



EUFORGEN

FOCUS ON FOREST GENETIC DIVERSITY
PRODUCING AND USING FOREST REPRODUCTIVE MATERIALS



THEME 4

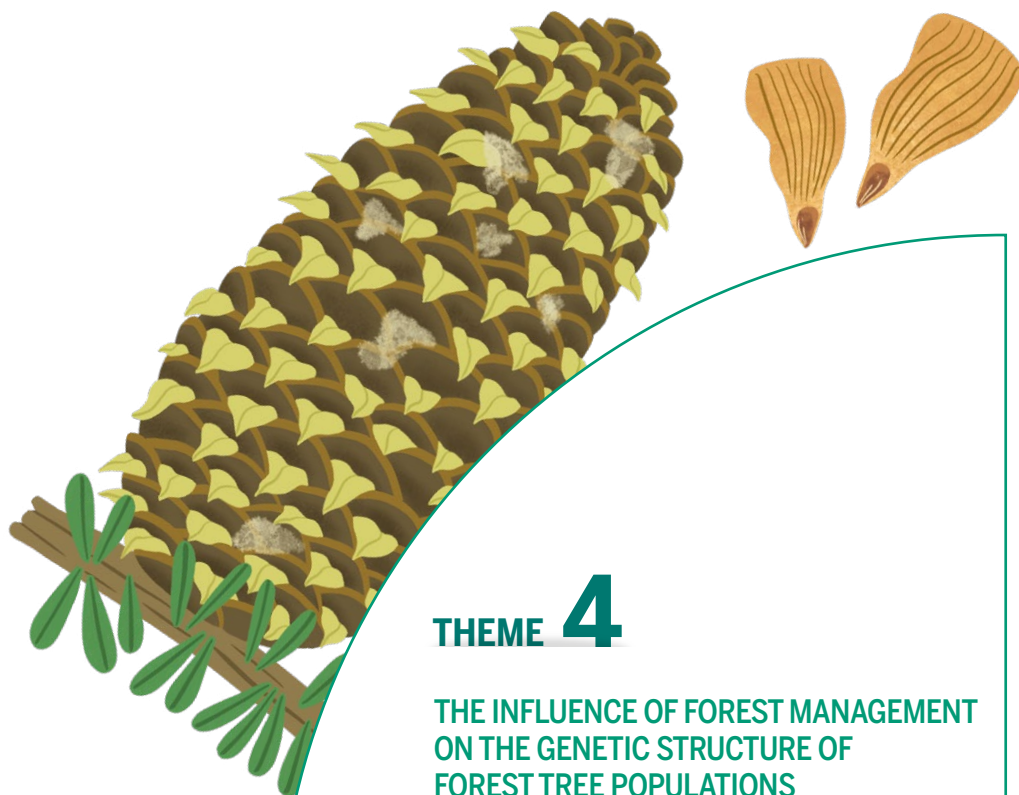
THE INFLUENCE OF FOREST MANAGEMENT ON THE GENETIC STRUCTURE OF FOREST TREE POPULATIONS

How choices in methods to establish and
manage forests affect forest genetic diversity



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How choices in methods to establish and
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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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Graphic design & illustrations: @dainagrafic / Aina Pongiluppi

Text adaptation: Czesław Kozioł,
Kostryca Forest Gene Bank, Miłków, Poland

Editing: Sarah Adams,
European Forest Institute (EFI), Joensuu, Finland
European Forest Genetic Resources Programme (EUFORGEN), Barcelona, Spain

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EUFORGEN Secretariat

c/o European Forest Institute (EFI)

Sant Pau Art Nouveau Site

C/ Sant Antoni Maria Claret 167

08025 Barcelona, Spain

euforgen@efi.int

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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

Forest managers are faced with many choices when it comes to establishing or managing the forest under their care. The genetic make-up of future forests can vary significantly both according to decisions taken before trees are planted, and as a result of interventions carried out subsequently.

