GUIDELINES FOR THE CHOICE OF FOREST REPRODUCTIVE MATERIAL IN THE FACE OF CLIMATE CHANGE

GUIDELINES

FORGER

TOWARDS THE SUSTAINABLE MANAGEMENT OF FOREST GENETIC RESOURCES IN EUROPE

Due to the long-lived nature of trees, silviculture is a practice that takes a long-term perspective. In a context of rapid projected climate changes, forest managers need to find ways to take decisions about the long-term management of forest stands without complete knowledge about what future conditions will be like. Existing knowledge does not allow us to determine precisely whether a close-to-nature approach (which relies on spontaneous, natural processes) or proactive interventions in forest regeneration is better suited to fostering adaptation in forest ecosystems.

Adaptation is the micro-evolutionary process enhancing the fitness of a population in accordance with the environmental conditions. One idea that has been proposed is human-assisted transfer of tree populations, guided by projections of future climate conditions, but it has not been widely accepted in Europe, partly because of uncertainties about the results of this approach and partly because climate changes have so far affected Europe to a lower extent than other regions, such as North America.

The present guidelines focus on issues related to the choice of forest reproductive material (FRM) in the face of climate change, based on knowledge generated by field studies and modelling. The objective is not to single out the most appropriate approach, valid in all conditions, but rather to present most recent research findings to support decision-making and analysis by forest managers, conservationists and field ecologists.

REPRODUCTIVE MATERIAL FOR THE NEXT GENERATION OF TREES

Future performance and resilience of regenerated forest stands depends on the inherited genetic quality of the FRM used. Knowledge about genetic aspects is therefore necessary for those who need to take informed management decisions. What are the most important facts to consider with regard to forest regeneration?

- Expected climatic changes will occur within the lifetime of a single tree generation.
- Future forest stands may survive and remain productive only if there is enough adaptive potential to enable them to cope with gradual changes and extreme events.
- Adaptive potential is based on sufficiently large species diversity (i.e. species mixture) and within-species diversity (i.e. genetic diversity).
- A specific characteristic of forest trees is an extremely effective gene flow, that is, an exchange of genes between tree populations. Forest trees, mostly wind pollinated, are generally effective in long distance gene flow through pollen. Gene flow is usually less effective through seed dispersal. Pollen can travel over long distances, so a large proportion of the male genetic contribution may come from outside, depending on local conditions. This could constitute an advantage, but could also have negative effects if unwanted gene flow is depleting the adaptive potential.
- Relying exclusively on the capacity of natural selection is appropriate only if regeneration (natural or artificial) is abundant and has sufficient adaptive potential.
- In established stands, gradual adaptation to changing site conditions may be achieved through frequent, relatively light thinnings, resulting in a stepwise adjustment of the genetic resources of the population.

These aspects underline that initial decisions about the regeneration method and the FRM to be used will be crucial for the adaptability, vitality and long-term profitability of the future forest stand.

RECOMMENDATIONS FOR CHOOSING FOREST REPRODUCTIVE MATERIAL

Is there a need to apply specific measures across different regions in Europe?

Across Europe, climate change trends follow different patterns. The differentiation in climatic change effects across Europe implies that both urgency and kind of measures to be but in place to contain the effects of the changes vary according to regional projections.
With regard to future projections, the Mediterranean south and the continental southeast of Europe will experience further significant increases in temperature and a decline in summer rainfall. This causes an expected gradual decline in productivity and, in some more exposed areas, also a loss of fitness, and increased attacks of pests and diseases. When reaching the genetically set tolerance limits to extreme drought, populations are subject to higher mortality and a consequent loss of adaptability. The application of adaptive silvicultural practices is therefore desirable.
Although temperatures are expected to rise in northern and western Europe too, higher temperatures are likely to prolong the vegetative season and accelerate growth, as long as sufficient precipitation compensates for higher transpiration demand. Pest and disease attacks, however, will be worsened by the climate changes, requiring constant monitoring and adaptive measures. Nevertheless, at the upper limits of distribution, the emergence of newly available suitable site conditions will lead to spontaneous colonization and a shift of distribution ranges of tree species, indicating a lower pressure deriving from climatic changes, and a consequent limited urgency of precautionary measures.

Arguments for and against human-assisted tree species migration

Provenances are defined as tree population(s) of a species obtained from an identified geographic location of the distribution range. The use of FRM of non-local provenances adapted to conditions which are expected in the future in a particular site, is debated, mainly because foresters tend to rely on the generally recognized high diversity of close-to-nature forests, which is the basis for adaptability. This is a valid argument, as long as the expected changes in temperature and precipitation remain within the limits of tolerance of the population, maintaining acceptable growth and vitality. In fact, field tests show that the adaptive potential of tree species is considerable, especially in sites located in the central part of the distribution range, as long as precipitation is sufficient. For instance, it has been observed that an increase of 2 C° in annual temperature has been tolerated by beech, oak and even by conifers.
On the other hand, field tests confirm that the extent of changes may exceed the adaptive potential of some tree population; it has to be remembered that the changes will occur within the lifespan of one generation. Therefore, actively supporting natural processes may be advisable in case of extreme changes.

