, particularly for species with a large distribution area. Lowland species can compensate for a lack of water by increasing altitude, as in the case of Scots pine, for example. Thus, it is needed to rely on objective criteria and compare them on the scale of the species' range, as defined in the MigFoRest project.

The suggested provenances are coming from the regions where the climatic conditions today are similar to the predicted future climate in the region of NWE.

Comprehensive literature research on genetic differentiation, phenological and morphological traits of populations and provenance trials in common garden setups have been done. The information on suggested provenances has been added to the shared Excel spreadsheet. Since only silver fir (*Abies alba*), sessile oak (*Quercus petraea*) and pedunculate oak (*Quercus robur*) have major ecological and economical value in today’s forest in NWE, among the selected tree species in the MigFoRest project, the results of the research on them are available.

For silver fir, of which natural habitat is spreading in the mountainous regions of central and SE Europe, it is expected that the provenances from the southern regions have a higher probability to adapt to future climate in NWE. There have been numerous studies with provenance trials of silver fir that provided insight into populations that already showed promising results in various European regions. Since silver fir will be mainly introduced in the pilot territory located in the Continental highland in Germany, the provenances were chosen to match the conditions in this region.

The areas of sessile and pedunculate oaks are widespread throughout the whole of Europe, which made it challenging to choose ideal provenances to implement assisted migration in NWE. For downy oak (*Quercus pubescens*) and species from *Sorbus* and *Tilia* genera, there are fewer available studies that could be confidently used to suggest the high performing provenances. For those species the European database FOREMATIS, with references to the Forest Reproductive Material (FRM) populations in the EU, was used as a source of potential provenances.

The species of deciduous trees will be implemented in six different pilot territories. The current climatic conditions for each territory have been observed separately and compared to those of the available provenances for each species. For these analyses, the IKS method was used, and the filtered lists were thoroughly examined and adjusted for each territory and each species individually.

As a result of the diversity of pilot territories in the partner countries, and their climatic conditions, the list of suggested provenances has been expanded to 206 with the intention to satisfy the specific needs for each pilot territory. One common provenance per species will be planted in each pilot territory as a control.

FVA (Germany), ONF (France), CRA-W (Wallonia, Belgium) and INBO (Flanders, Belgium) were the key contributors in this activity. All partners involved have been contributing to creating the shared database of provenances per territory. The deliverable was reviewed and consolidated by the consortium.

Method for provenance selection using the IKS model

What is IKS?

IKS[1] is a model based on the actual species niche that aims to predict the possible future suitable area for a tree species under climate changes. It uses 3 pedoclimatic indicators:

The **annual water deficit** (DHYa as "Déficit HYdrique Annuel", in the ClimEssences terminology) of the stands. This is the annual accumulation of the monthly water deficits calculated by making a cumulative monthly balance of precipitation minus potential evapotranspiration (ETP), considering the maximum useful soil reserve and, in simplified terms, whether the precipitation is in the form of snow or not. Key factors for calculating DHYa include:

- Monthly minimum and maximum, and average temperatures
- Monthly precipitation
- Maximum useful soil reserve
- Latitude of the site

To minimize bias from initial conditions, calculations are averaged over three years, retaining only the final year's data.

The **minimum annual temperature** (TMIa, as "Température MInimale Annuelle" in the ClimEssences terminology) which, below a minimum threshold, corresponds to the limiting factor of **cold excess**.

The **sum of annual Day Degree** (SDJa, as "Somme des Degrés Jours Annuels" in the ClimEssences terminology) which is the sum of daily average temperatures where the average temperature is above 5°C. When below a minimum threshold, it corresponds to the limiting factor **lack of heat**.

It is possible to calculate these indicators for seed sourcing areas allowing comparison between them and with planting areas regarding pedoclimatic conditions.

[1] The IKS model is precisely described on the ClimEssence platform developed by ONF and CNPF-IDF: climessences.fr

Selecting provenances with IKS

Selecting a provenance from the above-described indicators by comparing them requires defining what makes a provenance more suitable than another.