First, the forest manager must choose whether to use natural regeneration from existing trees or artificial regeneration, involving sowing seeds or planting seedlings or saplings from other sources. For more information on natural and artificial regeneration, please refer to [Theme 1: Silvicultural practices and their role in mitigating effects of climate change: the effects of regeneration strategies on genetic diversity of forest stands](#).

Then, site fertility and topographical and climatic conditions may influence various elements, including the choice of tree species to be regenerated, the choice of genetic characteristics of forest reproductive material (FRM), and the size of seedlings to be planted. As forest tree species are characterized by long biological cycles, it is recommended that forest managers use a high genetic diversity of FRM in productive plantations to improve their resilience over time, even if this might reduce overall productivity. A high level of genetic diversity is also preferred in material used for stands with non-productive functions.

Once these initial decisions have been taken, the following management interventions can further influence forest genetic diversity:

- site preparation
- number and density of seedlings
- direct seeding
- protection against pests, insects, and herbivores
- tending to young stands
- enrichment planting.

These interventions, described in this booklet, can have a strong impact on tree survival and juvenile growth, and thus will affect the genetic structure of the new stand.

The EUFORGEN community offers these guidelines to support practitioners in making decisions on the management practices they will use to establish or manage their forests in order to maximise forest genetic diversity. Based on a scientific knowledge of forest tree population genetics, this handbook is written for forest managers, decision makers, advisors and authorities who may play a role in establishing and managing forests.

01 SITE PREPARATION

Both natural and artificial regeneration can be enhanced by preparing the site. This might involve clearing the site of trees and vegetation or other forms of ground cover such as the woody debris left after harvesting a tree crop. However, removing remnants of previous trees may disrupt the establishment of mycorrhizal associations of bacteria and fungus on seedling roots, which can be critical to the survival and productivity of the trees.

Soil preparation

Site preparation might also involve preparing the soil to bring mineral soil to the surface.

In dry areas, soil preparation is crucial to enhance infiltration and storage of precipitation in the subsoil and thus increase water availability for young plants.

In mountainous areas, tillage across the slope can also enhance water infiltration, reduce surface water run-off, protect the soil from erosion, and harvest rainfall. On very steep slopes, terracing will be needed.

Conservation tillage – soil preparation techniques that minimize disturbance of the soil – can reduce water and wind erosion. Superficial tillage to a maximum depth of 30 cm after ploughing or scarification can improve contact between roots and soil and remove weeds, both of which will enhance establishment and survival of seedlings.

Deep soil tillage can reduce biological activity in surface layers and upset nutrient cycles, largely by reducing the organic matter content of the soil or transferring it to deeper layers. In Germany, for example, forest certification systems do not allow the exposure of mineral soil during regeneration operations to avoid these negative effects.

Shallow soils and those with low organic matter contents should be tilled only when young plants are planted. In this case, soil preparation should consist of digging holes of at least 40×40×40 cm into which seedlings are planted. These allow the young roots to grow rapidly and reach soil moisture in deeper layers. This approach helps reduce loss of mineral nutrients, especially in hot, arid environments, and minimizes soil erosion.

Soil scarification

Soil scarification is the exposure of mineral soil by removing the humus layer, while soil mounds involve creating a mineral soil layer on top of the humus layer. This can:

- reduce incidents of pest and diseases by disrupting their lifecycles
- raise root-zone temperature (positive in northern countries, but negative in southern regions)
- increase root-zone porosity (depending on soil type)
- enhance nutrient decomposition and availability (but can also result in leaching of nutrients)

- reduce competition from other plants and increase the microbiome and mycorrhizae that promote plant growth
- reduce night frost caused by outward longwave radiation
- optimize water supply (but it can also induce faster drainage and therefore possible drought conditions)
- simplify plantation work.

However, soil scarification can have negative consequences, such as higher mineralization, transpiration, and loss of nitrogen. It is not common practice in all regions.