Local adaptation – is it valuable for the future?

Contrary to the commonly held concept 'local is best', it has frequently been observed that the performance of local provenances is not necessarily better than that of non-autochthonous tree populations. This can be explained most probably by the action of other genetic effects (gene flow, migration background, inbreeding) operating in parallel to natural selection. The debate about the value of locally adapted populations is somewhat surpassed by the effects of projected climate change, which will alter considerably, and in some cases quite rapidly, local site conditions.

Procedure for the selection of suitable FRM

The selection of suitable FRM should be based primarily on information about the expected climate changes for a particular region. If the projections indicate that the local conditions will change drastically during the rotation period, causing a significant decline in vitality of the stand, the use of FRM of alternative provenances may be considered. Field tests, and complementary information from silvicultural practice, provide indication on the climate sensitivity of a particular species.
The difference in provenances survival and growth across field trials indicates a need for caution in a selection of foreign provenances, originating far away from the site where they are going to be used, based solely on an assessment of their performance and growth recorded at an early age (juvenile). Other criteria should be considered in addition, such as the ability to genetically adjust to changing conditions, that is, the potential tolerance of, and adaptability to, extreme climatic events and damage.

How to match FRM with future climates

A decision to use locally sourced FRM for regeneration should be founded on the results from test sites and/or silvicultural experiments. These should assist to define what climatic thresholds should be used for different alternative management options. Results from provenance tests are the most reliable basis for estimating the climate sensitivity of a species and determining adaptive management options. Such information is, however, limited to only a few main forest tree species and to a handful of properly evaluated test sites. Therefore, managers should systematically gather and evaluate available regional observations on climate change effects, considering local site conditions, in order to develop a vision for potential threats (vitality loss, damage by antagonist organisms, successional changes) in a particular region. Damage observed should be appraised in the context of extreme weather episodes (above all extreme and consecutive drought events). This requires the monitoring of recent and current weather conditions. For the assessment of likely future climatic changes, detailed (downscaled) maps of decisive climate parameters for present and future climate conditions are needed for the site of interest. To identify a provenance that matches coming climatic conditions, a future climate reference period has to be selected. Keeping into account the uncertainties of forecasting, the reference proposed is a 30-year average of projected climate (see example on beech in Box 1). Following the estimation of the magnitude of climatic changes and their importance for the respective species, a preferred management option can be chosen (see Box 2). Concrete climate sensitivity thresholds for options, as mentioned in Box 1, need detailed analysis of extensive field data and observations.

If the option of introduction of non-local, better adapted populations is chosen, a location within the species range should be identified where the current climate conditions resemble those expected in future at the planting site.

Detailed European distribution maps of widespread important tree species are available on the EUFGIS portal.
Altitude is a key variable to consider in the selection process: 'southern' origins are not necessarily adapted to a warmer or drier climate, as they may grow at a higher altitude.

Provenances from extreme, isolated sites

In the southern area of distribution, where conditions become less optimal, populations of a particular species may have a more dispersed spatial distribution and may be mixed with other species. If the selection of provenances that are ideal for future conditions leads to the identification of populations in peripheral, isolated sites, a decision about their use in other locations is more challenging because these populations may have undergone severe climatic selection, or experienced heavy human influence (selective cutting, coppicing etc.). These provenances may be valuable as having accumulated higher tolerance of extremes, but may also be genetically depleted and less adaptable to other environments; they should be chosen only if information is available about their favourable phenotypic traits. The same is true for provenances from high altitudes or high latitudes: their use should be limited to sites with similar, extreme conditions. The large scale adoption of human-assisted migration is limited by the sparse information actually available, and by the hitherto low consensus about its application in Europe.

Provenances not present in the required climatic conditions

The xeric limit of the distribution range of a species is the edge of the geographic distribution located at low altitudes or low latitudes, where high temperature and dry conditions limit the expansion of the species. When a stand to be regenerated is located close to the xeric limit, it may not be possible to find suitable populations within the current climatic niche of the species. In this case, an alternative, more tolerant species should be considered.

BOX 1. Approach for choosing provenances adapted to future climates: the example of beech

Here an approach is presented to take decisions on how to identify provenances expected to be adapted to future climate conditions in a particular site. Based on results from a field trial in Hungary, preliminary guidelines were formulated for provenance selection, considering the expected change of mean drought exposure of beech stands, expressed by Ellenberg's index (EQ). EQ is the ratio between the mean temperature of the warmest month and the annual precipitation. Low values indicate cool and moist climatic conditions; high values indicate warm and dry conditions. Due to the high uncertainty in the predictions, it was considered reasonable to take as a reference the climate conditions expected to occur at one-third of the planned rotation, i.e. 40 years. If the projected change (ΔEQ) is:

- **below 6 ΔEQ:** the plasticity of the populations would be sufficient to cope with the change;
- **between 6 and 12 ΔEQ:** local adaptation could be enhanced by integrating imported reproductive material, adapted to the future conditions (see figure 1);
- **between 13 and 17 ΔEQ:** to avoid a significant growth decline (>25%), regeneration with reproductive material transferred from other sites, adapted to the future conditions, is proposed;
- **above 17 ΔEQ:** regeneration of a mix of better adapted species is advisable.

