There is a distinction between different situations, depending on the observed impact of climate change.

The diagnosis of dieback attributed to climate change must be verified and refined, specifically in the light of past management practices :

a) **Where there is no significant dieback in local stands,** encourage natural selection through high levels of genetic diversity in the earliest stages of growth in the stand :

- In the case of natural or artificial regeneration, ensure sufficiently dense regeneration relative to the size of the final target population (distinction between social and scattered species) ;
- In the case of natural regeneration, maximise the genetic diversity in the seedlings by increasing the contribution from a maximum number of reproductive trees (also considering the duration of the regeneration phase).

b) **If the areas of dieback** significantly reduce the potential number of reproductive trees in the stand but spare at least half the healthy individuals, we recommend that regeneration be supplemented or the stand replanted, using FRM fully representative of the selected stands in the local region of provenance. In order to enhance adaptability, the use of "genetic enrichment" can be considered by using FRM representing neighbouring regions of provenance (in principle, with a hotter, dry climate).

c) **If the dieback is generalised,** affecting all age classes, and if local extinction of the species appears inevitable across the entire forest, there will be no alternative except the introduction of exotic provenances of the same species, considered to be better adapted to future conditions, or, if unavailable, to the changing of the target species. Then, the emphasis should be put on the genetic diversity of the introduced material and on its provenance, including that used for infilling and reinforcement planting (all documentation relating to this material should be retained). Meanwhile, particular attention should be paid to surviving trees possibly carrying specific genetic characteristics advantageous to adaptation. After unusual events, adjustments to the conservation strategy will need to be considered.

Before planting (genetic enrichment, transfer, substitution), it will be necessary to obtain guarantees of high genetic quality for the FRM from the seed and plant industry (broad genetic base, adaptation, phenotypic plasticity). The current recommendations given for the use of FRM, which are based on concepts of local adaptation and performance in a constant environment, will need to be adjusted to reflect the changing conditions. The definitions of regions of provenance and the use of FRM must over time take into account changes in the climatic zones. This is not to cast doubt in any way on the advantages of regulating trade in FRM, which guarantees quality of information provided to users. Indeed, it is the only efficient tool to ensure the diversity of the FGR actually used. The use of forest varieties with a narrow genetic base must be thoroughly evaluated and controlled in order to avoid excessive homogeneity, with a view to maintaining genetic diversity in the countryside. Additionally, regulatory control of FRM makes it possible to monitor all movements of genetic resources, this being of fundamental importance in the context of the climatic instability now being encountered.

IN BRIEF

- **If the rotation period is shorter than 20 years (poplars, short-rotation coppice and plantation), choose the best adapted FRM while avoiding excessive uniformity across the region.**
- **If the rotation period exceeds 20 years, it will be necessary to take into account adaptation and adaptability. The higher the harvest age, the greater the environmental changes experienced between juvenile and harvest time, and thus the more urgent need for genetic diversity.**
- **For mature stands, adaptation of forestry practices must also take into account the preparation of regeneration phases to ensure adequate seedling quantities and genetic diversity.**
- **During the renewal phase, whether based on natural regeneration or planting, seek to ensure sufficient genetic diversity to allow for subsequent natural selection.**

Websites to visit: http://agriculture.gouv.fr/sections/thematiques/foret-bois/conservation-ressources
http://agriculture.gouv.fr/sections/thematiques/foret-bois/graines-et-plants-forestiers
http://www.brg.prd.fr/brg/pages/les_rg_en_france/rgv_arbresForestiers.php

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MINISTERE DE L'AGRICULTURE ET DE LA PÊCHE
DGPAAT/SOUS-DIRECTION DE LA FORÊT ET DU BOIS

Commission on Forest Genetic Resources

Preservation and use of the diversity of forest genetic resources to strengthen the adaptability of forests to climate change

Genetic resources cover an area of biodiversity of actual or potential value. In forests, genetic diversity of trees is also a key factor which fosters general biodiversity of the ecosystem and interacts with its function. The diversity within species is not always easy to observe but it exists between and within populations of trees. Driven by the laws of genetics, it is dynamic, through seed and pollen flows between stands and by selection, be it natural or artificial. In the context of climate change, sustainable long term preservation of this legacy is both supportive and dependent upon the local management of forest.

We deal here with the management of genetic diversity within each species, while acknowledging that mixed species silvicultural treatments are, of course, fully justified for sustainable management in the context of climate change.

We make some important general recommendations, without systematically detailing each type of forest management. In many cases, several options are open and there is no unique solution.

In parallel to these recommendations devoted to standard forest management, specific programmes for conservation and experimental transfer of genetic resources will be led by researchers, in particular on CRGF 's initiative

Commission Ressources Génétiques Forestières/Commission on Forest Genetic Resources (*)
(*) This commission, whose membership is made up of scientists, public and private forest managers, and a representative of the "forest" network of France Nature Environnement, advises the Ministry of Agriculture, Food & Fisheries, implements a strategy for the evaluation and the conservation of genetic diversity in forest tree species in France.
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1 – The climatic context: a continuous change with sharp annual and regional variations

The experts of the Intergovernmental Panel on Climate Change (IPCC) predict a significant change in the climate over the next century, with a sharp rise in average temperature, changes in rainfall and more frequent extreme events (heat waves, droughts, floods, storms, etc.). These changes, while certain, will vary from one region to another. Many uncertainties remain as to the amplitude of annual variations (e.g. will the increase in average temperature be accompanied by the disappearance of frost risk ?) as well as global ecological changes induced by climate change (parasites, mycorrhizae, pollinators, seed dispersers, new invasive species etc.).