Site preparation trade-offs

While site preparation, especially soil management, can increase seedling survival and thus reduce loss of genetic variation in the seedlings planted, it may have negative results, such as

oxidation of organic soil and loss of minerals, nitrogen, and other nutrients. This is most likely to occur on sites with steep slopes or shallow soils with limited organic matter contents. These conditions will favour the survival of seedlings of species that are adapted to them, altering the genetic make-up of the forest that is established.

Intensive site preparation can also reduce natural regeneration from some species previously growing on the site but promote regeneration of other species. This may alter the pattern of diversity at genetic and species levels.

Forest managers should carefully assess the likely impacts of site preparation on genetic and species diversity in the planting material used and adjust their site preparation plans accordingly.

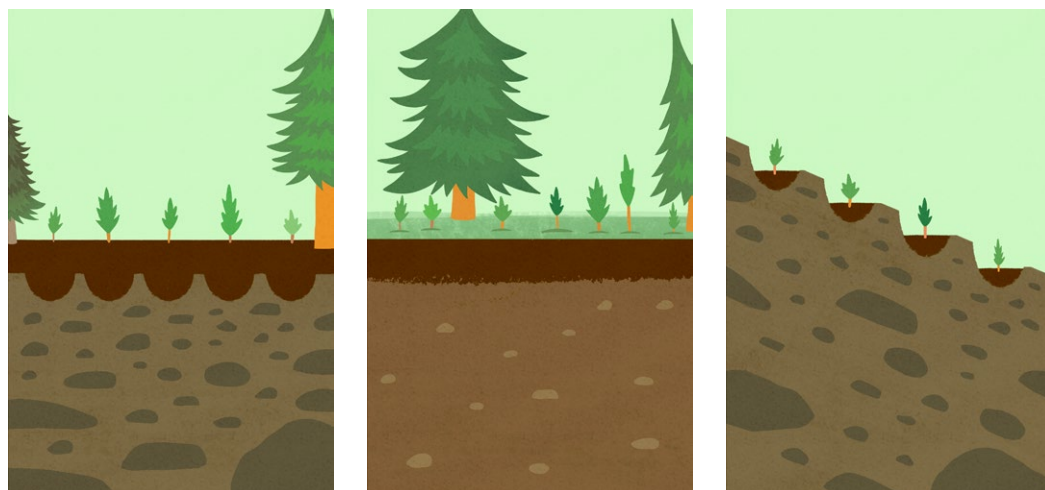


Fig. 1: Site preparation trade-offs. On deep, rich soils (centre), seedlings survive and the stand regenerates naturally with the same species, maintaining genetic diversity. On shallow soils (left) or steep slopes (right), where organic matter and nutrients are limited, few plants survive or only better-adapted species establish, shifting the genetic and species composition of the forest.

