



EUFORGEN

FOCUS ON FOREST GENETIC DIVERSITY
PRODUCING AND USING FOREST REPRODUCTIVE MATERIALS



THEME 1

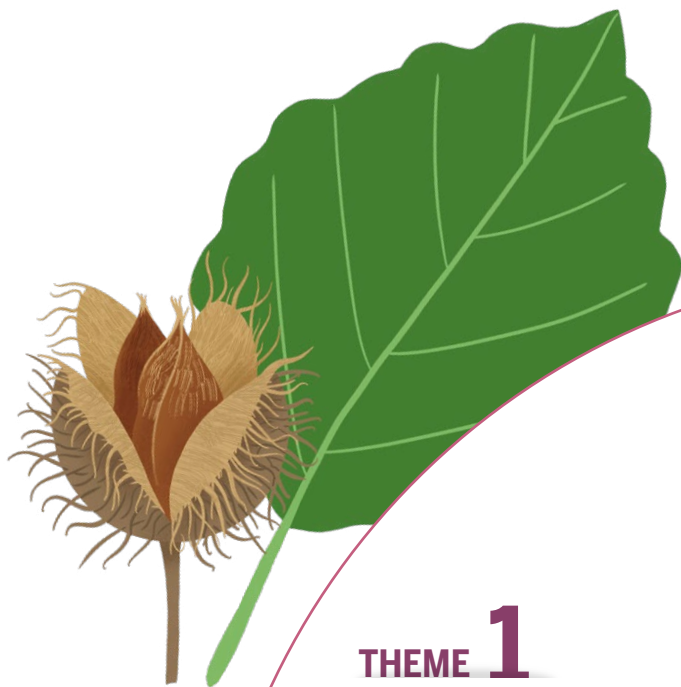
SILVICULTURAL PRACTICES AND THEIR ROLE IN MITIGATING EFFECTS OF CLIMATE CHANGE

The effects of regeneration strategies on
genetic diversity of forest stands



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The European Forest Genetic Resources Programme (EUFORGEN) is an international cooperation programme that promotes the conservation and sustainable use of forest genetic resources in Europe as an integral part of sustainable forest management. Experts from member countries come together within EUFORGEN to exchange information and experience, analyse policies and practice, and develop science-based strategies, tools and methods to improve the management of forest genetic resources. EUFORGEN is hosted by the European Forest Institute and is funded by its member countries.

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SILVICULTURAL PRACTICES AND THEIR ROLE IN MITIGATING EFFECTS OF CLIMATE CHANGE

The effects of regeneration strategies on genetic diversity
of forest stands

Silvicultural practices can influence how genes move and change within tree populations, affecting both the growth and adaptability of forests. When faced with the impacts of rapid climate change, forest managers can enhance tree species' ability to adapt to these new conditions or take measures to maintain or increase the genetic diversity of both tree species and forests. This can help trees and forests to adapt to future conditions and cope with unexpected changes.

The EUFORGEN community offers these guidelines to help practitioners understand how their forest management practices can affect the conservation of forest genetic diversity, and focuses particularly on regeneration strategies. Based on scientific knowledge of forest tree population genetics, this handbook supports forest managers, forestry professionals, advisors, and authorities to take into consideration the effects of their decisions on forest genetic diversity.

01 REGENERATION OF FORESTS UNDER CLIMATE CHANGE

Forest managers and forestry professionals have two choices when considering forest regeneration. They can either rely on the natural capacities of tree species to cope with environmental changes or actively enhance this capacity.

The first approach relies on genetic diversity that already exists within forest stands to deliver natural regeneration. The latter involves modifying the genetic composition of forest stands through management practices or adding genetic diversity by planting materials from elsewhere, known as artificial regeneration.

Which would be the best approach depends largely on the genetic variation within tree populations forest managers are working with and how long they have to achieve their goals.

Overview on tree species in Europe

Most European tree species produce a lot of fruits or seeds that are widely dispersed by wind, water, or birds and animals. Many have large populations that are widely distributed. They also show the ability to change their growth habit to adapt to environmental changes such as increased heat or declining rainfall – so-called phenotypic plasticity.

