Alternative, Adapted Seed Sources Handbook
&
Map of trans-alpine provenance regions

Stefan Kapeller, Silvio Schüler

Federal Research and Training Centre for Forests, Natural Hazards and Landscape

Vienna, 2012
Utilization of alternative seed provenances for future climate and transnational seed transfer

The utilization of alternative tree species in forestry is considered to be one of the most likely and promising strategies to adapt forest ecosystems to climate change (Thuiller et al., 2006). However, this might implicate negative consequences for forest owners and managers due to lower productivity of alternative tree species (Hanewinkel et al., 2012), and therefore, the cultivation of provenances of the same species but being better adapted to future conditions has been discussed as another management option (Matyas, 1994; Rehfeldt et al., 1999).

Generally, both, the utilization of alternative tree species and the cultivation of other provenances of the same species require the selection of suitable seed sources and more artificial regeneration, because today the most suitable species or provenances are often not present in their potential future habitats. Thus, the selection of the most suitable provenances of current and alternative species and the transfer of seed material over larger regions needs to be evaluated and optimized to allow climate resistant forests in the future.

From a scientific point of view, the transfer of forest seeds or seedlings, i.e. forest reproductive material (FRM), within and among regions or countries, should follow the natural pattern of local adaptation within the species range. The best data basis to identify such patterns for a given species are provenance and/or nursery tests, where a wide number of adaptive and other quantitative characteristics are evaluated. However, for the most tree species - in particular for alternative trees in future climates - such data are not available.

Another option for provenance recommendation and transfer schemes are the use of provenance regions. The concept of provenance regions is an essential part of national legal regulations of forest reproductive material in all countries of the European Union, following the Council directive 1999/105/EC. Also Switzerland is using forest regions (or forest production regions) as basis for seed harvest, nursery and transfer schemes. Generally, provenance regions are based on a biogeographic delineation of a country. These delineations do not consider the regional patterns of adaptation directly, but by dividing the country into regions with varying soil and/or climate regimes, it can be used as a reasonable approximation for the putative forces underlying local adaptation. In the present handbook, we give a short overview on the review of provenance trials in the Alpine space, which has been undertaken in MANFRED to develop alternative and transnational provenance recommendations. Also, the provenance regions of all countries in the Alpine space were merged and overlaid by a European bioclimatic classification in order to account for the various different classification systems among countries.

Quantitative genetic variation = adaptation potential

The adaptation of forest ecosystems to climate change is a major challenge in forest science and management. Climate change might induce an increasing mortality or de-
creasing productivity due to less precipitation and an increasing number of drought periods and damages from intensified disturbance regimes. Besides such negative effects climate change also offers potential for an increasing productivity due to prolonged vegetation periods and higher photosynthetic rates. Whether forests will undergo negative or positive effects of climate change depends on the local climatic preconditions, the expected degree of change and the adaptive potential of the respective tree species and provenances. Quantitative genetic variation of species and provenances provides the basis for an adaptation towards climate changes. Therefore, the selection and use of suitable reproductive material for forest regeneration will be a key factor for both, mitigating negative effects and taking advantage of putative positive effects. To develop provenance utilization schemes, an understanding of the intraspecific variation in climate response is strongly required for natural tree species in Alpine space.

Provenance trials - investigating quantitative genetic variation

Local adaptation of tree populations to their natural habitat and their adaptive potential at other site conditions has long been investigated in provenance experiments (e.g. Langlet (1971), Morgenstern (1996)). These experiments were used for seed transfer and utilization schemes, and more recently also to develop adaptation measures for climate change (e.g. Matyas (1994), Rehfeldt et al. (1999), Wang et al. (2006), McLachlan et al. (2007), St. Clair and Howe (2007), Ukrainetz et al. (2011)). The establishment of provenance tests for the investigation of intraspecific variation among tree populations goes back to the 18th century. Langlet (1971) credits the comparative cultures of pine established by H.L. Duhamel du Monceau between 1745 and 1755 as the first milestone of such genecological studies (König, 2005). In Alpine space the altitude of population origins has been recognized as a particular important factor. For example, in Austria, Cieslar compared tree growth among Norway spruce offspring from different altitudinal ranges at three planting sites (Melzer, 1937; Günzl, 1979), and Engler established a similar experiment with five Suisse provenances of Norway spruce planted at 16 sites in altitudes from 380 m to 2150 m (Engler, 1905; Nägeli, 1931). In both experiments, considerable differences in survival, growth and tree shape among provenances were found.

However, to use data of provenance experiments for the development of adaptation schemes, the field data have to fulfill few requirements:

- Seed collections and the seed origins have to be well documented.
- Seed origins should be mostly autochthonous in order to find adaptations to the local climate.
- Provenances should be planted on a wide spectrum of test sites covering at least the natural range of climate conditions under which the species lives, or should
even go beyond the natural range.

- Origins of selected provenances should cover a wide climatic range for investigation of climate transfer effects.
- Uniform seed collection at provenance origins uniform and forest management at test sites.
- The measurement data of the field trials should still be available in the raw form.

Within the present project, provenance experiments of two conifer species Norway spruce and Silver fir within the Alpine space were reviewed and rated according to these criteria. A list of these trials and their specifications is presented in Kapeller et al. (InPress).

For Norway spruce we collected information about ten provenance test and test series that cover Alpine space. These include national trials in Austria (Melzer, 1937; Nather and Holzer, 1979), Suisse (Nägeli, 1931), France (Bouvarel, 1961), Germany (Liesebach et al., 2010), Slovenia (established 1984 by Pavle) and three IUFRO test series from 1938 (+39), 1964/1968 and 1972. Based on their specifications and test design seven out of ten would potentially allow either climate response or climate transfer analyses. However, for many old provenance trials only little information about applied methods of seed collection or forest management at test sites is available. Also, measurement data are often not available in the raw form. The three IUFRO trial series (1938, 1964/68 and 1972) are especially interesting for potential climate related analyses, since both the test sites and the utilized provenances cover a wide climatic range. However, data are not fully available and despite many efforts, data exchange among involved institutions, many of them outside the Alpine space, was not successful until now.