02 NUMBER AND DENSITY OF SEEDLINGS

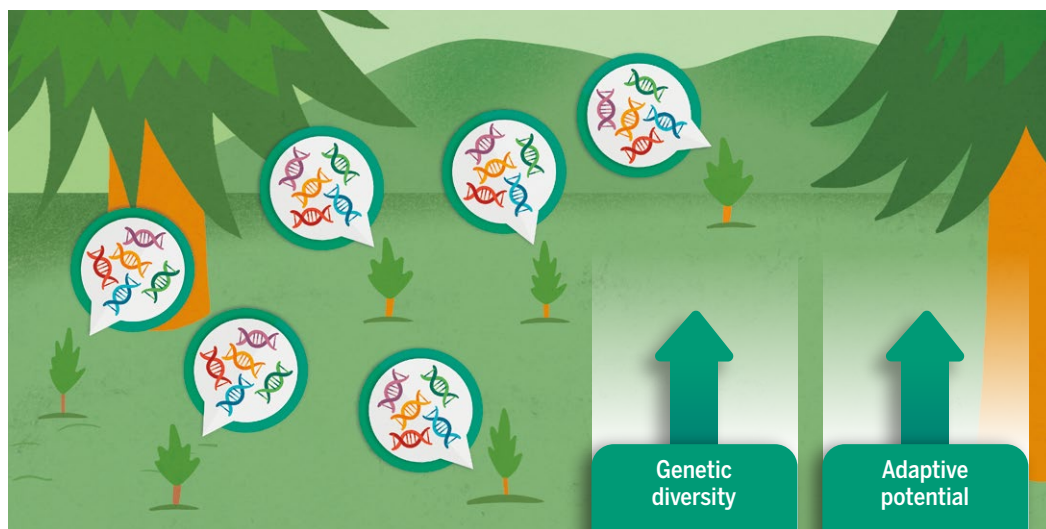


Fig. 2: Number and density of seedlings. A larger, denser stand of the same species holds greater genetic variation, which in turn raises the forest's adaptive potential to cope with change (climate, pests, drought).

The number of plants in a stand will affect the genetic structure and diversity of the stand. The greater the genetic diversity of the stand, the greater its adaptive potential is likely to be.

Many European countries specify the minimum number of plants to be planted for artificial regeneration or afforestation, with the numbers differing depending on the species and regeneration methods used.

Forest legislation in Sweden, for example, sets a minimum acceptable number of plants, usually between 2,000 and 2,500 plants per hectare. Naturally regenerated plants of certain species can be included in this number if they perform well.

Germany has recommendations for the minimum number of plants to be used in state forests and afforestation measures, with the number differing significantly according to the species, e.g. 10,000–12,000 plants per hectare for Scots pine (*Pinus sylvestris*) and 2,000 for Douglas fir (*Pseudotsuga menziesii*).

Similarly, state forest regulations in Poland specify the minimum number of seedlings to be planted, again with the number depending on the species, e.g. 8,000–10,000 plants per hectare for Scots pine and 1,500–3,000 for European larch (*Larix decidua*).

03 DIRECT SEEDING

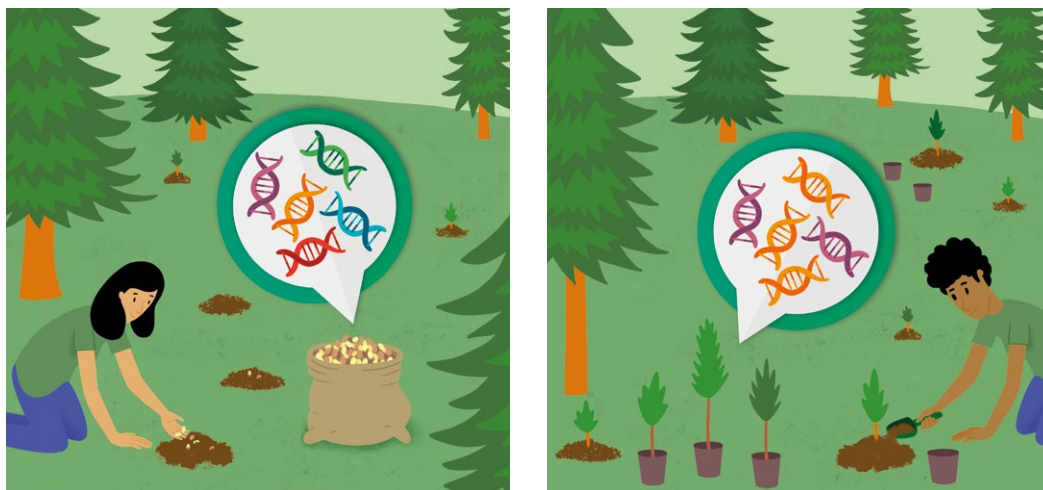


Fig. 3: Direct seeding versus nursery stock. Sowing seed directly on site preserves more of the original genetic diversity, whereas diversity may narrow along the nursery chain.