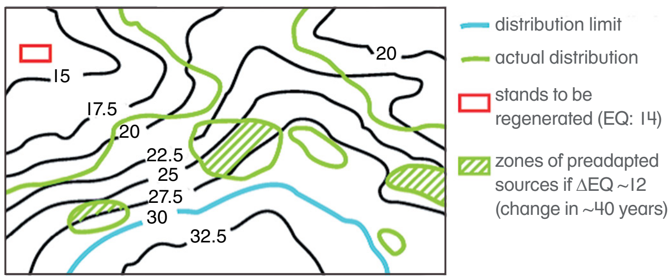

Figure 1. ***Identifying beech seed sources adapted to a future warmer climate.*** In the figure, the gradient of climatic conditions is indicated by EQ. The distribution of the species is patchy (green lines) and limited at the EQ value of 30, which constitutes the limit of drought tolerance. Considering a general drought index increase (ΔEQ) in the next 40 years of 12 units, in the stand to be regenerated (red rectangle) the future EQ value will increase from the present 14 to 26 EQ. Reproductive material for enrichment planting should be selected in the stands that presently experience a similar EQ to the one expected in future in the planting site (eg. 25–27.5). These occurrences, indicated by shaded green, could be sources of reproductive material preadapted to the climate conditions expected in future in the stand to be regenerated (design: Mátyás and Rasztovits, unpublished).

BOX 2. Alternative options for selecting suitable FRM in sites exposed to climate changes

- **relying on local adaptability of tree populations:** the stability of local populations will be sufficient for adaptive adjustment, therefore FRM will be sourced locally;
- **limited interference:** if stability of the local populations is threatened, local adaptation may be enhanced by selecting an admixture of preadapted to future climatic conditions FRM;
- **assisted gene flow:** if strong decline of stability and tolerance is envisaged, use of FRM preadapted to future conditions is suggested;
- **assisted species migration (species change):** if the projected climatic conditions are significantly beyond the climatic niche of a species, regeneration with a better adapted species is advisable.

Further requirements for selecting sources of FRM

Seed sources selected should be of registered origin (e.g. seed stand) and their identity should be documented in the management plan. Stability is one important trait of the FRM chosen, to balance part of the risk of uncertainty of climate projections. In forestry, phenotypic stability (or, frequently, phenotypic plasticity) indicates a relatively consistent performance of a provenance, population or clone, across a range of environments. A provenance highly adapted to particular conditions may have an inferior performance in other environments, i.e. it would be less stable. Stability partly helps to cope with the uncertainty of climate projections, as it entails broader tolerance and more reliable performance across a broad range of sites. For certain seed regions, stability characters are already known (e.g. for the Eastern Carpathian provenances of Norway spruce). Stability may vary significantly between regions and needs more attention in the future.

Given that the selection of FRM has the objective of ensuring adaptation to specific climate conditions, the selected seed source should be as autochthonous as possible, or a seed orchard should be established with autochthonous material. Admixing better adapted provenances with local sources (enrichment) or mosaic planting of various seed sources, may increase stand adaptability. To minimize risks, it is advisable to plant species mixtures in locations more exposed to climate extremes.

There are no generally valid rules for choosing FRM; decisions about what forest regeneration strategy to adopt should be taken locally, and should consider local conditions and specific threats influencing climate tolerance (e.g. threats of antagonist organisms, soils with low water holding capacity, etc.).

Risks of climate changes are very high in forestry as neither the possible climatic extremes, nor the exact response of forest ecosystems is known with sufficient accuracy. In addition to taking advantage of genetic diversity within a tree species to identify suitable sources of FRM in the face of climate change, in case of a manifest decline in tree yield and vitality, adaptive silviculture should take into account the possibility of replacing sensitive tree species with others better adapted, on sites exposed to extreme conditions.

Suggested further reading

Konnert, M., Fady, B., Gömöry, D., A'Hara, S., Wolter, F., Ducci, F., Koskela, J., Bozzano, M., Maaten, T. and Kowalczyk, J. 2015. Use and transfer of forest reproductive material in Europe in the context of climate change. European Forest Genetic Resources Programme (EUFORGEN), Bioversity International, Rome, Italy. xvi and 75 p.

These guidelines present recommendations that are based on the findings from the FORGER project.

Reference to the document:
Guidelines for the choice of forest reproductive material in the face of climate change

Author: Csaba Matyas (NymE)
FORGER Guidelines 2016

Photos credits:
© Bioversity International

www.fp7-forger.eu

For more information on FORGER:
Dr. Koen Kramer, Project Coordinator
Alterra, Wageningen, The Netherlands
E-mail: koen.kramer@wur.nl
Tel.: +31-317-485873

The FORGER project is financially supported by the European Commission under the 7th Framework Programme