All these characteristics help European tree populations to survive and adapt to changing environments. However, one downside of many European tree species is that they take a long time to mature and reproduce, reducing their ability to respond to rapid changes in their environment.

02 HOW TREES ADAPT TO THEIR LOCAL ENVIRONMENT

Trees adapt to local conditions when better-adapted genotypes emerge and spread in the population. This happens either through cross-fertilization between trees in a local population or by introducing new genetic variation from outside it by cross-pollination with more-distant trees.

Persistence of tree populations in their existing habitats relies on a combination of local adaptation through natural selection and phenotypic plasticity, which is trees' ability to change their growth pattern and acclimatize to changes in their environment.

Natural selection

Local adaptation through natural selection is a slow process in trees because of how long they take to reach maturity and produce the next generation. How quickly forest populations can adapt to changes in their environment depends on population size, heritability of traits related to fitness (e.g. heat tolerance), interconnection between populations to facilitate gene flow, and the intensity, direction, and duration of selection pressures.

Environmental stress, such as short-term drought, can increase selection pressure. However, severe environmental stress, such as long-term or extreme drought, may kill a large proportion of trees or drastically reduce their growth, reducing the genetic base of the population and causing a loss of forest ecosystem services.

Therefore, relying on local adaptation through natural selection may be a high-risk approach if the pace of climate change is too fast, the frequency of extreme climatic events is too high, and the genetic diversity too low for natural selection to cope with.

Phenotypic plasticity

Phenotypic plasticity is the ability of an organism to change its form or behaviour in response to changes in its environment. A good example of this is the budburst date in European beech (*Fagus sylvatica*), which seems to vary according to local conditions. In conifers, cessation of growth and frost hardiness are both determined by day length and temperature during the period when the embryo is developing. Such plasticity is heritable and thus can be selected in breeding programmes. However, climate appears to play a relatively minor role in determining the distribution of tree species except at the southern limits of their distributions.

Of more importance are biotic interactions, such as competition from other species and the occurrence of pests and diseases. Many of these can be controlled to a greater or lesser extent by silvicultural practices, allowing forest managers considerable scope for mitigating the effects of climate change.

03 REGENERATION STRATEGIES

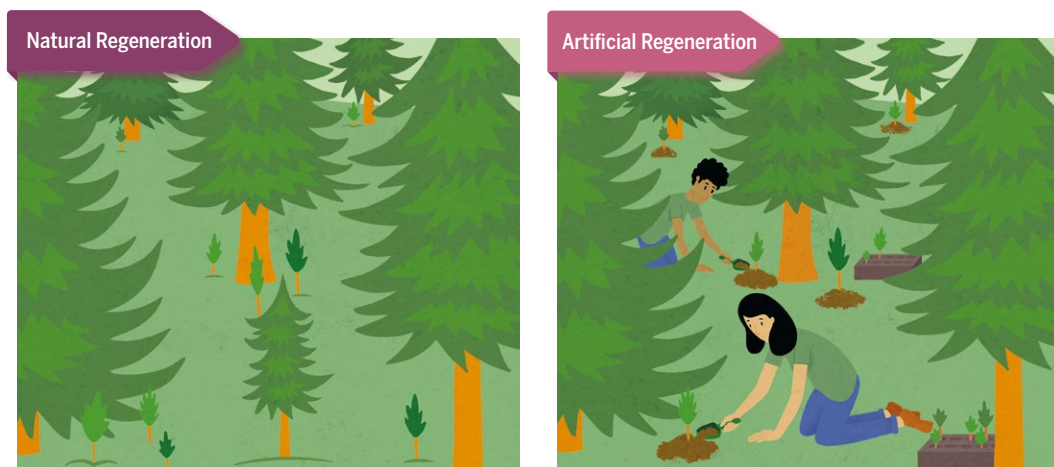


Fig. 1: Natural regeneration (left) relies entirely on the genetic diversity of existing trees to naturally seed the forest floor. Artificial regeneration (right) involves actively planting seedlings, which allows forest managers to introduce new genetic material or improved planting stock where needed.