Direct seeding is an effective alternative to planting seedlings or saplings when trying to establish forest stands with high adaptive potential. It generally ensures greater genetic variability than using seedlings, as genetic diversity may decrease along the nursery chain as a result of nursery conditions and production methods. In direct seeding, the seed germinates on the site where the trees are to be grown so the genetic diversity of the stand is affected only by selection pressure exerted by local site conditions.

Regional perspectives

Direct seeding is widely used in beech (*Fagus* spp.) and oak (*Quercus* spp.) forestry in Central Europe. In Germany, it is also used to establish deciduous

species in older pine and spruce stands as a method for forest conversion.

In northern Fennoscandia, direct seeding is commonly used to establish Scots pine (*Pinus sylvestris*) stands, although its popularity has decreased in Sweden, where it now represents only 3% of the reforested area. In Finland, pine is direct seeded on 20,000 ha annually – one-fifth of the annual regeneration area – and consumes two-thirds of the tree seed used in the country each year.

Direct seeding is widely applied in the (sub-) Mediterranean regions of Europe after forest fires. In some countries, such as Slovenia, it can involve seeds of more than 30 forest tree species per site.

Success factors

The success of direct seeding depends on the species chosen and site conditions. Species chosen should be well adapted to the current and expected future environmental conditions of the site. Site conditions should be managed to enhance germination and establishment of seedlings. This includes measures to improve soil conditions and water-holding capacity of the soil, especially if the site is drought-prone, and control of weeds that would compete with the seedlings.

Measures should also be taken to prevent removal or damage to seed by birds and insects and damage to the seedlings by animals, such as wild boars, deer, and rodents (see chapter 4). If such measures are not taken, only a small proportion of the seeds used in direct seeding are likely to develop into trees.

Where plantations are not fenced, mixtures of seeds of species attractive to herbivores may be planted to provide a preferred source of food for grazing and browsing animals, which will help minimize damage to the main tree species of interest.

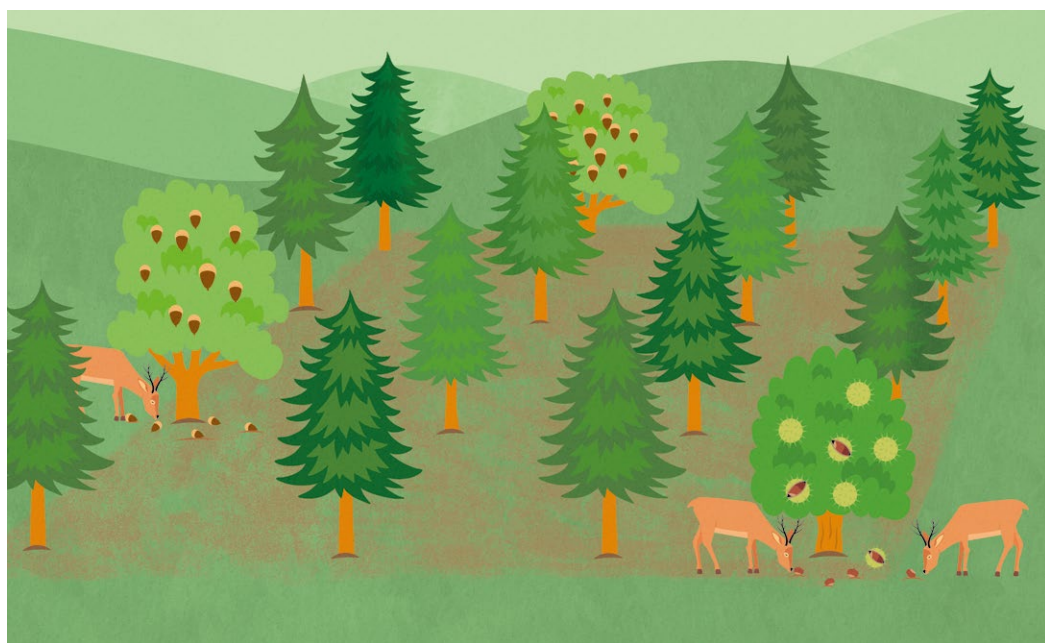


Fig. 4: Protecting the main crop without fencing. Interplanting palatable species such as chestnut and oak among the conifers gives grazing and browsing animals a preferred food source, minimising damage to the main tree species of interest.