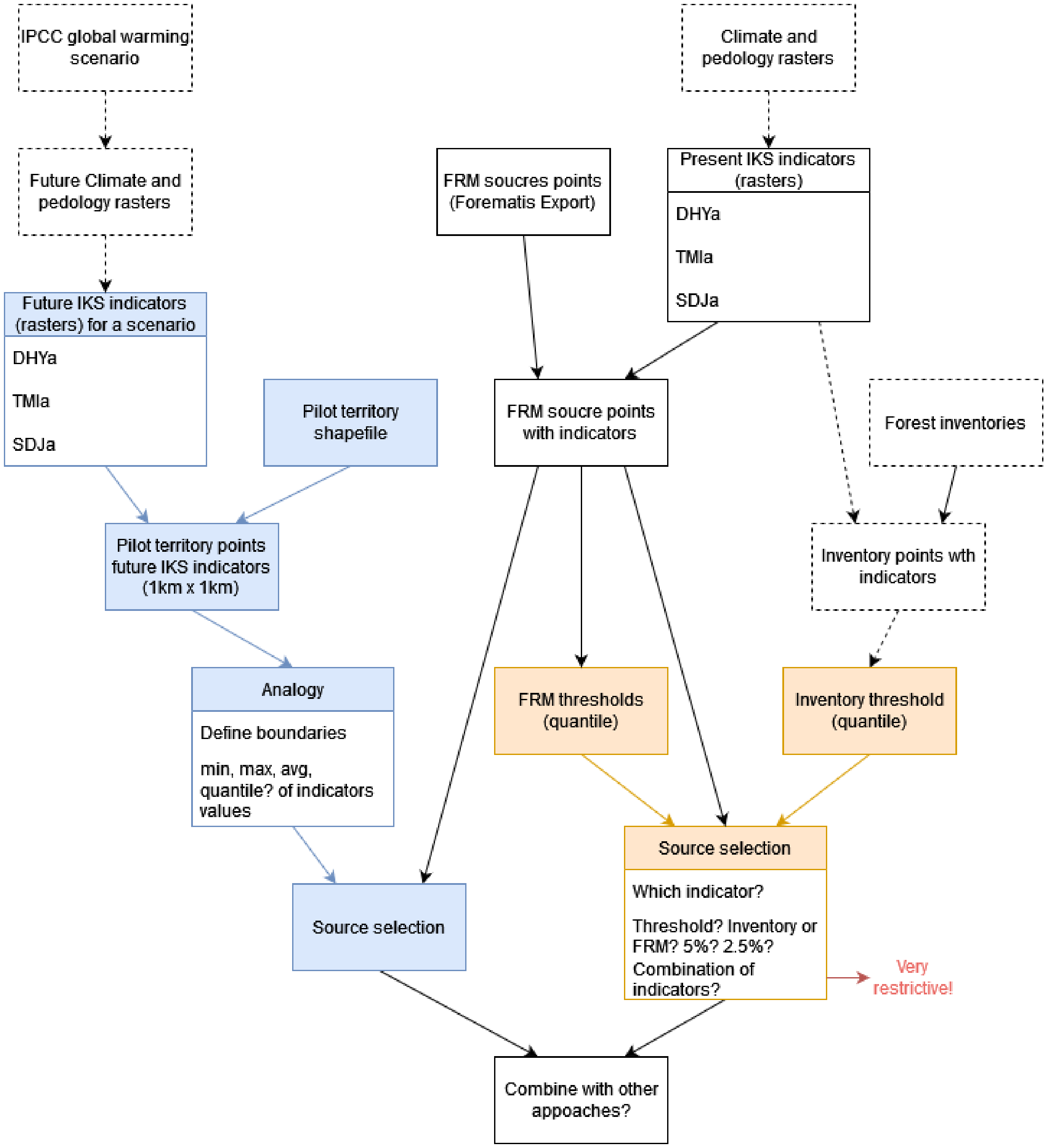


Figure 1:Schematic representation of the two possible process of provenance selection using IKS.

Two approaches were thought of: selecting the extremes of the variables (example: driest seed sources; orange path) or selecting seed sources in similar conditions to the planting areas (Climate analogy, blue path).

The European database FOREMATIS references the Forest Reproductive Material (FRM) populations in EU, with their coordinates for the stands of selected category or better. It can be used to assign IKS values to a specific FRM and to compare them. Seed sources of the identified category were excluded from the analysis as it is a region of provenance and not a precise stand (except for Italy where the stand coordinates are given). Data from countries where the coordinates given where not precise enough or in an un- exploitable format were excluded. The countries included in the analysis were Austria, Belgium, Bulgaria, Czechia, Denmark, Finland, France, Italy, Letton, Lithuania, Luxemburg, Poland, Spain.

It was chosen to look for provenances growing under conditions "similar" to the predicted future climate in the project areas, as it better matches the project objective. It is also better for taking multiple limiting factors into account.

In ClimEssences, the climate analogy is defined as follow:

- Present[2] DHYa of the target (in our case, seed source) is between the maximum and the minimum of the reference area (pilot territory) in the future,
- Present TMIa of the target is above or equal to the minimum of the reference in the future,
- Present SDJa of the target is above or equal to the minimum of the reference in the future,
- The extreme values (the 2.5% lowest and the 2.5% highest) for the parameters (DHYa, TMIa, SDJa) on the reference area were removed before calculating a threshold value of the parameter.

This definition was chosen for a generic situation and did not match what is needed for seed source selection. For example, it did not look relevant to consider that the seed source should not support more extreme cold temperatures than the future of the reference. This approach has been adapted for assisted migration.

The future climatic conditions of the reference area can be obtained from a specific climatic scenario based on the 5th IPCC report RCP (emissions) curves. Data on the IKS indicators of RCP 4.5 and RCP 8.5[3] only are available, both are divided in three sub-scenarios: pessimistic, average and optimistic, as there is a rather large uncertainty around the RCP curves and applied for two time-horizons; 2050 and 2070.

The scenario used is RCP 8.5 average, which is the most likely scenario regarding the current warming trend in the available dataset despite being still pessimistic. It is used at horizon 2070, which better corresponds to the trees' time of maturity.