In the context of climate change, relevant regeneration strategies include natural regeneration and artificial regeneration, which includes enrichment planting and assisted migration. The choice of which strategy to pursue should be based on the adaptability and plasticity of the material available.

In many European countries, however, the choice of regeneration strategy is constrained by legislation, voluntary forest certification schemes, and public perception of forest policies. Currently, two certification schemes, the Programme for the Endorsement of Forest Certification (PEFC) and the Forest Stewardship Council (FSC), are adopted for a substantial part of European forests.

Limiting choice to natural regeneration (as in e.g. some forest certification schemes) can lead to oversight in considering the need for a variety of solutions according to local environmental and socioeconomic conditions. Forest reproductive material (FRM) – seeds, cuttings, and planting material used in forest establishment – from local sources is not always the best material for regenerating forests and the speed of climate change is outstripping the ability of tree populations to adapt solely through natural evolutionary processes. Thus, exclusive use of natural regeneration may not be the best option.

Policymakers and the wider public should be made aware of the benefits and challenges of adding enrichment planting of transferred FRM to natural regeneration, as well as artificial regeneration more broadly.

04 NATURAL REGENERATION

Under a natural regeneration strategy, forest managers apply practices that improve conditions for adaptive processes. This ensures that maximum benefit is taken of the genetic diversity in the local seed trees and in the selection processes operating on the seedlings produced. Natural regeneration may lead to a much stronger population than regeneration based on cultivation, especially planting. This is because natural regeneration ensures a much higher seedling density than can be obtained by planting, and the strong selection acting on natural regeneration ensures that the trees produced are well adapted to local conditions.

However, genetic diversity and adaptive potential may vary across the range of the species involved and will depend on local

ecological conditions and tree populations. This could severely limit the capacity of populations to evolve under the most severe climate changes. As such, forest managers should not rely indiscriminately on local forest material as it may not have the characteristics or diversity needed to adapt to environmental changes, particularly at the limits of species ranges and at ecological edges.

Natural regeneration should be recognized as just one component of close-to-nature forestry, rather than its final aim. Forest managers should also focus on managing the structural diversity of stands and maintaining low-growing stocks and optimum species mixtures, thus enhancing the resistance and resilience of forest ecosystems to climate change.

05 ARTIFICIAL REGENERATION

Changes in both climate and soil conditions in recent years have reduced the potential for old-growth forest stands to regenerate naturally in many European countries. In this case, artificial establishment of a new forest plantation is the only way to ensure continuity of forest vegetation in a given area.

As a result, the most common forest regeneration practice in Europe is artificial regeneration through planting genetically improved trees. This delivers rapid reforestation and works well on most sites.

It is important to use appropriate FRM when artificially renewing forest stands. This is particularly true when the objective is to increase species diversity and enhance the adaptation of the forest

following large-scale disturbances or other objectives, such as establishing forest for recreational purposes. Under this approach, FRM is used mainly to regenerate species that are unable to regenerate naturally.

Artificial regeneration is also used in some cases simply for economic reasons, as it allows improved material with higher productivity to be used, has a shorter regeneration time than natural regeneration, and offers a quicker and simpler workflow.

Moreover, the large areas of monoculture forest in Europe today require urgent measures to diversify species, and this can best be done through artificial regeneration using FRM of genetically suitable provenance.

Notes for forest managers

Forest managers must pay attention to the origin and level of genetic diversity of the planting material they use. Poorly managed nurseries may produce FRM with limited genetic diversity so it is essential that forest managers use FRM only from nurseries that follow good practices designed to maintain genetic diversity of the FRM they produce.

Managers must also pay attention to the local conditions of forestation sites, including climatic conditions, and pests and diseases affecting forest tree species. Selected FRM should adapt well to the existing or projected conditions, and may be from local sources or from elsewhere.