04 PROTECTION AGAINST PESTS, INSECTS, AND HERBIVORES

Many pests can cause severe damage to tree seedlings and saplings. This can be mitigated by planting materials that are resistant to important pests found at the establishment site. For example, genetic variation has been observed in resistance of seedlings of Norway spruce (*Picea abies*) and Monterey pine (*Pinus radiata*) to damage from pine weevil (*Hylobius abietis*).

Browsing and grazing can prevent both natural regeneration and success of planting, particularly in areas with large populations of livestock, such as sheep, or wild ungulates, such as deer.

Browsing can be prevented by fencing off areas where trees are being established, or by using tree guards or repellents on

individual seedlings or trees. Plantations may need to be fenced for several decades when working with species that are particularly attractive to ungulates (e.g. the European silver fir (*Abies alba*) and Douglas fir (*Pseudotsuga menziesii*)).

Some protection from browsing may be provided by scarification of conifer stems to the height at which they are usually browsed by ungulates.

Choice of seed source can also help prevent browsing damage. For example, a trial using silver birch (*Betula pendula*) in southern Finland found that moose damage was more severe in trees growing from seeds sourced from furthest away from the trial site, possibly related to differences in digestibility and palatability.

05 TENDING TO YOUNG STANDS

During the establishment phase of a forest stand, the number of seedlings and saplings is much greater than the number of trees at the end of a rotation. This is especially true for naturally regenerated stands and those established by direct seeding. There may be several tens of thousands of seedlings per hectare in the case of natural regeneration, compared with between 1,000 and 10,000 seedlings per hectare in planted stands.

Pruning and thinning

Stands need regular maintenance – pruning and thinning of trees and management of undergrowth – to ensure the trees enough space to grow and develop and to ensure ecosystem stability. This maintenance not only increases trees' productivity but can also maintain the genetic diversity of the stand. For example, beech (*Fagus* spp.) stands that have been thinned have been found to be more genetically diverse than unmanaged control plots.

However, excessive thinning can reduce genetic diversity of the remaining trees. For example, removing 75% of the trees in old stands of eastern white pine (*Pinus strobus*) was found to significantly reduce genetic diversity and result in loss of rare alleles. Thinning of stands of younger Scots pine (*Pinus sylvestris*) has also been found to cause significant loss of rare alleles.

Tending

Tending includes a variety of forest treatments, including thinning, fertilizing, and pruning. Tending does not have a significant effect on the genetic diversity of stands established from a single clone but may be important if a clonal mixture has been used to establish a stand. If a clonal mixture has been used, the actual clonal composition of the mature stand may have changed over time in response to site conditions, so any thinning should aim to retain as many different clones as possible.