As water deficit is expected to be a more limiting factor in the future, DHYa is the first indicator to look at. For assisted migration, the source should support the expected future water deficit on at least part of the reference territory. After testing different possibilities, the threshold was put at the first quartile. In other words, the provenance should be suitable on at least 25% of the territory regarding the water

[2] Present climatic conditions are those of a reference climatic period: 1979 – 2013.
[3] RCP4.5 and RCP8.5 are Representative Concentration Pathways (RCPs) used by the IPCC to model future climate scenarios based on greenhouse gas emissions. RCP4.5 represents a stabilization scenario where emissions peak around 2040 and then decline, leading to a moderate increase in global temperature (~2.4–3°C by 2100). RCP8.5, often referred to as a 'high-emission scenario,' assumes continued high fossil fuel use and rapid economic growth, leading to a more significant temperature rise (~4.3–5.4°C by 2100). These scenarios help assess potential climate impacts and inform mitigation strategies.

deficit. Using the minimum of the distribution was leading to absurd results in a case where the minimum expected future water deficit on the territory was 0, filtering provenances on cold limitations only. This case still could happen with the first quartile but would either mean that the territory is not subject to drought increase in the future, in which case it is not a good target for assisted migration, or that there is an important heterogeneity on the territory so it's borders should be reworked. Twenty five percent is only a small part of the territory and might not look enough since the whole territory will be planted, but the provenance used is likely to be with a higher DHYa, therefore suitable for a larger part. Also, the chosen scenario being rather pessimistic, the actual DHYa over the territory is expected to be lower than predicted in the future, and so all selected provenance to be suitable on a larger area.

Optionally, if there are too many provenances to choose from, it is possible to limit the water deficit of the source by the maximum predicted on the reference area, thus limiting the transfer distance.

As planting starts in the season 2024-2025, the seedlings should be adapted to the present limiting factors of the planting area, which is expected to be the cold temperatures.

Both IKS indicators TMIa and SDJa translate this aspect in a different way. For both, it was considered that the seed source should be in an environment at least as limiting as the reference area in its totality.

As for the climate analogy in ClimEssences the thresholds were calculated on 95% of the distribution, removing extreme values that might not be representative.

For MigFoRest, the climate analogy for seed sources selection was therefore defined based on the following conditions:

- **Condition 1:** Present DHYa of the seed source is equal or above the 25% lowest values of the pilot area in the future.
- **Condition 2:** Present DHYa of the seed source is equal or below the maximum of the pilot area in the future.
- **Condition 3:** Present TMIa of the seed source is below or equal to the minimum of the pilot area in the **present conditions**.
- **Condition 4:** Present SDJa of the seed source is below or equal to the minimum of the pilot area in the **present conditions**.
- **Condition 5:** The extreme values (the 2.5% lowest and the 2.5% highest) for the parameters (DHYa, TMIa, SDJa) on the reference area were removed before calculating a threshold value of the parameter.

Filtering the seed sources based on these conditions resulted in different numbers of possible sources depending on the species and territory? In some cases, the options were too limited, therefore the results were adjusted as follows:

Conditions 1, 3, 4 and 5 on RCP 8.5 were used for the first filtering

Condition 2 was used for more stringent filtering when too many results were obtained.

Condition 4 was removed in case the selection led to insufficient number of results. The excess of cold is expected to be a more limiting factor than the length of the vegetation period for assisted migration. Extreme cold temperatures could kill young seedlings, while a shorter vegetation period would result in a slower growth at young age. However, some species have a very limited transfer response, especially for oaks, early blooming period could persist resulting in damages to the flowers by late frosts and so a limited ability to reproduce. Yet by the time the trees reach their maturity, the SDJa should have increased under the effect of climate change, partially negating this issue. Late frosts will still be possible as extreme events are expected to increase in frequency and intensity, so the seed sources satisfying the condition of SDJa should still be preferred when possible.

When removing condition 4, the provenances picked were the closest to the SDJa threshold.

If there were still not enough results, the scenario was changed for a more optimistic one, RCP 4.5 average with conditions 1-3-4-5, bringing more provenances to complete the list obtained under RCP 8.5

At the end of the process, a larger list than required was obtained, with up to ten provenances by territory (see the document “List of suitable provenances to implement AM in NWE.xlsx”). It is intended as the final choice of provenance should be done in consideration with multiple other factors than the 3 ones used by IKS. It should be crossed with information from scientific and technical literature and can be checked with seed certifying authority representatives of the origin country. Hence, the provided list is large enough to be filtered again.

Limits of the method proposed for provenance selection.