Enrichment planting

Some scientific studies indicate that many tree populations are not adapting quickly enough to environmental challenges driven by climate change. This is particularly true of marginal populations at the rear edge of species ranges (i.e. where conditions are becoming unfavourable for the species) and at ecological boundaries (e.g. mountain ranges) within species ranges.

As such, forest managers should also consider using silvicultural practices and enrichment planting in naturally regenerated forests to speed up evolutionary processes, particularly in forests at high risk from climate change.

Enrichment planting can increase genetic diversity of forests by facilitating the emergence of new genetic combinations and the spread of the best-adapted

genotypes. One approach is to fill the empty patches that occur in natural regeneration, using artificial planting.

The success of enrichment planting depends on choosing the right provenances and species, which is challenging. Choosing suitable forest genetic resources is hampered by both the uncertainty of climate-change projections (and future pressure from known and unknown pests) and the limited information available from trials where provenances and species have been planted in new locations. In addition, site conditions can vary widely over the lifespan of individual trees, which makes it even more difficult to select appropriate FRM for enrichment planting.

Enrichment planting should make use of existing diversity within species and rely on better-adapted provenances of



Fig. 2: Enrichment planting in practice. By integrating natural regeneration with FRM sourced from a different site, forest managers can introduce new genetic diversity to help local forests better withstand future climate pressures.

native species rather than non-native species. Depending on local conditions, planting strategies may involve a mix of provenances and species alongside the current natural population.

Enrichment planting and breeding programmes using parental material from multiple populations can deliver high genetic diversity, especially if they use material from warmer and drier climates. The success of enrichment planting depends on an adequate supply of seed and seedlings of suitable provenances being available from seed stands, seed orchards, and nurseries.

For regional perspectives and species choice to consider in enrichment planting, please refer to **Theme 4: The influence of forest management on the genetic structure of forest tree populations. How choices in methods to establish and manage forests affect forest genetic diversity.**

Assisted migration

The inability of trees to adapt quickly enough to the rapid rate of climate change will have serious effects on forest growth and composition. Possible approaches for aiding adaptation to a new climate include assisted migration, which is the intentional translocation of individuals within or outside the natural range of a species.

Current forest policies often restrict the transfer of FRM from one region to another, limiting the application of assisted migration in practice. Caution is centred on factors such as:

- potential unknown disturbances to, or interactions with, indigenous flora and fauna
- use of ill-adapted genetic resources potentially leading to large-scale failures (e.g. possible maladaptation of southern populations to extreme cold events in the north)
- the introduction of pests and diseases.

There is also insufficient scientific knowledge on what material can be translocated successfully and difficulties associated with obtaining and migrating enough genetic diversity.

Despite these concerns, assisted migration may be necessary in certain circumstances. In populations facing challenges due to climate change (e.g. drought or warmer and longer growth periods), the genotypes best adapted to this new climate may be found more commonly elsewhere in the species range.

Forest managers can therefore select provenances from such areas that are expected to be suitable for the predicted future climate. For example, seedlings that are moved from milder to cooler locations should match the future temperature and moisture regimes better than local populations. However, this might require changes to existing rules concerning movement of FRM between seed zones.

Choosing the right provenances and species is vital for success. Such choices are challenging and are impeded both by the uncertainty of climate-change projections and by the still-limited

knowledge acquired from provenance and species translocation trials (see *Provenance trials in assisted migration strategies below*). Therefore, the current

recommendation is that assisted migration should be limited to FRM originating from within a few degrees of latitude of the target site.