For Silver fir we collected information about five provenance test series, including national trials in Slovakia (Korpel and Paule, 1984), Austria (Mayer et al., 1980), Germany (Rütz et al., 1998) and two IUFRO test series (1982/86 and 2000/05). Based on their specifications and test design all five would potentially allow either climate response or climate transfer analyses. However, as with Norway spruce provenance tests, only little information about forest management activities at test sites is given and measurement data are often not available in the raw form. Unfortunately, in spite of detailed plans for a joint evaluation of the 1st IUFRO test series and a central database in Vienna (Kramer, 1980), the data were recorded individually and published separately without any coordination (Kapeller et al., InPress).

From the many trials that were established in the past 100 years, most do not fully meet the aforementioned requirements. Apart from deficient documentation of utilized seed sources and applied management methods at test sites, scarce availability of raw measurement data inhibits detailed analyses of climate response and development of climate change adaptation measures. Due to the long observation time necessary, from many trials data were only available in form of published tables or figures but not within their raw form. Moreover, in many cases provenances were tested only under “colder” climate conditions, but not in warmer environments. Generally, only few test sites are
Alternative, Adapted Seed Sources

established at the edges of the natural climatic range of tree species. Those climatically extreme sites are most valuable to detect upper and lower limits of tree species and tree populations and to calibrate well-founded response functions. Therefore, for future provenance tests we recommend to include test sites at the edges of the natural range of the respective tree species or even beyond. Meaningful statistical climate response analyses require considerable ranges of climate conditions both for test sites and provenance origins. Therefore, transnational exchange of data and joined analyses are strongly needed, in order to cover the natural range of the respective species. However, the numerous trials established in the past are based on a laborious work from their initial establishment to the often comprehensive and numerous measurements. Today, such data are strongly needed for a better understanding of the intraspecific variation of climate response of tree species and for the development of provenance transfer and deployment schemes in the light of climate change. If data from old trials are available, they can anew be analyzed despite smaller deficits in test design utilizing new statistical methods. As a case study, we analyzed data from the Austrian provenance test with Norway spruce from 1978 in the present project.

Austrian provenance test with Norway spruce 1978 - a case study

A comprehensive provenance test with Norway spruce has been established in 1978 at 44 sites across Austria including seeds from 480 Austrian provenances and 60 provenances from other countries (Nather and Holzer, 1979). At tree age 15, height has been recorded at 29 of these 44 trial sites. These data have been used in the present project to analyze the intraspecific variation in climate response (Kapeller et al., 2012). In order to reveal more general insights, provenances with similar climatic conditions were aggregated in provenance clusters. The response of the nine resulting clusters to a heat-moisture index was calculated using a Gaussian distribution model.

The results hardly revealed any declines in potential tree growth of Norway spruce throughout its current distribution range in Austria. In fact, for most parts of Austria we found an expected increase of tree heights up to 45 percent until 2080. In general, provenances from currently warm and drought prone areas seem to be well adapted to respective climate conditions and may be appropriate candidates for extended utilization in future. However, the impact of a warming climate is different for individual provenance groups. Thus, an optimized choice of seed material according to prospective future climate conditions has the potential for an additional increase of productivity up to 11 percent (Kapeller et al., 2012). Although this study sets focus on provenances of the eastern Alps and the Bohemian Massif in Austria, some results of this most extensive provenance trial in the Alpine space can be generalized beyond the Austrian border, because firstly, although the provenances origin from a relatively small part of the natural range of Norway spruce, they cover the three main refugial lineages which build the basis of all natural Norway spruce populations in Central and Western Europe,
Alternative, Adapted Seed Sources

Figure 1: Gaussian function of tree heights at age 15 of all provenances belonging to certain clusters fitted to heat-moisture index AHM (mean annual temperature +10/ (Annual precipitation sum /1000)) of planting sites. Response functions are given for all nine climate similarity clusters. Grey area denotes AHM-regions beyond current maximum (32) to future maximum (42.3) limits.

and secondly, the provenance trial series has been established along a wide gradient of climate conditions ranging from 2.6°C to 9.2°C mean annual temperature and annual precipitation values from 535 mm to 2392 mm. Thus, it covers not only a large part of current Norway spruce habitats (Fig. 1), but also extends into sites at the warm and dry edge of its distribution, making it highly suitable to analyze the potential response to a changing climate.

**Transnational seed transfer**

Seed transfer across national borders is already a common praxis. However, exact provenance recommendations for the future climates are not yet possible for many tree species and regions in the Alpine space due to a lack of appropriate field test data. Moreover, the delineation of provenance regions differs strongly among countries and hinders the optimal utilization of seed reproductive material. In the present project, the provenance regions of the Alpine countries were merged within a single map and the climatic stratification of (Metzger et al., 2005) was added (Fig. 2). Based on twenty of the most relevant available environmental variables and principal components analysis (Metzger et al., 2005) provide a detailed stratification of Europe into 84 strata, that can be aggregated into 13 environmental zones. We suggest using these strata to optimize current seed transfer in the Alpine space and assigning provenances to the optimal cultivation area if no further test data are available. This would mainly facilitate vertical transfer, whereas for altitudinal transfer, it is suggested to rely on the altitudinal level of the seed source.
Figure 2: Map of trans-alpine provenance regions including bioclimatic stratification (filled areas) from Metzger et al. (2005) overlaid by current provenance regions of Alpine countries (lines).
References