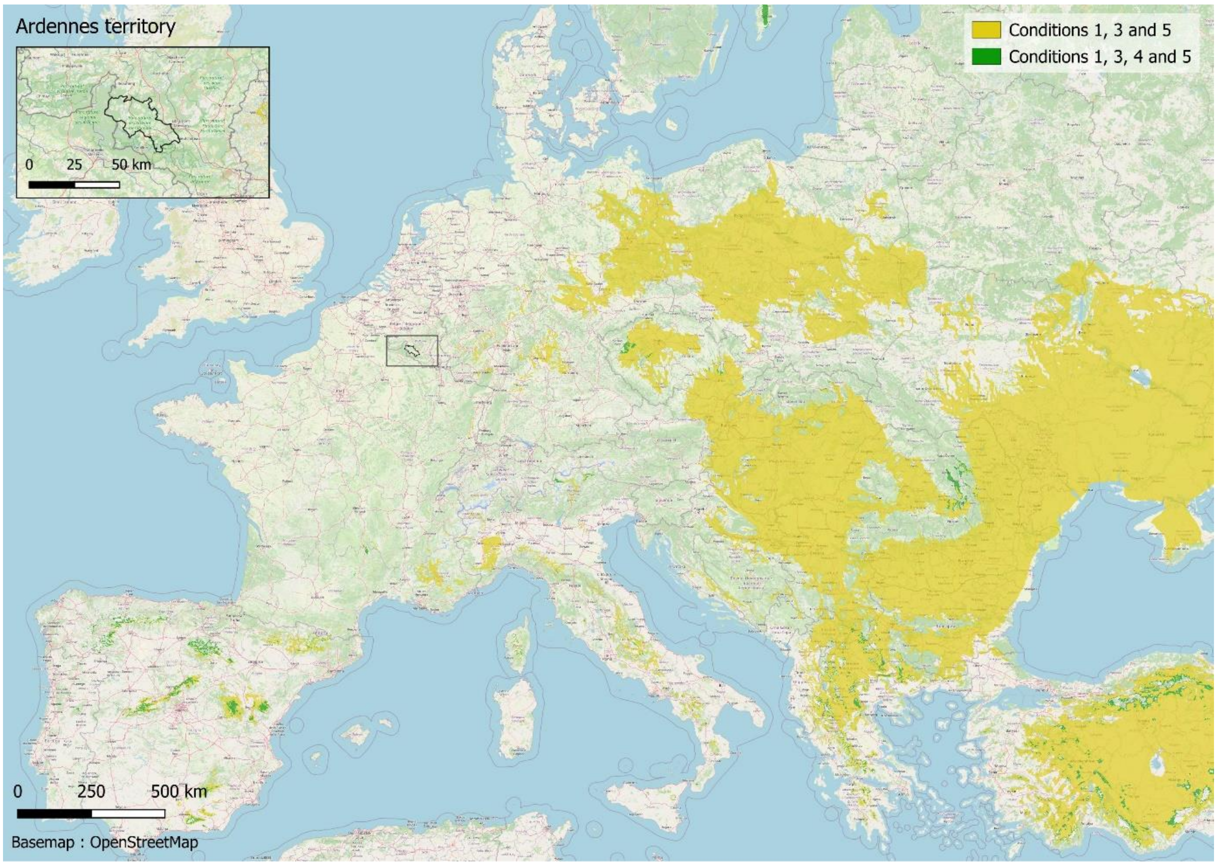
This method relies on the available data of existing seed sources, as previously stated, the European database FOREMATIS is partially unexploitable as it is. More sources could be included in this analysis by reformatting the coordinates given in the database, which was not possible for this deliverable timeframe. Some stands will remain unexploitable as they coordinates are blurred (e.g., Germany, large area instead of a single point). Using this method for the deployment of AM in Europe requires sharing precise information on seed sources from every country.