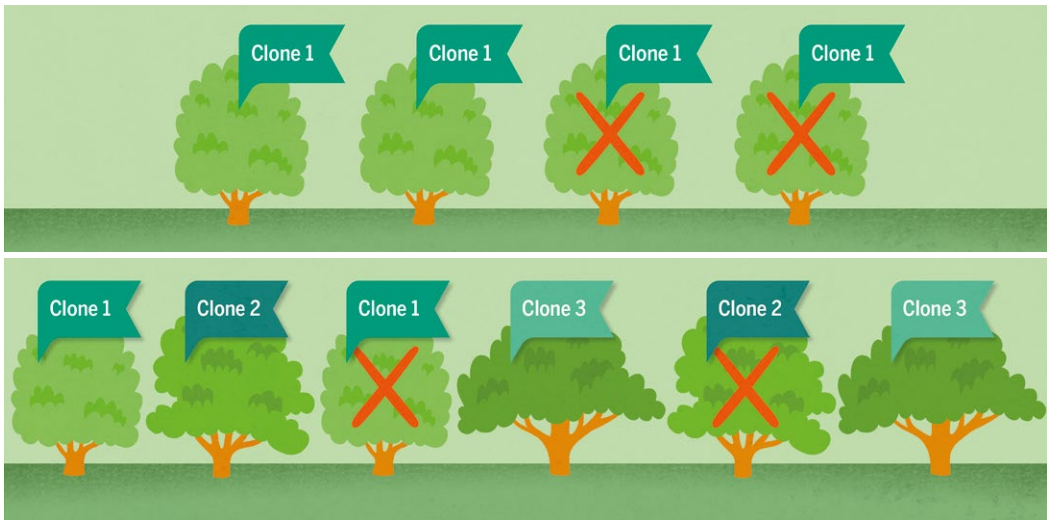


Fig. 5: Tending and genetic diversity. Thinning a single-clone stand (top) does not affect genetic diversity. In a clonal mixture (bottom), thinning should retain some individuals of every clone so that no clone is lost.

06 ENRICHMENT PLANTING



Fig. 6: 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.

Enrichment planting involves planting seed or seedlings in gaps in an established forest stand where natural regeneration has failed. It is a valuable approach for maintaining or increasing the biodiversity of tree species or within-species genetic variation in forest stands. For more information on enrichment planting, please refer to [Theme 1: Silvicultural practices and their role in mitigating effects of climate change: the effects of regeneration strategies on genetic diversity of forest stands](#).

Regional perspectives

In Türkiye, for instance, enrichment planting is commonly used where natural regeneration success is lower than 80%. Site conditions permitting, a variety of species is planted to create mixed stands, such as enriching stands of European black pine (*Pinus nigra*) with oriental beech (*Fagus orientalis*).

In Central Europe, mature stands of Norway spruce (*Picea abies*) are often underplanted with local, site-adapted species, such as common beech (*Fagus sylvatica*) and silver fir (*Abies alba*), to convert adult monocultures into mixed stands or to add trees of different species and ages to create diverse, multi-layered forests.

After harvest

Planting valuable broadleaved tree species such as wild cherry (*Prunus avium*), elm (*Ulmus* spp.), wild service tree (*Sorbus torminalis*), and small-leaved lime (*Tilia cordata*) in gaps and patches left after stands have been harvested increases the biodiversity of the stands and enhances the ability of the forest ecosystem to adapt to climate change. However, most plantations of this nature need to be fenced to ensure their survival.

Adding value

Enrichment planting can also be used to increase the genetic diversity of the trees in a forest, providing additional material on which natural selection can work. This facilitates the emergence of new genetic combinations and the spread of the best-adapted genotypes and conserves genetic diversity to enable long-term selection.

FIND OUT MORE!

These guidelines and recommendations have been synthesized from:



D. Gömöry, K. Himanen, M. M. Tollefsrud, C. Uggla, H. Kraigher, S. Bordács, P. Alizoti; S. A'Hara, A. Frank, G. F. Proschowsky, J. Frýdl, T. Geburek, M. Guibert, M. Ivanković, A. Jurše, S. Kennedy, J. Kowalczyk, H. Liesebach, T. Maaten, A. Pilipović, R. Proietti, V. Schneck, A. Servais, B. Skúlason, C. Sperisen, F. Wolter, T. Yüksel and M. Bozzano. 2021.

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EUFORGEN Secretariat
European Forest Institute (EFI)

Sant Pau Art Nouveau Site
Carrer de Sant Antoni Maria Claret, 167
08025 Barcelona – Spain
euforgen@efi.int
www.euforgen.org
[linkedin.com/company/euforgen](https://www.linkedin.com/company/euforgen)
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