Climate change is a long- term process. During the course of the next century, forests will need to cope with a series of environmental conditions which are difficult to foresee and will no doubt be completely novel as regards their physical (temperature, drought) and biological dimensions. It is over the same timescale that today's decisions will produce effects.

2 – Genetic context: an adaptive potential to be fully used...

If current forest ecosystems are to remain in good health, much will depend on the capacity of existing trees to survive and reproduce and on adaptive changes in the forthcoming regeneration phases. The adaptive potential of a forest is its capacity to evolve genetically from one generation to the next. The drivers of genetic evolution can be natural, artificial, or both.

It is generally difficult to predict existing trees' capacity to respond to the changes they will experience in coming years (notwithstanding the uncertainty as to future climatic and ecological scenarios). On the other hand, what we do know is that forest trees are usually characterised by wide genetic diversity within individual stands: such diversity is the essential "fuel" for the proper functioning of natural selection, the mechanism which leads to adaptation. Diversity within stands varies between species (generally more limited for species whose areas are fragmented), and also for the same species from the centre to the margin of its distribution area. However, historical examples of forest material transfer have shown that genetic diversity is sufficient to encompass major adaptive changes in no more than one or two generations.

Convinced that major ecological changes will occur, but unable to describe accurately the environment of the future, we need to take maximum advantage of the adaptive potential. Consequently, we must follow two objectives:

- **the maintenance of genetic diversity over the long term by using appropriate forestry practices, and**
- **the fostering of evolutionary processes to keep stands adapted to their changing environment as closely as possible in what is a "race for change".**

QUALITY NOTIONS IN GENETIC RESOURCES

The "best quality" = a subjective criterion based on multiple parameters (economic, ecological, etc.) in relation to the goals assigned to the forest at a given time.

Adaptation = quality of population survival, growth and reproduction in the prevailing environment.

Adaptability = capacity of a population to change in a changing environment, including the plasticity (variation in morphology or physiology as a response to environmental change) of existing trees and genetic evolutions from generation to generation.

Local regions of provenance offer guarantees of good adaptation to local conditions. Their adaptability will not necessarily be sufficient : this will depend on their genetic diversity and on the intensity of environmental change.

3 – Recommendations: graduated responses matching dieback intensity in forest ranges or regions

There is today a need for gradual response to raising issues, and for avoiding ill-founded measures of adaptation. While remaining active and vigilant, two pitfalls must be avoided:

- the substitution of provenances or species may be necessary in some cases, but hasty moves towards complete replacement and reckless elimination of genotypes which might survive in new conditions would not meet the objective of fostering the evolution of our genetic resources in the long term.
- the immoderate use of a single Forest Reproductive Material (FRM) supposed to be the panacea, which might endanger the preservation of genetic diversity in our resources.

Forestry practices may influence genetic diversity and evolution processes in the context of climate change. Natural selection between seedling or sapling is an important evolutionary process. Choosing natural re-generation allows the most effective advantage to be taken from the genetic diversity available within the stand. Planting can be beneficial using FRM from recommended sources and varieties selected for their adaptive characteristics or plasticity. In this case, a higher initial density of the species will enhance the opportunity for further natural selection.

Renewal by:	Natural regeneration	Planting of material from the local region of provenance	Planting of introduced material (in an area where the species is already present)
Advantages	- good adaptation - good sampling of locally available genetic diversity - allows natural selection to operate - good integration into the ecosystem, reinforcing its general resistance (co-adaptation)	- good adaptation - material usually from selected stands chosen for their quality - fairly good integration into the ecosystem, ensuring satisfactory general resistance	- remedies a lack of local genetic diversity - contributes to new adaptations
Disadvantages	- risk of a limited number of effectively reproducing trees - risk of a small number of seedlings - risk that local genetic diversity is too limited and ultimately unable to adapt to the scale of changes	- risk of poor sampling of the genetic diversity during seed harvest - leaves less room for natural selection - risk that regional genetic diversity is too limited and ultimately unable to adapt to the scale of changes	- risk of maladaptation - risk that overall genetic diversity will decline in case of massive introduction of material with a narrow genetic basis - risk of inducing "genetic suffocation" of a local resource under threat - risk of further disturbance to an already weakened ecosystem
Recommended management practices	- maximise the effective number of reproductive trees - ensure sufficient seedling density at least in the very early stage, or consider additional planting	- mix selected stands within the region of provenance where technically feasible - increase the initial planting density	- introduce material originating from a neighbouring region, in principle one with a drier climate - introduce material with a broad genetic base