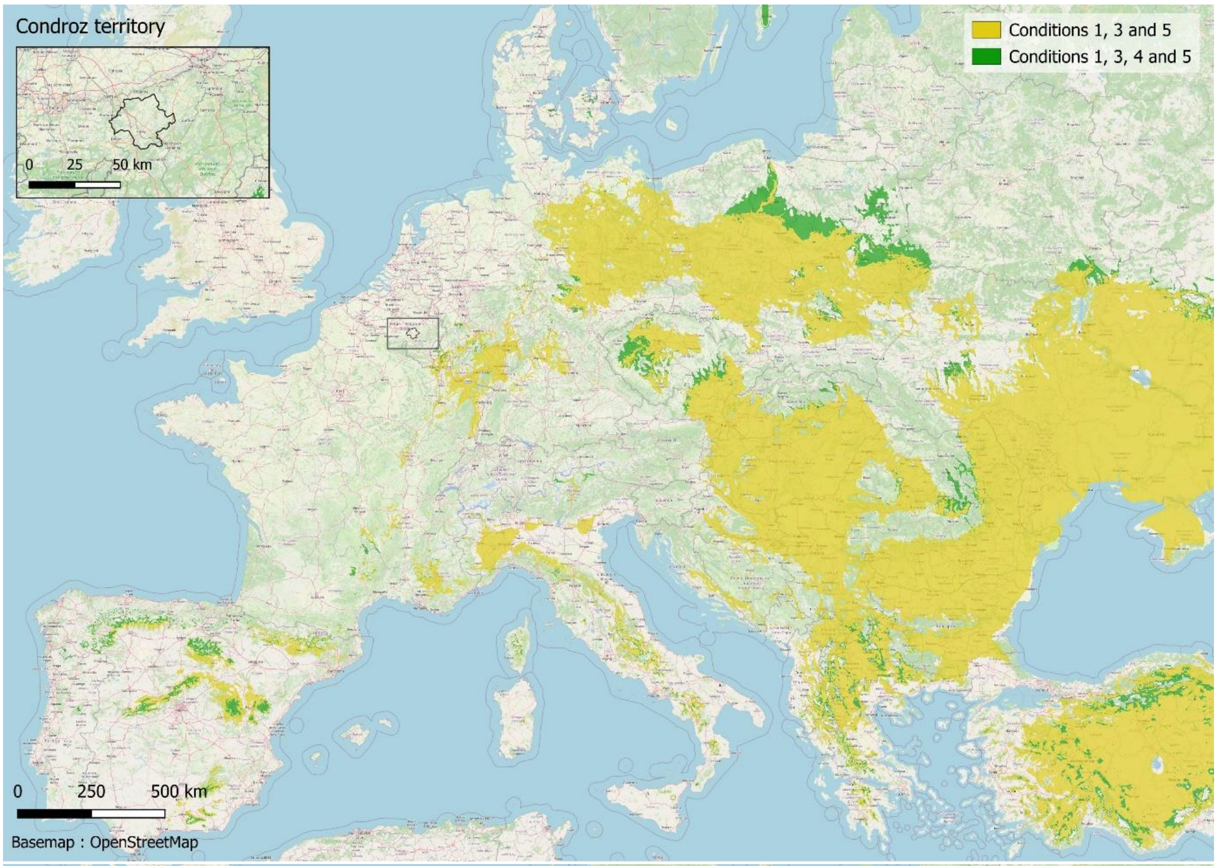
The resolution of IKS raster data is 1km², it is a tool designed to provide information on a larger area than selected seed sources. In this case, we are on the limit of the model capacity by using it on a geographic point. Local heterogeneities create a risk of having a false positive result. Yet, the harvested populations are estimated to be on areas large enough to be synthesized by the value on the 1km² pixel. Areas of the FRM sources are available in FOREMATIS.

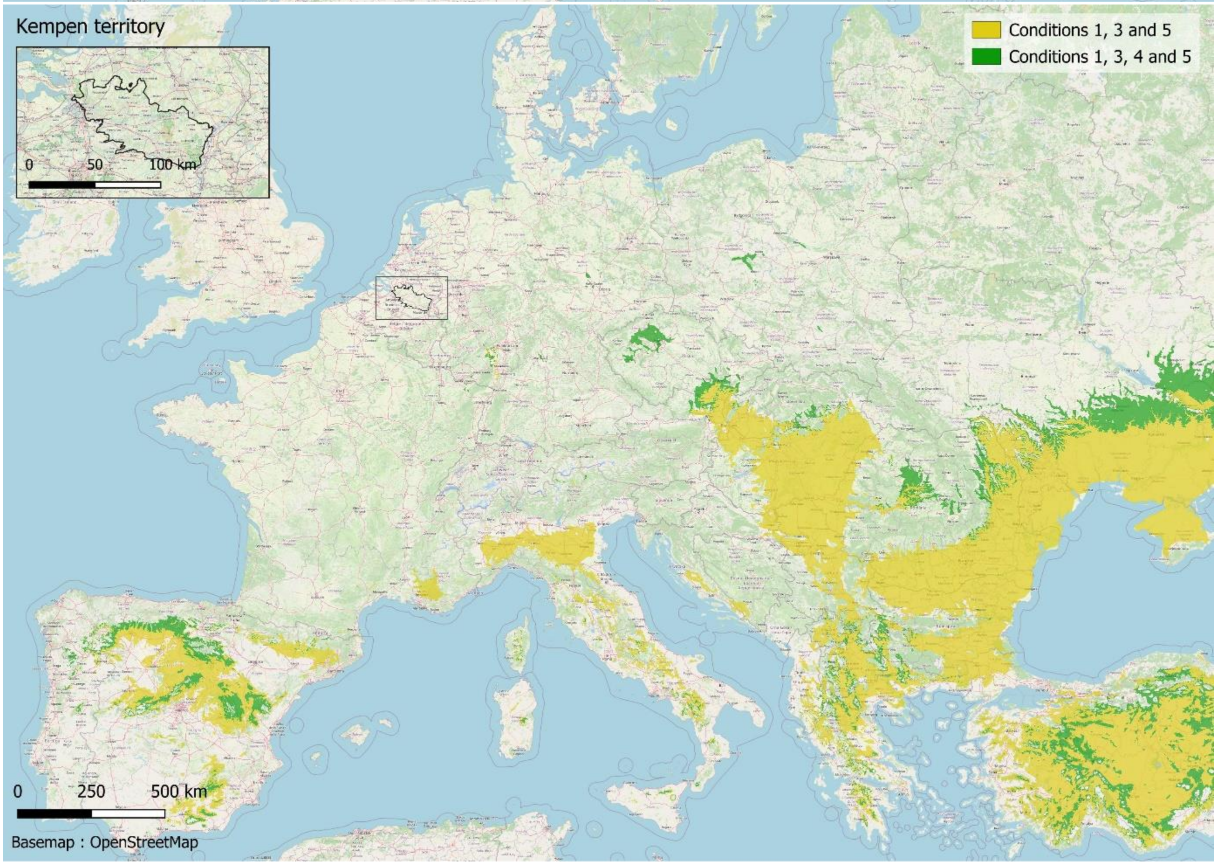
This method provides a theoretically appropriate list of provenances for the project planting sites. But the actual choice of provenance will have to be done from what the seed suppliers can provide, which is another reason for the list obtained with this method to be larger than what we aimed for the project (3 provenances by species by territory, with possible common provenances across the territories).