06 PROVENANCE RECOMMENDATIONS

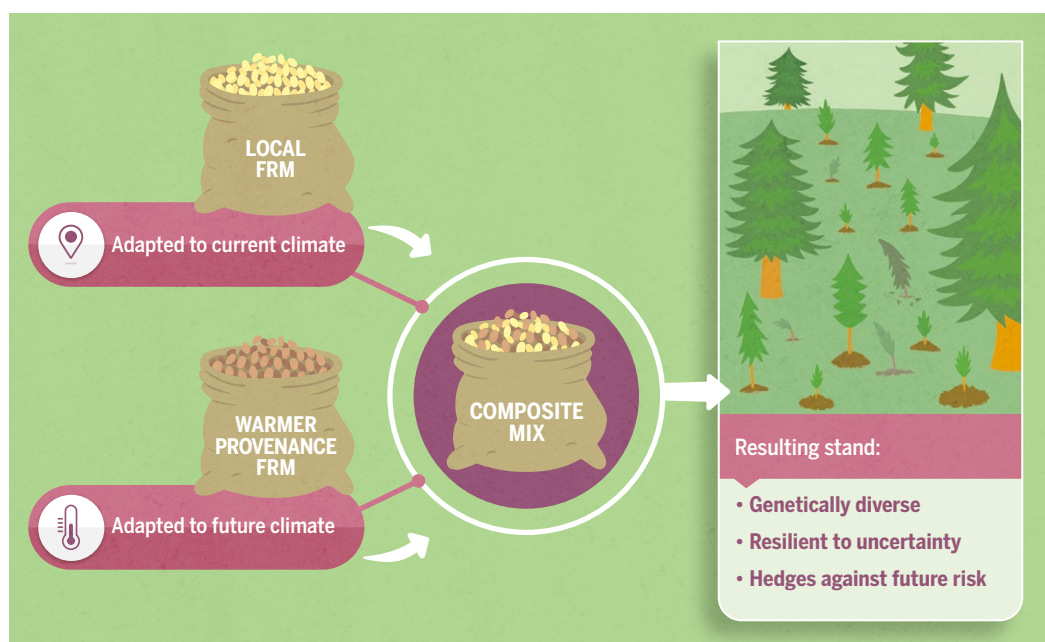


Fig. 3: Combining multiple seed sources by mixing local seeds with those sourced from sites adapted to the predicted future climate increases the chances of survival for the new plantation.

The choice of provenance is a challenge, given the need to ensure that the material chosen will establish and survive under current conditions as well as perform well under future predicted environmental conditions.

Composite provenancing

Composite provenancing refers to the use of multiple seed sources in one generation to increase genetic diversity and buffer against future climate uncertainty. Such mixtures commonly include both FRM adapted to the current climate, e.g. from local seed sources, and FRM adapted to predicted future climate.

For example, genes for traits such as drought and heat tolerance introduced via assisted migration may help local tree populations adapt to the changing climate.

Vigilance is needed to monitor the establishment of introduced provenances, in particular if there might be frost-related risks. Phenotypic plasticity can help trees overcome stressful conditions, for example, during establishment and early life stages.

Provenance trials in assisted migration strategies

The choice of which provenance and species to use in assisted migration strategies should ideally be based on the results from range-wide and long-term provenance trials. These data are very useful for predicting the performance of natural tree populations or plantations

under climate change, and for selecting the most suitable populations for plantations under particular climate-change scenarios.

Unfortunately, such large provenance trials are rare because they are time-consuming and expensive, often requiring scientific collaboration at international level to cover species ranges.

Existing provenance trials were established mostly for stand-forming conifers and broadleaved tree species rather than for noble hardwoods and rare stand-forming tree species. This means it is difficult to put assisted migration into practice for many species at a local level, making it essential to ensure the transfer of existing knowledge to local and applied levels.

07 ADAPTIVE FORESTRY

Human-facilitated forest regeneration can help forests adapt to climate-change-related challenges, maintaining functional ecosystems and productivity, and protecting genetic biodiversity. Forest ecosystems naturally adapt to environmental changes, but may not be able to adapt quickly enough given the speed at which climate is expected to change in this century. In particular, natural adaptation favours the best-adapted trees, regardless of species, and hence will not necessarily protect commercially important tree species.

A framework is needed for designing adaptive strategies that will sustain or enhance forest growth, health, and ecosystem services under new climates. To meet future challenges, forest managers will need to apply multiple spatial and temporal measures and adopt more adaptive and flexible management approaches (e.g. shorter rotations and species diversification). Artificial regeneration practices, including enrichment planting and assisted migration, will play crucial roles in this.

FIND OUT MORE!

These guidelines and recommendations have been synthesized from:



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