Alternatively, maps of the compatible areas for seed sourcing for every pilot territory were produced and can be used to estimate the suitability of available provenances.

Maps for each pilot territory




Condroz territory
Conditions 1, 3 and 5
Conditions 1, 3, 4 and 5
0 25 50 km
0 250 500 km
Basemap : OpenStreetMap


Kempen territory
Conditions 1, 3 and 5
Conditions 1, 3, 4 and 5
0 50 100 km
0 250 500 km
Basemap : OpenStreetMap

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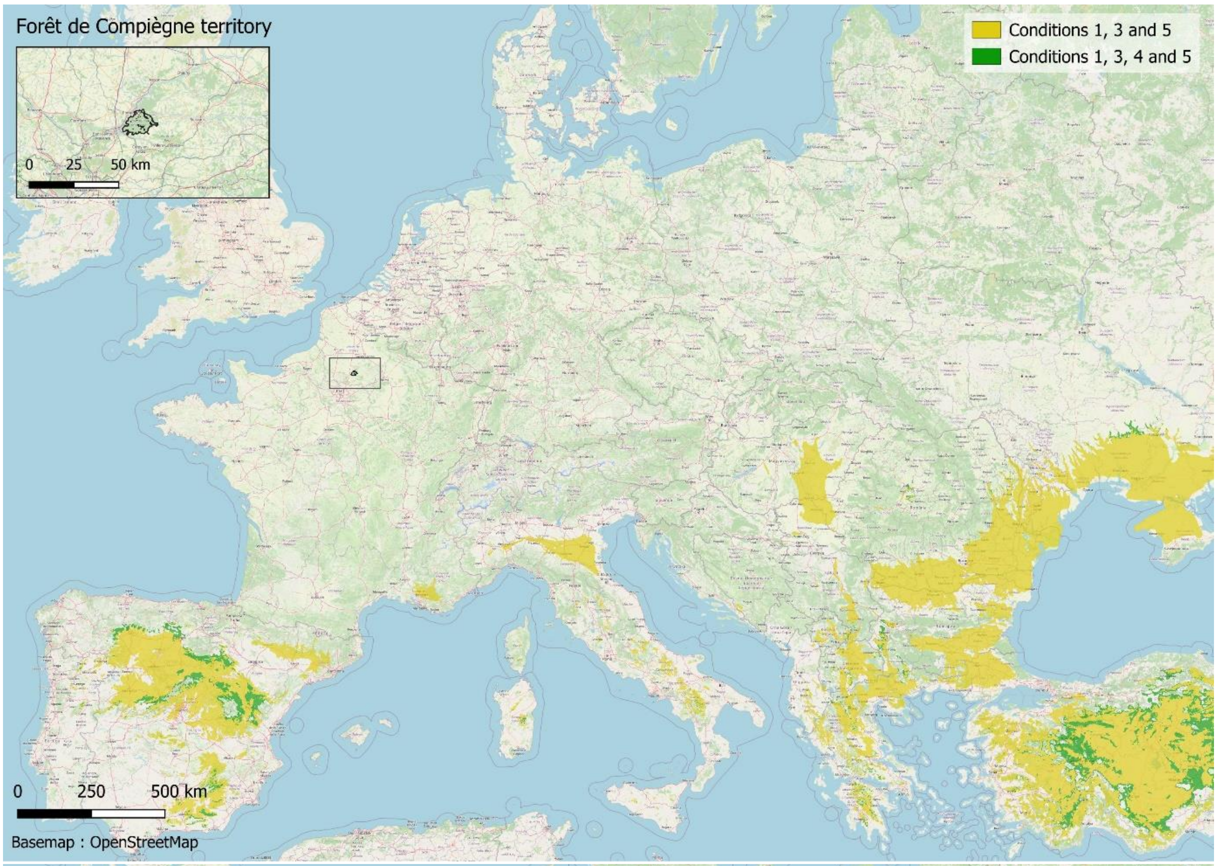
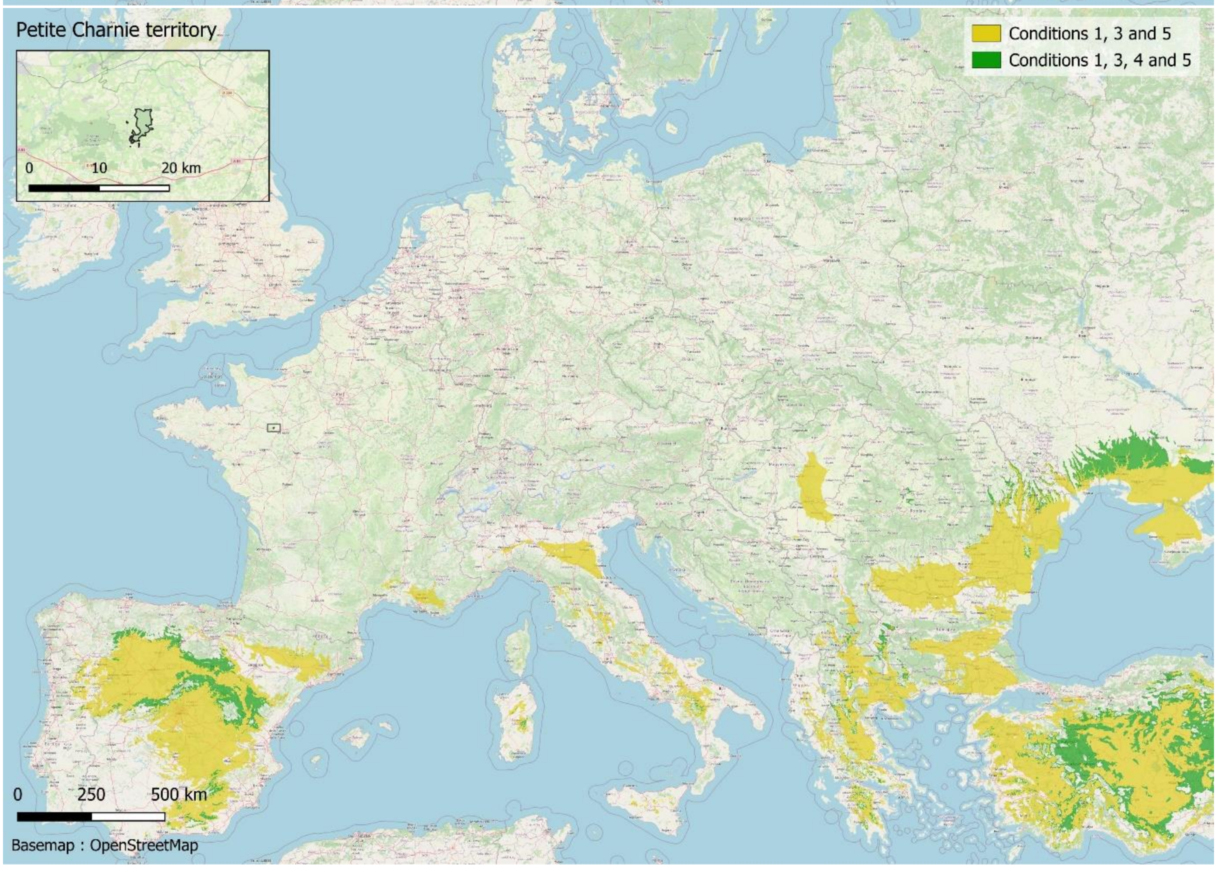
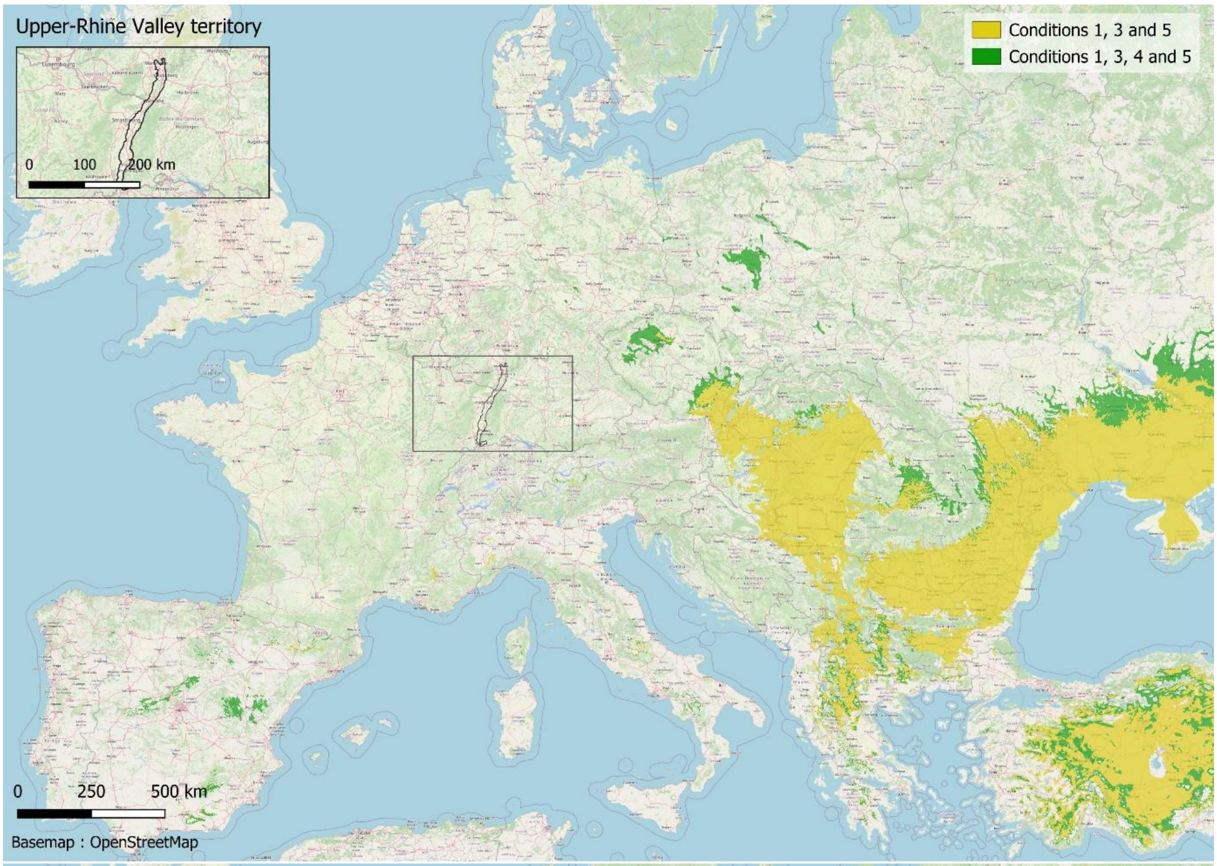
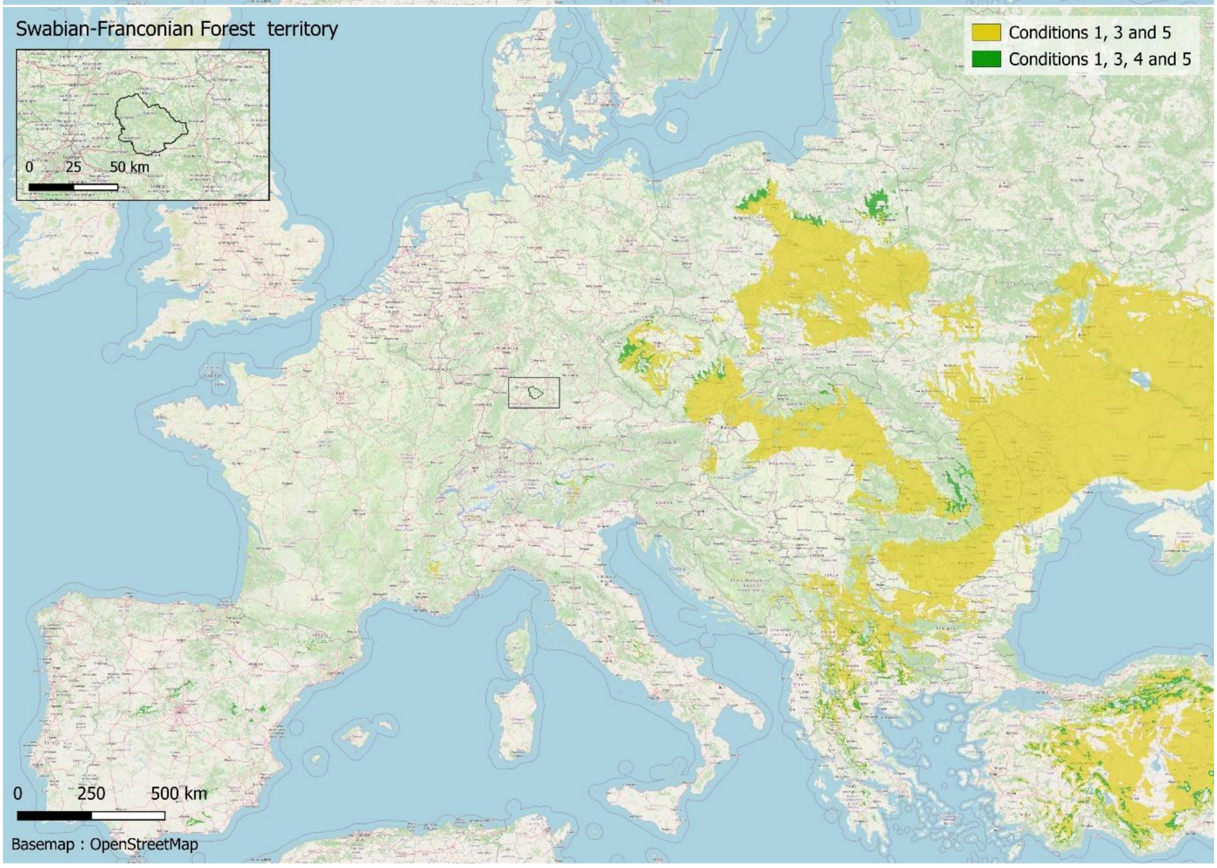





Upper-Rhine Valley territory
0
100
200 km
Conditions 1, 3 and 5
Conditions 1, 3, 4 and 5
0
250
500 km
Basemap : OpenStreetMap


Swabian-Franconian Forest territory
0
25
50 km
Conditions 1, 3 and 5
Conditions 1, 3, 4 and 5
0
250
500 km
Basemap : OpenStreetMap

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